# What's Wrong With Pricing Errors?

# Essays on the Difference Between Price and Value

Sjoerd van Bekkum

This book is no. 484 of the Tinbergen Institute Research Series, established through cooperation between Thela Thesis and the Tinbergen Institute. A list of books which already appeared in the series can be found in the back.

Cover design: Crasborn Graphic Designers bno, Valkenburg a.d. Geul

ISBN 978-90-3610-192-9

What's Wrong With Pricing Errors? Essays on the Difference Between Price and Value

(Wat is er mis met prijsfouten? Essays over het verschil tussen prijs en waarde)

Proefschrift

ter verkrijging van de graad van doctor aan de
Erasmus Universiteit Rotterdam
op gezag van de rector magnificus
Prof.dr. H. G. Schmidt
en volgens het besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op

donderdag 9 september 2010 om 15:30 uur

door

Sjoerd van Bekkum
geboren te Roosendaal

ERASMUS UNIVERSITEIT ROTTERDAM

**Promotiecommissie:**

**Promotors:**

Prof.dr. E. Pennings

Prof.dr. H. Smit

**Overige leden:**

Prof.dr. B. van Ark

Prof.dr. A. Kemna

Prof.dr. W. Verschoor

*To Claire, the inexhaustible wind beneath my wings.*

# Contents

# List of Tables

# List of Figures

# Preface

My journey towards this book started in the Spring of 2006, when I was offered a PhD position at Erasmus University. A few months earlier, it was Han Smit who had introduced me to the world of science, and shared with me his passion for research. Without his trust, patience and enthousiasm, I would probably not have dared to start a multi-year project which, at the time, I was not sure would fit me well. In retrospect, I can say now, it changed my life.

In the years that followed, I have had the good fortune to be supervised by Han Smit and Enrico Pennings, who turned out to be great colleagues and highly complementary researchers. Exciting research requires Han's highly contagious enthusiasm, his ability to ask questions and the composition of manuscripts that have impact. But at the same time, it also requires Enrico's relentless attention to detail, his skillfulness in modeling answers and the art of powerful measurement. While the journey to write a dissertation is strewn with triumphs, failures and near misses, the results of our cooperation in this book have been developed swiftly and on time. I believe this to be the result of a harmonious triangular alliance. Now that I have fled the nest, I hope to have incorporated a mix of their capabilities.

What appears as a single book is in reality a randomly evolved collection of articles which, in hindsight, appears to be not so random after all. The Aims and Scope in the Introduction are nevertheless a retrospect, rather than a grand scheme of development. For an important part, doing research has turned out to be a matter of muddling through, and I have gradually embraced this disorganized state of affairs over the years.

But the journey would not have been as pleasurable without the company of some fellow travelers that walked along. The number of people who I should thank is too

numerous to list by name, but I would like to thank Guido Baltussen for motivating me to pursue my current stay at the Stern School, Thomas Brok for evading train strikes during exam rounds, Selene Fagel for her willingness to talk about research when all others have lost their tolerance, Jorn Zenhorst for his ability to share an office with me, Gus Garita, Amit Kothiyal, Sjoerd van den Hauwe, Sandra Phlippen, Cerag Pince, and Julia Swart for being a sounding board and helping me procrastinate during unscheduled breaks, and Bas Karreman, Rick Murrugarra, and Sanne Struijk for sharing food, thoughts and fun.

Part of the research in this book was done in New York, with the support of research grants awarded to me by the Niels Stensen Foundation and The Conference Board. I am grateful for their financial support. I would also like to thank Bart van Ark, Ingolf Dittmann, Angelien Kemna, and Willem Verschoor for taking the time to read this book and their willingness to take place in my thesis committee.

In addition to all the foregoing, I am indebted to my friends and family for their moral support and friendship. My heart goes out to my father, mother, and two sisters for their loving kinship and patient efforts to understand my academic fixations, to Cheryl and Guido for providing warm company across countries and locations, to Merrill for reminding me of what the real world looks like, to Nick for long conversations in public swimming pools, to Selene and Thomas for making me feel at home wherever they are, and to Bob, Erik, Sicco, and Ties for all adventures we had together. And finally, of course, to Claire: this book's dedication partially expresses how instrumental you have been in sending me on, and bringing me back from this journey. This book is for you.

Sjoerd van Bekkum

New York, July 2010

# Chapter 1

# Introduction

"The pure and simple truth is rarely pure and never simple."

*Oscar Wilde (1854-1900)*

## 1.1 Aims and Scope

What is the meaning of stock prices? And what is exactly the value of a firm? In theory, the fundamental value of a firm equals the value that can be generated from the firm's assets. This includes the replacement value of the assets themselves, as well as current and future profits that can be generated from exploiting these assets. Financial markets, then, should reflect this value by determining the price at which the firm is traded. However, this does not concur with empirical findings – market prices are well-known to deviate from fundamental values, and do so for prolonged periods of time. It is this divergence of market value from fundamental value that this dissertation is mostly about.

The difference between fundamental value and market value is caused by imperfect information about an uncertain future, which only gradually becomes available. Market prices reflect the expected value of a firm, and are therefore an approximation of future firm value that anticipates future performance. Fundamental value, on the other hand, is calculated from information that is already reported in financial statements, which mainly document information about performance in a recent past. Hence, deviations between market value and fundamental value indicate how expectations of investors differ from materialized information, and arise from an imperfect relationship between the expectations about a firm's future value (which is inherently forward-looking) and a firm's realized current value (which is determined backward-looking). Clearly, market value and fundamental value can't both be right at the same time.

If market prices legitimately deviate from fundamental value, then expectations are correct (or "rational") and market value is a more up-to-date version of fundamental value. It follows that current market prices can be interpreted as predictions of the future value of a firm. This is valuable information for many stakeholders who are related to the firm. For instance, investors could use predictions to develop profitable trading strategies, directors could use predictions to benchmark the efficacy and sustainability of the firm, and managers could immediately gauge the effect of their investments. Therefore, Chapter 2 examines this assumption by linking the price-value difference to statistical characteristics that are associated with rational expectations under uncertainty. Before doing so, however, this chapter describes previous studies on the price-value divergence and we identify several problems with their estimates. We then examine price deviations using a more refined approach that resolves these issues.

Chapters 2 and 3 show that price-value deviations can indeed be explained rationally, in part. Unfortunately, the analogy between market prices and firm value predictions only works up to a certain extent. Expectations of future value are generated by a range of processes that are mostly unobservable, and we will see in Chapter 3 that the price-value residual remains subject to noise. This indicates that share prices can deviate from fundamental value without economic justification, which is inconsistent with the rational expectations hypothesis – in other words, market prices could erroneously deviate from fundamental value. Particularly in Chapter 4, we review several studies that provide empirical evidence for both theories.

These mixed findings are reflected in the names that previous studies have assigned to the price-value difference, which depend on the perspective that is taken[1]. Those assuming expectations to be rational, for instance, would call it real options, growth options, or the present value of growth opportunities. Those regarding the difference as erroneous would call it mispricing, over or underpricing, or a pricing error. Trying to take a neutral position, I will call it a price residual or value residual in this book.

We re-examine price residuals in Chapter 4 in order to remove some of the ambiguity. In this chapter, we distinguish between the two explanations for why market value deviates from fundamental value: either by (correct and rational) expectations of future growth opportunities, or by shareholders who pay too much for their shares. This distinction is made against a backdrop of mergers and acquisitions, since previous research has documented large differences between market value and fundamental value for both acquirers and targets. These deviations can be explained by either rational or irrational expectations, and empirical evidence has provided mixed support for both explanations. We jointly consider both by disentangling growth opportunities from mispricing, and it turns out that both explanations are important to explain these price residuals. In Chapter 4, we argue that bidders deviate from fundamental value because their equity is overpriced, while targets deviate from fundamental value because they contain substantial growth opportunities. This indicates that firms bid for other firms if they have less growth opportunities than their share price suggests, and select targets that increase their growth options.

A completely different approach is taken in the final chapter. If we assume that investor expectations are correct, so that the difference between market price and fundamental value can be interpreted as an aggregated portfolio of investment opportunities. This portfolio has synergy and risk characteristics that are determined by co-movement and interactions between these opportunities. In Chapter 5, we model co-movement of a new project with an existing portfolio, in order to investigate the intricacies of risk diversification if two or more projects interact. We analyze how these interactions affect the total risk of a portfolio, and show that this relation is different from what one would expect. We present a methodology that can be used to correctly calculate portfolio risk, and derive several

[1]In fact, the views on how to precisely measure price-value divergencies is equally inconclusive, and ranges from market-to-book and price-earnings ratios to R&D expenses. As can be seen in the following chapters, I have also (quite arbitrarily) used different definitions over the years.

insights that are relevant to project development under uncertainty.

Chapters 2, 4 and 5 are currently being considered or have been accepted for academic publication. Because Chapter 5 is reasonably self-contained, the remainder of this chapter is an introductory background to Chapter 2, Chapter 3 and Chapter 4. In a sense, the next sections contain information that enhanced my understanding of the topic, but were irrelevant for submission to academic journals. First, Section 1.2 conveys the theoretical link behind the value–price difference and future investment opportunities. This provides background for Chapter 2 to Chapter 4. Next, in Section 1.3, I will elaborate on the endogeneity problem and explain why traditional estimation techniques are inappropriate. These sections can be skipped to the reader's convenience. Finally, Section 1.4 will give a plot summary of each of this book's chapters.

## 1.2 Residual Value: Theory

Defining market value in excess of fundamental value as "growth value", Miller and Modigliani (1961) extend the dividend-discount model to account for price–value differences. Using deterministic investments, earnings and discount rates, they decompose firm value into two parts: the value of maintaining current earnings and the value of future growth opportunities.[2] In other words, Miller and Modigliani isolate perpetual net profit creation from *previously* invested capital from the present value of *future* growth opportunities. Their model implies that a firm is not rewarded to be innovative by merely expanding – however large the growth in assets may be, the value of growth will be zero if the return on investment equals the discount rate.

More recently, however, it is shown that uncertainty and managerial flexibility are important for the value of future investment opportunities. The value of uncertainty gained importance after the canonical contribution of Black and Scholes (1973): a manager's decision to invest or not could resembles a call option that could now be analyzed in

[2] Miller and Modigliani (1961) represent the value of firm $i$ at time $t$, $t > 0$, as a perpetual function of its future earnings $X_{it}$ and investments $I_{it}$, all discounted appropriately. They specify equity value as $V_{i0} = \sum_{t=0}^{\infty} [X_{it} - I_{it}] (1+\rho)^{-(t+1)}$, where $\rho$ is the discount rate. For ease of notation, we drop the subscript $i$. By defining the time-varying profit rate $\pi_t$, intertemporal profits can be modeled as $X_t = X_0 + \sum_{\tau=0}^{\infty} \pi_\tau I_\tau$. After substituting this back into the value function, the result can be simplified to $V_0 = \frac{X_0}{\rho} + \sum_{t=0}^{\infty} I_t \frac{\pi_t - \rho}{\rho(1+\rho)^{t+1}}$.

closed-form. I found the following interpretation of the value-price residual by Berk, Naik en Green (1999) insightful. I have limited their framework to include only the features that are relevant for the purpose of linking the price residual to future growth opportunities.

Consider an investment $I$ in a project. At date $t$, the cash flows $C_j(t)$ from a project that was undertaken at date $j < t$ are assumed to follow some exogenous process. Since projects may die suddenly, define a set of indicator variables $\{\chi_j(t), t > j\}$ which are equal to 1 if the project that is undertaken at time $j$ is still alive at time $t$, and zero otherwise. The price at date $t$ of a random cash flow $C(t)$, delivered at date $T > t$, is assumed to be given by the stochastic discount factor $\mathbb{E}_t\{[z(T)/z(t)]\,C(T)\}$, governed by a second exogenous process. The value of a single project can then be represented as

$$V_j(t) = \mathbb{E}_t\left[\sum_{s=t+1}^{\infty}\frac{z(s)}{z(t)}C_j(s)\chi_j(s)\right].$$

Next, future investment opportunities ($V_j^*$) enter the model as the option to invest in such projects. The option represents a choice: managers may choose to invest (in which case the firm earns future project value $V$ minus investment $I$), or not (in which case the value of the future project is zero). Hence:

$$V^*(t) = \mathbb{E}_t\left[\sum_{s=t+1}^{\infty}\frac{z(s)}{z(t)}\max\left[V_s(s) - I, 0\right]\right].$$

Finally, the equity value of the firm ($P$) equals the value of cash flows that stem from existing projects and the value of future investment opportunities that could be undertaken:

$$P(t) \equiv \sum_{j=0}^{t} V_j(t)\chi_j(t) + V^*(t). \tag{1.1}$$

Hence, the value residual can be interpreted as the value of growth opportunities. This definition incorporates uncertain project survival, stochastic cash flows and a stochastic discount factor with option mechanics (i.e., the max-operator). In their model, Berk et al. split firm value into a profit-based component that is based on *past* investments and a component that is related to *future* decisions. For the purpose of valuation, it can also be shown that the feature of randomly terminating projects is equivalent to assuming that expected project cash flows depreciate at a rate $\Delta = -\log \pi$. In this definition, $\pi$ represents the probability that $\chi_j(t+1) = \chi_j(t)$, and $1-\pi$ represents the probability that $\chi_j(t+1) = 0$.

## 1.3 Residual Value: Empirics

The decomposition in Eq. (1.1) depicts a framework that can be used for estimation. Eq. (1.1) can be quantified, because equity value ($P$) is observable and the first right-hand-side term is found by discounting a profitability measure (e.g., operating cash flows, reported earnings, earnings forecasts or net operating profits) using a predetermined discount rate $\Delta$. It follows that residual value $V^*(t)$ can be backed out from Eq. (1.1).

Since the above interpretation provides a rational explanation for the price–value residual that can be measured empirically, many previous studies have used the decomposition to add economic rationale to empirical facts. For instance, Eq. (1.1) lies at the core of explaining size and value anomalies in asset returns in Berk et al. (1999). Using a similar approach, a complementary explanation for the same asset pricing anomalies is offered by Carlson, Fisher and Giammarino (1999). Estimating Eq. (1.1) directly through different proxies for $\sum_{j=0}^{t} V_j(t)\chi_j(t)$, financial research has also found economic explanations of systematic risk (Chung and Charoenwong 1991), abandoning a firm for its liquidation value (Berger, Ofek and Swary 1996), the pricing of initial public offerings (Chung, Minsheng and Yu 2005) and the time trend of idiosyncratic risk (Cao, Simin and Zhao 2006). Similar progress has been made with regard to issues in strategic management, including (but not limited to) the decision to acquire additional equity (Folta and Miller 2002), the decision by established firms to enter a new industry (Folta and O'Brien 2003), the timing of market entry (Miller and Folta 2002), the downside risk of multinational operations (Tong and Reuer 2008) and the value of international joint ventures (e.g. Tong, Reuer and Peng 2008b). These studies all build on Eq. (1.1), and find results that are consistent with this notion. However, the assumption of real options and growth options value being analogous is empirically untested. Furthermore, as we will see in Chapter 2, it is not immediately clear which causes what.

**Endogeneity Issues.** For instance, while more options may increase firm value through investment opportunities, more firm value can also increase option value through increased volatility. Because options are a levered position in the underlying asset, the market-to-book ratio is higher for stocks that contain substantial real options, and causes volatility to always be higher as well. Hence, the growth option–volatility relationship is endogenous – do risky and option-like investments enhance future growth opportunities, or does option leverage increase volatility without any changes to the investment opportunity set?

When analyzing the relation between residual value and investment as in Chapter 3, a similar problem arises. Investments in, for instance, research and development are expected to increase the price-value residual, because equity investors should appreciate future discoveries that are not yet reflected in earnings. At the same time, managers may cut on R&D investments if their stock performs poorly because the firm becomes more financially constrained, or increase R&D spending when the stock performs well. Such endogeneity problems favorably bias the results and potentially lead to spurious results.

One possible solution is the introduction of a lagged dependent variable, which controls for the effect of a large price-value residual on volatility (Chapter 2) and investment (Chapter 3). Including lagged residual value ensures that current volatility or intangible investments are unaffected by last year's market valuations. Because it takes time to make something happen, any effect on the dependent variable can now safely be attributed to the explanatory variables. After a small adjustment in notation, the data-generation process for firm $i$ in year $t$ can thus be summarized as follows:

$$\begin{aligned} V_{it}^* &= \alpha V_{it-s}^* + \beta X_{it-\tau} + \varepsilon_{it}, \\ \varepsilon_{it} &= \mu_i + \upsilon_{it}, \\ \upsilon_{it} &= i.i.d., \end{aligned} \tag{1.2}$$

where $V_{it}^*$ represents residual value for firm $i$ at time $t$, and $\alpha$ and $\beta$ are vectors of coefficients. The size of these vectors depends on the number of regressors $X$. Finally, $s \subset \{1, 2, ...\}$ and $\tau \subset \{0, 1, ...\}$ are time lags. This approach is extensively discussed and demonstrated in Chapter 2 and Chapter 3. While this approach should solve endogeneity issues, it also introduces new estimation problems. We will first discuss these problems, and then show how they can be resolved.

**Estimation Problems.** Including a lagged dependent variable $V^*_{it-1}$ could generate inconsistent results because an increase in residual value at time $t$ (which enters as a regressor at $t+1$) will automatically lead to a decrease in the residual in the successive time period. This causes regressors to be correlated with $\varepsilon_{it}$ through $\upsilon_{it}$, and ordinary least squares (OLS) or fixed-effects panel estimates to be inconsistent. Additionally, as ordinary least squares will wrongly assign impact of unobserved effects to the lagged dependent, the strong relationship between lag and error would render inconsistent results. Nickel (1981) shows how an increase in $V^*_{it}$ also increases the fixed effect for that firm. As a consequence, in the next period $t+1$, both $V^*_{it-1}$ and the fixed effect are higher, which is a source of positive correlation between regressors and the residual, and which causes OLS to be biased upward. A related problem arises when left-out variables are correlated with any of the regressors. For instance, residual value is complementary to intangibles, which are persistent and firm-specific value drivers that are mostly positively correlated with capital quantity. This too causes regressors to be positively correlated with $\varepsilon_{it}$.

To solve the problem of regressors correlated with $\varepsilon_{it}$, consistent estimates can be obtained using lags to instrument regressors. Exploiting the panel structure, we may use lags $t-2$ and beyond as instruments because lags are correlated to current values, but not to the error term. A potential solution is a specification that eliminates fixed effects. For instance, it is common practice to transform Eq. (1.2) by subtracting the time series mean, which gets rid of fixed effects and yields the Within Groups estimator. With lagged endogenous variables on the right-hand side, however, time averages lead to a downward bias: if $V^*_{it-1}$ increases, then necessarily $\upsilon_{it-1}$ goes down and enters the equation through $\bar{\upsilon}_i = \frac{1}{(T-1)}(\upsilon_{i1} + ... + \upsilon_{iT-1})$ (Bond, 2002). As a result, disturbances for all periods are introduced in the error term $(\upsilon_{it} - \bar{\upsilon}_i)$ that are correlated with regressor $V^*_{it-1}$. Therefore, Arellano and Bond (1991) eliminate fixed effects by estimating Eq. (1.2) in first differences. This approach is used in Chapter 2.

It has been shown, however, that differencing may lead to weak instruments in some cases, for instance if the panel is "short" and the number of observations per firm is small

(Blundell and Bond, 1998). In Chapter 3, for instance, lagged investments are poor predictors of contemporaneous investment and differences are non-informative. An alternative solution is offered by Arellano and Bover (1995) and Blundell and Bond (1998). While the Arellano and Bond use lags as instruments after purging the estimation equation from fixed effects, Arellano and Bover add an additional set of instruments. This is done by differencing the instruments as well, making the instruments independent of fixed effects. This approach is used in Chapter 3.

**A Suggested Solution.** Estimates using instrumental variables, introduced above, can be obtained by two-stage least squares (Anderson and Hsiao, 1982). Arellano and Bond (1991) instrument explanatory variables using the Generalized Method of Moments (GMM), however, because GMM is better equipped to model complex error structures that arise from heteroskedasticity and autocorrelation. GMM assumes an orthogonality condition (the moment) to be true, which is a fairly mild and flexible assumption. OLS, for example, is based on the condition that all errors are orthogonal to the right-hand variables, or $\mathbb{E}\left[x_i(y_i - x_i\beta)\right] = 0$. GMM calculates this product for each observation, takes a sample average and estimates $\beta$ by making the average as close to zero as possible.

I found it illustrative to examine what this exactly entails for the univariate case and a panel of three time periods (we set $t = 1, 2, 3$ to allow for differencing and an exogenous lag). Ignoring all exogenous regressors and including only the lagged version of $V^*$, the moment condition that goes with the Arellano and Bond approach is $\mathbb{E}\left[V_{i1}^* \hat{\varepsilon}_{i3}\right] = 0$. The (now scalar) parameter $\alpha$ can be found by the GMM estimator after minimizing the quadratic form

$$Q_N(\alpha) = \left(\frac{1}{N}\sum_{i=1}^{N} V_{i1}^*(V_{i3}^* - \alpha V_{i2}^*)\right)^2 \sigma_{\mathbf{N}}^{\mathbf{-1}},$$

where we have substituted $\varepsilon_{it}$ to include the parameter $\alpha$ in Eq. (1.2). The moment conditions' standard error $\sigma_{\mathbf{N}}^{\mathbf{-1}}$ is a scalar in this example, but becomes a variance-covariance (VCV) matrix when instruments increase or when explanatory variables are added. It reflects confidence in each moment-matching condition: a high variance or strong correlation between two conditions leads to a smaller weight.[3] If models have autocorrelated

[3] In subsequent chapters, we use Windmeijer (2005) corrected standard errors for $\sigma_{\mathbf{N}}^{\mathbf{-1}}$ that correct for

disturbances and instruments are likely to be heteroskedastic, it is this weighing matrix that is an important advantage over two-stage least squares estimation. In System-GMM, additional moment condition are used, defined as $\mathbb{E}\left[\Delta V^*_{it-1}\varepsilon_{it}\right] = 0$ for each $t \geqq 3$, where the expectations operator is taken over $i$:

$$Q_N(\alpha) = \left(\frac{1}{N}\sum_{i=1}^{N} \Delta V^*_{i2}(V^*_{i3} - \alpha V^*_{i2})\right)^2 \sigma_{\mathbf{N}}^{-\mathbf{1}}.$$

This is a valid moment condition because the first term $\Delta V^*_{i2}$ is observed, whereas the second is an expectation. This holds if the fixed effect and $\alpha$ offset each other in expectation across the whole panel.

## 1.4 Main Findings

In Chapter 2, we analyze the conventional approach to estimate residual value, and use the methodology from the previous section to gauge the validity of the residual. We find that residual value can be significantly explained by growth opportunities. In Chapter 3, we assume that residual value is *exclusively* explained by growth opportunities, in order to estimate intangibles. We find that this is problematic. In Chapter 4, we therefore allow residual value to be partly erroneous, and partly explained by growth opportunities. We find that this works well in the context of mergers and acquisitions. In Chapter 5, we take a more theoretical approach, in order to examine how the risk of a growth options portfolio changes when correlation increases or decreases. To further explain how these studies are interrelated, I present a short summary of these chapters.

Chapter 2 shows why conventional estimates of residual value may be inconsistent, and suggests a different estimation methodology. Contradicting previous work, it is shown that the effect of idiosyncratic risk on growth options is much stronger than the effect of residual value on idiosyncratic risk. As a demonstration, this method investigates whether the measure for residual value in Eq. (1.1) is truly analogous to a portfolio of real options. Specifically, we test whether systematic risk, idiosyncratic risk, skewness, R&D investments, size, book-to-market, leverage and industry effects have an effect on the value–price

small sample bias.

residual, similar to real options. It is found that this is generally the case, so that residual value contains a significant real growth options value component.

Chapter 3 reverses the argument: if the price residual contains significant growth value, we might also use the residual to approximate the growth potential of investments. In collaboration with The Conference Board, we take this approach to generate more robust and reliable estimates of the impact of intangible capital on firm value. Under current U.S. accounting principles, intangible investments are considered expenses instead of investments, and the costs involved are expensed instead of capitalized. This is an example of the *ex ante/ex post* dichotomy in Section 1.1: intangibles do not appear on the balance sheet, but intangible investment outlays are incurred to create future value. To quantify the link between (forward-looking) residual market value and (backward-looking) intangible investment, we compare the extend to which intangible investments are capitalized between sectors and countries. Consistent with previous literature on innovation and market value, we find that important differences exist between industries, and between countries for each given industry. However, our approach does not deliver more robust and reliable estimates. This indicates that price residuals only partly consist of rational expectations about future growth.

Building on this insight in Chapter 4, we decompose the price residual into a growth value component and a mispricing component. This proves a useful distinction in the context of corporate takeovers, since growth opportunities and overpriced equity are both valid explanations in previous literature. By allowing both growth options value and mispricing to coexist, we show that both explanations play an important, but distinct role in takeovers. It is found that takeover activity increases when bidders are more overpriced. Furthermore, a high market value for bidders is primarily due to mispricing, while a high market value for targets is primarily due to growth options. This indicates that bidders tend to buy targets with a lower overpricing component and higher fundamental growth option value, in order to cushion against a downward price correction.

In Chapter 5, we examine how the risk of two milestone projects can be diversified, in order to minimize the risk of a portfolio. Milestone projects have a payoff structure that is similar to a call option, in that the project's payoff is conditional on some criterion. Conditionality limits losses for projects in isolation when, for instance, a drug development project is scaled up if (and only if) test results are favorable. However, it is unclear how conditionality affects the sharing of risk between two or more projects. It is demonstrated that conditional projects limit diversification benefits when projects are negatively correlated, but increase diversification benefits when projects are positively correlated. In essence, the sensitivity of portfolio risk to correlation is smaller for conditionally financed (typically high-risk) projects than for unconditionally financed (typically low-risk) projects. This implies that diversification not always eliminates risk as one might expect, and that conditionalizing projects is at times more effective. Furthermore, *not* diversifying conditional projects is less dangerous as one might expect it to be.

# Chapter 2

# Interpreting Residual Value

*Positive residual value exists when market value exceeds the value of assets in place, and this chapter examines whether the residual can be attributed to growth opportunities. We comprehensively re-examine and extend the empirical framework of previous studies on growth opportunities, and use instrumental variables to overcome methodological problems. Our evidence suggests that residual value behaves consistently with real option theory: it is positively related to R&D investments, systematic volatility, firm-specific volatility, and market-to-book; and negatively related to size, leverage and competition. While this does not imply that growth opportunities can be measured without error, we conclude that the price residual can be significantly explained by growth opportunities.*

## 2.1 Introduction[1]

Firm market value typically contains a residual component, as stock prices generally exceed the value derived from discounted cash flows under a no growth policy. Because the value of assets in place is based on a zero or constant growth assumption, it is often assumed that a positive residual stems from future growth opportunities. Hence, the price residual or value residual (both terms are equivalent) is often interpreted as a "growth value" component that follows from investment projects that the company *might* undertake. Such opportunities have a conditional and prospective nature similar to a portfolio of real options (e.g., see Pindyck 1988).

The residual value–growth options analogy provides deeper insights into a number of empirical observations. For instance, empirical research has explained a wide range of phenomena such as the impact of systematic risk (Chung and Charoenwong 1991), abandoning a firm for its liquidation value (Berger et al. 1996), the pricing of initial public offerings (Chung et al. 2005) and, interestingly, the time trend of idiosyncratic risk (Cao et al. 2006)[2].

While previous work assumes this analogy to hold, there is very little evidence of an actual link between option-like behavior and residual value. This could be explained by complex issues that arise when carefully examining this link. First, estimating the causal relationship between residual value and idiosyncratic risk is often complex. For instance, the implicit leverage effect of growth options leads to high idiosyncratic risks in future project value, while higher idiosyncratic risk of the (conditional) project cash flows amplifies option value as well. Second, we note that option value increases by the options on future investment opportunities, as well as by the embedded options of the firm's assets. Third, abandonment options, IPO pricing, and market or specific firm volatility are likely to be affected by unobserved factors that vary over time and between firms, which complicates their relationship with growth option value.

This chapter comprehensively examines whether the value residual is an option-like

[1] This chapter is co-authored with Han Smit, and drawn with minor editing from a working paper entitled "Growth Value in Price Residuals".

[2] The approach has also been popular among management scientists, who have explained issues such as the timing of market entry (Miller and Folta 2002), the downside risk of multinational operations (Tong and Reuer 2007) and international joint ventures (e.g. Tong et al. 2008).

component of firm value, by testing the assumption that residual value has properties similar to a portfolio of real options. Resolving endogeneity issues, we relate the value residual to security return characteristics and find that all these characteristics affect the residual as predicted by real option theory. Specifically, the value residual is positively related to R&D investments, systematic volatility, firm-specific volatility, and market-to-book; and negatively related to size, leverage, and competitors' residual values. We conclude that the value residual indeed contains an option-like component, and important growth opportunities.

The remainder of this chapter is organized as follows: Section 2 introduces the option component in share prices and links the residual to real options characteristics that should be present in returns. Section 3 explains how unobserved heterogeneity can lead to a spurious relationship, formalizes the problem in a simple framework and proposes an empirical specification that is robust to this problem. Section 4 describes the data and variables used in our empirical analysis. Section 5 demonstrates how instrumental variables change the result by Cao et al. (2006), and provides evidence that residual value behaves analogously to a portfolio of real options after empirical issues are resolved. Section 6 concludes.

## 2.2 Literature Review

Myers (1977), Pindyck (1988) and Berk et al. (1999) show that the stock price can be divided into two value components, each with a distinctly different nature – the expected value of the assets in place, and the value of future growth opportunities. Their line of argument was explained in the introduction, and leads to an interpretation of equity value as the value of cash flows that stem from existing projects and the value of future investment opportunities that *could* be undertaken:

$$P(t) \equiv \sum_{j=0}^{\infty} V_j(t)\, \chi_j(t) + V^*(t)\,, \tag{2.1}$$

where $P(t)$ is the equity value of the firm, and $V_j(t)$ the value of a project at date $j < t$. Since projects may die suddenly, Berk et al. define a set of indicator variables $\{\chi_j(t)\,,\ t > j\}$ that are equal to 1 if the project undertaken at time $j$ is still alive at time

$t$, and zero otherwise. The second term, $V_j^*(t)$, is the value of the option (not the obligation) to invest in such projects in the future. We will refer to $V_j^*(t)$ as "residual value." More recently, Carlson et al. (2004) derive similar results via alternative reasoning. According to their definition, residual value is prospective and consists of investments that the company could make, rather than the results of past decisions (Hevert et al., 1998).

Derived from "an uncertain future in which management may adapt and revise decisions as the future unfolds" (Merton 1988), the option component $V^*(t)$ should be related to well-known real options characteristics such as firm-specific volatility, systematic volatility, R&D investments, and skewness, after controlling for other measures that might affect the proportion of growth options to the firm. These controls include size, market-to-book, leverage, and industry competition. If the assumption holds that financial markets perceive the implied residual value of a firm as a bundle of real options, we expect similar effects on the present value of growth opportunities. The range of real options characteristics are summarized in Table 2.1, along with the expected effects on residual value. In the remainder of this section, we thoroughly discuss the impact of these characteristics on residual value, which is sometimes complex. For instance, idiosyncratic volatility and market volatility have a complex relation with a firm's option value, as each affects both the equity option on a firm's assets and the growth options that constitute a firm's investment opportunity set. Moreover, for these characteristics, unobserved heterogeneity is an important problem and the direction of causality is ambiguous. We will discuss the consequences of endogeneity at greater length in Section 3.

**Idiosyncratic Volatility.** Cao et al. (2006) argue that the equity option on a firm's assets is positively related to idiosyncratic risk. Managers of levered firms select investment projects that are likely to increase the idiosyncratic variance of the firm, at the expense of debt holders. At the same time, causation may also run in the opposite direction, since equity is a call option on the value of the firm. The (total) volatility of equity is likely to be higher due to financial leverage, which is a function of the moneyness of the option to default. While the equity value itself can be viewed as an option on the firm's assets, the assets themselves contain future growth opportunities.

Table 2.1: Key Characteristics of Growth Options

| **Variable** | **Expected Sign** | **Description** |
|---|---|---|
| *Residual Value* | *N/A* | The residual share of market value. This definition is assumed to proxy growth options. It is thus closely related to the market-to-book ratio, but should separate more specific growth options value from the value of assets in place. |
| *R&D/Sales* | + | The portfolio mix of growth options. The more growth options generated through innovation, the larger the growth options share of firm value. It is estimated as research and development expenses, normalized over sales. |
| *Systematic Volatility* | +/ - | Market volatility of stock returns. The strategic, input cost or commercial uncertainty of projects is reflected in market uncertainty of the firm's stock returns. The market uncertainty is estimated as the standard deviation of fitted values from the Fama and French (1993) three factor model, or a one-factor market model. |
| *Idiosyncratic Volatility* | + | Firm-specific volatility of stock returns. By definition, a favorable shock to a firm's profitability is not shared by its competitors. Firm-specific volatility is estimated as the standard deviation of residuals from the Fama and French (1993) three factor model, or a one-factor market model. |
| *Skewness* | + | The skewness of the return distribution is related to the value share of growth options. Firms with more skewed distributions generate more growth opportunities and have higher residual value. It is estimated over a fiscal year's daily returns. |
| *Log of Size* | - | We control for the explanatory power of size (see Fama and French 1993, Knez and Ready, 1997). Defined as ln(book value)$\times 10^{-3}$. |
| *Asset Market-to-Book* | + | Controlling for a firm's market-to-book ratio ensures that the correlations we find for residual value are not due to correlations between average Q or market-to-book and the other variables. Defined by Cao et al. (2006, see text). |
| *Leverage* | - | Since we proxy uncertainty using firm-specific and systematic measures of volatility, we control for uncertainty, induced by the firm's financial leverage. Firms operating with a high proportion of growth opportunities have lower debt capacity due to the intangible and uncertain nature of growth options. Definition by Baker and Wurgler (2002, see text). |
| *Competitor's Residual Value* | - | A positive industry-wide shock to profitability (i.e. market value) needs to be shared with competition. This measure ensures that we measure a firm's capabilities to deal with shocks vis à vis its competitors. Defined by Tong et al. (2008, see Section 4.5). |

In addition to the equity option, option value also stems from growth opportunities. Since management can flexibly respond to firm-specific shocks, returns are a convex function of the shock and an increase in uncertainty leads to more option value. In previous empirical work, Chan et al. (2001) positively relate firm-specific risk to R&D expenditures, and Vassalou and Apedjinou (2004) find that firm-specific risk is related to an alternative measure for innovation. Cao et al. (2006) argue that, since R&D and innovations could generate real options, so can unsystematic risk be related to real options. Berk et al. (2004) show that new ventures typically have multiple stages, and that idiosyncratic R&D uncertainty leverages up market uncertainty in the later stages of development. At the same time, causality also works in the opposite direction: the volatility of these stocks is higher due to the implicit leverage effect of growth options, which amplifies the uncertainty of the underlying value of the equity options. Therefore, it is expected that firm-specific uncertainty raises residual value, and residual value raises firm-specific uncertainty.

**Market Volatility.** To examine the effect of market volatility on the equity option on a firm, we also use the Galai and Masulis (1976) model, similar to Cao et al. (2006). In Section 6.1, we demonstrate that systematic equity risk $\beta_S$ can be seen as a function of option parameters with the partial derivative $\frac{\partial S}{\partial \beta_S} < 0$. This indicates that the value of the equity option on the firm increases when systematic risk decreases, and is inversely related to market risk. Again, and for the same reasons as above, reciprocal causality occurs due to the effect of financial leverage on the option to default.

The impact of systematic risk on the equity option stands in contrast to its documented impact on the growth option of a firm. In previous literature, systematic risk increases if the proportion of growth options increases (e.g. Berk et al., 1999; Carlson et al., 2004). Also, the effect of a firm's residual value on beta proves to be positive (Chung and Charoenwong, 1991), and firms with a substantial growth component have higher betas (Jaquier et al., 2001). A higher rate of return is positively related to a firm's covariance with the market, which lowers the incentive to invest (Craine, 1989). Similarly, aggregate demand- and input cost uncertainty have a positive influence on option value. On the other hand, a higher rate of return decreases the value of the underlying asset, decreasing the value of all options that are 'written' on it, and Chen et al (1986) and Ben-Horim and Callen (1989) argue that Tobin's Q and the market beta of equity are inversely related due to market power considerations. Furthermore, causality works in the opposite direction as well, due to the implicit leverage effect of growth options.

We conclude that the sign of the market volatility on the proportion of residual value is debatable. This is consistent with Sarkar (2003), who shows that growth options reduce the overall beta of the firm only if the growth rate of a project exceeds the risk-adjusted discount rate, and Berk et al. (1999), who argue that systematic risk changes over time as growth options are exercised.

**R&D Investment Rate.** Firms with a low R&D-to-sales ratio derive most of their equity value from directly measurable cash flows of current operations and simple commercialization options. Corporations with a high R&D-to-sales ratio are more involved in exploration opportunities with multi-stage or compounded options, and create value before undertaking the project. For this reason, R&D is routinely included as a control variable for growth opportunities in many studies. The positive relationship has been widely empirically confirmed (Chan et al, 2001; Long et al., 2005, Smit, 2000; Vassalou and Apedjinou, 2004). We thus expect corporations with more exploratory investments in R&D to have a higher share of residual value in the investment portfolio.

Causality also runs in the opposite direction, however. An inflow of equity capital not only increases residual value, but also loosens financing constraints that have prevented the firm from investing in projects that do not immediately generate profits. An increase in residual value, therefore, may also induce more R&D investment.

**Skewness.** From previous findings on investor preferences, it is known that investors are willing to accept a lower average expected return if it is skewed positively (Harvey and Siddique, 2000). Consistent with this study, Coval and Shumway (2001) find that considering their systematic risk, both call and put options earn exceedingly low returns. Real options theory suggests that lower returns are rational in exchange for a positively skewed risk-return profile: the higher moments of the distribution of a firm's returns reflect the choice mechanism of a business strategy, particularly if growth opportunities contribute a significant proportion of equity value relative to the value of assets in place. Optimal investment in uncertain markets implies that losses are truncated while gains are not, and each growth option introduces an asymmetry similar to the value of a call option. When financing rounds are conditional, the downside is limited further when the number of financing rounds (stages) increases. We conclude that the skewed nature of a call option introduces positive skewness in the stock's return distribution[3].

**Leverage.** Through the option to default by equity holders, there are important interactions with leverage and growth option value. Due to this contingent claim nature of equity, equity holders only have limited liability while they are entitled to claims if the upside potential of projects is realized. In contrast, debt holders bear the risk of bankruptcy while their payoff cannot exceed the initial debt repayment plus interest. Therefore, more risky projects tend to be financed by equity whereas debt is more common for projects with predictable cash flows. It follows that growth firms have less deb,t and leverage is expected to have a negative effect on the equity value of growth options.

**Size.** Option value decreases with firm size because small firms are have few direct, measurable cash flows. Large firms spend a larger portion of capital on simple options while growth stocks have a more explorative nature that results in a higher portfolio mix of multistage, or compound, real options. Therefore, holding small firms will likely lead to a few major successes and many minor disappointments (Knez and Ready, 1997). Small firms also tend to have a longer investment horizon which increases option maturity. Finally, as firms mature, residual value decreases relative to assets in place. The share of residual value is therefore negatively related to size.

As noted above, there are important interactions with leverage (the option to default) and residual value. Due to the contingent claim nature of equity, equity holders only have limited liability while they are entitled to claims if the upside potential of projects is realized. In contrast, debt holders bear the risk of bankruptcy while their payoff cannot

[3]Clearly, since returns are measured in percentages and vary between -100% and infinity, arithmetic returns are lognormally distributed and skewed positively by construction. For instance, a stock that goes from $10 to $5 in one month and back to its old price of $10 in the subsequent month will have returns of -50% and +100%. We control for 'skewness by contruction' by taking log-differenced returns.

exceed the initial debt repayment plus interest. Therefore, more risky projects tend to be financed by equity whereas debt is more common for projects with predictable cash flows. It follows that growth firms have less debt and leverage is expected to have a negative effect on residual value.

**Market-to-Book Value.** Firms with a higher fraction of their value invested in growth projects will have a higher residual value component because growth opportunities will be valued by the market, but will not add to book value or the value of continuing operations. The market-to-book ratio is used as the de facto measure of a firm's growth opportunities, but is known to measure other things (e.g. mispricing). Therefore, in addition to measuring growth options, the inclusion of market-to-book as a control variable ensures that the correlations we find for residual value are not due to correlations between market-to-book ($M/B$) and other variables, e.g., investor sentiment, outdated book values of assets, or certain types of intangibles unrelated to growth[4]. As far as the option element in $M/B$ goes, residual value is positively related to the $M/B$ value.

**Competitors' Residual Value** The growth options in an industry need to be shared with rivals, and one of the companies could appropriate a disproportional share of the new opportunities. By combining real options models with game theory, predictions of growth option value can be made for investors in evolving industries. Several studies provide an integrated analysis of how firms are able to preempt the growth options in an industry vis-a-vis its competitors; see Smit and Trigeorgis (2004) for an introduction. The basic premise of an option-game perspective is that the organization should pursue a strategic position with its investment path, or make committed investments of "assets in place" to become better equipped to capture and extract value from the industries options in an endogenous competitive setting. Consequently, competitive interactions erode option value, and the company's residuals are likely to be negatively related to the residuals of rivals.

[4]Examples of such intangibles include customer goodwill, employee morale and increased bureaucracy.

## 2.3 Understanding Residual Value

A common approach for estimating the impact of firm characteristics on growth options is to regress residual value on variables such as systematic risk (Chun and Charoenwong, 1991), abandoning a firm for its liquidation value (Berger et al., 1996), the pricing of initial public offerings (Chung et al., 2005) and the time trend of idiosyncratic risk (Cao et al., 2006). This section explains how cross-sectional estimation of residual value could lead to spuriously positive or spuriously negative results, and suggests an empirical approach that alleviates this problem using instrumental variables.

### 2.3.1 Empirical Problem

As an example of unobserved heterogeneity that could lead to spuriously negative results, consider two identical firms except for one's larger intangible capital base. Because of its superior ability to transform capital into valuable goods and services, each R&D project requires a lower investment outlay to create an equivalent amount of growth options value. If intangible assets are omitted from the specification, a regression of growth options value on R&D investment will spuriously indicate a negative correlation, because the amount invested is negatively related to intangible capital. Causation could also run in the opposite direction; as an increase in residual value loosens financing constraints by the inflow of new capital, managers might invest more when residual value rises. This especially holds for R&D projects, for which profits are uncertain, difficult to measure and may take years to substantiate.

As an example of unobserved heterogeneity leading to spuriously positive results, we take the correlation between growth options and total volatility of returns, which consists of idiosyncratic and market risk. It is well-known that volatility of the underlying asset affects growth option value. Due to the conditional nature of future projects, growth options are most valuable in uncertain markets. This uncertainty should eventually be reflected in idiosyncratic and systematic uncertainty around the company's stock prices. However, as options are a levered position in the underlying asset, volatility of stock returns should be higher for stocks that contain substantial residual value. If option leverage is omitted from the specification, a regression of growth options value on idiosyncratic risk will spuriously indicate a positive correlation, because option leverage is positively correlated to volatility. Furthermore, simultaneity bias exists; risky, high-growth, and option-like investments enhance a company's future growth opportunities and, at the same time, the implicit leverage of high growth options increases stock volatility.

We can generalize these examples in a simple analytical framework, demonstrating how standard orthogonality conditions are violated. We assume the existence of a public firm $i$ at time $t$, and let $x_{it}$ and $u_{it}$ denote observable and unobservable characteristics that determine how future cash flows are generated. Assuming a linear functional form, we summarize this relationship as

$$\sum_{s=t}^{\infty} V_{it,s}\chi_{it,s} = \beta_1 x_{it} + \gamma_1 u_{it} + \epsilon_{it}, \tag{2.2}$$

where $\epsilon_{it}$ measures an i.i.d. measurement error.

We know that a firm's capability to generate earnings ultimately determines market value. However, exactly how revenues are translated into operating income (and from there into firm value) is determined by operating leverage ($L_{it}$). Operating leverage is defined as the capitalized value of cash flows net of the capitalized costs of operating the assets. Therefore, operating leverage depends critically on $\sum_{s=t}^{\infty} V_{it,s}\chi_{it,s}$, $s \geq t$. Furthermore, like the value of current and future cash flows, $L_{it}$ is affected by characteristics that are partly measured by $x_{it}$ (e.g., operating costs) but are otherwise unobserved and included in $u_{it}$ (e.g., the amount of operational flexibility, which determines how easily $L_{it}$ can be adjusted). We represent this by the following relationship:

$$L_{it} = \theta \sum_{s=t}^{\infty} V_{it,s}\chi_{it,s} + \beta_2 x_{it} + \gamma_2 u_{it} + \upsilon_{it}. \tag{2.3}$$

Finally, it is well-known that high operating leverage introduces a larger exposure of a firm's assets to underlying economic risks (e.g., Lev 1974), which leads to significantly higher financial market returns (Carlson et al. 2004; Novy-Marx 2010). Therefore, operating leverage must affect the value residual, together with the vector of observed and unobserved firm characteristics. This is represented by:

$$V_{it}^{*} = L_{it} + \beta_3 x_{it} + \gamma_3 u_{it} + \eta_{it}. \tag{2.4}$$

From the logic above, it can be seen that $L_{it}$ represents an indirect link between $\sum_{s=t}^{\infty} V_{it,s}\chi_{it,s}$ and $V_{it}^{*}$. This follows from Berk et al. (1999) and Carlson et al. (2004), who use operating leverage to explain why the value of future cash flows translates imperfectly into prices, so that market value and fundamental value may diverge. Combining Eqs. (2.3) and (2.4), we can derive the following relation between market value and future cash flows:

$$V_{it}^{*} = \zeta\theta \sum_{s=t}^{\infty} V_{it,s}\chi_{it,s} + (\zeta\beta_2 + \beta_3)\, x_{it} + (\zeta\gamma_2 + \gamma_3)\, u_{it} + \zeta\upsilon_{it} + \eta_{it}.$$

After some simplifying re-arrangements, we observe the following regression specification:

$$V_{it}^{*} = a_0 + a_1 \sum_{j=s}^{\infty} V_{its}\chi_{its} + a_2 x_{it} + \varepsilon_{it}. \tag{2.5}$$

Eq. (2.5) is a specification commonly used in previous empirical literature, in which the value of growth opportunities is regressed on several observable covariates. From an empirical viewpoint, this has two important implications. First, any results in this form are clouded by the ambiguous direction of causality. Both future cash flows and operating leverage appear on both sides of the equations, sometimes explained by (un)observables and sometimes explanatory themselves. Second, the specification will yield consistent results in a cross-section of firms, as long as the error term $\varepsilon_{it} = (\zeta\gamma_2 + \gamma_3)u_{it} + \zeta\upsilon_{it} + \eta_{it}$ is uncorrelated with both $\sum_{j=s}^{\infty} V_{its}\chi_{its}$ and $x_{it}$. However, as can be seen from Eq. (2.2), the value of assets in place depends on a wide range of idiosyncratic contingencies that are not observed by the researcher. More specifically, consistent estimates can result only if the following condition is satisfied:

$$\mathbb{E}\left[\sum_{s=t}^{\infty} V_{it,s}\chi_{it,s} \cdot \varepsilon_{it}\right] = \mathbb{E}\left[(\beta_1 x_{it} + \gamma_1 u_{it})(\zeta\gamma_2 + \gamma_3)u_{it} = \gamma_1(\zeta\gamma_2 + \gamma_3)\sigma_{\upsilon}^{2}\right] = 0. \tag{2.6}$$

In other words, the expectation in Eq. (2.6) will be zero only if the assets in place, or both operating leverage and residual value, do not depend on unobserved firm characteristics ($\gamma_1 = 0$). Clearly, these conditions are easily violated. Specific to this study, this statement is equivalent to assuming that determinants of current *and* future cash flows are completely observed at time $t$. Alternatively, Eq. (2.6) requires that the link between assets in place and residual value does not depend on unobserved firm characteristics. It is probable that these assumptions will be violated, so that least squares techniques do not consistently estimate Eq. (2.4).

### 2.3.2 Proposed Solution

While previous work has relied on a fixed-effects estimator to solve the endogeneity problem, we expect unobserved heterogeneity $u_{it}$ to vary over time. The latter is important, since it is likely that sources of unobserved heterogeneity (such as intangible assets and option leverage) change over time in the firm's environment. We therefore extend this line of research by using instrumental variables that change over time as well. Additionally, instrumental variables enable us to include a lagged dependent variable - this resolves the causality problem as well. Since the natural instruments –the observed firm characteristics– are already included on the right-hand side of the valuation equation in Eq. (2.4), we use lagged observations of the right-hand side variables. We obtain consistent estimates by taking first differences and employing the Arellano and Bond (1991) estimator. This estimator also allows the inclusion of lagged residual value $V^*_{it-1}$ to determine causation, which is similarly instrumented.

More specifically, the option leverage effect is estimated by regressing residual value on idiosyncratic volatility. In order to investigate how growth options and volatility are related after establishing causation and dealing with unobserved heterogeneity, a simple specification suffices with the two variables of interest. To deal with the question of causality, we include current and lagged versions of the dependent variable, $V^*_{it}/P_{it}$. Because this variable will be constructed from return on equity ($ROE$) over four previous years (see below), we include four lags of $V^*_{it}$. We first regress volatility on residual value,

$$\sigma^I_{it} = \beta_1 \sigma^I_{it-s} + \beta_2 V^*_{it-\tau}/P_{it-\tau} + \varepsilon_{it}, \tag{2.7}$$

and then regress residual value on volatility,

$$V^*_{it}/P_{it} = \beta_1 V^*_{it-s}/P_{it-s} + \beta_2 \sigma^I_{it-\tau} + \varepsilon_{it}. \tag{2.8}$$

Lags are present in both equations, so that $\beta_i$ are column vectors whose size depends on the number of included regressors. We define lags and the error term as follows:

$$\begin{aligned} \varepsilon_{it} &= \mu_i + \upsilon_{it}, \\ \upsilon_{it} &= i.i.d., \\ s &= \{1,2,3,4\} \text{ and} \\ \tau &= \{0,1,2,3\}. \end{aligned}$$

In a similar vein, we can test the hypothesis that residual value is an option-like component of market values by the following equation:

$$\begin{aligned} (V^*/P)_{it} &= \beta_0 + \beta_1 (V^*/P)_{it-s} + \beta_2 LEV_{it} + \beta_3 SIZE_{it} + \beta_4 \left(\tfrac{R\&D}{SALES}\right)_{it-s} \\ &+ \beta_5 \sigma^S_{it-\tau} + \beta_6 \sigma^I_{it-\tau} + \beta_7 \bar{V}^{-i*}_{t-\tau} + \beta_8 SKEW_{it} + \textstyle\sum_{t=1966}^{2006} 1_t + \varepsilon_{it}. \end{aligned} \tag{2.9}$$

This equation regresses residual value on lagged residual value, leverage ($LEV$), size ($SIZE$), R&D investments ($R\&D/SALES$), market volatility ($\sigma^S_{it-\tau}$), idiosyncratic volatility ($\sigma^I_{it-\tau}$), industry-wide residual value ($\bar{V}^{-i*}_{t-\tau}$), and skewness ($SKEW$). Year dummies ($1_t$) are included to control for unobserved time-specific effects due to changes in interest rates, moneyness of the options, and maturity and volatility of the firm over time[5]. The lag structure and error term are defined as before.

Estimation uses two-step generalized method of moments (GMM) and finite-sample corrected standard errors (Windmeijer, 2005). We instrument lagged residual value, current and lagged volatility, and lagged R&D investments using further lags than those included in Eq. (2.9). As an initial (and liberal) rule of thumb in determining how many lags to include, we choose our instrument set so that the number of instruments is smaller than the number of firms. To more formally test whether our instruments are orthogonal to the errors, we report the Hansen $J$ - statistic, which consistently tests for overidentify-

[5]To conserve space, we do not tabulate dummy results.

ing restrictions when error terms are non-i.i.d. To check for first-order autocorrelation in levels, we apply the Arellano-Bond test for second-order autocorrelation to the differenced residuals.

## 2.4 Data and Variables

### 2.4.1 Data

Our sample includes common stocks (share code 10 and 11) listed on the NYSE, AMEX or NASDAQ exchanges in 1966 through 2006. We obtain daily and monthly stock trading data from the Center for Research in Security Prices (CRSP), and accounting data from COMPUSTAT. Daily factor returns and industry definitions are from Kenneth French's website. The sample for this chapter covers all non-duplicate merged CRSP/COMPUSTAT firm-year observations.

Our estimation procedure requires a set of several instruments for each firm-year observation. Because this instrument set is rather large to work with, we downsize our sample by imposing four conditions on the data. First, since firms are typically brought into the COMPUSTAT database with two years of historical data, the power of the book-to-market ratio explaining returns may be spurious (Kothari er al. 1995). Failed young firms may confer less valuable growth options, and we eliminate the first two years of CRSP/COMPUSTAT observations in our final dataset to prevent surviving young firms to bias our results favorably. Second, a minimum of four years of consecutive non-missing COMPUSTAT data is needed to construct our dependent variable. Third, we require firms to end their fiscal year in December, to make sure that the match between CRSP and COMPUSTAT is accurate. Finally, for our largest model, a natural restriction arises from our panel regressions, which can be run only on observations that contain non-missing data on R&D, sales, volatilities, skewness, size and leverage. By imposing these conditions, we estimate the largest model on a panel of appropriate size for our analysis, consisting of roughly 10,000 firm-year observations for about 1,000 firms.

As a more general remark, one inevitably faces a trade-off when matching security returns with accounting data. When COMPUSTAT data are matched to CRSP prices to calculate residual value at fiscal year end, accounting variables are not yet known[6]. On the other hand, using price data some months after the end of the fiscal year, when accounting data are available, will inevitably be more noisy. We choose to match accounting data with fiscal year end pricing data because our empirical setup will allow for the inclusion of current- and lagged return measures. This ensures us that a possible publication lag is properly captured by lagged regressors while keeping our measurements as clean as possible. Some effect may, however, spill over from one year to the next because differences between two years are no longer clear-cut.

### 2.4.2 Decomposing Share Price.

In traditional valuation models, value is created by the current assets that are sustained. The implied stock value therefore equals the present value of the expected future earnings per share discounted at the opportunity cost of capital. The latter, $r_i$, incorporates the risk of a project being terminated and is constant under the assumption of constant uncertainty and a hypothetical no-growth policy. Therefore, we quantitatively implement Eq. (2.1) as follows:

$$\sum_{j=0}^{\infty} V_j\left(t\right)\chi_j\left(t\right) = \frac{E_1}{1+r} + \frac{E_2}{\left(1+r\right)^2} + ... + \frac{E_H}{\left(1+r\right)} + \frac{r-g}{\left(1+r\right)^H} = \frac{E_1}{r}.$$

Here, $g$ is the earnings growth rate under regular investment, assumed zero, and $r$ is the opportunity cost of capital. The residual value $RV_{it}$ of firm $i$ at time $t$ can now be backed out from the value of assets in place $(\sum_{j=0}^{\infty} V_j\left(t\right)\chi_j\left(t\right))$ and market value $(P)$ , and is taken as a percentage of the firm's market value, $P_{i,t}$.

It is noted that the value of $V^*/P$ can be larger than one if earnings are negative, or smaller than zero when the market value falls below a firm's perpetual stream of earnings. Dividing $V^*$ by $P$ creates highly influential extreme values when the market value is negligible relative to its (absolute) earnings[7]. These outliers are without economic importance,

[6] For instance, Fama and French (1992, 1993) and many others resort to measuring returns from June of year $t$ to June of year $t+1$.

[7] It should be noted that the construction of $PVGO/P$ does not imply that values are restricted to be between zero and one: negative residual values may exist if the earnings perpetuity exceeds market value and if earnings are negative, $PVGO/P$ may become larger than one. Inconsistency due to truncated or censored data, therefore, is not an issue.

and become more prevalent in highly volatile industries and for firms in some form of distress. To limit their impact on our results, we trim the upper and lower 5% of $V^*/P$. This leads to the number of observations reported in Table 2.2, and adds to the robustness of the dependent variable by reducing sample variation in $V^*/P$ from $\sigma^2 = 457.72$ to $\sigma^2 = 48.740$.

### 2.4.3 Measuring Assets in Place

In the previous equation, $\sum_{j=0}^{\infty} V_j(t)\,\chi_j(t)$ is the capitalized value of earnings generated by the assets in place if the firm were to follow a hypothetical strategy of no growth and full pay-out of earnings. $E_{i,t}$ is the next-period estimated earnings from sustaining current operations, which can be estimated in a variety of ways. Results of estimating long-term value, however, are sensitive to earnings, which are volatile and can be smoothed at the discretion of management. This can be resolved for long enough panels by time-averaging earnings, and two approaches are proposed in the literature by Trigeorgis and Lambertides (2006) and Long et al. (2005). We adopt the latter approach to facilitate comparison, since it has been re-tested and applied by Cao et al. (2006) .

In the Long/Wald/Zhang approach, earnings $E_{i,t}$ are estimated by multiplying common equity by smoothed return on equity (ROE). Common equity is estimated by the beginning period book value of long-term liability not including debt, i.e., total assets (d6) – current liabilities (d5) – preferred dividends (d19). The result includes the net shareholders' equity plus long-term liabilities such as deferred taxes. First, we estimate annual ROE by the operating cash flow divided by the beginning period book value of common equity. Second, we use previous four years' ROE to compute a weighted average ROE for year t :

$$R\bar{O}E_t = w_1 \times ROE_{t-1} + w_2 \times ROEt{-}2 + w_3 \times ROE_{t-3} + w_4 \times ROE_{t-4}, \tag{2.10}$$

where $w_1 = 40\%$, $w_2 = 30\%$, $w_3 = 20\%$, and $w_4 = 10\%$. This weighting scheme gives greater weights to more recent observations. In this procedure, ROE is defined as operating cash flow (d308) divided by common equity. Third, we calculate projected earnings by multiplying $R\bar{O}E$ by the end-of-period common equity. Observations with negative earnings are deleted.

Average earnings are discounted by the cost of capital, which is estimated using a CAPM model with an annualized one-month Ibbotson T-bill rate from Kenneth French's website. We estimate adjusted betas (Blume, 1975) over 24 or 60 monthly returns, using a value-weighted market portfolio and a constant market risk premium and controlling for size- and $M/B$ effects when estimating betas by the 3 factor regression, presented below in Eq. (2.11). As noted by Cao et al. (2006), using the required return on equity to proxy the cost of capital is appropriate if the probability of bankruptcy is low. In a different context, Kaplan and Ruback (1995) note that a pre-tax discount rate is appropriate for the riskiness of the cash flows, and that the weighted average costs of capital is more difficult to implement and requires additional assumptions about the firm's tax rates to generate cash flows assuming an all-equity capitalization.

### 2.4.4 Measuring Risk

From CRSP, we calculate log-differenced returns for our volatility- and skewness measures. Following, among others, Spiegel and Wang (2006), Ang, Hodrick, Xing and Zhang (2006, 2009), Cao et al. (2006) and Grullon, Lyandres and Zhdanov (2008), we estimate idiosyncratic risk for firm $i$ during fiscal year $t$ as the standard deviation of the daily residuals $\varepsilon_{i\tau}$ from the following 3-factor regression (Fama and French, 1993):

$$r_{i\tau} - r_{\tau}^{f} = \alpha + \beta_{1_{it}}(MKT_{\tau} - r_{t}^{f}) + h_{it}HML_{\tau} + s_{it}SMB_{\tau} + \varepsilon_{i\tau}, \tag{2.11}$$

where $r_{i\tau}$ is the return on firm i's stock during day $\tau$ , $r_{\tau}^{f}$ is the daily risk-free rate, $MKT_{\tau}$ is the daily return on the value-weighted market portfolio, and $HML_{\tau}$ and $SMB_{\tau}$ are the daily returns of high-minus-low and small-minus-big zero-investment portfolios. Market risk is estimated as the standard deviation of fitted values from this regression. Alternatively, we also estimate idiosyncratic risk and market risk from a standard, 1-factor CAPM model.

We consider size and value important determinants of growth opportunities, and we include these explicitly as explanatory variables for reasons mentioned earlier. However, size and value effects are also known to explain the cross-section of stock returns, and the definition of idiosyncratic- and market risk in Eq. (2.11) includes the value and size factors indirectly. If real options systematically explain size and value effects, it follows that the common definition of risk in Eq. (2.11) is inappropriate. We therefore estimate this model using a one-factor and a three-factor definition for idiosyncratic risk.

### 2.4.5 Other Variables

In our empirical analysis, R&D expenses (COMPUSTAT item 46) are scaled by total sales (COMPUSTAT item 12). Because R&D has long gestation lags and may take some time to create value, we include lags of R&D as well. We follow Xu (2007) and use daily log returns to calculate volatility and skewness using one fiscal year of daily observations. Skewness is the third-order centralized moment calculated as $E\left(x-\mu\right)^3/\sigma^3 = 1/n\sum_{t=1}^{n}\left(x_i-\bar{x}\right)^3/\hat{\sigma}_x^3$, where $\bar{x}$ and $\hat{\sigma}_x^3$ are the sample mean and standard error. Market leverage is defined as in Baker and Wurgler (2002) by 1 – market equity/market value, where the market value of assets is the market value of equity (CRSP price (COMPUSTAT item 25)$\times$ shares outstanding (item 199)) + book assets (item 6) – book equity (item 60) – deferred taxes (item 74). We define size as the log of total assets (COMPUSTAT item 6).We define market-to-book as (total assets (COMPUSTAT item 6)– total common equity (item 60) + market value) / book value, where market value equals the fiscal year-end closing price (item 199) times the number of shares outstanding (item 25).

Clearly, firm dynamics may differ widely across industries[8]. To control for industry effects, we use the average residual value for all *other* firms in the industry. This time varying, firm-specific variable enables us to estimate option characteristics for the aggregate economy while controlling for industry effects at a fairly precise level. Again, due to averaging earnings in measuring residual value, dependence is introduced between the four lagged values of residual value. As alluded to in Section 3.2, we control for this by including up to four lags of $V^*/P$ in our regression equations.

[8]For instance, firms in growth industries derive more value from the detection or creation of further valuable investment opportunities whereas in income industries, residual value stems primarily from simple commercialization options. Also, because of implicit leverage effects of options-on-options, growth stocks face higher firm-specific uncertainty than income stocks do.

## 2.5 Results

### 2.5.1 Average Option Characteristics

Estimated for the 1966-2006 sample period, we present some preliminary evidence using the (equal-weighted) industry averages of dependent and explanatory variables in Table 2.2, split into 12 Fama and French (1992) sectors and sorted on residual value. We see pronounced differences between firms with the highest and lowest $V^*/P$ values. Sectors with a high average residual value share include Business Equipment (Computers, Software, and Electronic Equipment) and Healthcare (Healthcare, Medical Equipment, and Pharmaceuticals), contrasted with low $V^*/P$ values in Energy (Oil, Gas, and Coal Extraction and Products) and Utilities. The table clearly shows that the former are the innovative industries.

From the $R\&D/Sales$ column, we can see that residual value is related to the option portfolio mix. It indicates that growth sectors invest more in innovation, as predicted by real option theory. Average R&D spending equals three times annual sales in the healthcare sector, consistent with zero-revenue firms having long gestation lags, and whose market value consists entirely of future growth potential. The relationship with firm-specific uncertainty is not immediately clear. While Business Equipment and Healthcare have the highest idiosyncratic uncertainty and Finance and Utilities the lowest, mean values are too close to be of any statistical significance. Market uncertainty is somewhat higher in high-tech growth industries than in income industries, due to the option leverage of compound options. Because growth stocks derive more value from future opportunities, the high market uncertainty of the underlying future simple options is further amplified by the higher option leverage. Again, however, mean values are less than two standard deviations apart. For market uncertainty, the energy sector has a rather large mean value, which hints towards the sector returns' sensitivity to the business cycle.

In summary, it is clear that residual value differs between industries. Table 2.2 also suggests that a substantial part of this variation stems from inter-industry differences in the growth option portfolio mix of individual firms.

Table 2.2: Characteristics of Sample Companies
Relationship between the firm's residual value and the option portfolio mix, firm-specific uncertainty, market uncertainty and skewness for companies in the full sample. The table reports observations count and mean values for residual value, exploration-exploitation mix, idiosyncratic volatility, systematic volatility and leverage. Industries are sorted on mean residual value.

| | *Obs.* | *Residual Value* | *R&D/Sales* | *Id. Vol.* | *Sys. Vol.* | *Skewness* |
|---|---|---|---|---|---|---|
| *Business Equipment* | 6,104 | 0.414 | 0.165 | 0.033 | 0.012 | 0.490 |
| *Healthcare* | 3,080 | 0.407 | 2.988 | 0.028 | 0.009 | 0.342 |
| *Chemicals* | 2,145 | 0.241 | 0.257 | 0.020 | 0.008 | 0.424 |
| *Nondurable goods* | 4,271 | 0.166 | 0.013 | 0.023 | 0.007 | 0.520 |
| *Telecom* | 1,876 | 0.163 | 0.021 | 0.022 | 0.009 | 0.482 |
| *Manufacturing* | 10,246 | 0.157 | 0.023 | 0.023 | 0.008 | 0.531 |
| *Other* | 7,611 | 0.144 | 0.035 | 0.027 | 0.009 | 0.550 |
| *Durable goods* | 1,912 | 0.127 | 0.020 | 0.023 | 0.009 | 0.460 |
| *Retail/Wholesale* | 3,619 | 0.121 | 0.004 | 0.028 | 0.008 | 0.554 |
| *Financial Services* | 13,374 | 0.113 | 0.006 | 0.019 | 0.007 | 0.428 |
| *Energy* | 3,570 | 0.085 | 0.048 | 0.026 | 0.009 | 0.504 |
| *Utilities* | 5,308 | -0.082 | 0.002 | 0.013 | 0.005 | 0.212 |

### 2.5.2 Can Residual Value Still Explain Idiosyncratic Risk?

We demonstrate the consequences of endogeneity by complementing the study by Cao et al. (2006), who find that growth options explain the trend in idiosyncratic risk. We first check whether our data is consistent with the findings of Cao et al. (2006) before dealing with endogeneity issues, because our approach is different in its level of analysis. Specifically, Cao et al. (2006) use value-weighted averages of individual firm time-series, while we use a large panel in which firm-level variables are not aggregated. Consequently, our measure for idiosyncratic risk is defined differently from Cao et al. (2006), who measure CAPM-based aggregate volatility as in Campbell et al (2001).

Table 2.3 presents least-squares estimates of idiosyncratic risk using the CAPM market model, regressed on a time trend and several growth options measures. We can observe that our coefficients are smaller than those in Table 3 of Cao et al. (2006). While Cao et al. (2006) find that aggregate idiosyncratic volatility is positively related to the level of growth options for each measure but the capital to fixed expenditures ratio, we find that firm-level idiosyncratic volatility is positively related to the level of growth options for

Table 2.3: Least Squares Estimates of Growth Options Measures on Idiosyncratic Risk
This table presents least-squares estimates of idiosyncratic risk using the CAPM market model, regressed on a time trend and several growth options measures. Variable definitions are according to Cao et al. (2006) and include the market value to book value of assets, Tobin's Q, the capital expenditures to fixed assets ratio, the debt to equity ratio, and residual value as in Eqs. (2.1) and (2.10). Significance levels are **: p<0.01, *: p<0.05, +: p<0.10. Standard errors are reported in parentheses.

| | Idiosyncratic Risk (Market Model) | | | | |
|---|---|---|---|---|---|
| $\left(\frac{AssetMarketValue}{BookValue}\right)_t$ | 0.001** | | | | |
| | (0.000) | | | | |
| *Tobin's $Q_t$* | | 0.001** | | | |
| | | (0.000) | | | |
| $\left(\frac{Capital\ Expenditures}{Fixed\ Assets}\right)_t$ | | | 0.001+ | | |
| | | | (0.001) | | |
| $\left(\frac{Debt}{Equity}\right)_t$ | | | | 0.000 | |
| | | | | (0.000) | |
| *Residual $Value_t$* | | | | | 0.002** |
| | | | | | (0.000) |
| *Time Trend* | 0.000** | 0.000** | 0.000** | 0.000** | 0.000** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *Constant* | 0.017** | 0.018** | 0.018** | 0.018** | 0.018** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *Number of Observations* | 56,526 | 56,526 | 47,227 | 55,871 | 56,308 |
| *R-squared* | 0.040 | 0.040 | 0.045 | 0.031 | 0.035 |

Table 2.4: Least Squares Estimates of Growth Options Measures on Idiosyncratic Risk
This table presents least-squares estimates of several growth options measures, regressed on a time trend and idiosyncratic risk using the CAPM market model. Variable definitions are according to Cao et al. (2006) and include the market value to book value of assets, Tobin's Q, the capital expenditures to fixed assets ratio, the debt to equity ratio, and residual value as in Eqs. (2.1) and (2.10). Significance levels are **: p<0.01, *: p<0.05, +: p<0.10. Standard errors are reported in parentheses.

| | $\left(\frac{Asset\ MV}{Asset\ BV}\right)_t$ | *Tobin's $Q_t$* | $\left(\frac{Cap.\ Ex.}{Fixed\ Assets}\right)_t$ | $\left(\frac{Debt}{Equity}\right)_t$ | *Residual $Value_t$* |
|---|---|---|---|---|---|
| *Id. $Volatility_t$* | 8.721** | 8.329** | 2.309** | 45.56 | 2.669** |
| | (0.977) | (0.972) | (0.694) | (36.44) | (0.297) |
| *Time Trend* | 0.015*** | 0.014*** | 0.0001*** | 0.078 | -0.007*** |
| | (0.001) | (0.001) | (0.000) | (0.067) | (0.000) |
| *Constant* | 0.964** | 0.431** | 0.156** | -0.775 | 0.270** |
| | (0.036) | (0.036) | (0.018) | (1.156) | (0.010) |
| *Observations* | 56,526 | 56,526 | 47,227 | 55,871 | 56,308 |
| *R-squared* | 0.023 | 0.023 | 0.003 | 0.000 | 0.018 |

each measure but the debt-equity ratio. It can also be observed that the combined explanatory power of growth options measures and a time trend is much smaller in our specification. Nevertheless, our results are qualitatively similar.

To investigate the consequences of the issues raised in Section 3, we now reverse the direction of causality in the regression equations of Cao et al. (2006). In Table 2.4, it can be seen that the results are at least as significant, and the coefficients have become much larger compared to Table 2.3. These findings obscure the results from previous work, as it is unclear whether idiosyncratic risk affects residual value, or vice versa. An (untabulated) Hausman test on whether the explanatory variables in Tables 2.3 and 2.4 are strictly exogenous is strongly rejected ($p = 0.000$ for Table 2.3 and Table 2.4), an indication that these specifications are problematic. Therefore, we continue by investigating the direction of causality between residual value and idiosyncratic risk using the proposed solution in Eqs. (2.7) and (2.8). Results are presented in Tables 2.5 and 2.6, in which we examine residual value and idiosyncratic risk after controlling for the issues raised in Section 3.

In both tables, two models are presented that tabulate results when idiosyncratic risk is estimated using Eq. (2.11) with or without size and value regressors. Models are considered well-specified if the Hansen $J$ - test fails to reject the absence of over-identifying restrictions, and the Arrellano-Bond test fails to detect second order autocorrelation. In the results below, the Hansen $J$ - test for the validity of the instruments at work is not rejected, and second-order autocorrelation is of no significance. We do observe dramatic changes in the volatility coefficients in comparison with the full model in Eq. (2.9), presented later in the text, indicating that the inclusion of control variables is important.

Eq. (2.7) corresponds to how Cao et al. (2006) interpret their results, i.e., residual value explains idiosyncratic risk. In Table 2.5, we observe that idiosyncratic volatility has a first-order autoregressive nature and is conditional upon last year's volatility level. We also observe that residual value indeed has a significant effect on idiosyncratic risk. However, the coefficients on residual value are much smaller than the AR(1) coefficient, indicating that this form of causality is of second-order importance. In fact, few of the significant coefficients have a magnitude larger than zero. Volatility remains persistent for different definitions of idiosyncratic risk in the two models and, while the size of coefficients remains very small, so do lags of residual value.

Turning to Eq. (2.8) and Table 2.6, we observe a stronger relationship when the direction of causality is reversed. We find significant effects of idiosyncratic volatility on residual value, with coefficients for risk of the same order of magnitude as for lagged $V^*/P$. All models show a significant positive effect of idiosyncratic risk on residual value for more multiple lags. In the three-factor model, the second and fourth lag are significant with coefficients of 1.9 and 1.5, respectively. In the market-factor model, it can be seen that coefficients increase, more lags become significant and that standard errors go down for all but the fourth lag. This suggests that something profound happens when idiosyncratic risk is measured differently: the value and size factors have a large impact on the growth options–idiosyncratic volatility relation. We will see this pattern in the next section as well, when we present the model including controls. For now, we conclude that idiosyncratic risk has a stronger effect on residual value than vice versa.

By examining the link between growth options and idiosyncratic risk, Cao et al. (2006) argued that individual stocks have become more volatile over time by the level (and variance) of growth options. They explain this link by managers of levered firms selecting investment projects that increase the idiosyncratic variance of the firm at the expense of debt holders. However, from Tables 2.5 and 2.6, it should be concluded that it is primarily firm-specific volatility that drives option value, not vice versa.

### 2.5.3 Does Residual Value Behave Analogously to Growth Options?

Results for our full model are presented in Table 2.7. As before, two different estimates are presented for the one-factor model and the three-factor model. The three-factor model estimates volatilities using Eq. (2.11) whereas the market-factor residuals include the size and value effect. In all these models, Hansen $J$ - tests for the validity of the instruments at work are not rejected, and second-order autocorrelation is of no significance[9]. All control variables have the expected sign.

For both models, all four lags of $V^*/P$ are significant, capturing the dependence over time that we introduced by construction, i.e. by using averaged return on equity. The

[9]Evidently, the residuals $\upsilon_{it}$ are themselves serially correlated of order one.

Table 2.5: Instrumental Variable Estimates of Idiosyncratic Risk on Residual Value
The dependent variable is idiosyncratic volatility, regressed on its lags and current and lagged residual value. The market model uses standard CAPM residuals to estimate volatility, while the 3-Factor Model includes firm-specific risk as defined in Eq. (2.11). Year Dummies are included but not tabulated. Significance levels are **: p<0.01, *: p<0.05, +: p<0.10. In the upper panel, standard errors are reported in parentheses. In the lower panel, numbers in parentheses indicate p-values of statistics.

| | Market Model | | 3 Factor Model | |
|---|---|---|---|---|
| *Idiosyncratic Volatility$_{t-1}$* | 0.310** | (0.022) | 0.218** | (0.057) |
| *Idiosyncratic Volatility$_{t-2}$* | -0.005 | (0.011) | -0.013 | (0.015) |
| *Idiosyncratic Volatility$_{t-3}$* | 0.002 | (0.001) | -0.009 | (0.015) |
| *Idiosyncratic Volatility$_{t-4}$* | -0.005 | (0.001) | -0.015 | (0.011) |
| *Residual Value$_{t}$* | 0.000* | (0.000) | 0.000 | (0.000) |
| *Residual Value$_{t-1}$* | -0.000+ | (0.000) | -0.000** | (0.000) |
| *Residual Value$_{t-2}$* | -0.000** | (0.000) | 0.000 | (0.0001) |
| *Residual Value$_{t-3}$* | 0.000 | (0.000) | -0.000+ | (0.000) |
| *Residual Value$_{t-4}$* | -0.000 | (0.000) | 0.000 | (0.000) |
| Estimation Statistics: | | | | |
| *Number of Observations* | 25568 | | 25590 | |
| *Number of Firms* | 2785 | | 2792 | |
| *Hansen J-statistic* | 1536 | | 1527 | |
| | (0.485) | | (0.553) | |
| *Test for $2^{nd}$ order autocorrelation* | 0.792 | | 0.169 | |
| | (0.428) | | (0.866) | |

Table 2.6: Instrumental Variable Estimates of Residual Value on Idiosyncratic Risk
The dependent variable is residual value, regressed on its lags and current and lagged idiosyncratic volatility. The market model uses standard CAPM residuals to estimate volatility, while the 3-Factor Model includes firm-specific risk as defined in Eq. (2.11). Year Dummies are included but not tabulated. Significance levels are **: p<0.01, *: p<0.05, +: p<0.10. In the upper panel, standard errors are reported in parentheses. In the lower panel, numbers in parentheses indicate p-values of statistics.

| | Market Model | | 3 Factor Model | |
|---|---|---|---|---|
| *Residual Value$_{t-1}$* | 0.396** | (0.015) | 0.392** | (0.014) |
| *Residual Value$_{t-2}$* | -0.114** | (0.011) | -0.117** | (0.011) |
| *Residual Value$_{t-3}$* | 0.002 | (0.010) | 0.000 | (0.010) |
| *Residual Value$_{t-4}$* | -0.035** | (0.009) | -0.036** | (0.009) |
| *Idiosyncratic Volatility$_t$* | 3.314* | (1.375) | -0.848 | (1.431) |
| *Idiosyncratic Volatility$_{t-1}$* | 1.248+ | (0.747) | 1.865* | (0.827) |
| *Idiosyncratic Volatility$_{t-2}$* | 2.232** | (0.653) | 0.801 | (0.709) |
| *Idiosyncratic Volatility$_{t-3}$* | -0.592 | (0.625) | 1.536* | (0.627) |
| Estimation Statistics: | | | | |
| *Number of Observations* | 25591 | | 25608 | |
| *Number of Firms* | 2791 | | 2793 | |
| *Hansen* J-*statistic* | 1678 | | 1641 | |
| | (0.310) | | (0.556) | |
| *Test for $2^{nd}$ Order Autocorrelation* | -0.309 | | -0.251 | |
| | (0.757) | | (0.802) | |

use of progressive weighting is reflected in decreasing coefficients and significance levels for longer lags.

From the three-factor model presented in Table 2.7, we observe that current and lagged firm-specific risk are not significantly different from zero. This contrasts with the empirical evidence and predictions from Section 2. Further investigation has yielded an explanation for this: the effect of idiosyncratic risk becomes significant at the 6% level if it is estimated using the residuals of the standard CAPM model, instead of those from the Fama-French model in Eq. (2.11). Because the latter definition effectively purges size and value effects from idiosyncratic risk, the results for both models suggest that value and size are partly determined by growth opportunities. This is in line with previous work (Berk et al. 1999; Carlson et al. 2004; Novy-Marx 2010). Extra support for this explanation comes from a decreased impact of skewness and $R\&D$ investment in the one-factor model, which become smaller and less significant. Limited liabilities and staging decisions, portfolio maturity, return intervals, and active management could well be related to idiosyncratic volatility as well as $R\&D$ and skewness, measuring either a direct or a more indirect effect. Therefore, if the size and value factors pick up growth opportunities, it is therefore plausible that the effect of idiosyncratic risk on residual value comes at the expense of the effect of skewness and R&D.

We find that market risk has a negative effect on residual value. This indicates that the negative effect of market risk on the equity option of the firm, as derived in Appendix A.2, is larger than the effect of the embedded growth options. As stated in Section 2, economic theory is is not conclusive about the effect of market risk on growth options; an increase in market risk has a positive impact on growth options by increasing the value to wait, but a negative impact by decreasing the underlying value. Our results show that the positive effect on the option to wait is dominated by the negative impact on the equity option and/or the value of underlying assets.

Skewness has a significant and positive effect on residual value for the three-factor model, consistent with compound growth options skewing the return distribution toward higher returns. This may result from active management limiting losses on the downside and changes in the maturity of the option portfolio, both of which change the return distribution. The skewed distribution in returns also results from changes in the value of the options bundle of options, when management cushions the downside risk of future investments while strengthening its ability to expand aggressively, or new options arise and change the maturity of the portfolio.

We also find a positive relationship between lagged R&D and residual value: innovation is a significant source of future investment opportunities. This, too, is consistent with previous real option literature. The insignificant effect of contemporaneous R&D suggests long gestation lags. Again, we see that coefficients decrease when lags increase, which is consistent with the uncertain outcome of innovation investments. Significance levels do not decrease, which confirms that innovation needs time to develop and become profitable. It also suggests that a majority of innovation investments are worthless, but the remaining few have high value.

Our control variables are also significant and have the expected sign. A significant relationship is found between industry competition and residual value. As the effect is predominantly negative, we infer that (current and lagged) residual value erodes in the presence of competition. In line with theory, the prospective value of future opportunities (growth option value) represents the value of pre-emptive moves to appropriate future opportunities in a game versus rivals. This is analogous to the "option to wait" in the real options literature, which goes to zero under perfect competition (e.g., Dixit and Pindyck (1994)). The market-to-book effect on residual value is also positive, indicating the existence of other factors that positively affect market-to-book while having no direct effect on residual value. In line with previous work (Lakonishok et al. 2004, Berk et al. 1999) this suggests that market-to-book is not a clean measure for growth opportunities and may question its validity. The negative effect of size on residual value indicates that as firms grow, they loose some of their predisposition to explore opportunities. While smaller firms contain a larger portion of future growth potential, large firms have more resources to exercise growth options and tend to have more capital employed. The negative effect of financial leverage on residual value is also significant. This suggests that financial flexibility allows a firm to leverage its capabilities, meet its obligations, and pursue growth opportunities as they arise. The evidence also shows that the volatility that increases the value of an option decreases the propensity to borrow, since debtholders are wary of risk.

From these empirical observations, we conclude that the link between real options and residual value is significant, and remains so after dealing with endogeneity issues. Except for idiosyncratic risk in the three-factor model, all option characteristics are significantly related to the residual value component. Therefore, residual value behaves analogously to the unobserved growth option component embedded in stock prices. For the one-factor model, and again with exception of idiosyncratic risk, it can be verified that none of the coefficients change by more than one standard error. This indicates some robustness for the proxies and controls. For idiosyncratic risk, the sign is now positive and significant, as predicted by theory and consistent with Tables 2.4 and 2.6. In contrast to the three-factor model, the market factor model finds a positive link between idiosyncratic volatility and residual value.

Finally, to assess robustness for our results, we substitute market-to-book for residual value as the dependent variable and repeat the procedure above in Table 2.8. It can be seen that most of the previous results hold, but to a lesser extent. Specifically, current $R\&D/Sales$ expenditure becomes significant, still monotonically decreases, but has smaller coefficients. The effects of size, leverage and competition on market-to-book are all significant and of the expected sign, but smaller in magnitude. Moreover, since we do not time-average market-to-book as in Eq. (2.10) we observe more variation in the coefficients, even to the extent that the direction changes for the effect of skewness on market-to-book. This is in line with previous results that market-to-book is not a clean measure for growth opportunities (Lakonishok et al. 2004, Berk et al. 1999). We also observe similar results for idiosyncratic risk, which is only significant when CAPM-residuals are used. Market risk is no longer significant for the three-factor model. In addition, the $M/B$ models' diagnostics show that significant second-order autocorrelation is present, so that we should take caution when interpreting standard errors and, therefore, significance levels.

Table 2.7: Instrumental Variable Estimates of Residual Value on All Variables
The dependent variable is current residual value. Regressors include lagged residual value, as well as lagged and current values for exploration-exploitation mix (*R&D/Sales*), idiosyncratic volatility, systematic volatility, leverage, log of size, skewness, asset market-to-book and average residual value of other firms with identical primary SIC code. The 3-factor model estimates firm-specific risk using Eq. (2.11), the market factor model omits size and value effects from this equation. Year Dummies are included but not tabulated. Significance levels are **: p<0.01, *: p<0.05, +: p<0.10. In the upper panel, standard errors are reported in parentheses. In the lower panel, numbers in parentheses indicate p-values of statistics.

| | Market Model | | 3 factor model | |
|---|---|---|---|---|
| *Residual Value*$_{t-1}$ | 0.144** | (0.0330) | 0.178** | (0.035) |
| *Residual Value*$_{t-2}$ | -0.174** | (0.032) | -0.133** | (0.033) |
| *Residual Value*$_{t-3}$ | -0.077* | (0.031) | -0.064+ | (0.033) |
| *Residual Value*$_{t-4}$ | -0.063* | (0.027) | -0.045+ | (0.026) |
| *R&D/Sales*$_t$ | 0.030 | (0.268) | 0.152 | (0.248) |
| *R&D/Sales*$_{t-1}$ | 0.410* | (0.190) | 0.552** | (0.195) |
| *R&D/Sales*$_{t-2}$ | 0.386* | (0.154) | 0.507** | (0.156) |
| *R&D/Sales*$_{t-3}$ | 0.224 | (0.143) | 0.278+ | (0.144) |
| *Systematic Volatility*$_t$ | -5.651** | (1.771) | 1.887 | (1.845) |
| *Systematic Volatility*$_{t-1}$ | 0.462 | (1.226) | -3.949** | (1.432) |
| *Idiosyncratic Volatility*$_t$ | 1.665 | (1.426) | -2.592 | (1.920) |
| *Idiosyncratic Volatility*$_{t-1}$ | 1.962+ | (1.061) | 1.115 | (0.901) |
| *Skewness*$_t$ | 0.015+ | (0.008) | 0.023** | (0.008) |
| *Skewness*$_{t-1}$ | 0.004 | (0.009) | 0.013 | (0.009) |
| ln(*Size*) | -0.009+ | (0.005) | -0.006+ | (0.004) |
| *Asset Market-to-book*$_t$ | 0.058** | (0.016) | 0.056** | (0.016) |
| *Leverage*$_t$ | -0.493** | (0.131) | -0.532** | (0.121) |
| *Competitors' Residual Value*$_t$ | -65.69** | (6.069) | -60.06** | (7.019) |
| *Competitors' Residual Value*$_{t-1}$ | 2.010 | (3.200) | 3.829 | (3.340) |
| *Competitors' Residual Value*$_{t-2}$ | -15.45** | (3.836) | -10.70** | (3.636) |
| *Competitors' Residual Value*$_{t-3}$ | -6.540+ | (3.882) | -5.142 | (3.991) |
| *Competitors' Residual Value*$_{t-4}$ | -3.663 | (3.177) | -2.247 | (3.091) |
| Estimation Statistics: | | | | |
| *Number of Observations* | 9,200 | | 9,204 | |
| *Number of Firms* | 1088 | | 1088 | |
| *Hansen J-statistic* | 811.8 | | 819.8 | |
| | (0.350) | | (0.280) | |
| *Test for* $2^{nd}$ *Order Autocorrelation* | -0.316 | | -0.827 | |
| | (0.752) | | (0.408) | |

Table 2.8: Instrumental Variable Estimates of Market-to-Book on Real Option Characteristics
The dependent variable is the current market-to-book-ratio. Regressors include lagged market-to-book, as well as lagged and current values for Research & Development (*R&D/Sales*), idiosyncratic volatility, systematic volatility, leverage, log of firm size, skewness, asset market-to-book and average residual value of other firms with identical primary SIC code. The 3-factor model estimates firm-specific risk using Eq. (2.11), the market factor model omits size and value effects from this equation. Year Dummies are included but not tabulated. We use two-step GMM and finite-sample corrected standard errors (**?**). Significance levels are **: p<0.01, *: p<0.05, +: p<0.10. In the upper panel, standard errors are reported in parentheses. In the lower panel, numbers in parentheses indicate p-values of statistics.

| | Market Model | | 3 factor model | |
|---|---|---|---|---|
| $Market\text{-}to\text{-}book_{t-1}$ | 0.006** | (0.002) | 0.006** | (0.00218) |
| $Market\text{-}to\text{-}book_{t-2}$ | 0.003 | (0.002) | 0.002 | (0.00171) |
| $R\&D/Sales_t$ | 0.030 | (0.268) | 0.147** | (0.0435) |
| $R\&D/Sales_{t-1}$ | 0.410* | (0.190) | 0.085* | (0.0417) |
| $R\&D/Sales_{t-2}$ | 0.386* | (0.154) | 0.077+ | (0.0418) |
| $R\&D/Sales_{t-3}$ | 0.224 | (0.143) | 0.052 | (0.0499) |
| $Systematic\ Volatility_t$ | -5.651** | (1.771) | 0.679 | (0.518) |
| $Systematic\ Volatility_{t-1}$ | 0.462 | (1.226) | 0.550 | (0.335) |
| $Idiosyncratic\ Volatility_t$ | 1.665 | (1.426) | 0.014 | (0.408) |
| $Idiosyncratic\ Volatility_{t-1}$ | 1.962+ | (1.061) | 0.377 | (0.238) |
| $Skewness_t$ | 0.015+ | (0.00815) | -0.005+ | (0.00255) |
| $Skewness_{t-1}$ | 0.004 | (0.00949) | 0.004+ | (0.00224) |
| $\ln(Size)$ | -0.009+ | (0.00465) | -0.002 | (0.00110) |
| $Asset\ Market\text{-}to\text{-}book_t$ | 0.058** | (0.0162) | 1.006** | (0.00252) |
| $Leverage_t$ | -0.493** | (0.131) | -0.148** | (0.0322) |
| $Competitors'\ Residual\ Value_t$ | -65.69** | (6.069) | -0.894 | (0.625) |
| $Competitors'\ Residual\ Value_{t-1}$ | 2.010 | (3.200) | 0.444 | (0.506) |
| $Competitors'\ Residual\ Value_{t-2}$ | -15.45** | (3.836) | -1.417** | (0.516) |
| $Competitors'\ Residual\ Value_{t-3}$ | -6.540+ | (3.882) | -1.042* | (0.448) |
| $Competitors'\ Residual\ Value_{t-4}$ | -3.663 | (3.177) | -0.211 | (0.411) |
| Estimation Statistics: | | | | |
| *Number of Observations* | 9,200 | | 9,204 | |
| *Number of Firms* | 1088 | | 1088 | |
| *Hansen J-statistic* | 735.1 | | 746.2 | |
| | (0.460) | | (0.350) | |
| *Test for* $2^{nd}$ *order autocorrelation* | -1.947 | | -1.968 | |
| | (0.0515) | | (0.0491) | |

## 2.6 Conclusion

This chapter has examined the residual component of market value, often referred to as the growth options component, which arises from stock prices exceeding the earnings capacity of assets in place. We tested an important but previously untested assumption underlying growth options studies, i.e., that the price residual has properties similar to a portfolio of real options. To this end, we reviewed eight characteristics that are theoretically related to real options, and tested whether they have the expected effect on the price residual.

In our analysis, we have shown that conventional estimates of growth options are likely to be inconsistent, and that the direction of causality is often ambiguous. We resolve these issues by means of instrumental variables, using the lags of regressors as instruments. It is then found that idiosyncratic risk, skewness, market-to-book, and *R&D* investments have a positive effect on the price residual, while market risk, leverage, and size have a negative effect on the price residual. These findings are all in line with theoretical predictions, and indicate that the residual indeed contains significant growth options value.

Furthermore, our results have two interesting implications related to idiosyncratic risk. First, we directly extended Cao et al. (2006) who show that stocks have become more volatile because of growth options, since managers in levered firms select investment projects that increase the idiosyncratic variance of the firm at the expense of debt holders. Our evidence indicates that this explanation is significant but of second-order importance. The effect is dwarfed by the reverse effect of growth options increasing because of idiosyncratic volatility, caused by timely managers who are able to translate idiosyncratic shocks into option value. This is one example of how estimation issues can have strong implications, and findings from other studies might be similarly affected if the analysis is based on conventional estimation techniques.

Second, purging size and/or value effects from the definition for idiosyncratic risk has led to an insignificant effect on the price residual. At the same time, effects of skewness and *R&D/Sales* become larger and more significant, suggesting that the effect of growth options on the price residual is transferred from idiosyncratic risk to skewness and *R&D*. This indicates that growth opportunities play a substantial role in value and size factors. Our empirical evidence is consistent with non-empirical work that provides economic intuition for size and value in a real options context. For instance, Berk, Green and Naik (1999) explain how systematic risk increases (decreases) in value (size) due to growth opportunities that change the risk of assets in place, and Carlson, Fisher and Giammarino (2004) explain the same phenomenon by relating systematic risk to operating leverage and growth opportunities.

We emphasize that our results do not imply that the combined value of a firm's growth options mechanically equals the price residual. Investors naturally have imperfect information about the firm, and estimates cannot be verified because the true value of growth opportunities is unobserved. Furthermore, market frictions and investor psychology may cause share prices to deviate from fundamental value without economic justification, which leads to additional measurement error. These possibilities, however, do not change our main result that deviations from fundamental value contain a significant real growth options value component.

# Chapter 3

# Applying Residual Value

*This chapter analyzes the link between (intangible) investments and future economic growth at the firm-level, and examines whether the residual value component can be used to value intangibles. The methodology from the previous chapters is used to calculate the residual value of a dollar invested in selling, general and administrative (SG&A) expenses, from which a capitalization rate of intangible investments can be calculated. This approach is tested for six sectors with different intangibles, spread amongst five countries. In all sectors and countries, SG&A expenses make a significantly positive contribution to residual value. This contribution, however, varies greatly between sectors and countries-within-sectors, according to their level of intangibles.*

## 3.1 Introduction[1]

It is beyond debate that investments in R&D, advertising, management skills and employee training are made to generate profits in the future, as do traditional investments in labor and tangible capital. Lev and Radhakrishnan (2004), for example, argue that organizational capital is the persistent creator of value and growth for business (p.2), or Hall et al. (1993, 1995, 2002, 2005). However, intangibles are not easily transferred and, as opposed to tangible assets, value is primarily created from the continuing use of intangibles. Therefore, the measurement and valuation of intangible capital is an open question, and has been subject to debate.

First, since traditional external accounting builds on the transaction-based principle of historical cost, financial accounting rules stipulate that innovation investments are treated as an expense, rather than an investment. Second, with a focus on *national* accounts – which cover production, income and expenditures of a nation – macro-economists have argued that intangible capital should be capitalized at full cost (e.g., Corrado, Hulten and Sichel 2005; 2006). Third, using the equity market as a forward-looking and conditional view on the total value of a firm, innovation economists derive the value of intangibles by deducting the value of tangible assets from market value (e.g. Hall 2001).

None of these views are foolproof. A clear drawback of traditional accounting is that it ignores the purpose of any investment, i.e. to create future value. Capitalizing intangibles at full cost, on the other hand, assumes that firms can order or hire intangibles as if they were capital and labor inputs such machinery. However, intangible capital describes how financial and physical capital is transformed into products and services. Finally, the use of equity markets to derive firm value depends critically on the quality of information investors have and the functioning of financial markets in general. The latter approach has been hampered by substantial variation in the measured effect of intangibles, whether measured across firms, countries or industries.

[1] For this chapter, I received support from a Robert H. McGuckin III Fellowship in Economics, provided by The Conference Board. I am grateful for the generous stipend to cover travel, housing and cost of living expenses in New York, from July to October 2008. I presented the essence of this paper at two brown bag seminars. I thank participants at those seminars as well as Janet Hao, Utsav Kumar, Vlad Manole, Ataman Ozyildirim, and Bart Van Ark for their comments; however, the views expressed herein are my own and are not necessarily shared by anyone else at The Conference Board.

This chapter aims to use the methodology from the previous chapter to generate more robust and reliable estimates of the impact of intangible capital on firm value. In the previous chapter, we established that residual value behaves analogously to future growth options. In this chapter, we try to reverse the argument and use the residual to approximate the growth potential of intangibles, which contribute importantly to these opportunities. Residual value analysis could provide a convenient tool for evaluating firm, sector and country performance, because all data is publicly available. This chapter also uses financial information, but tries to improve on the existing methodology in several ways.

First, to measure intangible value, we use residual value instead of total firm value by backing out earnings and book value from market value, as these do not affect innovation. Using market prices net of accounting data preserves the forward-looking perspective of equity investors, while it adds precision to financial market signals. This allows us to assess the value of intangible assets using a more precise and conservative financial market measure. Second, the instrumental variables approach from the previous chapter remediates potential flaws in previous studies, which might lead to inconsistent results. Third, we link residual value to intangible investments through capitalization rates, so that coefficients can be interpreted as the average return on intangibles. For instance, expensing intangibles according to traditional accounting regulations implies a capitalization rate of zero. The full-cost capitalization approach, on the other hand, assumes a capitalization rate of one, as intangible investments are seen as a one-to-one increase in firm value. The equity market approach implies that investments have a positive (or negative) return, so that capitalization rates should be larger (or smaller) than one. Capitalization rates thus allow for a comparison of the business strategy, financial reporting and national accounting views on intangibles.

In the remainder of this chapter, we compare capitalization rates for six different sectors across five different countries. It is shown that residual value and capitalization rates have a significant relation with intangibles, but that the exact nature of this relation varies considerably across industries. For the computer-related industries, for instance, full-cost capitalization seems reasonable whereas for service industries, SG&A are more treated as an expense. Therefore, we are not able to provide a clear guideline regarding the fraction of the SG&A expenditure that should be capitalized. In fact, neither can we determine whether SG&A expenditure should be capitalized at all. Furthermore, large international differences exist as well, and the impact of SG&A expenditures on the value residual could often not be estimated: our design results in too few observations to estimate the regression for all sector-country pairs. This is an important cost of better econometric technique and more comprehensive value definitions.

Considering the implications from chapter 2 and the context of intangibles, this chapter interprets residual value as a measure for growth opportunities. While it is typically referred to as "growth value" or "growth options value" in the literature, we adhere to the term "residual value" for consistency. We proceed as follows. Section 2 motivates our particular measure for intangible capital and the investments that generate it. Section 3 describes the international data and sample construction, as well as the empirical model and measurement procedure. Section 4 summarizes the data and presents results, and Section 5 concludes.

## 3.2 Literature Review

### 3.2.1 Measuring Intangible Value

The current state of affairs is that investments in R&D, education, on-the-job training and other intangible investments are recorded as an expense in financial statements. The motivation is simple yet compelling: by the very nature of intangibles, investors have no objective information on how to value them. Therefore, moral hazards need to be minimized by requiring that accounts always record the least favorable position of an asset – if not, managers could create "value" merely by spending money. As a consequence, however, accounting regulations may err in recognizing the capabilities, competencies and value creation that are so central to the organization (Hand and Lev, 2003). Hence, they are ill-suited to answer questions about what exactly constitutes the knowledge economy, and how it contributes to economic growth.

Taking a different approach, Corrado, Hulten and Sichel (CHS; 2005, 2006) propose an accounting treatment of intangibles that capitalizes innovation expenses on a macro level.

These U.S.-focused studies have been replicated for other countries, including the U.K. (Marrano and Haskel, 2006; Marrano, Haskel and Wallis, 2007), Japan (Fukao, Hamagata, Miyagawa, and Tonogi, 2007), The Netherlands (Van Rooijen-Horsten, Van Den Bergen and Tanriseven, 2008), and France and Germany (Hao, Manole and Van Ark, 2008). The rationale is twofold: first, traditional, tangible assets are valued at their traditional costs as well. Second, the value of a project is at least partly revealed by its price, which can be considered a lower bound of the expected value of profit streams. The internal flow of value is ignored, however, while returns on innovation are subject to uncertain times and costs of development, gestation lags, competitive forces and limited protection against knowledge diffusion. Moreover, since it assumes that more money creates more value, it fails to distinguish a good idea (which is cheap and creates much value) from a bad investment (which is costly and creates no value). Capitalizing intangibles also bypasses the immediate effect of the investment outlay on current earnings, as current investments drive down the current year's profits, and investments that generate immediate profits are foregone.

Finally, a growing literature has used financial market value as an an indicator of the firm's expected innovation value. While intangibles themselves are not traded in the marketplace, the private economic "value" of a firm – which is the sum of tangible and intangible assets – is. Because firm value and the value of tangible assets can be observed, intangibles can be proxied by the difference between the two. Equity markets have the additional advantage of incorporating a forward-looking view on future stock returns. The results, however, have often been modest: especially on an industry level, most findings are unstable or inconclusive with a volatile R&D coefficient between and within studies. This may be due to fluctuations in firm value that are caused by an abundance of other causes, so that the signal is quite noisy.

This study uses residual value to estimate intangible capital, in which the value of a firm ($P$) is partitioned into present value of future growth opportunities and the value that is currently generated by its assets in place (Miller and Modigliani 1961 and Berk, Green and Naik1999) .

Let us re-state the key equation from Chapter 1 and 2 again:

$$P_{it} \equiv \sum_{j=0}^{\infty} V_{ijt}\chi_{ijt} + V_{it}^{*}. \tag{3.1}$$

Following Tong, Reuer and Peng (2008a) and Tong, Alessandri, Reuer and Chintakanda (2008b), we will use an economic profit model (Stern, 1991) to estimate the summation above, and represent firm value as the sum of capital invested ($CI$) and capital employed. In these studies, the value of future cash flows can be represented as a sum of capital invested and the present value of economic profit ($PVEP$, also known as Economic Value Added$^{\mathrm{TM}}$):

$$\sum_{j=0}^{\infty} V_{jt}\chi_{jt} = CI_{it} + PVEP_{it}. \tag{3.2}$$

The present value of economic profit can be calculated by a perpetuity that discounts current economic profit. Eq. (5.4) splits the first term on the RHS of (5.1) in two terms, explicitly measuring assets and earnings. Intuitively, instead of using earnings before interest and taxes that implicitly includes the value of invested capital, Tong et al. (2008a, 2008b) use a measure of net operating profits *after* repaying investors, and explicitly calculate the value of invested capital (which we assume to equal book value).

In contrast to the financial and national accounting approaches, future growth potential recognizes that intangible value is derived from how capital and labor are translated into products and services. In contrast to other equity market approaches, residual value incorporates current profitability and adjusts it for investment risk. Furthermore, to relate profit streams to observed stock prices, this study uses a firm-specific and time-varying discount rate that incorporates country, debt and equity risk.

### 3.2.2 Measuring Intangible Investments

One of the earliest studies on the intangibles problem is Griliches (1981), who found a significant relationship between market value on one hand and past R&D expenditures and the number of patents on the other. Since then, previous work has (partially) examined many aspects of this relationship (e.g. Pakes 1985; Chan, Lakonishok and Sougiannis, 2001; Hall, Jaffe and Trajtenberg 2005; Hall and Oriani 2006). This study deviates from this literature and follows Lev and Radhakrishnan (2005) by considering SG&A as a measure.

SG&A include (but are not limited to) investments in R&D, employees training, brand enhancement, fees for strategy and systems consulting, as well as IT and the set-up of Internet-based supply and distribution channels (Lev and Radhakrishnan, 2004). Although this measure also includes payroll costs (including payroll and social security taxes, non-sales salaries, commissions, and travel expenses of executives, sales people and employees), some payroll costs may generate growth potential in attracting well-skilled personnel. Finally, other administrative costs (such as lease, delivery and bad debt expenses) are also included, which have no intangible value. Because less than 100% of SG&A is spent on intangibles, the effect of intangibles will therefore be biased downwards and the capitalization rates below should be considered a lower bound. Being on the safe side serves our purpose well, however, as conservative estimates of intangible capital will enhance our results.

In addition, and contrary to R&D, SG&A is to be reported in all countries by law, and therefore better suited for an international comparison. Also, the *SG&A* measure is crude but comprehensive: while some *SG&A* items are not related to intangible investments, it includes innovation investments (through R&D), investments in human capital (through employee training), organizational capital (through consulting fees) and brand equity (through advertising). This leads to a more conservative measure, for coefficients will be biased downwards if intangible investments are smaller than total SG&A.

### 3.2.3 Estimating Intangibles

As we described in Section 2.3, a firm with a larger intangible capital base is better in transforming capital into valuable goods and services, because each R&D project requires a lower investment outlay to create an equivalent amount of residual value. If intangible assets are omitted from the estimation, a regression of residual value on R&D investment will spuriously indicate a negative relation, because the amount invested is negatively related to intangible capital. It was also shown that causation could run the other way - because an increase in residual value loosens financing constraints by the inflow of new capital, managers might invest more when residual value has risen. This holds in particular for R&D projects, for which profits are uncertain, difficult to measure, and may take years to substantiate. We use the previous chapter's empirical approach that alleviates this problem using instrumental variables.

The following setup includes a lag of the dependent variable, $V^*_{t-1}$, and instruments this and (current and trailing) $SGA$ investments using lagged observations. Fixed effects are purged using a panel setup, which also controls for variation in intangibles across firms. Yearly dummies are included for time-specific effects. Using lags as instrumental variables yields consistent results, even when regressors are correlated to the error term. While it seems reasonable to assume that current market value is unrelated to lags of SG&A, each model will test for this assumption using the Hansen $J$ - test. Endogeneity issues are resolved by including a lagged dependent variable.

Given the volatile nature of equity markets, this last feature is important, as it controls for a difference that, for many reasons, may exist between the equilibrium share price and the previous year's share price. Because of the long gestation lags associated with intangible investments such as R&D, reputation and organizational capital, the model also includes lagged versions $\tau$ of $SGA$, in addition to current $SG\&A$ stock.

The data-generation process can be summarized, similarly to Chapter 1:

$$\begin{aligned} V^*_{it} &= \alpha V^*_{it-s} + \beta SGA_{it-\tau} + \varepsilon_{it}, \\ \varepsilon_{it} &= \mu_i + \upsilon_{it}, \\ \upsilon_{it} &= i.i.d., \end{aligned} \tag{3.3}$$

where $\alpha$ and $\beta$ are vectors of coefficients, the size of which depends on the number of regressors included, and $s \subset \{1, 2, ...\}$ and $\tau \subset \{0, 1, ...\}$ are time lags.. In most estimates below, $\alpha$ has only a single element and $\beta$ has up to three. By the evasive nature of intangibles, any study can still miss the role of omitted explanations that distinguishes a successful firm from its less successful peers (Cummins, 2004), and arbitrarily distributed fixed effects $\mu_i$ may significantly affect how investments are translated into value. To control for some general correlation between the residuals $\upsilon_{it}$, we also include time dummies for every year. As a result, this model assumes the disturbances to have a firm-specific, a time-specific and an idiosyncratic component.

Table 3.1: Regressors Correlations Matrix
Reported are correlations between the main regressors in Eq. (3.3).

| | $SG\&A_t$ | $SG\&A_{t-1}$ | $SG\&A_{t-2}$ | $SG\&A_{t-3}$ | $SG\&A_{t-4}$ | $SG\&A_{t-5}$ |
|---|---|---|---|---|---|---|
| $SG\&A_t$ | 1 | | | | | |
| $SG\&A_{t-1}$ | 0.1056 | 1 | | | | |
| $SG\&A_{t-2}$ | 0.0659 | 0.0717 | 1 | | | |
| $SG\&A_{t-3}$ | 0.0002 | 0.0006 | 0.0005 | 1 | | |
| $SG\&A_{t-4}$ | 0.0000 | 0.0002 | 0.0001 | -0.0000 | 1 | |
| $SG\&A_{t-5}$ | -0.0000 | 0.0000 | 0.0001 | -0.0000 | -0.0000 | 1 |

To remediate omitted variable bias while precluding panel inconsistencies (Nickel, 1981), we deviate from Chapter 2 by transforming Eq. (5.3) as in Arellano and Bover (1995) and Blundell and Bond (1998). It has been shown that this transformation is superior to the better-known Arellano and Bond (1991) transformation if weak correlation exists between the regressors and the lagged levels of the instruments. While lags of residual value are informative, it can be seen from the insignificant correlations in Table 3.1 that this is not true for any lags of *SG&A*. This may be due to the small number of observations per firm (as compared to the number of firms) (Blundell and Bond, 1998) and managerial discretion over some SG&A items. Finally, the Arellano-Bover/Blundell-Bond estimator is augmented to accommodate Windmeijer (2005) corrected standard errors.

In order to prevent over-fitting instruments and increase computational speed, we use one instrument for each variable and lag distance, rather than one for each time period, variable, and lag distance (see, e.g. Roodman 2006). To maximize the number of observations when taking first differences that purge fixed effects, we also follow Arellano and Bover (1995) in subtracting the average of all future available observations of a variable from the current one, instead of simply the previous observation. It should be noted that the estimation procedure above can be readily implemented with several software packages, such as Stata, Gauss, Ox, etcetera.

## 3.3 Data and Methods

### 3.3.1 Data

The sample consists of yearly data from Thomson Worldscope over the period 1998-2007, and consists of all firm-year observations for which residual value can be calculated. Worldscope standardizes international differences in accounting terminology, presentation, and language to facilitate comparability. The sector classification is taken from thirt sector definitions by Kenneth French. Although data are collected from 481,480 firms, this doesn't yield 481,480 observations. First, not all firms exist for the full 10 years. Second, those firm-year observations that do exist do not necessarily report the data needed to construct the $V^*$ measure. Third, some of the resulting $V^*$ values are unrealistic due to very small market values in the $V^*/P$ ratio, a very small $WACC$ in the $PVEP/WACC$ ratio or irregular pricing data to calculate the betas. To deal with these (otherwise uninformative) outliers, we replace the upper and lower 1% of all $V^*$ values by missing values. As a result, the final dataset contains 148,102 valid $V^*$ observations. Hence, 70% of the data are lost: this is an important drawback of using residual value as a measure for intangible value.

### 3.3.2 Variables

The measure for investments in intangible assets, SG&A, is readily available from financial statements. As a continuous rate of intangible investments is an important determinant for success, we proxy stocks of organizational capital by accumulated SG&A expenditures that are discounted over time. Conventionally (e.g., see Hall, 2005), the stock variable $SGA$ is calculated using the perpetual inventory method with a discount rate of 15%. So the accumulation of capital $S_t^{SGA}$ is described by $S_t^{SGA} = I_t + \delta S_{t-1}^{SGA}$, with expense $I_t$ taken from the income statement and $\delta$ the discount factor 1/1.15. To estimate the dollar return on investments, we scale *SG&A* stock to market value (still denoted SG&A in the analysis below).

To construct the dependent variable $V_{it}^*$, capital invested $CI$ and $PVEP_{it}$ are backed out from the market value at fiscal year-end. Capital invested is defined as total assets minus accounts payable and other current liabilities. Let us define $PVEP_{it}$ in Eq. (5.4) by

$$PVEP_{it} = \frac{NOPLAT_{it}}{k_{it}} = \frac{EBIT_{it} - TAX_{it} + (DTAX_{it} - DTAX_{it-1})}{k_{it}},$$

where, for firm $i$ at time $t$, $NOPLAT$ is net operating profits less adjusted taxes, $TAX$ is income taxes, $DTAX$ is deferred taxes and $\rho$ is the weighted average cost of capital ($WACC$):

$$k_{it} = \frac{D_{it}}{D_{it} + E_{it}} k_{d,it} + \frac{V_{it}}{D_{it} + E_{it}} k_{e,it}.$$

In order to calculate the firm-specific and time-varying $WACC$, we find $D$ and $E$ (the total value of debt and equity), and $k_d$ and $k_e$ (the cost of debt and equity).

Because the correlations between emerging and developed markets are low, so will the beta with any global (either U.S. or world) index be. This will result in a cost of equity that is equal or lower than the U.S. risk-free rate. Harvey (1995) confirms this empirically, and finds that the country variance does a better job of explaining the cross-sectional variation in expected returns. This is modeled through a cost of equity based on credit ratings that specifically deals with country risk and institutional differences between countries. we add sovereign yield spreads to the traditional CAPM model, which is the spread between a country's government 10 to 30-year bond yield or equivalent (denominated in dollars) and the U.S. Treasury yield. Yield spreads are obtained (in order of availability) from the Economist Intelligence Unit, the International Monetary Fund or a nation's central bank. Since sovereign bond yields are not available for many countries, we run a regression on available sovereign spreads and country-risk ratings, and use implied values for all countries (Erb, Harvey and Viskanta, 1996). Specifically, we estimate the following equation using a fixed-effects panel:

$$SS_{jt} = \alpha_1 + \alpha_2 RR_{jt} + \varepsilon_{it},$$

in which for country $j$ at time $t$, $SS_{jt}$ is an available sovereign spread and $RR_{it}$ is a country risk rating. The $R^2$ of this regression is 0.65. Country risk ratings are collected from Institutional Investor's semi-annual survey of bankers – Institutional Investor rates each country on a scale of 0 to 100 with 100 representing the smallest risk of default, and attaches weights to these responses based on a bank's perceived level of global prominence and the detail of their credit analysis. The cost of equity is then calculated by a standard

CAPM model with 5-year forward-looking (i.e. adjusted) betas using weekly pricing data, i.e.:

$$k_e = r_f + \beta_i \left[R_m - r_f\right] + \widehat{SS}_j.$$

Finally, a "synthetic" cost of debt is found by linking the interest coverage ratio (*EBIT / interest expense*) and firm size to credit ratings and default spreads. The credit ratings are obtained from Bonds Online. If applicable, operating leases are converted into debt iteratively (as this requires an initial cost of debt), and negative earnings are replaced by averaged 5-year earnings (Damodaran 2002).

### 3.3.3 Analysis

The analysis consists of several estimations for the 6 largest industries and 5 different countries that are pragmatically selected, based on data availability. As each industry or country has different value dynamics, there does not exist a single estimation model that is well-specified for all (sub)samples. An additional complication is that little guidance is offered by economic theory about the nature of the measurement error. Therefore, a sub-sample's model specification will be evaluated and selected using three diagnostic tests.

One test is the autocorrelation test by Arellano and Bond (1991). The second test is the $J$ - statistic of Hansen (1982) for overidentifying restrictions, to test whether the model is correctly specified and the instruments are valid. Following Roodman (2009), the $J$ - statistic is used as a specification test and models with Hansen's $p$ value higher than 0.25 are considered well-specified. A natural question concerns the number of lags that should be included. We iteratively search for an optimal number of lags – if lags are insignificant, they are excluded. We may add an extra lag to prevent variation in this period to be attributed to the next's, or delete a lag to add degrees of freedom and increase efficiency. As a third test that compares iterations, each functional form can be evaluated using a Wald test that tests whether all the coefficients (except the constant) are jointly zero.

## 3.4 Results

This section presents results on the six sectors and five countries with enough observations to provide meaningful estimates. Specifically, we present results on the services; health care; business equipment; wholesale; financials and construction sectors[2], and break these down into results for the United States, the United Kingdom, Japan, China and Taiwan. We observe considerable variation in residual value between these sectors and countries: most future growth value lies in sectors with much intangible capital and countries with well-developed financial markets.

### 3.4.1 Sample Statistics

Table 3.2 shows how firms are distributed over countries. The five largest countries constitute about 61% of the total number of observations; the Worldscope database clearly focuses on Asian and North-American stock markets. The largest median residual values are found in the United Kingdom ($V^* = 0.703$) and the United States $V^* = 0.797$), and the lowest in China ($V^* = -0.057$) and Taiwan ($V^* = 0.317$). Average and median values of $V^*$ show that developed countries have a higher $V^*$ component than less developed countries. This suggests that residual value incorporates risk adjustments – Western financial markets are more efficient, and legislation better protects shareholders. The *negative* $V^*$ for China may represent a discount on the expected cash flows from operations and the value in place. In general, dispersion is large and varies considerably across countries.

Table 3.3 shows that important differences exist between sectors. It can be observed that the standard deviation is more constant across industries, indicating that sector subgroups are more homogeneous than country subgroups. Most sectors have a larger residual value at the mean than at the median, which indicates that in most industries, some companies have very large residual value. The highest residual value is found in the services sector ($V^* = 1.880$) and healthcare sector ($V^* = 1.751$). Returns in these industries are more volatile and earnings more risky for many firms, which increases their residual value.

[2] Services include personal and business services. Healthcare represent medical equipment and pharmaceutical products. Business Equipment represents computers, software, and electronic equipment. Wholesale represents wholesale of durable and non-durable goods. Finance represents banks, insurance companies and other financials. Construction includes construction and construction materials.

Table 3.2: Residual Value by Country

Summary statistics of residual value, reported by country for the full sample period (1998-2007). Reported are the number of non-missing observations, as well as mean, median and standard deviation of residual value. Only the six largest countries are reported.

| | Obs. | Mean | Med. | St. Dev. |
|---|---|---|---|---|
| United States | 36,730 | 1.607 | 0.797 | 4.145 |
| Japan | 23,056 | 0.548 | 0.309 | 2.733 |
| United Kingdom | 10,293 | 1.232 | 0.703 | 3.445 |
| China | 7,876 | 0.459 | -0.057 | 5.278 |
| Taiwan | 6,344 | 0.685 | 0.317 | 2.495 |

Table 3.3: Residual Value by Sector

Summary statistics of residual value, reported by sectors for the full sample period (1998-2007). Sector definitions are based on the Industry-30 classification, as provided by Kenneth French on his website. Reported are the number of non-missing observations, as well as mean, median and standard deviation of residual value. Only the six largest sectors are included.

| | Obs. | Mean | Median | St. Dev. |
|---|---|---|---|---|
| Services | 16,732 | 1.880 | 0.908 | 4.438 |
| Healthcare | 8,489 | 1.751 | 0.966 | 4.028 |
| Bus. Equipment | 13,908 | 1.405 | 0.770 | 3.854 |
| Wholesale | 9,551 | 0.600 | 0.303 | 3.660 |
| Finance | 20,379 | 0.454 | 0.304 | 3.376 |
| Construction | 10,022 | 0.445 | 0.199 | 3.750 |

Services include personal and business services. Healthcare represent medical equipment and pharmaceutical products. Business Equipment represents computers, software, and electronic equipment. Wholesale represents wholesale of durable and non-durable goods. Finance represents banks, insurance companies and other financials. Construction includes construction and construction materials.

Table 3.4: Residual Value for 6 Large Industries and Countries
Summary statistics of residual value, reported for the six largest sectors and countries over the full sample period (1998-2007). Sector definitions are based on the Industry-30 classification, as provided by Kenneth French on his website. Reported are the number of non-missing observations, as well as mean, median and standard deviation of residual value.

| | | Finan. | Servs. | BusEq. | Constr. | Whlsl. | Hlth. | Total |
|---|---|---|---|---|---|---|---|---|
| U.S. | Obs. | 5,119 | 6,346 | 4,502 | 977 | 1,493 | 4,164 | 22,601 |
| | Mean | 0.448 | 2.674 | 2.128 | 0.532 | 1.210 | 2.426 | 1.826 |
| | Median | 0.269 | 1.190 | 1.035 | 0.389 | 0.647 | 1.298 | 0.911 |
| Japan | Obs. | 1,806 | 1,838 | 1,810 | 2,538 | 2,541 | 569 | 11,102 |
| | Mean | 0.644 | 0.596 | 0.662 | 0.868 | 0.334 | 0.437 | 0.609 |
| | Median | 0.274 | 0.447 | 0.499 | 0.289 | 0.159 | 0.369 | 0.329 |
| U.K. | Obs. | 2,989 | 1,877 | 567 | 500 | 501 | 451 | 6,885 |
| | Mean | 0.767 | 1.964 | 2.114 | 0.544 | 1.291 | 2.076 | 1.312 |
| | Median | 0.734 | 0.867 | 0.929 | 0.178 | 0.495 | 1.446 | 0.765 |
| China | Obs. | 639 | 277 | 610 | 571 | 325 | 522 | 2,944 |
| | Mean | 0.622 | 1.020 | 0.419 | -0.131 | 0.620 | 0.625 | 0.472 |
| | Median | 0.293 | 0.200 | 0.174 | -0.400 | -0.121 | 0.018 | 0.048 |
| Taiwan | Obs. | 256 | 242 | 2,297 | 470 | 393 | 110 | 3,768 |
| | Mean | 0.647 | 1.264 | 0.869 | 1.006 | 0.598 | 0.200 | 0.849 |
| | Median | 0.273 | 0.332 | 0.426 | 0.293 | 0.126 | 0.220 | 0.375 |
| Total | Obs. | 10,809 | 10,580 | 9,786 | 5,056 | 5,253 | 5,816 | 47,300 |
| | Mean | 0.626 | 1.504 | 1.238 | 0.564 | 0.811 | 1.153 | 1.013 |
| | Median | 0.368 | 0.607 | 0.612 | 0.150 | 0.261 | 0.670 | 0.486 |

Furthermore, these sectors are characterized by a large number of small firms, which do not yet have scale economies and consist largely of immaterialized value. In these sectors, a large portion of the value can be ascribed to intangible assets. In contrast, construction ($V^*$ =-0.445) and wholesale ($V^* = 0.600$) exhibit the lowest residual value. For these more stable, low-growth income sectors, earnings are more predictable and scale economies are important for every firm in the sector. This increases the importance of the value of assets in place and decreases the proportional importance of intangibles.

We can add more detail to these statistics by the decomposition in Table 3.4, which shows similar statistics for country-sector combinations and their totals. This table shows that countries differ greatly in natural endowments and productive inputs. For instance, the United Kingdom displays a great dependence on financial services, whereas Taiwan is mostly active in computer equipment. We can also see that sectors with few intangibles make up a smaller portion of total firms for developed countries. We can also observe that for a given sector, there exists large variation in the residual value across countries. These findings are in line with Tong et al. (2008b), who find that country effects matter for growth options, and are consistent with theories of comparative advantages (e.g. Krugsman and Obstfeld, 1997).

### 3.4.2 Panel Results

The effect of $SGA$ stock on the present value of growth opportunities is examined per sector, as industry structure and value dynamics are expected to have a large effect on future growth opportunities. This also holds for different geographic regions. Within national economies, however, different sectors have different sources of intangible value and a wide range of intangible assets are aggregated. Effects of *SG&A* on the $V^*$ are significant only after the creation of homogeneous (sectoral) subsamples. We will therefore compare sectors internationally, and not country aggregates.

#### 3.4.2.1 Business Equipment

Table 3.5 shows that for none of the models, the $J$ - test rejects the null of over-identifying restrictions. As the Arellano-Bond test for independent AR(1) disturbances is not rejected either, the models are considered well-specified. The significance of the lagged dependent variable, $SGA_{t-1}$, indicates that endogeneity issues need to be controlled for and the dynamic panel specification is necessary. The coefficients represent capitalization rates, where a positive return implies a rate larger than one and full expense implies a rate of zero. A unity capitalization rate implies both a break-even return and capitalization at full cost.

An easy observation is that the two best represented countries (Taiwan and the U.S.) show a significantly higher residual value contribution of SG&A to intangible value. This supports theories of comparative advantage (such as a shared benefit of a nation's endowments) and knowledge spillovers between geographically similar firms. As we observe positive effects of $SGA$ on $V^*$, we can infer that $SGA$ investments are positively valued by the market and are not merely expenses. Moreover, about 82% of all *SG&A* is capitalized at year-end, and an additional 12% is capitalized one year later. These effects ignore the fraction of *SG&A* spent on intangible capital and depreciation, and provides a lower bound of the capitalization rate. It could therefore be expected that intangibles earn a return that is normal to positive, as the coefficient for $SGA_{t-1}$ does not differ significantly from unity, whereas it is significantly different from zero. The coefficient of $SGA_{t-2}$ lies somewhere between zero and one, indicating that in addition to the return of the year before, *SG&A* creates a bit more value in year two. It seems reasonable to conclude that SG&A investments contribute importantly to the intangible asset base of corporations in the business equipment sector. This result supports full-cost capitalization as an estimate of fair intangible value.

A different picture emerges, however, if these general results are broken down to country level. It can be seen that large international differences exist between corporations in business equipment industries. The United States shows a rate of capitalizing SG&A that is similar to the whole sector, which is not surprising considering the number of U.S. firms in the sample. Taiwan, however, earns a significantly higher return of about 40%. This should be interpreted with care, as these are *average* returns. Therefore, there may not be a structural explanation for why the Taiwanese yield such a large return on investment in business equipment. But in the most conservative case, even if all of SG&A is meant to increase the intangible capital stock, at least 97% of all SG&A investments are capitalized on a 95% confidence level. It is clear that for business equipment in Taiwan, expensing SG&A investments ignores many capabilities and competencies that these investments create. Full-cost capitalization may also potentially underestimate these benefits.

For the United Kingdom, Japan and China, SG&A outlays seem to be expenses, rather than investments. Neither of the capitalization rates is significantly different from zero after one or two years. In fact, SG&A is significantly negative in the third year for Japan[3] and the United Kingdom , which suggests that value is actually destroyed, on average, by SG&A outlays. This is a confusing result. More detailed analysis is required to examine why this is the case, but we conjecture that the fraction of intangible investments of total SG&A is low in these countries (leading to downwardly biased estimates). A possible economic explanation could be efficiency losses, due to an increase in overhead costs.

[3]It should be noted that for Japan, the estimation may suffer from a proliferation of instruments and the model is poorly specified.

Table 3.5: Residual Value in Business Equipment

Regression results – for the business equipment sector – from regressing residual value on lagged residual value ($V^*_{t-1}$), Selling, General and Administrative expenses ($SGA_{t-\tau}, \tau = 0, 1, 2$), and a constant. Both variables are scaled by market value. Results on year dummies are unreported; all coefficients are significant. Additional statistics are the number of observations (*Obs.*), the number of firms (*Firms*), test statistic and $p$-value of Arellano and Bond's (1995) test for autoregressive residuals in first differences (*AR(2) test*, $P(AR(2) > z)$) and test statistic and p-value of Hansen's J-test of overidentifying restrictions. In the upper panel, Z -statistics are in parentheses under coefficient estimates. In the lower panel, $p$-values are in parentheses under $Z$ and $\chi^2$ statistics. + significant at 10%; * significant at 5%; ** significant at 1%.

| | | United States | Taiwan | Japan | United Kingdom | China |
|---|---|---|---|---|---|---|
| *Residual Value*$_{t-1}$ | 0.157** | 0.108* | 0.151* | -0.022 | 0.206 | 0.132 |
| | (5.73) | (2.02) | (2.01) | (0.41) | (1.13) | (1.92) |
| *SG&A*$_t$ | 0.82** | 0.826** | 1.392** | 0.131 | 0.117 | 0.587 |
| | (6.91) | (4.97) | (6.49) | (1.07) | (1.34) | (0.71) |
| *SG&A*$_{t-1}$ | 0.12** | 0.123** | | 0.137 | -0.16 | 0.301 |
| | (3.96) | (4.41) | | (1.38) | (0.83) | (0.28) |
| *SG&A*$_{t-2}$ | | -0.002 | | -0.192** | -0.458** | -1.116 |
| | | (0.16) | | (2.93) | (4.85) | (1.02) |
| *Constant* | -0.409 | -0.779 | -0.76** | 0.212 | 2.114** | 2.101** |
| | (1.84) | (1.49) | (2.77) | (1.34) | (3.48) | (3.47) |
| Diagnostic Tests ($p$-values in parentheses): | | | | | | |
| *Observations* | 11034 | 3572 | 1829 | 1521 | 455 | 408 |
| *Firms* | 2284 | 689 | 425 | 252 | 88 | 105 |
| *AR(2) - test* | 0.01 | -0.005 | 1.011 | 1.168 | 1.151 | -0.409 |
| | (0.992) | (0.996) | (0.312) | (0.243) | (0.250) | (0.683) |
| *Hansen J-test* | 6.264 | 9.045 | 14.766 | 18.063 | 13.628 | 10.045 |
| | (0.713) | (0.770) | (0.394) | (0.155) | (0.401) | (0.69) |

#### 3.4.2.2 Other industries

The analysis for the business equipment sector is ideally repeated for the remaining 5 sectors. Unfortunately, it is not always possible to obtain a well-specified model with significant coefficients. For China and the wholesale and construction sector, it turned out impossible to reliably estimate[4] Eq. (5.3). For the remaining 3 sectors, one or more countries suffered from identical problems. Of those firms remaining, the following results are found.

**Finance** In the aggregated financial sector, financial investors in the first year consider about 22% of SG&A expenses a contribution to intangible capital and 78% expense. An additional capitalization 14% in the following year is significant. These rates differ significantly from zero and unity, indicating that current accounting practice underestimates, but full-cost capitalization overestimates the accumulation of intangible capital. These results markedly differ from previous findings in business equipment.

When we examine the finance sector per country, the estimated capitalization rate in the U.S. (good for 32% of observations) is 18% per dollar invested in SG&A followed by 8% in the next year. The U.K. (good for 12% of observations) shows a rate of 25%. These rates are not significantly different from one another, and may indicate the high level of global integration in financial markets. This too is quite different from previous findings in business equipment, where large international differences were found.

**Business and Personal Services** The services sector shows the most heterogeneous picture. For the sector as a whole and the U.S., capitalization takes a year to substantiate and is smaller than in sectors described previously (about 5%). Small rates make sense, because services are labor-intensive and low-skilled personnel is a primary cost driver. This implies that relatively few intangible capital is created from SG&A investments, but also that results are more biased downwards than for other sectors. It also shows that increased spending on *SG&A* yields a negative return after that year, although the coefficient is small.

[4] For these subsamples, the Hansen $J$ - test detected the presence of overidentifying restrictions, due to an abundance of instrumenting lags. We had more success in specifying models using first-differences GMM for these sectors. The problem of weak instruments turned out severe, however, and no significant results could be obtained.

This can be explained similarly. For services, the *SG&A* measure appears particularly noisy. Examining country differences, the results for the U.S. look similar to those of the sector as a whole. This is not surprising, considering that U.S. firms account for more than a third of the whole sector.

**Health care** In the smallest sector under examination, the intangible capital is significantly determined by intangibles of up to two periods back, a persistence that may reflect the long gestation lags so typical for the industry. While intangibles are also important in this sector, the resulting contribution of *SG&A* is substantially lower than in business equipment. Only 44% of all SG&A is considered as an investment that increases residual value. While this may indicate that SG&A entails more than intangible capital (as compared to business equipment), it may also reflect the technical uncertainty that may be larger than in any other sector (e.g. drug development programs). This may also be causing the negative effect of SG&A one year hence – after an initial capitalization of 43%, the same investment decreases intangible capital by 14% after a year.

## 3.5 Discussion

This study compares residual values of intangible investment across sectors and countries-within-sectors. In doing so, it adds to a long discussion in the empirical literature that discusses the relationship between market value and innovation. Because many previous studies have problems finding a link between innovation and market value, we use a broader definition of innovation and a more narrow definition of market value, as an attempt to overcome these problems. Intangible investments are measured through SG&A, which is easy to obtain globally from the financial statements but includes additional expenses that are not related to intangibles. The link found in the present study is significant and robust across countries and sectors, but several pitfalls have been exposed during the process.

First, after taking into account biases and inconsistencies that result from endogenous regressors, omitted variables, capital markets efficiencies and unobserved heterogeneity across firms and over time, this study should have ideally produced a five-country comparison of intangible capitalization across six sectors. It turns out, however, that insufficient

Table 3.6: Residual Value in Other Industries

Regression results – for the financials, services and healthcare sector – from regressing residual value on lagged residual value ($V^*_{t-1}$ and $V^*_{t-2}$) and Selling, General and Administrative expenses ($SGA_{t-\tau}, \tau = 0,1,2$), and a constant. Both variables are scaled by market value. Results on year dummies are unreported; all coefficients are significant. Additional statistics are the number of observations (*Obs.*), the number of firms (*Firms*), test statistic and p-value of Arellano and Bond's (1995) test for autoregressive residuals in first differences (*AR(2) test*, $P(AR(2) > z)$) and test statistic and p-value of Hansen's J-test of overidentifying restrictions. For omitted sectors (i.e., wholesale and construction) and countries (e.g. China and Taiwan), no well-specified model with significant coefficients could be established. In the upper panel, $Z$-statistics are in parentheses under coefficient estimates. In the lower panel, $p$-values are in parentheses under $Z$ and $\chi^2$ statistics. + significant at 10%; * significant at 5%; ** significant at 1%.

| | Finance | | | Services | | | Health | |
|---|---|---|---|---|---|---|---|---|
| | All | U.S. | U.K. | All | U.S. | U.K. | All | U.S. |
| *Residual Value*$_{t-1}$ | 0.189** | 0.291** | 0.238** | 0.173** | 0.198** | 0.155** | 0.152** | 0.127* |
| | (5.97) | (7.11) | (3.01) | (8.09) | (5.71) | (3.48) | (3.90) | (2.30) |
| *Residual Value*$_{t-2}$ | | | | | | | 0.074* | |
| | | | | | | | (2.31) | |
| *SG&A*$_t$ | 0.221** | 0.179* | 0.245* | | | | 0.426** | 0.296* |
| | (4.63) | (2.42) | (2.35) | | | | (4.77) | (2.49) |
| *SG&A*$_{t-1}$ | 0.14** | 0.076+ | | 0.054** | 0.053** | 0.186** | -0.142* | -0.176* |
| | (2.78) | (1.82) | | (5.50) | (3.23) | (3.04) | (2.37) | (2.08) |
| *SG&A*$_{t-2}$ | -0.009 | | | -0.007* | -0.006* | -0.158** | | |
| | (1.09) | | | (2.53) | (2.40) | (5.07) | | |
| *Constant* | -0.157** | -0.612** | 0.194* | 1.209** | 1.873** | 0.838** | 0.993** | 1.746** |
| | (2.78) | (6.77) | (2.01) | (15.84) | (12.70) | (4.60) | (5.71) | (5.29) |
| Diagnostic Tests: | | | | | | | | |
| *Observations* | 15864 | 3959 | 2473 | 12595 | 4734 | 1485 | 5244 | 3311 |
| *Firms* | 3253 | 872 | 424 | 2855 | 1073 | 291 | 1174 | 631 |
| *AR(2) - test* | -0.382 | 0.116 | 1.041 | 0.047 | -1.087 | 0.358 | 0.466 | 0.318 |
| | (0.702) | (0.002) | (0.015) | (0.963) | (0.000) | (0.721) | (0.641) | (0.751) |
| *Hansen J-test* | 7.487 | 5.256 | 18.609 | 7.937 | 6.332 | 88.065 | 5.345 | 18.872 |
| | (0.278) | (0.629) | (0.232) | (0.338) | (0.502) | (0.144) | (0.50) | (0.17) |

observations, large $PVGO$ variation and/or weak instruments in the wholesale and construction sector prevent us from finding a well-specified model. The same holds for most results on China and Taiwan. Furthermore, if a sector is well-estimated, it often turns out impossible to break down these results to a sector-country level. We have only succeeded in doing so for the business equipment sector. Since similar methodology and accounting definitions do not cause problems in Chapter 2 and Chapter 4, this raises important questions about how to calculate residual value in an international context. Furthermore, the loss of data could cause a bias in the remaining set of firms.

Second, we have tried to generate more robust and reliable estimates of the impact of intangible capital on firm value, using the methodology from Chapter 2, a more precise definition of intangible value, and a more comprehensive measure of intangibles. Unfortunately, the $SGA \leftrightarrow V^*$ link persists to vary a lot, so that we have not succeeded in doing so. The relationship is strong and significant in all 4 sectors, which demonstrates that part of SG&A expenditure should be capitalized. However, average $SG\&A$ capitalization varies from 5% of $SG\&A$ in services, to 20% in finance, to 40% in healthcare and 90% in business equipment. Also, substantial international differences exist within sectors. In a globally integrated industry as the financial sector, differences are not significant and capitalization rates seem to be comparable between the U.S. and U.K. (18% and 25%, respectively). In business equipment, however, a dollar invested in SG&A creates \$1.39 of intangible capital in Taiwan but only \$0.31 in Japan. These findings suggest that natural endowments play a role between nations, and that this depends on the nature of resources that are characteristic to the sectors.

Hence, the main result of the paper is that there are cross-industry and cross-country differences in the impact of intangibles on firm value, which is not very surprising. Nevertheless, the results can be casually interpreted after recognizing that each sector differs in the importance of intangibles, and each country differs in its stage of financial and economic development. SG&A costs in computer-related firms are largely incurred from research and development, computer programming and consulting, which strongly contribute to a firm's intangible capital. In contrast, while labor input also plays a large role in the services sector, workers are typically less skilled and intangible investments make up a much smaller fraction of SG&A. On a country-sector level, the globally integrated and fairly homogeneous financial industry shows similar coefficients for different countries. At the same time, computer-related industries show significant differences between Taiwan and the United Kingdom that indicate institutional differences such as differences in labor costs or technological infrastructure and reliance. Future research should relate these impacts to firm or industry characteristics, in order to understand why there are such heterogeneities and what causes them.

This article has combined measures from accounting statements and equity markets in order to derive more accurate results than previous work. Since residual value is calculated from financial statements, it is readily available to external stakeholders who are concerned with innovative value creation, as well as to managers as an instrument for self-analysis. On a firm-by-firm basis, it allows management to link investment policy to changes in residual value and by comparing it amongst its peers. By comparing it amongst a firm's peers, the value residual may also yield insights on strategic and competitive positioning for individual firms. However, it does not provide a clear general guideline regarding the fraction (if any) of the SG&A expenditure that should be capitalized.

# Chapter 4

# Decomposing Residual Value

*Excessively high pricing by bidders and targets can either be explained by new growth opportunities created by the merger, or by irrational mispricing in financial markets. Both explanations of takeovers are well-documented, but are presently separate bodies of research. We integrate both explanations through a new decomposition of firm value, and investigate whether it is "true" growth value or mispricing that drives takeover waves. We find that "bidders buy smart": bidders have high market values following from overpricing rather than from growth value, and select targets that are less overpriced and have strong fundamental growth value. Indeed, a high market value for bidders (targets) is primarily due to mispricing (growth options). Bidders also seem to "time smart": takeover activity increases when bidders are more overpriced, and bidders buy targets with a lower overpricing component. These bidders tend to buy fundamental growth option value in order to cushion against an inevitable correction.*

## 4.1 Introduction[1]

To justify their intended business strategies in takeover announcements to shareholders, management teams frequently argue that new synergies and growth opportunities arise from the combined entity. Yet, previous research has found conflicting evidence for what drives merger activity. In view of the vast literature on mergers and acquisitions (M&A), explanations for M&A can be roughly classified into two classes that both have found empirical support: a rational explanation and a behavioral explanation.

Consistent with neo-classical rational theory, prior studies show that high market values of bidders and a takeover premium for targets reflect rational expectations of cost efficiencies, synergies, market power, and growth options, accordingly appreciated by financial analysts and equity investors. Mergers may reallocate assets more efficiently in response to industry shocks (e.g., Mitchell and Mulherrin 1996) and deregulation, removing "longstanding barriers to merging and consolidation, which might have kept the industry artificially dispersed" (Andrade, Mitchell, and Stafford 2001, p. 108). Consolidation is found to have been the driving force behind acquisitions in the 1990s (Holmstrom and Kaplan 2001; Andrade et al. 2001). In line with a rational view, real options theory implies that acquisitions confer valuable new growth opportunities for the combined entity.

In contrast to rational theories, two distinct behavioral views offer alternative explanations for what drives merger waves (Baker, Ruback, and Wurgler 2007). Besides from the biases of decision makers[2], market inefficiencies may arise when financial markets fail to price firms correctly (e.g., Shiller 2000). High market values are strongly related to merger activity (Rhodes-Kropf and Viswanathan 2004) and managers of overvalued firms buy targets that are less overvalued (Rhodes-Kropf, Robinson, and Visnawanathan 2005).

While the different explanations for M&A may at least partly be due to a wide range of methodologies applied (e.g., Baker *et al.* 2007), they may also indicate common ground. This makes intuitive sense. The scope for valuation errors or mispricing is greater when

[1] This chapter is co-authored with Han Smit and Enrico Pennings, and drawn with minor editing from a working paper entitled "Buy Smart, Time Smart: Are Takeovers Driven by Growth Options or Mispricing?". This paper is conditionally accepted for publication in Financial Management.

[2] Decision makers – the bidder's CEOs and management teams – may act irrational. CEOs may suffer from overconfidence and overoptimism (Roll 1986; Larwood and Whittaker 1977; March and Shapira 1987), and managers may use their discretion to over-invest (Malmendier and Tate 2005).

"elusive" growth options value is a major source of expected value than when value gains arise from exploiting established products and established markets. Hence, if takeovers are jointly explained by both theories, combining theories for mispricing and investment opportunities offers a stronger theoretical base for high market values in takeovers. To facilitate an integrated analysis, we devise a new measure for fundamental[3] growth options value that adjusts market-based growth options value for mispricing.[4]

We find that takeovers do confer valuable growth opportunities, but these are strongly contingent on market sentiment. The conventional (market-based) growth options measures should be used with care, as they can be driven by overvaluation and needs to be corrected for mispricing. By analyzing firm properties (e.g., involvement in a merger and the role of the target or bidder) and deal properties (e.g., form of payment, acquisition financing, and deal attitude), we find that deal properties that favor overvalued bidders are significantly related to bidder overpricing (but not growth options value) as well as growth options value of targets (but not overpricing). These results lead to two key implications.

First, "bidders buy smart." Although bidders are highly valued in the market, they have little fundamental growth options value relative to non-bidders and target firms. This indicates that their overpriced equity allows them to finance their acquisitions inexpensively. Their targets are also highly valued, as compared to firms not involved in a merger, but have a relatively high growth options value that persists after controlling for mispricing. This indicates undervaluation – at least with respect to the bidder's equity – and fundamental growth option value. Second, bidders time their takeovers accordingly. Specifically, when excess pricing for bidders is high, takeover activity is high as well. Acquisitions are thus made by firms that are overvalued, relative to their peers. For targets, in contrast, growth options value is negatively related to takeover activity. Hence, when bidders are overvalued, they acquire targets that are undervalued relative to the bidder. In effect, this will cushion against an eventual correction in share price.

These results are validated using a large international dataset. By using market-implied growth options value and controlling for pricing errors, we avoid using sophisticated option models that introduce substantial model- and parameter uncertainty. In a 12-year panel

[3]I.e., based on company fundamentals such as book value, net income, and leverage.

[4]I.e., unrelated to fundamental value creation.

of over 30,000 observations, we use t-tests to show that bidders buy smart. In order to show that bidders also time their acquisitions smart, we estimate the correlation over time between growth opportunities or mispricing and takeover activity. These findings are then enhanced by estimating multiple equation models in a multivariate setting.

This paper proceeds as follows. In Section 2, we position our contribution into the literature. In Section 3, we derive the hypotheses. Section 4 describes the data and decomposition employed, followed by a presentation of the results in Section 5. Section 6 concludes and presents implications for further research.

## 4.2 Literature Review

### 4.2.1 Real Options Theory in M&A

Recent real options models explain the dynamics of mergers and acquisitions decisions under uncertainty, such as the timing of takeovers under competition (Morellec and Zhdanov 2005), the associated division of the surplus between acquirer and target, the pro-cyclical nature of waves when they are motivated by economies of scale (Lambrecht 2004), and the timing of mergers when they are driven by diversification (Thijssen 2008).[5] Smith and Triantis (1995) suggested that – aside from flexibility and divesture options – acquisitions contain significant growth options. In addition to the value of future cash flows and synergy values, joined forces may enhance the value of the option to invest in new products and the option to acquire other competitors. Takeovers also limit competition by eliminating the target's option to grow, and the combined entity may more effectively allocate resources between markets of bidder and target.

For the bidder, executing an acquisition is effectively exercising an option to exchange the acquisition price (either in cash or the acquirer's shares) for the value of the target (Margrabe 1978). The opportunity to acquire a target's equity can thus be seen as an option while, in addition to that, the target itself is a portfolio of real growth options. The target's strategic growth options generate follow-on opportunities that are part of the underlying

[5] An exchange option can be viewed as a call option on the benefits of the merger. The costs of a merger, then, are represented as the exercise price. While these studies interpret takeovers as a call option, we refer to these options as exchange options to stress the difference from strategic options.

value of the option to exchange. Relative to the earnings capacity of assets in place, the value of growth options is elusive and difficult to estimate, which may influence the timing and value of the option for the bidder. Hence, acquisitions become more attractive when the bidder's equity is overvalued and the acquisition can be paid for or financed with equity, or when the fundamental growth option value of the target is high and the target is less overvalued or even undervalued. In terms of fundamental value, the real exchange option is more in the money when the bidder is overvalued relative to its target. This, however, is not necessarily observed in financial markets.

### 4.2.2 Empirical Real Options Analysis

Miller and Modigliani (1961) and Berk et al. (1999) showed that a firm's market value ($P(t)$) can be partitioned into the value of a firm's assets in place ($\sum_{j=0}^{t} V_j(t)\chi_j(t)$) and the present value of future investments in growth opportunities ($V^*(t)$):

$$P(t) \equiv \sum_{j=0}^{t} V_j(t)\chi_j(t) + V^*(t).,\tag{4.1}$$

where $\sum_{j=0}^{t} V_j(t)\chi_j(t)$ is approximated by an appropriately discounted, perpetual stream of earnings from the assets in place.

Under the assumption of no further growth, all earnings are equal to those in the current period.[6] Data on market value and the value of assets in place are readily available, so the value of growth options $V^*$ can be "backed out" from Eq. (5.1). Real options theory has underpinned growth options value with strong theoretical foundations (e.g. Myers 1977; Dixit and Pindyck 1996; Trigeorgis 1996). In this study, we will extend Eq. (5.1) so that it incorporates irrational behavior in financial markets.

A company's portfolio of real options can be valued "bottom-up" through the estimation of individual option parameters. This entails the use of binomial lattice (e.g., Trigeorgis 1996) or simulation models (e.g., Longstaff and Schwarz 2001), which makes it possible to adjust the option valuation to case-specific characteristics (e.g., Copeland and Antikarov 2001). In reality, a firm's growth opportunities consist of a complex combination of growth

[6]This assumption is nonrestrictive, since all future growth (either positive or negative) should end up in the $V_{GO}$ term.

options resulting from intra-firm option interactions. The combined value of an options portfolio is typically not the sum of the options (e.g., Trigeorgis 1996), and real options should sometimes be combined sequentially, sometimes in parallel and sometimes not at all (e.g., Childs et al. 1998). Two merging firms complicate the options portfolio even further. To avoid estimating option and interaction parameters, we follow a less involved "top-down" approach, which uses financial market information of publicly listed firms, and calculates the combined growth options value that is embedded in the stock price.

Differences in growth options value were first empirically studied by Kester (1984). More recently, growth options value has been related to systematic risk (Chung and Charoenwong 1991), R&D, uncertainty, and the skewness of returns (Smit 1999), to the pricing of initial public offerings (Chung, Minsheng and Yu 2005), to idiosyncratic risk (Cao et al. 2006), to firm, industry, and country effects (Tong et al. 2008a), to downside risk of multinational corporations (Tong and Reuer 2008), and to international joint ventures (Tong et al. 2008b).

This market-based measure for growth options value, however, hinges on the assumption that market prices adapt fully and immediately to price-relevant information. This assumption is quite strong, since the elusive value of growth options can easily be over- or underestimated in financial markets. Any erroneous market pricing will introduce noise in growth options value, and we will adjust the growth options value in Eq. (5.1) for this.

### 4.2.3 Irrational Capital Markets

Due to market inefficiencies (e.g., Barberis and Thaler 2003; Shleifer 2000), the market price $P(t)$ in Eq. (5.1) may not reflect fundamental firm value. Corporate managers have superior information about their own firm (e.g., Muelbroek 1992; Seyhun 1992) and rational managers can gain by timing anomalies that result from irrationality in the markets (Jenter 2004; Baker and Wurgler 2002). Managers may also "cater" to short-term investors by maximizing appeal (Baker et al. 2007). In these situations, managers influence the market value of a firm without creating fundamental value. In a takeover context, when potential market value deviates from fundamental values, takeover activity may be strongly related to stock market valuation (Rhodes-Kropf and Viswanathan 2004; Dong et al. 2006). This is in line with previous evidence on information asymmetries: firms issue equity when they are overvalued, since acquisitions are in effect a form of equity issuance (e.g., Ritter 1991; Loughran and Ritter 1995; Jenter 2004).

Empirical studies on overvaluation typically separate market value into an intrinsic part and a mispricing part. A popular proxy for mispricing is the market-to-book ratio ($M/B$: e.g., Barberis and Huang 2001; Daniel et al. 2001; Dong et al. 2006; Rhodes-Kropf et al. 2005). For instance, Rhodes-Kropf *et al.* (2005) find that bidders have a larger $M/B$ than targets, but both have higher $M/B$s than non-mergers. Alternatively, Dong *et al.* (2006), who report more studies that use $M/B$ in this context, compare a firm's market-to-book ratio with its market-to-value ratio, where value is measured as a perpetual stream of (forecasted) earnings. They too find that both bidders and targets have high market-to-book ratios due to mispricing. Our findings are consistent with both studies.

Besides mispricing, however, the market-to-book ratio is also a well-known proxy for growth opportunities (e.g., Berk, Green, and Naik 1999; Anderson and Garcia-Feijoo 2006). Hence, in terms of market-to-book, overpriced targets, as in Rhodes-Kropf *et al.* (2005), may also be targets with a large potential for economic growth. Dong *et al.* (2006) address this issue by measuring intrinsic value, and find that targets are less overvalued and have a lower $M/B$ ratio. Not comparing $M/B$ with non-merging firms, however, also fails to explain the selection of targets from a growth options perspective. We will therefore resort to a different, "cleaner" measure than $M/B$ and compare it among bidders, targets, and non-merging firms. Our approach shows that market-to-book consists of both growth opportunities and mispricing, and that this distinction is of great importance for analyzing takeovers.

## 4.3 Hypotheses

### 4.3.1 Bidders are Overvalued

Several takeover motives exist that are related to share prices, but many of them are not aimed at creating fundamental value.[7] Rhodes-Kropf and Vishnawanathan (2004) propose

[7] For instance, Myers (1976) shows that takeovers may boost short-term earnings-per-share but depress long-term growth.

a theory that explains why merger waves occur during valuation waves; in their model, overall valuation error of share prices leads to overestimation of synergies after a takeover. In addition, Shleifer and Vishny (2003) argue that bidders are overvalued relative to the target, and buy smart using their overvalued stock. Firms may thus inexpensively acquire targets by taking advantage of financing with their overvalued equity.[8]

What these models have in common is that managers maximize firm value when financial markets may not represent company value[9], which leads to the following empirical observation that serves as a building block for further theoretical reasoning.

**Empirical Observation:** *Bidders are overpriced relative to non-merging firms.*

This empirical observation has implications for a company's growth options value. When markets fail to price growth options correctly, growth options value tends to be overpriced and conventional growth options measures may at times be inappropriate. This bias is likely to differ over time and across industries, and the surveyed literature on mispricing indicates that it is also associated with takeover activity. Mispricing arguments state that market value in excess of fundamental value is a pricing error. The implication is that growth options value would be substantially smaller if it could be backed out from fundamental value, instead of overvalued market price, in Eq. (5.1).

### 4.3.2 Bidders Buy Smart

As noted, a company can be viewed as a basket of assets and growth options. Valuable growth options of a target can be an important rational reason to bid, for instance when the acquirer can create synergies and provide instant access to many new resources and capabilities. Organic growth options may result from novel technologies or re-shaped market conditions (e.g., Bettis and Hitt 1995). When the value of the company's growth options develops favorably – e.g., positive changes in product demand and further development of technological trajectories – a firm appropriates future profits by exercising its options

[8]This model is in line with evidence on information asymmetries, where firms issue equity when they are overvalued, since acquisitions are in effect a form of equity issuance (e.g., Jenter 2004).

[9]This is not necessarily true. For instance, an acquisition may also result from managers who overestimate their ability to create synergies after the merger (Roll 1986), and managers may have objectives that reduce firm value (Morck et al. 1990). However, without precluding value-destroying managers, we abstain from drawing this distinction, as both aspects lead to our first proposition.

through investment. In addition to these embedded growth options that are complementary to the bidder, a target may also provide an initial foothold in a market with high entry barriers (as in Miller and Folta (2002), or function as a platform for follow-on acquisitions (Smit 2001). The target then generates additional growth option value, to be obtained through follow-on acquisitions.

Real options are related to mispricing through two untested but relevant implications from Shleifer and Vishny (2003), and we will adopt their terminology. First, targets in acquisitions "*are undervalued relative to the bidders*" (p. 308), or less overvalued; if not, bidders may well select a target that offers better market value for their overvalued equity. Therefore, targets should be less overpriced. Second, targets may also be "*underpriced in terms of fundamentals*" (p. 308); clearly, bidders may also aim to buy undervalued targets at a price below fundamental value. Therefore, targets should possess more growth option value.

When related to the work of Shleifer and Vishny (2003), real options theory offers a novel explanation of who is likely to acquire or become a target; overpriced bidders with below-average fundamental growth options value prefer to buy targets with above-average fundamental growth options value. These targets may also be overvalued at times. But in contrast to bidders, the difference between fundamental and market-based growth options value should be smaller. Such a real options view of the Shleifer and Vishny (2003) model implies that, when overvalued bidders have little growth options value, they exercise an option to exchange by buying targets with abundant growth options value. Therefore, we derive the following hypotheses:

**Hypothesis 1a:** *Bidders have high market values that are mostly due to mispricing, and less to fundamental growth opportunities.*

**Hypothesis 1b:** *Targets have high market values that are mostly due to fundamental growth potential, and less to mispricing.*

### 4.3.3 Bidders Time Their Bids Smart

Mentioned as another implication by Shleifer and Vishny (2003), bidders prefer targets that can limit losses when prices eventually correct. When expecting a downward correction, overvalued firms may use their overvalued equity to acquire strong targets and try to cushion against ta future downfall. We expect that takeover activity increases with overvaluation, because inappropriately high market values will provide an incentive to acquire. In effect, mispricing provides a window of opportunity to inexpensively buy targets that give more "value for money" and possess strong growth opportunities. If these considerations explain the bidding of firms, we should observe that – over time – takeover activity is positively related to excess pricing. Therefore, we derive the following hypothesis:

**Hypothesis 2a:** *For bidders, mispricing is positively related to takeover activity.*

### 4.3.4 Bidders Buy Their Targets Smart

When bidders are overvalued, they derive value by acquiring targets whose price is less subject to overpricing, relative to their own. While fundamental growth options value makes a firm more attractive to buy, additional value is created if the equity of the target has not been subject to overpricing (so that the target is inexpensive). Hence, while it induces firms to become bidders, overpricing makes a firm less attractive as a target. It is expected that targets' mispricing is not positively (and potentially negatively) related to takeover activity. Therefore, we derive the following hypothesis:

**Hypothesis 2b:** *For targets, mispricing is not positively related to takeover activity.*

Mispricing can also be related to several characteristics of M&A transactions. If deal characteristics differentially affect bidders' and targets' fundamental growth option value and mispricing, this provides further support for hypotheses 1a and 1b. Furthermore, by estimating the effect of takeover activity after controlling for deal characteristics, we also perform a robustness check for hypotheses 2a and 2b. To this end, we will examine how deal payment (through stock), deal financing (by means of a stock offering), and deal attitude (i.e., hostile or friendly) are related to the growth and mispricing components of share price. These characteristics are related to overpriced bidders as follows.

First, if a bidder is overvalued, it can be expected that this bidder will prefer to pay for a target in equity. In terms of "true" value, this makes the deal cheaper and protects bidding firms from future drops in share price. The target's board of directors may require a cash deal, however, so that all risk of adverse price movements of the merger is borne by the bidder. Bidding firms may still put their overvalued equity to work, then, by financing the deal through a seasoned equity offering. Since the offering raises cash that can be used to buy the target, this too protects bidding firms from a future correction in share price. If management still opposes the deal, the bidding firm may resort to a hostile takeover that is not approved by the target board.

## 4.4 Data and Sample Characteristics

To study the hypotheses, we examine how year-by-year changes in growth opportunities and mispricing are related to year-by-year changes in takeover activity[10], and whether over-priced bidders relate to targets with fundamental growth options. We then examine growth options value and mispricing as time evolves. Finally, we extend the analysis to a multivariate approach.

From the Security Data Company (SDC)'s Platinum M&A database, we selected announcement dates and SEDOL codes in the period from 1995 to 2006, of all completed and unconditional public takeovers for a stake of at least 95%. For each deal, we collect accounting data using Worldscope and use Datastream to obtain yearly market equity values of firms involved in takeovers. To these datasets, we add auxiliary data on the cost of equity (using weekly pricing data from Datastream) and the synthetic cost of debt (using yearly data from Thomson One Banker (TOB)) to construct the weighted average cost of capital required for estimating the assets in place. We also classify a firm's primary SIC code into the Fama and French 12-sector definitions. As the mining sector is characterized by many takeovers, we add an extra sector using the Fama/French 30-sector definition for mining.

We merge these sources into a sample at firm-level that is used to calculate growth

[10] It offers no further insight to relate mispricing and growth opportunities directly to market values, as these are related to share prices.

options value[11] and mispricing. We follow the procedure as provided in Rhodes-Kropf *et al.* (2005), by matching "fiscal year-end data [...] with [...] market values occurring three months afterward. Because firms have different fiscal year end dates, this involves compensating for [,] so that the year of the data corresponds to the year in which the accounting information was filed. Then, we associate [TOB and Datastream] observations with an SDC merger announcement. If the announcement occurs between the fiscal year-end and one month after the [Datastream] market value, we associate the merger announcement with the previous year's accounting information".[12] To increase sample size and facilitate comparison between takeovers and non-takeovers, "firms that are ultimately involved in mergers [are grouped] in the non-merger category in the years in which they have no merger activity."[13] We then count the number of announced merger events for every year. Some targets are private firms for which we have no financial data. Other targets are located in other countries than those covered by Worldscope, and lack (part of) the information needed to calculate the value of assets in place. It also happens that several firms bid for a single target, or that bids are rejected. Finally, targets disappear from the sample after a completed acquisition. For these reasons, the firm-level sample contains roughly three times more bidders than targets. Due to spurious and invalid SEDOL codes in the SDC database, we are forced to drop more targets than acquirers that lack data from Worldscope. We keep the deal's counterpart if that observation can be matched. This results in a sample that consists of 30,000 firm-year observations over a 12-year period. We refer to Table 4.1 for a comparison with two closely related studies.

Finally, we merge the measures for growth options, fundamental value, and market value back to the SDC data. This sample focuses on the M&A transaction level to further test whether our mispricing measure is valid. It also allows us to analyze which M&A attributes and firm characteristics explain the value components of bidders and targets. We match firm-level data (recorded at fiscal year-end) to the last reported fiscal year on

[11] This procedure is described in detail in the Annex.

[12] When a firm's fiscal year end is unreported, we assume the fiscal year to coincide with the calendar year.

[13] To test whether the Rhodes-Kropf et al. sampling approach may introduce bias into the results, we have repeated their estimation procedure below on the full cross-section of firms (without regard to M&A transactions). The regression results turned out to be fairly similar to their 2005 article, with comparable $R^2$s and coefficients. Results are available upon request.

deal level. If this item is not available, we match firm-level data to the year, previous to the date that a merger was officially announced. Because a firm's balance sheet is no longer drawn up after a takeover, bidders also comparably outnumber targets in the deal-level sample.

## 4.5 Variable Definitions

### 4.5.1 Growth Options Value

To back out the value of growth options from Eq. (5.1), we follow the definition of assets in place ($\sum_{j=0}^{t} V_j(t)\chi_j(t)$) as suggested by Tong and Reuer (2008) and Tong *et al.* (2008a, 2008b). They use an economic profit model for valuing the firm, and define the value of assets in place as

$$\sum_{j=0}^{t} V_j(t)\chi_j(t) = CI_t + PV(EP)_t, \tag{4.2}$$

where $CI$ is capital invested and $PV(EP)$ is the present value of economic profit (see Annex). Eq. (4.2) shows that the value of assets in place represents the replacement value of capital invested and the present value of perpetual earnings, again assuming no growth and a constant discount rate for each year's estimate of assets in place. This setup has the advantage that invested capital can be directly calculated from the financial reports. As a result, the annuity $PV(EP)$ becomes smaller and Eq. (4.2) as a whole is less sensitive to changes in the discount rate. Furthermore, economic profit is arguably a more accurate proxy for profitability than accounting earnings, as it adjusts these earnings to cash measures.

Defining market value $P_{it}$ as the fiscal year-end closing price times common shares outstanding, we can now calculate $V^*$ from Eq. (5.1). We delete the highest and lowest 5% of $V^*$ observations from the sample because the normalized growth option equation (5.1) does not always behave well; the value can be larger than 1 if earnings are negative, or smaller than 0 when the market value falls below a firm's perpetual stream of earnings. Also, due to normalizing Eq. (5.1), when the market value is negligible relative to its earnings (in absolute terms), the likelihood of (highly influential) extreme values increases.

Table 4.1: Comparison of Studies

| | *Rhodes-Kropf et al. (2005)* | *Tong et al.(2008a)* | *This study* |
|---|---|---|---|
| **Primary focus** | Overvaluation of bidders and targets | Growth value of multinational companies | Growth value and overvaluation of bidders and targets |
| **Key variables** | • Market-to-book value<br>• Implicit value ($\widehat{V}$) | • Market value of growth options<br>• Country, industry, time effects | • Market value of growth options<br>• fundamental value of growth options<br>• Industry, time effects<br>• Mispricing ($V - \widehat{V}$) |
| **Method of Analysis** | OLS | Variance components | SUR |
| **Definition of industry** | 4-digit SIC | 4-digit SIC | 4-digit SIC |
| **Definition of sector** | Fama and French | First digit of SIC | Fama and French |
| **Number of sectors** | 12 | 7 | 13 |
| **Observations** | Year observations for U.S. firms mentioned in merger announcements | Year observations for the largest publicly traded companies | Worldwide year observations mentioned in merger announcements, M&A transactions |
| **Number of observations** | 110,877 | 6,655 | 23,419 |
| **Number of firms** | 8350 | 2352 | 3976 |
| **Number of years** | 1977-2000 | 1997-1999 | 1995-2006 |
| **Data sources** | CRSP, Compustat, SDC M&A Database | Worldscope, Datastream, Compustat, Stern Stewart | Worldscope, Datastream, Thomson One Banker, SDC M&A Database |

This becomes more prevalent in highly volatile industries and for firms in some form of distress.

### 4.5.2 Fundamental Value

Particularly for takeovers, assuming Equation (5.1) to hold would ignore a vast existing mispricing literature. We will therefore refer to the previous definition of the price residual $V^*$ in Eq. (5.1) as the *market* growth value, or $V_M^*$, and re-write equation (5.1) by adding $(\widehat{P} - \widehat{P})$:

$$\begin{aligned} P &= \textstyle\sum_{j=0}^{t} V_j(t)\chi_j(t) + \quad (\widehat{P} - V_{AIP}) \quad + \quad (P - \widehat{P}) \\ &= \textstyle\sum_{j=0}^{t} V_j(t)\chi_j(t) + \qquad V_F^* \qquad + \quad XSP, \end{aligned} \tag{4.3}$$

where $V_F^*$ measures *fundamental* growth value, $\sum_{j=0}^{t} V_j(t)\chi_j(t)$ can be estimated using Eq. (4.2), $XSP$ is the excess price and $\widehat{P}$ is a measure for fundamental value. We normalize by dividing the three components by $\widehat{P}$. To estimate $\widehat{P}$, we adopt the methodology as recently applied in a takeover context by Rhodes-Kropf *et al.* (2005), who estimate fundamental value (as opposed to observed market value) from an asset pricing model by Fama and MacBeth (1973). In this model, fundamental value is estimated as the predicted value from a series of simple OLS regressions, estimated by year and industry. This procedure is also employed in the accounting literature on value-relevance (e.g., Penman 1998; Francis and Schipper 1999; Barth, Beaver, and Landsman 2001), and one advantage of this measure is that it measures mispricing at the firm level, which serves our purpose in estimating Eq. (4.3). The fundamental value of firm $i$ in an industry $j$ at time $t$ is derived from the regression equation

$$\ln(P_{ijt}) = \alpha_{0jt} + \alpha_{1jt}\ln(B_{ijt}) + \alpha_{2jt}\ln(NI)^+_{ijt} + \alpha_{3jt} I_{(<0)} \ln(NI)^+_{ijt} + \alpha_{4jt} LEV_{ijt} + \varepsilon_{it}. \tag{4.4}$$

where $P$ is market capitalization, $B$ is the book value, $NI^+$ the absolute value of net income, $LEV$ the leverage of a company defined as $\textit{total debt}/(\textit{market value} + \textit{total debt})$, and $I_{(<0)}\ln(NI)^+_{it}$ an indicator function for negative income observations.[14] Time-averaged

[14] This allows for including firms with negative income so that $\alpha_{2jt}$ can be interpreted as an earnings multiple while, at the same time, firm value is adjusted downward through $\alpha_{3jt}$ if an industry has negative

regression results are reported in Table (4.2); accounting for varying discount and growth rates, the regressions coefficients are allowed to vary over time and across industries.

In this setup, under the assumption that similar assets sell at similar prices, we define fundamental value $\widehat{P}$ as the fitted value of the regression in Eq. (4.4), and excess price as the difference between the observed value and the model-based value:

$$XSP_{ijt} = \frac{P_{ijt} - \widehat{P}_{ijt}}{\widehat{P}_{ijt}}$$

From Eq. (4), it follows that the expected value $\mathbb{E}\left[\ln(P_{ijt}) - \ln(\widehat{P}_{ijt})\right]$ is zero for each industry-year. The ratio $P_{ijt}/\hat{P}_{ijt}$ is lognormal with mean greater than 1. As a result, the mean of XSP is greater than 0 and, using the property of the mean of a lognormal distribution, dependent on the standard deviation of the error term in Eq. (4). Intuitively, the coefficients link accounting information to firm value, much akin to conventional measures such as market-to-book and price-to-earnings. Hence, the coefficients have a (conditional) accounting multiple interpretation. This approach simultaneously considers different accounting measures, so that we link accounting numbers to prices over multiple dimensions of firm value.

Table 4.3 reports correlations between the three value components in Eq. (4.3) – market-based growth options value, fundamental growth options value and excess pricing. It can be observed that the correlation between market-based growth value and fundamental growth value, and the correlation between market-based growth value and mispricing almost add up to one. Additionally, correlations between excess pricing and fundamental and market-based growth option value almost cancel out. Table 4.4 reports excess pricing and the mean growth options value by industry over our firm-level sample, and Table 4.5 does so by year. As a first observation of growth value across industries and years, large differences exist between firms: a standard deviation of around 1.5 is common in most years and sectors. This shows that large differences exist in the appropriation of option values; the market rewards firms that are better able to capitalize upside potential.

income in a given year.

Table 4.2: Fundamental Value Estimation

Results from regressing market value on the log of book value ($\ln(B)_{ijt}$), net income ($\ln(NI)^{+}_{ijt}$), and leverage. The fitted values of these regressions are estimates of fundamental value $\widehat{P}$. To increase the number of observations, we include absolute values of net income (which can be negative) and include a dummy variable, equal to 1 if net income is negative ($I_{(<0)} \ln(NI)^{+}_{ijt}$). Columns indicate time-series average regression coefficients for the Fama French 12-industry classification, plus mining. For each sector-year sample, the cross-sectional model from Eq. (4.2) is estimated. Reported are the coefficients that represent the time-series average multiple relating the accounting variable to market value. Also reported are time-series average sample size and $R^2$. Fama-Macbeth standard errors are reported in parentheses. ** and * indicate significance at the 1% level and 5% level, respectively.

| | BusEq | Chems | Durbl | Enrgy | Hlth | Manuf | Mines | Money | NoDur | Other | Shops | Telcm | Utils |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\ln(B)_{ijt}$ | 0.46** | 0.4** | 0.44** | 0.43** | 0.38** | 0.41** | 0.46** | 0.38** | 0.39** | 0.43** | 0.41** | 0.41** | 0.3** |
| | (0.06) | (0.08) | (0.11) | (0.03) | (0.05) | (0.05) | (0.03) | (0.06) | (0.05) | (0.06) | (0.06) | (0.02) | (0.04) |
| $\ln(NI)^{+}_{ijt}$ | 0.40** | 0.36** | 0.43** | 0.36** | 0.48** | 0.38** | 0.3** | 0.47** | 0.44 | 0.38** | 0.41** | 0.44** | 0.46** |
| | (0.06) | (0.06) | (0.09) | (0.05) | (0.08) | (0.06) | (0.06) | (0.06) | (0.07) | (0.07) | (0.07) | (0.05) | (0.09) |
| $I_{(<0)} \ln(NI)^{+}_{ijt}$ | - | -0.10 | 0.09 | -0.14 | - | 0.15 | -0.36 | -0.23 | 0.04 | -0.12 | -0.18 | 0.06 | -0.02 |
| | 0.12** | | | | 0.47** | | | | | | | | |
| | (0.02) | (0.59) | (0.39) | (0.42) | (0.17) | (0.15) | (0.41) | (0.29) | (0.24) | -0.22 | (0.19) | (0.41) | (0.41) |
| leverage | - | - | - | - | - | - | - | - | - | - | - | -2.67** | -2.93** |
| | 2.94** | 2.53** | 2.63** | 2.96** | 3.46** | 2.77** | 2.99** | 1.95** | 3.05** | 2.44** | 2.55** | | |
| | (0.32) | (0.45) | (0.49) | (0.36) | (0.52) | (0.27) | (0.19) | (0.23) | (0.39) | (0.32) | (0.31) | (0.36) | (0.46) |
| Constant | 2.84** | 3.53** | 2.98** | 3.44** | 3.27** | 3.32** | 3.18** | 2.87** | 3.19** | 3.06** | 3.14** | 3.15** | 3.96** |
| | (0.24) | (0.55) | (0.46) | (0.53) | (0.4) | (0.26) | (0.08) | (0.27) | (0.37) | (0.32) | (0.31) | (0.41) | (0.57) |
| Obs. | 284 | 69 | 68 | 86 | 126 | 256 | 41 | 462 | 145 | 240 | 210 | 67 | 86 |
| $R^2$ | 0.72 | 0.61 | 0.68 | 0.73 | 0.77 | 0.63 | 0.75 | 0.61 | 0.69 | 0.61 | 0.66 | 0.75 | 0.62 |

Table 4.3: Correlation Between Value Components

Reported are coefficients of correlation between the three value components on firm level, i.e., market-based growth options value ($V_M^*$), fundamental growth options value ($V_F^*$), and excess pricing ($XSP$). We report standard errors in parentheses. All correlations are significant at the 1% level.

| | $V_M^*$ | $V_F^*$ | $XSP$ |
|---|---|---|---|
| $V_M^*$ | 1 | | |
| $V_F^*$ | 0.4122 | 1 | |
| | (0.0058) | | |
| $XSP$ | 0.5023 | -0.5808 | 1 |
| | (0.0055) | (0.0052) | |

### 4.5.3 Growth Options and Mispricing by Sector

In terms of market-based growth options value, important differences exist between sectors[15]: the highest market-based growth options value is found in the business equipment ($V_M^* = 1.14$) and health-care sectors ($V_M^* = 1.02$). These industries have more volatile demand and earnings, which increase their option value. Furthermore, these sectors are characterized by a large number of small and young firms, which do not yet have scale economies and consist largely of immaterialized value. This is consistent with real option theory and previous empirical work, as these industries involve more unexpected technological changes and moves by competitors. In contrast, utilities ($V_M^* = 0.42$) and financial services ($V_M^* = 0.55$) exhibit the lowest growth options value. For these more stable, low growth income sectors, earnings are more predictable and scale economies are important for every firm in the sector. This increases the importance of the value of assets in place and proportionally decreases growth value.

Because the ratio $P_{ijt}/\hat{P}_{ijt}$ is estimated for each sector separately, $XSP$ at the sector level has no clear interpretation of mispricing between sectors. However, by breaking the sample down into bidder and target subsamples within each sector, $XSP$ can be used as a measure of overpricing at the firm level. It can be observed that bidders are generally more overpriced than targets, and that this fluctuates randomly over industries.

[15] Our growth options value and excess pricing measures need scaling by a common denominator, which is $\widehat{P}$ instead of $P$. For this reason, our values for $V_{GOM}$ are somewhat higher than for previous studies (Kester 1984; Tong *et al.* 2008a).

Table 4.4: Summary Statistics by Sector

Summary statistics, reported per sector between 1996 and 2006. Sector definitions are based on the classification as provided by Kenneth French on his website. For each sector, the second column reports the number of observations with non-missing values for market-based growth options value ($V_M^*$), fundamental growth options value ($V_F^*$), and excess pricing ($XSP$). Remaining columns report sample means of $V_M^*$, $V_F^*$ and $XSP$, respectively, with standard errors in parentheses. $V_M^*$, $V_F^*$, and $XSP$ are normalized to $\widehat{P}$. To make the $XSP$ mean consistent with Eq. (4.3), we ignore observations that have non-missing values for $XSP$ but not for $V_M^*$ and $V_F^*$.

| | ALL | | | | BIDDERS | | | | TARGETS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector | $N$ | $V_M^*$ | $V_F^*$ | $XSP$ | $N$ | $V_M^*$ | $V_F^*$ | $XSP$ | $N$ | $V_M^*$ | $V_F^*$ | $XSP$ |
| Business Equipment | 3,920 | 1.12 | 0.71 | 0.41 | 505 | 1.21 | 0.72 | 0.49 | 102 | 1.28 | 0.85 | 0.42 |
| | | (1.45) | (1.33) | (1.33) | | (1.49) | (1.27) | (1.27) | | (1.5) | (1.24) | (1.24) |
| Healthcare | 1,772 | 1.01 | 0.49 | 0.52 | 219 | 1.30 | 0.51 | 0.79 | 62 | 1.01 | 0.58 | 0.43 |
| | | (1.45) | (1.49) | (1.49) | | (1.49) | (1.61) | (1.61) | | (1.3) | (1.33) | (1.33) |
| Mining | 560 | 0.95 | 0.50 | 0.45 | 93 | 0.97 | 0.36 | 0.61 | 17 | 0.98 | 0.88 | 0.10 |
| | | (1.6) | (1.33) | (1.33) | | (1.69) | (1.68) | (1.68) | | (0.8) | (0.6) | (0.6) |
| Telecom | 968 | 0.91 | 0.21 | 0.70 | 156 | 1.22 | 0.37 | 0.86 | 28 | 1.18 | 0.76 | 0.42 |
| | | (1.59) | (3.30) | (3.30) | | (1.63) | (1.94) | (1.94) | | (1.62) | (1.33) | (1.33) |
| Other | 3,339 | 0.82 | 0.30 | 0.52 | 383 | 0.98 | 0.31 | 0.66 | 71 | 0.92 | 0.65 | 0.27 |
| | | (1.54) | (1.69) | (1.69) | | (1.71) | (1.59) | (1.59) | | (1.47) | (1.05) | (1.05) |
| Chemicals | 999 | 0.79 | 0.14 | 0.65 | 98 | 0.61 | -0.15 | 0.76 | 24 | 0.68 | 0.60 | 0.08 |
| | | (1.49) | (2.00) | (2.00) | | (1.67) | (2.31) | (2.31) | | (1.02) | (0.93) | (0.93) |
| Manufacturing | 3,594 | 0.77 | 0.31 | 0.46 | 365 | 0.79 | 0.28 | 0.51 | 100 | 0.72 | 0.54 | 0.18 |
| | | (1.48) | (1.51) | (1.51) | | (1.58) | (1.55) | (1.55) | | (1.58) | (1.22) | (1.22) |
| Shops | 3,085 | 0.74 | 0.25 | 0.49 | 355 | 0.88 | 0.17 | 0.71 | 83 | 0.36 | 0.25 | 0.11 |
| | | (1.5) | (1.73) | (1.73) | | (1.56) | (1.79) | (1.79) | | (1.33) | (1.34) | (1.34) |
| Nondurables | 2,119 | 0.73 | 0.21 | 0.53 | 216 | 0.98 | 0.15 | 0.82 | 41 | 0.56 | 0.20 | 0.36 |
| | | (1.48) | (1.75) | (1.75) | | (1.49) | (2.57) | (2.57) | | (1.62) | (1.29) | (1.29) |
| Durables | 889 | 0.71 | 0.18 | 0.53 | 90 | 0.78 | 0.07 | 0.71 | 21 | 0.83 | 0.15 | 0.68 |
| | | (1.57) | (1.8) | (1.8) | | (1.51) | (1.87) | (1.87) | | (1.91) | (1.81) | (1.81) |
| Energy | 1,270 | 0.69 | 0.19 | 0.50 | 148 | 0.82 | 0.17 | 0.65 | 28 | 0.93 | 0.67 | 0.26 |
| | | (1.57) | (1.46) | (1.46) | | (1.79) | (1.62) | (1.62) | | (1.67) | (1.15) | (1.15) |
| Finance | 1,043 | 0.56 | 0.30 | 0.27 | 108 | 0.78 | 0.08 | 0.70 | 14 | 0.89 | 0.81 | 0.08 |
| | | (1.39) | (1.4) | (1.4) | | (1.71) | (1.97) | (1.97) | | (1.17) | (1.3) | (1.3) |
| Utilities | 1,148 | 0.40 | -0.09 | 0.48 | 114 | 0.61 | -0.25 | 0.87 | 51 | 0.51 | 0.00 | 0.51 |
| | | (1.49) | (1.54) | (1.54) | | (1.58) | (2.09) | (2.09) | | (1.44) | (1.2) | (1.2) |
| Total | 24,706 | 0.82 | 0.33 | 0.49 | 2,850 | 0.97 | 0.31 | 0.66 | 642 | 0.83 | 0.52 | 0.30 |
| | | (1.51) | (1.69) | (1.69) | | (1.60) | (1.76) | (1.76) | | (1.48) | (1.24) | (1.24) |

### 4.5.4 Growth Options and Mispricing over Time

From the reported mean growth options value by year in Table 4.5, we can observe that differences in growth options value are much smaller over time than between industries. The highest sample-wide growth value is observed in 2001, and the lowest in 1996 and 2003. For fundamental growth options value, the highest growth value is observed in 2002, and the lowest in 2003. Compared to the sample average, excess pricing for bidders is higher in every year; for targets, it is lower. It can also be seen that variation of mispricing is not as random between years as between sectors. In most years, fundamental growth value for bidders is lower than the sample average; for targets, it is higher.

## 4.6 Firm-Level Results

This section examines aggregate evidence that real growth options and mispricing play a significant role in aggregated M&A transactions. First, indicating that bidders buy smart, Table 4.6 provides a comparison of firm-level summary statistics, based on whether a firm was involved in a merger or not and, if so, their role as either bidder or target. Second, to indicate that bidders also time smart, we relate a time series of aggregate growth value and mispricing to takeover activity. Takeover activity is measured per year as the total of bidder and target announcements in a sector as a fraction of all firms observations in the sector. Table 4.7 presents the time series correlations of takeover activity with average mispricing and (fundamental and market) growth values. Assuming cross-sectional normality, testing the null hypothesis of no correlation is done by the standard t-test for inference on correlations: $t = r\sqrt{n-2}/\sqrt{1-r^2} \sim t_{(n-2)}$, where $n$ refers to the 12-year sample period and $r$ denotes the estimated correlation. Unless mentioned otherwise, results are significant at a 99% confidence level.

### 4.6.1 Bidders are Overvalued

From Table 4.6, we confirm that bids are placed by "the very highest $M/B$ firms" ($M/B =$ 4.60 for bidders; $M/B = 4.26$ for targets; $M/B = 4.00$ for non-takeovers; cf. Rhodes-Kropf et al. 2005, p. 570). Firms that are involved in takeovers have a higher $M/B$ than

Table 4.5: Summary Statistics by Year

Summary statistics, reported per year between 1996 and 2006. The second column reports takeover activity per year (Activity), defined as $(N_{Bidders}+N_{Targets})/N_{All}$. The first column of each subsample reports the number of observations with non-missing values for market-based growth options value ($V_M^*$), fundamental growth options value ($V_F^*$), and excess pricing ($XSP$). Remaining columns report sample means of $V_M^*$, $V_F^*$ and $XSP$, respectively, with standard errors in parentheses. $V_M^*$, $V_F^*$, and $XSP$ are normalized to $\widehat{P}$. To make the $XSP$ mean consistent with Eq. (4.3), we ignore observations that have non-missing values for $XSP$ but not for $V_M^*$ and $V_F^*$.

| | | ALL | | | | BIDDERS | | | | TARGETS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Activity | $N$ | $V_M^*$ | $V_F^*$ | $XSP$ | $N$ | $V_M^*$ | $V_F^*$ | $XSP$ | $N$ | $V_M^*$ | $V_F^*$ | $XSP$ |
| 1995 | 5.3% | 1,287 | 0.65 | 0.15 | 0.51 | 57 | 0.66 | 0.05 | 0.61 | 11 | 1.22 | 0.69 | 0.53 |
| | | | (1.40) | (1.64) | (1.64) | | (1.76) | (1.45) | (1.45) | | (1.26) | (1.38) | (1.38) |
| 1996 | 7.6% | 2,347 | 0.72 | 0.30 | 0.43 | 109 | 0.81 | 0.27 | 0.54 | 70 | 0.89 | 0.55 | 0.35 |
| | | | (1.42) | (1.42) | (1.42) | | (1.57) | (1.49) | (1.49) | | (1.52) | (1.30) | (1.30) |
| 1997 | 12.3% | 2,454 | 0.83 | 0.26 | 0.56 | 178 | 1.01 | 0.34 | 0.66 | 125 | 0.82 | 0.41 | 0.41 |
| | | | (1.44) | (2.26) | (2.26) | | 1.56) | (1.46) | (1.46) | | (1.33) | (1.16) | (1.16) |
| 1998 | 16.6% | 1,870 | 0.91 | 0.46 | 0.45 | 246 | 1.11 | 0.34 | 0.77 | 64 | 0.80 | 0.75 | 0.05 |
| | | | (1.44) | (1.51) | (1.51) | | (1.71) | (1.86) | (1.86) | | (1.28) | (0.92) | (0.92) |
| 1999 | 19.8% | 2,316 | 0.84 | 0.32 | 0.52 | 349 | 1.09 | 0.27 | 0.82 | 109 | 0.76 | 0.50 | 0.26 |
| | | | (1.52) | (1.55) | (1.55) | | (1.69) | (1.64) | (1.64) | | (1.32) | (1.15) | (1.15) |
| 2000 | 17.8% | 2,149 | 0.79 | 0.27 | 0.52 | 324 | 0.89 | 0.08 | 0.81 | 58 | 0.78 | 0.37 | 0.41 |
| | | | (1.63) | (1.78) | (1.78) | | (1.71) | (2.55) | (2.55) | | (1.68) | (1.45) | (1.45) |
| 2001 | 14.3% | 2,103 | 0.95 | 0.45 | 0.50 | 266 | 0.97 | 0.36 | 0.61 | 35 | 1.44 | 0.8 | 0.64 |
| | | | (1.55) | (1.70) | (1.70) | | (1.41) | (1.67) | (1.67) | | (1.91) | (1.61) | (1.61) |
| 2002 | 11.0% | 2,078 | 0.92 | 0.47 | 0.45 | 203 | 1.04 | 0.44 | 0.6 | 25 | 1.04 | 1.18 | -0.14 |
| | | | (1.58) | (1.46) | (1.46) | | (1.53) | (1.53) | (1.53) | | (1.71) | (0.76) | (0.76) |
| 2003 | 13.0% | 2,037 | 0.73 | 0.21 | 0.51 | 230 | 0.78 | 0.18 | 0.6 | 34 | 0.51 | 0.08 | 0.42 |
| | | | (1.63) | (2.00) | (2.00) | | (1.71) | (1.73) | (1.73) | | (1.8) | (1.59) | (1.59) |
| 2004 | 13.3% | 1,837 | 0.79 | 0.28 | 0.51 | 225 | 1.04 | 0.4 | 0.64 | 19 | 0.48 | 0.35 | 0.12 |
| | | | (1.49) | (1.67) | (1.67) | | (1.52) | (1.82) | (1.82) | | (1.38) | (1.29) | (1.29) |
| 2005 | 16.7% | 2,124 | 0.84 | 0.41 | 0.43 | 308 | 0.91 | 0.35 | 0.56 | 47 | 0.94 | 0.56 | 0.38 |
| | | | (1.45) | (1.49) | (1.49) | | (1.56) | (1.61) | (1.61) | | (1.69) | (1.48) | (1.48) |
| 2006 | 19.0% | 2,104 | 0.84 | 0.37 | 0.47 | 355 | 1.01 | 0.42 | 0.58 | 45 | 0.59 | 0.49 | 0.10 |
| | | | (1.45) | (1.45) | (1.45) | | (1.54) | (1.43) | (1.43) | | (1.24) | (0.90) | (0.90) |
| Total | 14.6% | 24,706 | 0.82 | 0.33 | 0.49 | 2,850 | 0.97 | 0.31 | 0.66 | 642 | 0.80 | 0.52 | 0.30 |
| | | | (1.51) | (1.69) | (1.69) | | (1.60) | (1.76) | (1.76) | | (1.48) | (1.24) | (1.24) |

firms that are not. Also, the market-based growth value for bidders is significantly larger than for non-takeovers ($V_M^* = 0.95$ versus $V_M^* = 0.80$). Both findings may indicate either growth opportunities or mispricing.

However, under the assumption that merging firms are randomly selected across sectors, bidding firms are on average more overpriced than non-merging firms ($XSP = 0.60$ versus $XSP = 0.47$). At the same time, the fundamental growth options value for bidders is small but significantly larger than zero. Mispricing and growth options value thus co-exist for bidders, and the high $M/B$ ratios in previous studies can thus not be entirely ascribed to mispricing. While mispricing and growth options are both significant, the mispricing component dominates. In terms of real option theory, the option to "exchange" its shares for another firm's shares is a more important argument for placing a bid than the growth options argument. This confirms our empirical observation and supports hypothesis 1a – bidders have highly priced equity that is mostly due to mispricing, and less to fundamental growth opportunities.

More insight is obtained by examining the difference between market-based growth options and fundamental growth options value. A correction for mispricing decreases the bidders' mean fundamental growth options value by two thirds. If anything, the "corrected" value is smaller for bidders than for non-merging firms (from $V_M^* = 0.97$ to $V_F^* = 0.31$, versus $V_F^* = 0.33$ for non-takeovers). This demonstrates how a conventional growth options measure overestimates the growth value for bidders.

### 4.6.2 Bidders Buy Smart

We also confirm that "targets have higher $M/B$ ratios than the average firm" ($M/B = 4.26$ for targets; $M/B = 4.00$ for non-takeovers; cf. Rhodes-Kropf et al. 2005, p. 569), but this difference is insignificant for our international sample ($p = 0.17$). Also, the market-based growth options value for targets is not significantly higher than for non-takeovers (resp. $V_M^* = 0.83$ versus $V_M^* = 0.80$). Consistent with Rhodes-Kropf *et al.* (2005) and Dong *et al.* (2006), targets have a lower market-to-book ratio than bidders ($M/B = 4.26$ versus $M/B = 4.60$). Again, both may indicate either growth opportunities or mispricing.

However, under the assumption of random selection across sectors, Table 4.6 shows that targets are underpriced relative to bidders and non-merging firms (resp. $XSP = 0.30$ versus $XSP = 0.66$ and $XSP = 0.47$) and possess significantly more fundamental growth potential than bidders and non-merging firms (resp. $V_F^* = 0.52$ versus $V_F^* = 0.31$ and $V_F^* = 0.35$). At the same time, excess pricing for targets is significantly larger than zero. Growth options value and mispricing coexist for targets as well. This supports Hypothesis 1b; targets are "undervalued" from a growth options perspective and have highly priced equity with relatively high fundamental value.

According to the conventional measure, targets have less growth options value than bidders ($V_M^* = 0.83$ versus $V_M^* = 0.97$), which is counter-intuitive. Controlling for mispricing decreases the targets' growth options value by a third (from $V_F^* = 0.82$ to $V_F^* = 0.52$) and the difference between $V_M^*$ and $V_F^*$ is only half the decrease for bidders. Furthermore, "corrected" growth options value is significantly higher for targets than for bidders as well as non-merging firms ($V_F^* = 0.52$ versus $V_F^* = 0.31$ resp. $V_F^* = 0.33$), consistent with Hypothesis 1b.

While mispricing and growth options value are both important, targets may thus be rationally selected from an options perspective. Additionally, the conventional growth options measure does a better job for targets than for bidders but ignores a significant mispricing component. This also supports Hypothesis 1b.

While bidders on average have lower $V_F^*$ than targets on average, it could be that many of the bidders have about similar or higher $V_F^*$ in realized deal pairs. To further examine this, we have also compared means on deal level, for matched deal pairs. The third panel shows that the means differ more between $XSP$ and $V_F^*$. However, the difference between means becomes insignificant for $V_M^*$. This is consistent with the notion that the conventional $V_M^*$ measure is confounded.

### 4.6.3 Bidders Time Smart

Although the next section will describe multivariate techniques to test Hypotheses 2, we can already present some preliminary evidence using simple correlations. For bidders, Table 4.7 suggests that market values play an important role. An increase in takeover activity is strongly related to an increase in mispricing ($\rho = 0.54$, $p = 0.03$), which explains changes in

Table 4.6: Characteristics of merger and non-merger firms

Summary statistics for size as measured by market value ($V$), capital invested ($CI$), market-to-book ($M/B$), excess pricing ($XSP$), market-based growth value ($V_M^*$), and fundamental growth value ($V_F^*$). Active firms are observed as either bidders or targets in the SDC database from 1996-2006, inactive firms are not. The column *t(diff)* reports the Student $t$-statistic for the hypothesis *H(0):* active firm - inactive firm = 0, or bidder - target = 0, correcting for unequal variances across groups using Satterthwaite's (1946) approximation formula for the degrees of freedom. Observations are required to have $M/B$ ratios between -100 and 100. $V_M^*$, $V_F^*$ and $XSP$ are normalized to $\widehat{P}$. To make the $XSP$ mean consistent with Eq. (4.3) in the three bottom rows, we ignore observations that have non-missing values for $XSP$ but not for $V_M^*$ and $V_F^*$. ** and * indicate significance at the at 1% level and 5% level, respectively.

| | | Non-mergers | Mergers | t(diff) | Bidders | Targets | t(diff) |
|---|---|---|---|---|---|---|---|
| V | Obs | 43328 | 7313 | | 5846 | 1467 | |
| | Mean | 2028 | 3718 | -8.507** | 4297 | 1413 | 10.572** |
| CI | Obs | 40606 | 5229 | | 4046 | 1183 | |
| | Mean | 1829 | 3652 | -6.826** | 4342 | 1290 | 8.393** |
| M/B | Obs | 39404 | 5754 | | 4869 | 885 | |
| | Mean | 4.00 | 4.55 | -3.827** | 4.60 | 4.26 | 0.941 |
| Bidders and Targets: All (Firm Level) | | | | | | | |
| | Obs | 21214 | 3492 | | 2850 | 642 | |
| $XSP$ | Mean | 0.471 | 0.598 | -4.141** | 0.664 | 0.304 | 6.106** |
| $V_M^*$ | Mean | 0.801 | 0.945 | -5.016** | 0.971 | 0.828 | 2.183* |
| $V_F^*$ | Mean | 0.331 | 0.347 | -0.584 | 0.307 | 0.524 | -3.708** |
| Bidders and Targets: Matched Deal Pairs (Deal Level) | | | | | | | |
| | Obs | | | | 787 | 787 | |
| $XSP$ | Mean | | | | 1.531 | 0.684 | 5.460** |
| $V_M^*$ | Mean | | | | -0.218 | 0.215 | -1.404 |
| $V_F^*$ | Mean | | | | -0.394 | 0.200 | -4.016** |

Table 4.7: Correlation with Average Takeover Activity over Time

Reported are coefficients of correlation between time-series of mean takeover activity on one hand, and time-series of mean market-based growth options value ($V_M^*$), fundamental growth options value ($V_F^*$), and excess pricing ($XSP$) on the other. To make the $XSP$ mean consistent with Eq. (4.3) and Table 4.5, we ignore observations that have non-missing values for $XSP$ but not for $V_M^*$ and $V_F^*$. We report Student's t-statistics in parentheses. ** and * and + indicate significance at the 1% level, 5% level and 10% level, respectively.

| | $V_M^*$ | $V_F^*$ | $XSP$ |
|---|---|---|---|
| Non-mergers | 0.47 | 0.45 | 0.17 |
| | (0.279)+ | (0.282) | (0.312) |
| Bidders | 0.65 | 0.29 | 0.54 |
| | (0.241) ** | (0.303) | (0.265) * |
| Targets | -0.38 | -0.22 | -0.21 |
| | (0.293) | (0.309) | (0.309) |

$V_M^*$ ($\rho = 0.65$, $p = 0.01$). So market growth value and mispricing of acquirers is positively related to economy-wide takeover activity, and bids are made at a time when the perceived market value of acquirers is high. Hence, we find strong support for Hypothesis 2a: bidders time smart by using overvalued equity.

For targets, mispricing is not significantly related to changes in takeover activity ($\rho = -0.21$, $p = 0.26$), nor is the market-based growth options value ($\rho = -0.38$, $p = 0.11$) or fundamental growth options value ($\rho = -0.22$, $p = 0.25$). Being insignificant, these correlations for targets are smaller than for bidders, so that targets will cushion negative returns, and future losses are limited. These findings suggest that targets are selected that are "cheap" relative to bidders, i.e., bidders buy smart, as in Hypothesis 2b.

## 4.7 Deal-Level Results

The previous section pooled together observations across countries and industries. Hence, the results may well be due to industry or country level effects, since capital markets in different countries have different momentums and idiosyncrasies and may not randomly occur across sectors. From Table 4.7, one may also expect generic macro-economic factors to play a significant role. Using deal-level evidence[16], this section controls for country,

[16] We thank an anonymous referee for this suggestion.

sector, and year effects. To examine whether country, sector and year, effects indeed have explanatory power, we estimate the following system of two equations in a setup that will serve as a basis for further inference. We estimate the two value components simultaneously because a change in mispricing will also affect fundamental growth, and vice versa. Let each equation contain $N$ observations:

$$\mathbf{Y} = \beta_0 + \{\mathbf{D}\} + \mathbf{e} \tag{4.5}$$

in which we have compactly written the stacked equations $\mathbf{Y} = [XSP, V_F^*]'$. Estimation of Eq. (4.5) is done separately for bidders and targets at the deal level. Specifically, for each deal we obtain the target's $XSP$ and $V_F^*$ and the bidder's $XSP$ and $V_F^*$, if available.

Each of the disturbances in vectors $e_i$ have zero mean, equal variance, and are uncorrelated, but covariances between the two vectors are potentially non-zero for a pair of equations. To allow for sufficient degrees of freedom, we exclude $V_M^*$ from the analysis (since it is a linear combination of $V_F^*$ and $XSP$). Two sets of dummies $\{\mathbf{D}\}$ (one for each value component) include the union of five subsets containing indicator variables for each year and, specific to bidders or targets, each sector and nation.[17] As a consequence of including target dummies for bidders and bidder dummies for targets, some observations are lost because not all deals can be matched into pairs. Hence, the number of observations included for estimation is smaller, compared to the univariate analysis above.

This specification is appropriate, since excess pricing and fundamental growth value may be significantly correlated and subject to similar shocks. It may therefore be difficult to disentangle the two value components. Using seemingly unrelated regressions (SURs) that allow for correlated error terms, we can pick up any overlap in growth opportunities or mispricing and disentangle them more effectively.

As can be seen from Columns (I) and (III) in Table 4.8, industry, year, and country effects explain a significant portion of variation in our value components. These effects explain 15% (8%) of variation in $V_F^*$ ($XSP$) for bidders, and 14% of variation in $V_F^*$ and

[17]Specifically, the set $\{D\}$ contains 13 bidder sector dummies, 13 target sector dummies, 84 bidder country dummies, 129 target country dummies and 12 year dummies, minus 1. Of the 251 dummies, 87 are dropped for reasons of collinearity. For the sake of brevity, we do not report the remaining 164 dummy results in subsequent analyses.

Table 4.8: Bidders Time Smart

Results from Eqs. (4.5) an(4.6), i.e. a seemingly unrelated regression of fundamental growth options value ($V_F^*$) and excess pricing ($XSP$) on a set $\{\mathbf{D}\}$of 13 sector dummies, 84 bidder country dummies, 129 target country dummies, and 12 year dummies, and/or takeover activity. Coefficients for sector, nation, and year dummies are not reported, but tested for joint significance. Results for bidders and targets are obtained separately. Normal standard errors are in round parentheses, bootstrapped standard errors are in square parentheses. ** and * and + indicate significance at the 1% level, 5% level and 10% level, respectively, based on standardnormal i.i.d. standard errors. ## and # indicate significance at the 1% level and 5% level, respectively, based on bootstrapped standard errors.

| | Bidders | | | | Targets | | | |
|---|---|---|---|---|---|---|---|---|
| | (I) | | (II) | | (III) | | (IV) | |
| | $V_F^*$ | $XSP$ | $V_F^*$ | $XSP$ | $V_F^*$ | $XSP$ | $V_F^*$ | $XSP$ |
| Takeover Activity | | | 0.046 | 0.451 | | | 0.245 | -0.232 |
| | | | (0.140) | (0.128)** | | | (0.247) | (0.103)* |
| | | | [0.143] | [0.175]## | | | [0.240] | [0.095]## |
| Sector | *YES***# | | *YES***# | | *YES*+ | | *YES*+ | |
| Country | *YES***## | | *YES***## | | *YES*** | | *YES***## | |
| Year | *YES***## | | *YES***## | | *YES*** | | *YES*** | |
| Obs. | 2398 | 2398 | 2398 | 2398 | 1086 | 1086 | 1086 | 1086 |
| $R^2$ | 0.154 | 0.082 | 0.154 | 0.087 | 0.139 | 0.142 | 0.14 | 0.146 |

$XSP$ for targets. From the reported $R^2$ statistics, one can observe that country, industry, and year effects are more important for overpriced targets ($R^2 = 14\%$) than for overpriced bidders ($R^2 = 8\%$), indicating that the "external shocks" motivation from Andrade et al. (2001) holds more for targets than for bidders.

### 4.7.1 Bidders Time Smart

The setup in Eq. (4.5) allows us to test our hypothesis in a multivariate context. For instance, to further examine the correlations with takeover activity in Table 4.7, we estimate the following system of equations:

$$\mathbf{Y} = \beta_0 + \beta_1 \star \mathbf{ACTIV} + \{\mathbf{D}\} + \mathbf{e}, \tag{4.6}$$

in which takeover activity (**ACTIV**) is defined as in the previous section. Specifically, we determine in which fiscal year a merger announcement takes place, and use it to match the bidder's and target's takeover activity. This yields two takeover activity values per deal, i.e., one for the bidder and one for the target. As previously, we estimate Eq. (4.6) separately for bidders and targets, with a different takeover variable for bidder and target estimates.

Columns (II) and (IV) in Table 4.8 provide further evidence that bidders time their acquisitions well, and most previous correlation results are confirmed. After controlling for country, sector, and year effects, over-pricing for bidders continues to be positively associated with takeover activity. Hence, when market prices of bidders are high, takeover activity is relatively large. This is further evidence in support of Hypothesis 2a.

We also observe that, in a multivariate regime, over-pricing for targets is negatively correlated with takeover activity. This indicates that bids are made for targets that are "undervalued" as compared to the bidder, a finding that was not significant in Table 4.7. The relationship is now significant at the 5% significance level, and provides evidence in favor of Hypothesis 2b.

After controlling for year, sector, and country effects, target growth value shows a positive relation with takeover activity. This suggests that buyers buy smart, and bid for targets that have growth potential. While the effect is not significant, it has the expected sign. This is in contrast with Table 4.7, where a negative correlation between fundamental growth value and takeover activity is found.

When interpreting these findings, it is important to acknowledge that some firms may have engaged in multiple bids, and that other firms may be targeted by multiple acquirers. As this would introduce correlation between residuals, it is possible that standard errors have been calculated under inappropriate assumptions. To account for this possibility, we repeat the estimation of Eq. (4.6) 1000 times, bootstrapping the standard errors by resampling observations from the data. It can be seen from Table 4.8 that the obtained nonparametric standard errors do not affect the validity of our results, and that the effect of takeover activity becomes slightly stronger.

### 4.7.2 Bidders Buy Smart

To demonstrate that our value components measure what they are supposed to measure in a multivariate context, we consider several M&A deal attributes that are desirable for over-valued bidders, compared to bidders with a relatively high proportion of fundamental growth potential. First, over-valued bidders gain from paying targets with stock rather than cash, suggesting the method of payment as an important consideration. Second, even if a deal is paid for in cash, an over-valued bidder can finance the acquisition inexpensively by raising the required amount of cash through a seasoned equity issuance. Third, it is expected that a target's board of directors will be unwilling to agree to merge with an over-valued bidder. Consequently, we expect hostile bids if bidders are overvalued. We estimate the following system of equations, again separately for bidders and targets:

$$\mathbf{Y} = \beta_0 + \beta_1 \star \mathbf{ACTIV} + \beta_2 \star StockPay + \beta_3 \star \mathbf{1}_{StockFin} + \beta_4 \star \mathbf{1}_{hostile} + \{\mathbf{D}\} + \mathbf{e} \quad (4.7)$$

In these equations, $\mathbf{Y}$ and $\{\mathbf{D}\}$ are as defined previously. In addition, $StockPay$ represents the percentage of consideration paid in stock, measured as the value paid in stock divided by total transaction value. $\mathbf{1}_{StockFin}$ represents an indicator variable, equal to 1 if the transaction was paid in cash but financed by issuing new equity, and zero otherwise. The indicator variable $\mathbf{1}_{hostile}$ is equal to 1 if the target company's management or board of directors has a hostile attitude toward the transaction or issues a negative recommendation, and zero otherwise. The SDC database does not always have information about the form of payment and, to a lesser extent, the attitude of the target. Hence, the number of observations drops further, compared to previous results.

In Table 4.9, the left (bidder) columns show that stock payment, stock financing, and a hostile attitude are all significant and positively related to bidder mispricing. Overvalued firms are associated with a high average stock pay percentage, and more often finance M&A transactions with equity issues. This indicates that bidders use their overvalued equity to finance their acquisitions cheaply, and may aim to protect themselves from future drops in share price. Overvalued firms also place hostile bids more often, indicating that target firms do not see much value in the merger. These deal characteristics have no relation to the bidders' fundamental growth value. These findings provide further support for Hypothesis 1a. However, nonparametric standard errors are much larger than those under the assumption of i.i.d. residuals, indicating that these results are driven by bidders engaging in multiple bids. We should take caution, therefore, to not read too much in these results.

After controlling for deal characteristics, takeover activity continues to be positively associated with bidder overpricing, providing further evidence that bidders with overvalued equity that anticipate a future price correction. This finding becomes only stronger when standard errors are obtained nonparametrically. This adds further support to Hypothesis 2a.

We also examine how these attributes affect each value component for targets. The right (target) columns of Table 4.9 present results for target firms and show that, from all deal level characteristics, only stock payment explains $V_F^*$. This is a strongly significant effect (at a 1% level of significance). M&A transactions that involve stock payments are thus also associated with targets with significant growth value. It implies that overpricing by bidders is strongly and positively related to growth options value from targets. We therefore infer that overpriced bidders primarily select targets with strong growth potential, which provides further support for Hypothesis 1b. It can be seen from Table 4.9 that bootstrapped

Table 4.9: Bidders Buy Smart

Results from Eq. (4.7), i.e. a seemingly unrelated regression of fundamental growth options value ($V_F^*$) and excess pricing ($XSP$) on deal payment, deal financing, and deal attitude, as well as a set $\{\mathbf{D}\}$of 13 sector dummies, 84 bidder country dummies, 129 target country dummies and 12 year dummies. Deal coefficients for sector, nation, and year dummies are not reported, but tested for joint significance. Results for bidders and targets are obtained separately. Normal standard errors are in round parentheses, bootstrapped standard errors are in square parentheses. ** and * and + indicate significance at the 1% level, 5% level and 10% level, respectively, based on standardnormal i.i.d. standard errors. ## and # indicate significance at the 1% level and 5% level, respectively, based on bootstrapped standard errors.

| | Bidders | | Targets | |
|---|---|---|---|---|
| | (I) | | (II) | |
| | $V_{GO^F}$ | $XSP$ | $V_{GO^F}$ | $XSP$ |
| Takeover Activity | 0.376 | 0.901 | 0.0796 | -0.0791 |
| | (0.22)+ | (0.26)** | (0.23) | (0.15) |
| | [0.228] | [0.328]## | [0.252] | [0.153] |
| Deal Payment | 0.00903 | 0.0157 | 0.0191 | -0.00539 |
| | (0.0066) | (0.0078)* | (0.0069)** | (0.0044) |
| | [0.009] | [0.006]## | [0.0087]# | [0.0050] |
| Deal Financing | -1.842 | 7.239 | 0.957 | -1.498 |
| | (2.69) | (3.17)* | (2.17) | (1.38) |
| | [3.008] | [7.470] | [1.590] | [1.179] |
| Deal Attitude | 0.467 | 7.569 | 0.500 | 0.315 |
| | (0.96) | (1.13)** | (0.86) | (0.54) |
| | [0.976] | [4.868] | [0.777] | [0.744] |
| Sector | YES | | YES | |
| Country | YES** | | YES | |
| Year | YES* | | YES** | |
| Obs. | 771 | 771 | 352 | 352 |
| $R^2$ | 0.37 | 0.16 | 0.19 | 0.16 |

standard errors do not affect the validity of this result.

Finally, for targets, takeover activity is not significantly associated with a target's overpricing after controlling for deal characteristics. This indicates that targets are selected that are less subject to overpricing, which has a cushioning effect on a future price correction. This is further evidence that bidders buy smart by selecting targets that have strong fundamentals, and adds support to Hypothesis 2b. Compared to Tables 4.7 and 4.8, the effect is now significant and has the expected sign. Again, nonparametric standard errors do not affect the validity of this result.

## 4.8 Conclusions

Considering the vast shifts in capital available for takeovers, the question of what drives these takeovers is of interest to a large group of scholars and practitioners. In answering this question, both rational explanations based on growth opportunities as well as behavioral explanations based on mispricing explanations have strong theoretical underpinnings and are backed by prior research in strategy and finance. We challenge an exclusive claim to wisdom from either strand of literature, and show that mispricing and rational growth options rationale coexist. This distinction explains merger activity by bidders that have high $M/B$ ratios because they are overpriced, even though genuine growth potential is present. Simultaneously, we explain target selection by targets that have above-average $M/B$ ratios, primarily because of fundamental growth potential (although some mispricing may remain).

### 4.8.1 Empirical Implications

First, bidders are overvalued. Bidders have on average less growth potential and more overpriced equity than targets and non-merging firms. When controlling for mispricing, growth options value decreases more for bidders than for other firms. Thus, although bidders seem to have growth options value, it is primarily caused by mispricing. Positive correlations with takeover activity show that bidders are able to time their bids smart; when bidders' mispricing increases over time, so does the frequency of bidding announcements.

Finally, regressions show that these results persist after controlling for country, industry, and year effects.

Second, bidders buy smart and time smart. Targets possess more growth potential and less mispricing than bidders and non-merging firms. When controlling for mispricing, growth options value decreases to a lesser extent for targets than for other firms. Hence, although some overpricing exists, a target's growth option value is based on fundamentals. Negative correlations of targets with takeover activity show that bidders time their acquisition smart; targets are undervalued relative to bidders when the bid is made. Buying fundamental growth may cushion bidders against a future drop in market value. Correlations semi-confirm (on a 90% confidence level) that targets are also undervalued relative to their fundamental value, an effect that persists after controlling for country, industry, and year effects.

These results follow only if more precise measures than conventional $M/B$ or market-based growth options value are used such as fundamental growth option value. This measure is straightforwardly implemented by an intuitive decomposition of a firm's share price. The market-based growth options measure – i.e., without correcting for mispricing – yields inconsistent results if used for bidders, and the fit can be substantially improved for targets by measuring fundamental growth options value.

Our decomposition of firm value offer new insights into each of the three value components. With respect to real options theory, this study is the first to provide evidence that takeovers confer significant embedded growth opportunities. It also shows, however, that correct application of real options theory is contingent on correct market valuations, takeover activity, involvement in a merger, the role of being a bidder or target and, more generally, time and sector differences. With respect to behavioral financing theory, this study validates untested predictions that follow from Shleifer and Vishny (2003), i.e., that high market values induce firms to bid for targets that are undervalued compared to the bidding firms. Our results are consistent with some firm- and deal characteristics. We have shown that these firms are likely to pay for the deal using their overvalued shares or finance it through equity issuance, and are more likely to conduct hostile takeovers. Bidding firms bid when takeover activity is high, and when future profit is likely to decrease.

The key contribution, however, lies in unifying arguments from both streams of literature and adding nuance to the rationality-irrationality dichotomy. Specifically, while Shleifer and Vishny (2003) argue that bidders select targets merely for being undervalued relative to the bidder, we show that these targets may also possess genuine growth potential. On the other hand, while real options theory predicts that takeovers are motivated by growth options value, we show that they are in fact triggered by overvalued equity. Thus, by considering the behavioral and growth option components simultaneously, this study shows that strategic arguments and behavioral finance are interrelated.

### 4.8.2 Future Research Directions

Integrating the two theories of takeover activity provides interesting directions for future research. We demonstrate the limitations of market-based measures for growth options value and offer a simple solution. While mispricing is a well-known factor in M&A, distinguishing between growth opportunities and mispricing may add further insights to previous studies in growth options value of international joint ventures and firm, industry, or country effects. Beyond the M&A context, the empirical framework is easily applied to other issues in business strategy. Additionally, our results validate real options explanations for takeovers, but call for analyses that pay specific attention to the irrationality in financial markets. Further theoretical development in real options theory may further explore the behavioral opportunities and pitfalls of the option to acquire.

More specific to the complicated nature of M&A transactions, we conjecture that the premium paid for target shares may be an important explanation for *why* targets go along with overpriced bidders, but future research is needed to address this question. Next, we have partly ignored the complexity of corporate takeovers, and this study does not integrate many previous findings on the selection of targets based on other grounds such as private information and managerial incentives. Since we have not controlled for such alternative explanations, future research could examine how these motives relate to the three components of market value.

The decomposition in this study can be applied to any setting in which market prices may deviate from fundamental value, and simultaneously have good reason to do so. The regression model that we use is thin, however, with book value, net income, and leverage being the only covariates. The decomposition of market-based growth options value could depend on other factors that affect growth options and mispricing. We have chosen to stay as close as possible to previous literature, but acknowledge that the specification leaves room for improvement.

We emphasize that fundamental growth options value and excess pricing are two residual terms, which we assume additively separable. However, these components are hard to tease apart or demarcate. For instance, we adjust for market sentiment using $\widehat{P}$ but use a single discount rate to take earnings to perpetuity. However, the market-based discount rate may need to be adjusted too if the markets are irrational.

From a practical perspective, growth options are an important concept for professionals who need to select profitable investment opportunities, and decide when to do so. From the recent burst of the U.S. real estate bubble and the subsequent condition of financial markets, the need to adjust for irrational pricing behavior has become abundantly clear. By incorporating irrationality into a rational decision framework, this study offers a tool to understand value creation in a modern, increasingly turbulent world.

# Chapter 5

# Real Options Diversification

*This paper shows that the conditionality of investment decisions in R&D has a critical impact on portfolio risk, and implies that traditional diversification strategies should be reevaluated when a portfolio is constructed. Real option theory argues that research projects have conditional or option-like risk and return properties, and are different from unconditional projects. Although the risk of a portfolio always depends on the correlation between projects, a portfolio of conditional R&D projects with real option characteristics has a fundamentally different risk than a portfolio of unconditional projects. When conditional R&D projects are negatively correlated, diversification only slightly reduces portfolio risk. When projects are positively correlated, however, diversification proves more effective than conventional tools predict.*

## 5.1 Introduction[1]

When the future outcomes of a firm's endeavors are unknown, a key strategy for dealing with such risk is betting on more than one horse. Successful research and development (R&D) policy therefore requires careful portfolio analysis to optimize the selection and the development of several concurrent alternatives. Diversification of risk plays a key role in this process. When the portfolio consists of risky R&D projects, however, conventional diversification arguments do not hold since conditionality causes the payoffs to become nonlinear. This is a direct result of the option characteristics that many R&D projects display.

Option characteristics follow from managerial flexibility to adjust decisions under uncertainty. Any possibility of altering a project as new information becomes available renders a project conditional. For instance, a project that is started now may be abandoned or expanded in the future, a decision based on a given performance criterion and usually taken when new costs need to be incurred. As the investment decision is conditional, it can be regarded as an 'option' that is acquired by making the prior investment. We will examine the differences between conditional and unconditional investments below, as well as their implications for portfolio analysis.

This paper examines diversification when conditional investment decisions are present in an R&D portfolio, and shows that reliance on traditional diversification strategies can be misleading. Negative correlation makes diversification a less effective instrument for eliminating risk amongst conditionally financed projects than for unconditional projects. Positive correlation, however, makes diversification more effective. As compared to unconditional projects, a portfolio of conditionally financed projects is less sensitive to changes in correlation when correlation is not highly positive, and risk is therefore more difficult to diversify. Our findings have implications for diversification strategies in portfolio analysis. This includes (but is not limited to) the strategic choice between a focused or diversified portfolio, diversification over time and risk measurement techniques such as Value at Risk (VaR), often used in risk management regulation.

[1] This chapter is an updated version of my graduate thesis, required for the M.Phil. degree from Erasmus University. It was published in 2009 under the title "A Real Options Perspective on Portfolio Diversification" in Research Policy, Volume 38, pp. 1150–1158 (with Enrico Pennings and Han Smit).

Real options analysis has become a well-known R&D project valuation technique for intertemporal risky investments in R&D. In their seminal paper, Black and Scholes (1973) consider equity of a real, levered firm as an option on its entity value. Using financial theory, Myers (1977) was the first to describe real options as "the opportunities to purchase real assets on possibly favorable terms". In the strategy literature, Bowman and Hurry (1993) and Bettis and Hitt (1995) propose real options theory as an alternative lens for looking at technology investments that closely resemble the behavior and characteristics of real options. In the R&D literature, Thomke (1997) indeed shows empirically that flexibility under uncertainty allows firms to continuously adapt to change and improve products. Hartmann and Hassan (2006) find that real options analysis is used as an auxiliary valuation tool in pharmaceutical project valuation[2]. In this context, a basic implementation is provided by Kellogg and Charnes (2000), and more sophisticated option valuation models for pharmaceutical research have been developed by Loch and Bode-Greuel (2001). Lee and Paxson (2001) view the R&D process and subsequent discoveries as sequential (compound) exchange options. Cassimon et al. (2004) provide an analytical model for valuing the phased development of a pharmaceutical R&D project. The empirical literature also confirms that R&D yields the positively skewed distribution of returns that is typical of options. For instance, Scherer & Harhoff (2000) investigated innovations and show that the top 10% returns captured 48% to 93% of total sample returns. They refer to Nordhaus (1989), who postulates that 99.99% of invention patents submitted per year are worthless, but that the remaining 0.01% have high values.

In concurrence with this literature, we analyze conditionally financed projects as options. R&D typically has a high chance of failure and can be deemed risky. High-risk projects in R&D are generally explorative in nature; examples include basic and fundamental research, or R&D in response to important changes in a firm's strategic environment. We will contrast the option-like projects to unconditional projects that typically

[2] The fundamental difference between real options and traditional discounted cash flow (DCF) valuation lies in the flexibility to adapt when circumstances change. Whereas DCF valuation assumes investments are fixed, an option is the right (not the obligation) to invest in R&D at some future date. If future circumstances are favorable, the option will be exercised; if not, the option will expire without any further cost. Such freedom of choice enables an investor to abandon the project in a timely manner so that further losses are avoided. Therefore, many unfavorable investments (with limited downside risk) can be financed by a few highly profitable investments (with unlimited upside potential). Profitable investments will account for the majority of returns, so the return distribution becomes positively skewed.

behave similarly to equity shares, have a low chance of failure and are subject to less risk. Low-risk projects in R&D are often of an incremental nature; examples include ‘me-too’ inventions that imitate a successful competitor’s invention, or investments into an already commercialized product. We refer to the first group as conditionally financed projects, conditional projects, or real options. We refer to the second as unconditional projects.

Most real options studies have primarily examined projects in isolation. Engwall (2003), however, argues that every project takes off from, or is executed in, an organizational context. Real options should therefore also be considered as part of a portfolio. Brosch (2001) considers the influence of interacting real options *within* projects. These positive and negative interactions between options make a portfolio’s value non-additive. Our focus, however, is on option interactions *between* projects, and we focus on the risk of the portfolio.

Smith and Thompson (2003, 2005) postulate a project selection strategy in sequential petroleum exploration, where the outcome of the prior drillings can be observed before investing in the next drilling. We are also involved with real option selection, but focus on simultaneous (non-sequential) development. Multiple assets have been examined by Wörner et al. (2002, 2003), who describe a firm as a ‘basket option’ that conducts several R&D projects, or as an option on a set of stochastic variables. Yet, as they focus on the value of a single claim that pertains to many random variables, their analysis does not derive results relevant to portfolio management (which inherently deals with the selection between multiple claims). Such rainbow or basket options are often used to describe R&D projects; Paxson (2003) surveys several real R&D option models and utilizes some of them in a case study.

When constructing an R&D portfolio, the selection of candidates comprises many important, non-monetary considerations. For example, Prencipe and Tell (2001) show that firms try to capture synergies that stem from learning processes. Several studies have therefore aimed to integrate risk diversification with expected costs and benefits, inter-project synergies, externalities, R&D quality and overall fit with the business strategy. Taking this angle, Linton et al. (2002) develop a framework that combines both quantitative and qualitative measures to rank and select the projects in a portfolio. In addition, Martino (1995) describes several methods for R&D project selection including cluster analysis, cognitive modeling, simulation, portfolio optimization, and decision theory. While these sources are suitable for handling technical and physical diversification, they seem less appropriate for allocating financial resources, compared to the Markowitz (1952) diversification principle. Markowitz's objective is to optimize risk given a return, or vice versa. Chien (2002) includes a survey of selection procedures and shows that several originated from Markowitz's work. A recent R&D selection model that is based on that of Markowitz (1952) can be found in Ringuest et al. (2004). Unfortunately, the Markowitz diversification strategy only applies when the distribution of project returns is symmetric, an assumption that does not hold for R&D projects with conditionality. Our argument supplements the Markowitz criterion in that it explicitly considers real option characteristics; we create a skewed distribution by simulating many real options.

Using a portfolio of two investment opportunities, we show that although the risk of an R&D portfolio always depends on the correlation between projects, the dependence differs between conditional projects and unconditional projects. In particular, we find that when projects are positively correlated, the overall portfolio risk for conditional projects is lower than for unconditional projects. Diversification is an important argument to create a portfolio of such projects, because it is more effective than one would expect from unconditional investments. In contrast, when projects are negatively correlated, we find that the overall portfolio risk for conditional projects is higher than for unconditional projects. Moreover, under negative correlation, portfolio risk is less sensitive to changes in correlation as compared to unconditional investment projects. Diversification is therefore less effective than one would initially expect from unconditional investments, and more weight should be placed on non-diversification arguments to motivate a portfolio of such projects, such as synergies and spillovers.

This paper is organized as follows: in Section 2, the theory behind a portfolio of real options is conveyed. In Section 3 we present the model and its results. Section 4 is dedicated to the implications of our findings. In Section 5, we conclude and provide directions for future research. In the Appendices A and B, a proof of our findings is provided, as well as a means to extend our analysis to a more realistic setting.

## 5.2 Conceptual Framework

We analyze a portfolio of individual projects that await conditional investments, and represent each project by a simple call. A portfolio of calls is a valid way to describe reality if the portfolio's constituents behave similarly to financial options. This happens if a portfolio consists entirely of conditionally financed projects, as is often found in pharmaceuticals, biotechnology, venture capital and software technology.

It is important to note that we examine a portfolio of multiple contingent claims. This differs from a single claim on several underlying stochastic processes, such as an option on the most valuable R&D project in a portfolio. A single claim does not fit our central goal of selecting and managing multiple claims. Each individual portfolio element may well be an R&D project or a venture facing several uncertainties and aiming for multiple markets, such that each element may be a rainbow or basket option. We study portfolios of these elements, however, and such portfolios consist of several claims (not their underlying values).

The symmetry of a project's value distribution has an impact on portfolio diversification. For unconditionally financed projects, the symmetrical distribution allows for a 'perfect hedge', and a riskless portfolio can be created; when two equity shares are perfectly negatively correlated, one goes down by the amount that the other goes up and vice versa[3], so that all deviation is offset. In line with Markowitz (1952), we call this hedging mechanism the "diversification effect" on the risk of a portfolio.

However, when the projects are conditionally financed, below-average results are no longer offset by above-average returns and Markowitz's (1952) diversification principle is no longer valid. Because the payoff from a call cannot fall below zero, an option already provides insurance against the negative payoffs by nullifying those payoffs that are lower than the exercise price. Hence, the value distribution of a portfolio of real call options becomes skewed from the left and ceases to be symmetrical. The would-be-negative payoffs are no longer available for diversification, and constructing a riskless portfolio is no longer possible. Paradoxically, in a portfolio of options, the option to abandon limits downside risk of the individual project, but complicates diversification and does not limit risk when

[3]That is, when uncertainty is constant and equal for both shares.

portfolio correlation is negative. In line with Jensen's Inequality, we call this the 'convexity effect', which affects the diversification effect. In Section 6.3.1, we derive this result as we examine the variance of a conditionally financed portfolio more explicitly.

In the next section, we will develop a Monte Carlo simulation model to show the effect of risky projects on a portfolio of R&D projects. The procedure is straightforward and can easily be used in practice with other portfolio selection criteria. Before we proceed, however, a proper description of our research subject is appropriate. This paper exclusively focuses on the risk (not the value) of a portfolio of options, and is therefore a supplement to the previously mentioned portfolio selection criteria. Their importance notwithstanding, for the sake of argument we group all these criteria under the heading of "non-diversification criteria". "Uncertainty" in our portfolio is completely determined by how the value of projects varies. Portfolio variance is a well-known measure for this dispersion, used in the financial sector under Basel II regulations. We confine our analysis to the relation between market values of projects, and assume the project costs to be independent and known. We prefer this setup because modeling more than one source of uncertainty would cause our results to become confounded. To more accurately reflect reality, the procedure can be easily extended to accommodate two or more related stochastic processes, such as uncertain costs and benefits.

## 5.3 Methodology and Results

### 5.3.1 Simulation Model

To find the volatility of an option portfolio, we estimate the volatility of payoffs for each option. We model a portfolio with two projects $i \epsilon \{1, 2\}$. Unless we consider the special cases in Section 6.3.1, it is not possible to determine the risk of an option portfolio analytically since the joint distribution of options is not analytically tractable. Instead, we model the behavior of both end-of-R&D values projects $V_i$ by a simple normal distribution, defined as follows:

$$V_i = \mu_i + \sigma_i \varepsilon_i \tag{5.1}$$

where $\mu_i$ is the project value, $\sigma_i$ is the standard deviation of project values when the project is completed and $\varepsilon_i$ is a random draw from a standard normal distribution. Assuming no dividend payouts for each project $i$, we calculate the option value $OV_i$:

$$OV_i = \max[V_i - X_i, 0]e^{-rT} \tag{5.2}$$

where $X_i$ is the investment needed to start or acquire the project, $r$ is the discount rate and $T$ is project $i$'s time to completion. The value of the project can now be calculated by taking the average value of equation (5.2) over $R$ simulation rounds, with $OV_{ij}$ representing the result of a single simulation round for $OV_i$. As the number of rounds increases, this value converges to its true value. To observe how project values are distributed, the volatility of a single option can be found as follows:

$$\sigma_{OV_i} = \sqrt{\frac{1}{R}\sum_j (OV_{ij} - \overline{OV_i})^2} \tag{5.3}$$

Extending to a portfolio of two projects, the relation between underlying values (not the option values) is measured by means of a correlation coefficient $\rho_{12}$ between $\varepsilon_1$ and $\varepsilon_2$. Assuming multivariate normality, the correlation between any number of assets can be calculated using the Cholesky decomposition. This process, as well as constructing a consistent variance-covariance matrix for cases where $i > 2$, is described in Section 6.3.2. For the two variable case, independent samples $y_1$ and $y_2$ are taken from a univariate standardized normal distribution and the correlated samples $\varepsilon_1$ and $\varepsilon_2$ are calculated as follows:

$$\begin{aligned} \varepsilon_1 &= y_1 && (5.4) \\ \varepsilon_2 &= \rho_{12}y_1 + y_2\sqrt{1-\rho_{12}^2} && (5.5) \end{aligned}$$

From one set of independent samples $y_1$ and $y_2$, we generate 21 pairs of correlated samples $\varepsilon_1$ and $\varepsilon_2$ (ranging from $\rho_{12} = -1.0$ to $\rho_{12} = 1.0$ with step size 0.10) by inserting the independent sample values into equations (5.4) and (5.5). Because, under the assumption of correlation between project values but no interactions between the options, the value of the portfolio is the sum of the project values $i$,

$$pf = \sum_i OV_i, \tag{5.6}$$

and the value of the portfolio can be calculated for each correlation. However, we are concerned with portfolio risk (measured by the variance of the summed option values) rather than the value of a portfolio of options. Similar to the case for a single option, the estimate of portfolio variance is based on a simulation of portfolios $pf_j$ for $j = 1, ..., R$ and averaging over $R$:

$$\hat{\sigma}_{pf=}\sqrt{\frac{1}{R}\sum_j (pf_j - \overline{pf})^2} \tag{5.7}$$

As a numerical example, we can show a potential simulation round using the numbers from the bivariate base case described in Figure 1. Assume one set of draws from the univariate distribution are the following: $y_1 = 0.5$ and $y_2 = -0.25$. Using equation (5.5), this independent pair of draws leads to 21 correlated pairs, including (for $\rho_{12} = -0.2$)

$$\varepsilon_1 = 0.5;$$

$$\varepsilon_{2:\rho=-0.2} = -0.2 \times 0.5 - 0.25 \times \sqrt{0.96} \approx -0.34.$$

Using equation (5.1), if the underlying values are somewhat negatively correlated and uncertainty is 25%, a feasible realization would be

$$V_1 = 20 + (25\% \times 20) \times 0.5 = 22.5;$$

$$V_2 = 20 + (25\% \times 20) \times -0.34 = 18.3$$

The value of each project and the portfolio is calculated using equation (5.2):

$$OV_1 = \max[22.5 - 25\,,\, 0]e^{-rT} = 0$$

$$OV_2 = \max[18.3 - 25\,,\, 0]e^{-rT} = 0$$

$$pf = 0 + 0 = 0$$

This procedure is repeated $R$ times for each of the 21 correlations. Of the resulting 21 correlation-specific sets of $R$-sized portfolio values, we calculate portfolio risk using the variance of the portfolio values and plot it against the correlation. In all graphs, portfolio risk is normalized by dividing over the summed variance of two independent calls. If we treat the two projects as unconditional, we would have used equation (5.3), leading us to calculate a 'naive' portfolio variance, as described below.

### 5.3.2 Simulation Results

The curved, solid line $\sigma^2_{pf}$ in Figure 5.1 shows the cumulative variance of 21 $\rho$-specific option pairs. As this paper is exclusively concerned with portfolio risk and our results cannot be compared with other pricing methods such as the seminal Black–Scholes equation[4], no further option values are reported. Nevertheless, values have been used in equation (5.7) to construct the *variance*, our measure for dispersion. To illustrate the difference between the actual portfolio risk and the calculated risk when using Markowitz diversification, we add a dashed line $\tilde{\sigma}^2_{pf}$ that shows the variance of the projects if we (wrongly) assume Markowitz diversification to be valid. This would only be appropriate if the separate projects are unconditional and behave as equity shares. The solid line connects the portfolio variance for 21 different correlations and for the dashed line, the following well-known formula to calculate portfolio variance is used:

$$\tilde{\sigma}^2_{pf} = \sigma^2_{OV1} + \sigma^2_{OV2} + 2\rho\sigma_{OV1}\sigma_{OV2} \tag{5.8}$$

Using equations (5.2) and (5.3), this line has the variance of individual option values $OV_1$ and $OV_2$ as inputs for $\sigma^2_{OV1}$ and $\sigma^2_{OV2}$. We observe that at $\rho = 0$, the variance of unrelated projects is the same for both $\sigma^2_{pf}$ and $\tilde{\sigma}^2_{pf}$. A third, dotted line $\sigma^2_0 \equiv \tilde{\sigma}^2_{pf:\rho=0} = \sigma^2_{OV1} + \sigma^2_{OV2}$ shows that the first line $\sigma^2_{pf}$ is cushioned towards a special case of $\tilde{\sigma}^2_{pf}$, which

[4] Our results also persist for other stochastic processes such as the geometric Brownian motion, on which the Black & Scholes option pricing model is built. Under this process, the project value's *changes,* instead of *levels*, would be normally distributed. This process is arguably more suitable for modeling skewed R&D project values, but causes an additional asymmetry in the distribution of portfolio values. To isolate the effects of the (also nonlinear) investment option, we choose a symmetrically distributed process; this makes it no longer possible to compare our results with other models.

Figure 5.1: Simulated Risk for Two Identical Investment Opportunities
Using portfolio variance as a measure for risk, the cumulative variance of two simulated call options changes along with the correlation between the underlying values. Using Equation (8) for calculating portfolio risk would be naive, as it neglects option characteristics. The correct portfolio risk is graphed by the variance of the sum of option values (values are obtained through simulation and not reported); portfolio risk is normalized by dividing over the summed variance of two independent calls. The correct variance develops similar to naive variance, but is compressed towards the horizontal line, i.e. portfolio variance when projects are independent ($\rho = 0$). Simulation parameters are the number of trials ($R = 50,000$), number of options ($n = 2$), project volatility ($\sigma_1 = \sigma_2 = 25\%$), amount invested ($X_1 = X_2 = 25$), project market value ($V_1 = V_2 = 20$), a discount rate ($r = 20\%$) and time to completion: ($T = 18$ months). No intermediate (dividend) payments are made.

`C:/Users/SvBekkum/Desktop/pic1.eps`

represents a portfolio of completely unrelated options or options that are both separate and unrelated.

The difference lies in the interpretation of the correlation coefficient $\rho$ that measures the correlation between projects (the horizontal line $\sigma_0^2$ illustrates the degenerate case where $\rho$ is zero). In the case of the naively calculated variance $\tilde{\sigma}_{pf}^2$, the projects are correlated one-to-one with the projects' market values and $\rho$ is a constant. In the case of the correct variance $\sigma_{pf}^2$, however, co-movement between real option projects is a function of market value *and* the probability that a project is terminated[5]. This probability, in turn, depends on the moneyness of the call options, the correlation between project values and the volatilities of each project value. A manager who doesn't recognize real option

[5]This fact has also been used in the theoretical derivations of our results in Section 6.3.1.

characteristics would end up calculating risk naively, and Figure 5.1 illustrates how naively calculated risk may differ from correctly simulated risk.

In Figure 1, the naive portfolio variance at $\rho = 0$ is equal to the simulated variance of the portfolio and the separate options. We also see that both $\tilde{\sigma}^2_{pf}$ and $\sigma^2_{pf}$ are reduced when projects are less than perfectly positively correlated, and that two perfectly positively correlated projects have a variance of 200% compared to $\sigma^2_0$, as proven in Section 6.3.1. When the projects are negatively correlated, both $\tilde{\sigma}^2_{pf}$ and $\sigma^2_{pf}$ are less then $\sigma^2_0$. All of these diversification effects are in line with the theory proposed by Markovitz.

The 'convexity effect', however, limits the most severe value drops but leaves all positive development intact, so that project payoffs are non-linear and the value distribution becomes skewed. Figure 5.1 and Section 6.3.1 both show that when individual projects can no longer be offset, naively applying Markowitz diversification may lead to significant miscalculations of risk. This is caused by the interaction between the diversification and convexity effects, which has both positive and negative consequences. When projects are positively correlated, the cushioning of convexity enhances diversification and overall risk becomes lower than under Markowitz diversification. When the projects are negatively correlated, however, the cushioning of convexity hampers the diversification effect, leading to a less effective hedge. As a consequence, options are more complex instruments for diversification than stock. In terms of the effect that correlation has on risk, the sensitivity of unconditional risk to changes in correlation is generally smaller than for unconditional risk, up to a correlation of about $\rho = 0.60$. For negatively correlated projects in particular, diversification changes the portfolio's risk only slightly. Stated more precisely, the variance of a conditionally financed portfolio is compressed towards the cumulative variance of two independent options. The range of a conditionally financed portfolio is smaller than the range of an unconditional portfolio, but the minimum is higher than the unconditional portfolio's minimum. We can formulate the following hypotheses:

**H1:** For positively correlated project values, conditionally financed projects diversify risk better than unconditional projects.

**H2:** For negatively correlated project values, unconditional projects diversify risk better than conditionally financed projects.

### 5.3.3 Robustness Analysis and General Applicability

The base case (Figure 5.1) shows what happens when two simple and identical options are out of the money. This setting is typical of many R&D projects. Four panels in Figure 5.2 show results of simulated options that have a lower volatility (Panel A), a different volatility (Panel B), are at the money (Panel C) or in the money (Panel D). In all these situations, the convexity effect persists. Changes in other parameters such as the discount rate have no effect on the results. In Panel A, we halve the volatility so that the project is not in the money until the value is equal to $\mu + 2\sigma$. In R&D, this means that the project is not continued in about 97.5% of the cases and hardly any of these projects are available for risk diversification. As a consequence, the diversification effect is nearly absent and all we see is the convexity effect; we might just as well not diversify at all. In the less extreme case when volatilities differ, Panel B shows that portfolio risk is less sensitive to changes in correlation than in Figure 5.1 and diversification is still quite ineffective. The unit change on the y-axis indicates that in this case, zero variance cannot be achieved by naive calculation either. When the moneyness increases in Panel C and Panel D, the curves move towards the straight line and our results become less distinct. This reflects the familiar fact that deeply in the money options will behave similarly to the underlying stock. As a consequence, the convexity effect becomes less pronounced and the diversification effect starts to dominate. In R&D, this means that if the value of the project is much higher then its costs, conditional financing doesn't make a large difference because the project will be exercised anyway.

Some general remarks can be made on applying our model to practice. Many projects are funded by multiple finance or subsidy rounds and our simple calls represent the last phase. A more complex example involves an R&D project that is split up into stages such that certain requirements must be met before it can enter the next development phase. This project design involves several 'compound' options, as each conditional investment is an option on the next phase. R&D in the pharmaceutical industry, for example, is typically characterized by six stages of development. This means that investing in the sixth phase is

Figure 5.2: Sensitivity Analysis of Simulation Results
Unless stated otherwise, all option parameters are identical to the base case in Figure 2.

`C:/Users/SvBekkum/Desktop/pic2a.eps`

(a): Volatility equals 2.5 instead of 5 for both options.

`C:/Users/SvBekkum/Desktop/pic2b.eps`

(b): Volatility equals 4 and 6 for each, instead of 5 for both options.

`C:/Users/SvBekkum/Desktop/pic2c.eps`

(c): Project value equals 25 instead of 20.

`C:/Users/SvBekkum/Desktop/pic2d.eps`

(d): Project value equals 30 instead of 20.

conditional upon completion of the fifth phase, which requires investments conditional on the fourth phase, etc.. These more realistic features can easily modeled by using compound options in the simulation. In the compounded case, we are stacking 'effect on effect'. This is not demonstrated here since such simulation results are highly dependent on the success of entering the next round. Arbitrarily chosen input parameters (especially for several stages) will have a critical influence on the portfolio variance and conceal the convexity effect. Compound options can easily be put to practice by means of the closed-form model of the successive phases from R&D to commercialization, developed by Cassimon et al. (2004). Likewise, simulation makes implementing other realistic features such as uncertain costs or time-to-completion straightforward . That, however, would also drive us away from the essential portfolio diversification problem.

For ease of exposition, we have limited the analysis to the smallest portfolio possible- a portfolio of two projects. The effect is also observable when we increase the number of assets. If we introduce a third asset and keep the step size fixed at 0.10, for example, then 21 correlated samples are ranked similarly for every random variable. For the 3-variable case we have a grid of 21 correlation points between variable 1 and 2, 21 between 1 and 3 and 21 between 2 and 3. Section 6.3.2 describes how a simulation procedure can be developed for three and more projects by constructing a consistent correlation structure, as in Hull (2006)[6].

## 5.4 Implications

The implications of our results can be readily applied to any research policy that concerns simultaneous development of projects, subject to conditional financing. While various examples may illustrate this, we limit ourselves to three: static diversification, diversification over time and capital reserve regulations that protect an organization from bankruptcy.

[6] At the same time, the number of possible correlations is smaller than 63. If, for instance, two projects $c_1$ and $c_2$ have a negative correlation of 0.99, the third cannot be highly correlated with both at the same time. In this three-variable case, the correlation between $c_1$ and $c_2$ and a third, single option can only be defined on the complete interval [-1, 1] when the correlation of the two projects $c_1$ and $c_2$ is held constant at $\rho = 0$.

### 5.4.1 Focus or Diversify?

An example of an application of our framework lies in resource allocation for a geographical area, in order to effectively spur innovation. For instance, a government may want to stimulate economic activity in a certain area. Does a government prefer to focus business activities, in order to create a specialized technology area such as Silicon Valley? Or would it diversify in order to prevent over-dependence on a few industries, which has proven problematic in Detroit, an area focused on construction and car manufacturing?

Our results provide an argument based on the risk characteristics of individual firms in both areas. Especially in an innovative field such as information technology, a start-up is often a risky business with option characteristics. This is not true for construction and manufacturing. We have shown that the risk of a group of positively correlated start-ups is lower than one would expect if conditionality is ignored. Hence, diversification can be a good argument for grouping innovative companies, as risk is more effectively reduced than within industries with a more stable cash flow. Therefore, total risk in Silicon Valley is not easily increased, even when moderate positive correlation exists between the value drivers of the region's companies. In Detroit, however, diversification is an important factor in the region's development.

### 5.4.2 Diversification Over Time

An important implication concerns the different effects of diversification as the portfolio matures: when positively correlated projects are still young and in the R&D phase, a portfolio consisting of such projects is less risky than one would expect. But as successful projects mature, uncertainty resolves and option characteristics become less relevant, so that the same correlation between projects leads to more diversification risk. As a result, portfolios need restructuring when projects evolve and policy makers need different diversification criteria over time. Each individual project's milestone will modify the risk characteristics of the portfolio as a whole. To minimize overall portfolio risk, for instance, some of the matured projects may therefore be sold in exchange for more negatively correlated projects with low-risk.

Put differently, Figure 5.1 indicates that risk first develops as the curvature, and later as the straight, dotted line. The gentle slope of the curve shows that although the risk of positively correlated ventures is still higher than the risk of negatively correlated ventures, the difference doesn't matter as much as standard portfolio theory predicts. Therefore, structuring a portfolio to minimize variance is not as important in the early stages: non-diversification arguments may still provide good reason to combine these projects, but risk reduction isn't one of them. Until the projects mature and risk diminishes, negatively correlated risky projects are less attractive portfolio candidates for risk diversification. When ventures mature, diversification becomes more important and the risk characteristics of positively and negatively correlated ventures become more pronounced.

This can be observed in the pharmaceuticals sector, where many small firms successfully focus on a few drugs, rather than become part of a portfolio of a large, diversified company. Why is risk diversification not necessary for small research ventures to be successful in such a risky business? One well-known argument is that in the early stages of development, economies of scale (for example in marketing) are not feasible yet. Another is that the R&D process is differently organized for small ventures than for big companies. Our results provide an additional argument for this phenomenon: under conditional financing, a strong focus only marginally increases the risk of the portfolio while it may strongly contribute to non-diversification criteria (such as synergies and spillovers) and preserve the upward potential. Only after several milestones have been completed do the results of these R&D programs become less uncertain; the cushioning by the convexity effect disappears and the projects behave more like stocks. In these later stages, the risk becomes more sensitive to changes in correlation, diversification of risk becomes important and the venture may well be sold to a diversified company.

In this context, it may be useful to provide examples of positively and negatively correlated risk. Positively correlated risk can be partially ascribed to non-diversifiable market risk. Another part may be ascribed to the medical context, if projects develop drugs for 'complementary treatment'. An example is the treatment of HIV, where a combination of three drugs is prescribed; if the side effects of one drug become less severe or effectiveness improves, the value of all three drugs will increase, since the quality of the treatment increases. Another example are drugs that treat closely related disorders such as lung cancer and cardiovascular diseases. Often, both have a common cause, such as an unhealthy lifestyle. When a patient can be treated for one illness, he or she will live longer and odds increase that he or she will suffer from the second illness. Ironically, this is good news for investors as the market value of both drugs increases. An example of negatively correlated risk are two development programs that aim to cure similar diseases; if one program yields a major discovery, the value of the other program automatically goes down.

The problem in both examples can be described by a trade-off between focus and diversification; when focusing, $\rho > 0$, and conditional portfolio risk is lower than than standard portfolio theory might suggest because the diversification effect is cushioned by the convex nature of options. When diversifying, $\rho < 0$, and the cushioning of convexity causes diversification to be less effective than would be expected from standard diversification arguments.

The implications of diversification over time can be summarized by the effectiveness of risk management; risk diversification is not important until other uncertainties (that justify conditional financing) have been resolved. In other words, when an investor's risk is minimized by a milestone financing requirement, choosing negatively correlated projects will not diversify the risk much further. Rather, having a strong focus is not as risky as one would expect, and non-diversification arguments are more important selection criteria. Until the correlation becomes more than moderate, diversification has an insignificant effect on total risk as long as other factors justify conditional investment decisions.

### 5.4.3 Capital Reserves

Using variance as a measure of risk lies at the basis of common financial risk measures such as Value at Risk (VaR). Over the period that a portfolio is held, it measures the value of the portfolio at risk that for a given confidence interval. Similar to our 'naively' constructed portfolio, the most common VaR model assumes portfolio value to be linearly dependent on the value of the underlying assets. In the R&D setting, however, this relationship is linear only between portfolio value and the value of the options.

When the number of conditional projects is sufficiently large, the value of the portfolio becomes normally distributed. If the number of conditional projects is not sufficiently large, our results imply that the linearity assumption is inappropriate. To determine the VaR correctly, the variance of a portfolio should be simulated to construct the confidence interval. We show that the standard deviation is significantly higher if projects are negatively correlated, and naively calculated variance leads to an underestimation of VaR. As an international standard for creating capital reserves regulations, the Basel Accords may recommend simulation as a tool for risk assessment. This is true particularly for industries in which conditional investment decisions are common practice.

## 5.5 Conclusion and Future Research Directions

In this article we have shown that the presence of conditional financing in R&D may invalidate diversification strategies for portfolio construction. Under negative correlation, emphasis should be placed on other (non-diversification) arguments when constructing a portfolio. Under positive correlation, by contrast, the advantages of diversification are larger than one may expect using Markowitz diversification. We have also demonstrated that due to the convexity of high-risk projects, the sensitivity of portfolio risk to correlation is smaller for high-risk projects than for low-risk projects.

The difference in risk between high-risk and low-risk projects can be quite substantial; for two negatively correlated risky projects of about $\rho = -0.5$, the uncertainty is reduced by only $10\%/50\% = 20\%$ as compared to low-risk uncertainty reduction. For $\rho = +0.5$, the uncertainty is increased by only $30\%/50\% = 60\%$ as compared to low-risk uncertainty. These differences can easily become more dramatic (Figure 2.A shows that diversification may become impossible for negative correlations), and our findings are robust to changes in the parameter structure of the model. We have provided examples to show why this is important for R&D portfolio analysis.

An important implication of our work is that when evaluating the risk of a portfolio of risky R&D opportunities, it is not sufficient to merely examine the risk-return properties between projects. It is also important to determine the presence of conditional investment decisions before drawing conclusions on how effective a project will be at reducing the risk of the portfolio. Furthermore, policy makers may need to change their selection criteria over time. As companies mature and the need for conditional financing disappears along with uncertainty, diversification of successful projects becomes more important in the future.

Extending the model in several ways facilitates the analysis of portfolio risk under more specific circumstances. As we have shown, one can easily construct a portfolio with projects that differ in volatility, time to maturity and moneyness. It is also possible to compound several options when additional parameters (such as success probabilities) are known. Using Section 6.3.2, it is easy to extend the analysis to a large portfolio, with each project having its own distinct features such as the required investment outlay, estimated date of completion and volatility of market value.

Applying our model in real-world case studies may yield interesting results in the future. The simulation procedure remains the same for several underlying stochastic processes and may include other case-specific properties such as mean reversion, barriers or autocorrelation. It is also possible to account for synergies on the cost side. To explore these directions, however, and to compare empirical results with our framework, real-life data is needed to provide realistic input parameters. Our study demonstrates the complexity of options in a portfolio context, but when additional information on project parameters is available to tailor the model to a specific problem, our framework can be helpful in formulating and assessing research and development policy by public and private parties.

# Chapter 6

# Appendices

## 6.1 Appendix Chapter 2

### Growth Options and Market Risk (Cao, Simin and Zhao 2006)

To link idiosyncratic risk to growth options, Cao et al. (2006) use the Galai and Masulis (1976) model, which expresses the value of equity $S$ as a European call option on the value of the firm's assets $V$:

$$S = VN(d_1) - e^{-r_f T} DN(d_2) \tag{6.1}$$

where $D$ is the face value of debt, $r_f$ is the risk-free rate, $T$ the time to maturity, $d_1 = [\ln(V/D) + r_f T]/\sigma\sqrt{T}$, $d_2 = d_1 - \sigma\sqrt{T}$ and $N(.)$ is the cumulative normal probability of the unit normal variate $d_1$. In the presence of debt, all equity investments have only limited liability: as financial leverage increases, equityholders have an increasingly valuable option to default and more risk is borne by debtholders. Cao et al. (2006) show that the risk of equity $\sigma^2_{\varepsilon_S}$ is increasing in idiosyncratic variance of the firm's assets $\sigma^2_{\varepsilon_V}$:

$$\sigma^2_{\varepsilon_S} = \left(\frac{\partial S}{\partial V}\frac{V}{S}\right)^2 \left(\sigma^2_V - \beta^2_V \sigma^2_{r_M}\right) = \left(\frac{\partial S}{\partial V}\frac{V}{S}\right)^2 \sigma^2_{\varepsilon_V}. \tag{6.2}$$

Here, total asset variance $\sigma^2_V$ is decomposed into a systematic part correlated with market return variance, $\beta^2_V \sigma^2_{r_M}$, and a nonsystematic part $\sigma^2_{\varepsilon_V}$. Eq. (6.2) implies that the idiosyncratic volatility of equity increases when the idiosyncratic variance of the firm increases. Because of the contingent claim nature of equity, shareholders of the firm are better off when investments are selected that increase idiosyncratic firm variance, as growth options do.

From the Galai and Masulis (1976) representation in Eq. (6.2), one can express the change in firm equity value by the standard Black-Scholes differential equation,

$$dS = \frac{\partial S}{\partial V}dV + \frac{\partial S}{\partial t}dt + \frac{\partial^2 S}{2\partial V^2}\sigma^2 V^2 dt.$$

Dividing by S and letting $dt$ go to zero, they obtain

$$\lim_{dt\to 0}\frac{dS}{S} = \frac{\partial S}{\partial V}\frac{dV}{S} = \frac{\partial S}{\partial V}\frac{dV}{V}\frac{V}{S},$$

where $dS/S$ can be interpreted as the rate of return on equity $r_s$ and $dV/V$ as the rate of return on a firm's assets $r_V$:

$$r_S = \frac{\partial S}{\partial V}\frac{V}{S}r_V.$$

This implies that $\sigma_S^2 = \left(\frac{\partial S}{\partial V}\frac{V}{S}\right)^2\sigma_V^2$. Since project beta and equity beta are (scaled) covariances between the market's return $r_M$ and, respectively, asset and equity returns, the equality can be re-written as

$$\beta_S \equiv \frac{\partial S}{\partial V}\frac{V}{S}\frac{\operatorname{cov}(r_s, r_M)}{\operatorname{var}(r_M)} = \frac{\partial S}{\partial V}\frac{V}{S}\beta_V. \tag{6.3}$$

If we differentiate the Black-Scholes equation, we obtain

$$\frac{\partial S}{\partial V} = N(d_1) + VN'(d_1)\frac{\partial d_1}{\partial V} - Xe^{-r_f T}N'(d_2)\frac{\partial d_2}{\partial V},$$

where it can be shown from the definition of $d_1$and $d_2$ and their derivatives that $\partial d_1/\partial V = 1/V\sigma\sqrt{T} = \partial d_2/\partial V$ (e.g. Hull, 2002). As a result, the latter two terms cancel and

$$\frac{\partial S}{\partial V} = N(d_1).$$

We can substitute this result into Eq. (6.3) and obtain

$$\beta_S = N(d_1)\frac{V}{S}\beta_V.$$

If we now substitute Eq. (6.1) for $S$ and divide by $VN(d_1)$, the result becomes

$$\beta_S = \frac{VN(d_1)}{VN(d_1) - De^{-r_f T}N(d_2)}\beta_V$$

or

$$\beta_S = \frac{1}{1 - (D/V)e^{-r_f T}N(d_2)/N(d_1)}\beta_V.$$

Since $0 \leqq N(d_1) \leqq 1$, it follows that $\partial S/\partial V > 0$ and since $D/V < 1$ and $e^{-r_f T} < 1$ and $N(d_1) \geqq N(d_2)$, it follows that $\beta_S \geqq \beta_V \geqq 0$ and $\frac{\partial \beta_S}{\partial S} < 0$.

## 6.2 Appendix Chapter 4

### Growth Options Value and Economic Profit

The value of the firm can be expressed as the sum of (1) invested capital that creditors and shareholders have entrusted to the firm over the years ($CI$), defined as

$$\text{total assets} - (\text{accounts payable} + \text{other current liabilities}),$$

and (2) the present value (PV) of all of the firm's expected economic profit (EP)

$$V = CI + PV\,(EP)\,,$$

where $PV\,(EP)$ consists of a current-level EP component, as well as an EP growth component that depends on the firm's investments in future growth opportunities:

$$PV(EP) = PV\,(Current\,EP) + PV\,(EP\,Growth)$$

Combining these equations, firm value (V) can be rewritten as

$$V = CI + PV\,(Current\,EP) + PV\,(EP\,Growth)$$

where CI and PV of Current-Level EP are the value of assets in place (i.e., $V_{AIP}$), and PV of EP Growth measures the value of growth options (i.e., $V_{GO}$). To calculate $V_{GO}$, we solve and scale by firm value (V):

$V_{GO}$ = [V – CI – PV of Current-Level EP] / V.

The PV of Current-Level EP is current-level EP, perpetually discounted by the cost of capital. For a single year, current-level EP can be expressed as[1]

[1]EP can be negative, if capital $CI * Wacc$ is larger than NOPLAT. In economic terms, this means that the invested capital (or retained earnings invested in capital) will cost a shareholder money, and that this investment should be better been paid out as a dividend. The present value of current-level EP is an annuity, and value destruction (i.e., negative EP) will lead to a negative present value. As a consequence, value destruction will lead to growth options that exceed firm value.

$$EP = NOPLAT - CI \times WACC$$

where NOPLAT is the firm's net operating profits less adjusted taxes. It is calculated by deducting all income taxes from operating profit and adjusting for increases/decreases in deferred taxes (from the balance sheet), which is a source of cash. If deferred taxes are known from the previous year are not known, no adjustment is made. WACC is the weighted average cost of capital, defined as

$$WACC = \frac{D}{D+E}\left(1-T\right)k_d + \frac{E}{D+E}k_e$$

where total debt ($D$)is the sum of long and short term debt, the market value of equity ($E$) equals share price$\times$total common shares outstanding, and income tax ($T$) is set at 30%.

The cost of debt ($k_d$) is calculated iteratively using interest coverage ratios and default spreads, as in Damodaran (2002). If the earnings are negative, we average earnings over the past five years. When companies are small (i.e., assets worth less then \$10m), we use different spreads. For financial firms, we also use different spreads.

The cost of equity ($k_e$) is found using a standard capital asset pricing model using five-year adjusted betas.[2] The most recent date is the same as for determining market value (see Section 4.1). The index used is the S&P 500 Composite Index. The market risk premium is assumed to be 8%. For each year, the corresponding average 10-year Treasury Bill rate is added to the spreads.

[2] Beta is the slope of regressing the security returns on the index. We therefore estimate beta over a rolling window of the current year and the 4 preceding years. Using weekly data, we have about 250 observations per estimate, while daily volatility does not affect the estimates. If less than 4 years are available, a one-to-three year estimate of $\beta$ or $k_e$ is used. We use Bloomberg's adjusted betas, which yield the most realistic $k_e$s of about 10-20%, and estimates future instead of historical betas. Adjusted betas equal $0.67 \times \mathrm{Raw\,Beta} + 0.33 \times 1$, to adjust for their long-term tendency to converge toward 1.

## 6.3 Appendices Chapter 5

### 6.3.1 Explicit Derivation of Main Results

To examine the variance of a risky R&D portfolio more closely, an analytical treatment of our theoretical framework will convey what happens when the correlation is perfectly positive, negative or absent. Because of the nature of options (i.e., the max operator), the variance of a single call option consists of two properly weighted variances, namely one variance in case the call value is positive – which we will denote by $Var(c^{+})$ – and one for the case the outcome is zero:

$$Var(\max[V-I,0]) = w_1 Var(V-I) + w_2 Var(0) = w_1 Var(c^{+}) \tag{6.4}$$

where $w_1$ and $w_2$ are the appropriate weights. The key to an analytical derivation of the variances is recognizing the outcome possibilities that exist in each of the three correlation scenarios, and construct a single variance from there, using a variance decomposition formula that is defined as:

$$Var(X) = E[Var(X|Y)] + Var(E[X|Y]) \tag{6.5}$$

We will consider a portfolio of two simple investment opportunities (calls) that are exactly equal two each other. Both require an investment $X$ that is, by assumption, equal to the expected value of the project (for ease of notation, we drop the subscript $i$ that we introduced in Section 3.1):

$$X_1 = X_2 = X = E[V_T] \tag{6.6}$$

As a consequence, for at the money options, each call will be distributed around $E[V_T]$(again, we drop the subscript $i$):

$$\Pr(V_T > X | X = E[V_T]) = \Pr(\varepsilon > 0) = 0.5; \varepsilon \sim N(0,1) \tag{6.7}$$

Furthermore, since both calls are identical, we know that the probability of being in the money is equal for both calls $i, j$:

$$\Pr(V_{i,T} > X) = \Pr(V_{j,T} > X) \tag{6.8}$$

The cases of perfectly positive, negative or absent correlation differ only in the correlation that exist between two projects, and each will yield a different expression for the portfolio variance, as expressed in terms of the option components' variance in 6.4.

### Perfectly positively correlated projects

For $\rho = 1$, either both calls are in the money or both calls are out of the money. This means that the portfolio consists of two possible outcomes:

$$Pf = (c_1^+ + c_2^+ | V_1 > X, V_2 > X) + (0 | V_1 < X, V_2 < X)$$

Because of equation 6.7 and equation 6.8, each outcome is equally likely. In this case (denoting the positive part of the portfolio by $pf^+$ and the negative by $pf^-$), the variance composites on the right-hand side are:

$$\begin{aligned} Var_{pf^+} &= Var(2c^+ | V > X) = 4 \times Var(c^+ | V > X) \\ Var_{pf^-} &= 0 \end{aligned}$$

Furthermore, we know that $E[pf^+] = 2E[c^+]$ since both projects are identical. From equation 6.5, it follows that the portfolio variance of a portfolio is:

$$\begin{aligned} Var(pf | \rho = 1) &= \frac{4Var(c^+) + 0}{2} + \frac{(2E[c^+] - E[c^+])^2 + (0 - E[c^+])^2}{2} \\ &= 2 \times Var(c^+) + E[c^+]^2 \end{aligned}$$

### Perfectly independent projects

For $\rho = 0$, we know from equation 6.7 and equation 6.8that each option can be in the money or out of the money with equal probability. In this case, we can therefore distinguish 4 possible outcomes :

$$\begin{aligned} Pf &= (V_1 - X|V_1 > X, V_2 < X) \\ &+ (V_2 - X|V_1 < X, V_2 > X) \\ &+ (V_1 - X + V_2 - X|V_1 > X, V_2 > X) \\ &+ (0|V_1 < X, V_2 < X) \end{aligned}$$

The variance of the first two terms on the right hand side is equal to $Var(c^+)$, and the expected value for both is $E[c^+]$. Since the non-linear payoff is accounted for in the last term, we can use Markowitz to find the variance of the third term, which is simply the sum of the variances $Var(c_1^+)$ and $Var(c_2^+)$ because $\rho = 0$. Furthermore, we know that the expected value of this term equals the sum of the expected values $E[c_1^+]$and $E[c_2^+]$. It follows from equation 6.5 that

$$\begin{aligned} Var(Pf|\rho = 0) &= \frac{Var(c^+) + Var(c^+) + 2var(c^+) + 0}{4} \\ &+ \frac{0 + 0 + (2E[c^+] - E[c^+])^2 + (0 - E[c^+])^2}{4} \\ &= Var(c^+) + 0.5(E[c^+])^2 \end{aligned}$$

This is exactly half of the variance found at $\rho = +1$, a finding that corresponds with the simulation results.

### Perfectly negatively correlated projects

For $\rho = -1$ and at the money options, we know that either one call or the other is in the money. But because both projects can never jointly be in- or out of the money at $\rho = -1$, this simply means that the variance is equal to either the variance of one call, or that of the other. More precisely, we can state that:

$$\begin{aligned} Pf &= (c_1^+ + 0|V_1 > X, V_2 < X) + (0 + c_2^+|V_1 < X, V_2 > X) \\ &= c_1^+ = c_2^+ = c^+. \end{aligned}$$

We can write the last line because the calls are identical under the given conditions. It follows directly that we can write:

$$Var(Pf|\rho = -1) = Var(c^+)$$

This demonstrates why in our results, the variance of a perfectly negatively correlated portfolio doesn't go to 0% in the limit but is of a magnitude between zero and the variance at $\rho = 0$. Indeed, diversification under these circumstances does not permit risk to be diversified away.

### 6.3.2 How to Generate Random Samples from a Multivariate Normal Distribution

In case a third stock enters our model, a third sample is drawn; $\rho_{13}$ and $\rho_{23}$ need to be defined in such a manner that the variances and covariance are consistent, for instance, if asset 1 and asset 2 strongly move together as well as asset 1 and 3 (i.e., the correlations $\rho_{12}$ and $\rho_{13}$ are highly positive), then the dynamics of asset 2 and 3 need to be positively related to some extent (i.e., $\rho_{23}$ needs to have a high positive value) as well. If we require 3 correlated samples from normal distributions, the required samples are defined as follows:

$$\begin{aligned} \varepsilon_1 &= \alpha_{11} x_1 && (6.9) \\ \varepsilon_2 &= \alpha_{21} x_1 + \alpha_{22} x_1 && (6.10) \\ \varepsilon_3 &= \alpha_{31} x_1 + \alpha_{32} x_1 + \alpha_{33} x_1 \end{aligned}$$

The Cholesky decomposition procedure sets $\alpha_{11} = 1$ and requires $\alpha_{21}$ to be chose such that $\alpha_{21}\alpha_{11} = \rho_{21}$ and $\alpha_{21}^2 + \alpha_{22}^2 = 1$. This yields

$$\alpha_{21} = \rho_{21} \tag{6.11}$$

and

$$\alpha_{22} = \sqrt{1 - \rho_{21}^2}. \tag{6.12}$$

For the third sample, $\alpha_{31}$ is to be chosen such that $\alpha_{31}\alpha_{11} = \rho_{31}$, yielding $\alpha_{31} = \rho_{31}$. Then $\alpha_{32}$ is to be chosen such that

$$\alpha_{31}\alpha_{21} + \alpha_{32}\alpha_{22} = \rho_{32}, \tag{6.13}$$

leading to

$$\alpha_{32} = \frac{\rho_{32} - \rho_{12}\rho_{13}}{\sqrt{1-\rho_{12}^2}}. \tag{6.14}$$

We conclude by the requirement that

$$\alpha_{31}^2 + \alpha_{32}^2 + \alpha_{33}^2 = 1, \tag{6.15}$$

leading to

$$\alpha_{33} = \sqrt{1 - \rho_{13}^2 - (\frac{\rho_{23} - \rho_{12}^2\rho_{13}^2}{\sqrt{1-\rho_{12}^2}})^2}. \tag{6.16}$$

We can simply generalize this case to $n$ by expanding the Choleski matrix in equation 6.10, for example to

$$\varepsilon_4 = \alpha_{41}x_1 + \alpha_{42}x_2 + \alpha_{43}x_3 + \alpha_{44}x_4 \tag{6.17}$$

and repeat this procedure. But correlations need to be chosen with more and more care as the number of projects increases. In case of 2 projects, the restriction imposed by (B2) implies that $\rho_{12}$ must be smaller than 1. Although not very demanding in the two-variable case, the requirements above pose more restrictions on the correlated projects for every project that enters the simulation. We initially consider a single drug. If we want to simulate two additional projects that both are correlated to this drug $\rho_{12} = \rho_{13} = -0.9$, then these projects need to be positively correlated. More specifically, if we let the third variable enter the simulation, it must satisfy:

$$\alpha_{31}^2 + \alpha_{32}^2 + \alpha_{33}^2 = 1 \tag{6.18}$$

or

$$\alpha_{33}^2 = \sqrt{1 - \alpha_{31}^2 - \alpha_{32}^2} = \sqrt{1 - 0.9^2 - \alpha_{32}^2} > 0. \tag{6.19}$$

Hence, the Choleski-variable $\alpha_{32}^2$ must not be larger than (1 - 0.81 = ) 0.19 and

$$\sqrt{0.19} \leqq \alpha_{32} \leqq \sqrt{0.19}. \tag{6.20}$$

Using this condition in the other requirement 6.13, we find the following range:

$$\begin{aligned} \rho_{23} \leq 0.90 \times 0.90 + 0.19 \times 0.19 &= 0.88 \\ \rho_{23} \geq 0.90 \times 0.90 - 0.19 \times 0.19 &= 0.62. \end{aligned}$$

If a fourth project enters the story and $\rho_{14} = \rho_{12} = \rho_{13} = -0.9$, it is required that

$$\alpha_{44}^2 = \sqrt{1 - \alpha_{41}^2 - \alpha_{42}^2 - \alpha_{43}^2} = \sqrt{1 - 0.9^2 - \alpha_{42}^2 - \alpha_{43}^2} > 0$$

and, similarly to equation 6.20, that

$$-\alpha_{22} \leq \alpha_{42} + \alpha_{43} \leq \alpha_{22},$$

meaning that $\alpha_{42} + \alpha_{43}$ are subject to the same constant as was $\alpha_{32}$. So any newly entering simulation variable is subject to all previous constraints plus 1. For instance, if we choose $\rho_{42} = \rho_{32}$(so $\alpha_{42} = \alpha_{32}$ and $\alpha_{41}, \alpha_{42}, \alpha_{43} = \alpha_{31}, \alpha_{32}, \alpha_{33}$), it must be true that

$$\alpha_{44} = \sqrt{1 - \alpha_{41}^2 - \alpha_{42}^2 - \alpha_{43}^2} = \sqrt{1 - 0.81 - 0.19 - \alpha_{43}^2} > 0$$

and the fourth project needs to be uncorrelated with the others for consistency.

# Chapter 7

# Recapitulation

In the first chapter of this book, I described the difference between fundamental value and market value and provided two alternative explanations for why the two measures for firm value do not coincide in reality. Either fundamental value does not reflect all information relevant to prices, or share prices contain more than value alone. In the first case, the difference exists because *ex post* calculations of fundamental value do not incorporate the *ex ante* expectations of investors about future value creation. This explanation assumes expectations are rational, so that prices contain valid information that is relevant to the value of the firm. In the second case, the difference exists because of changes in the investors' willingness to buy shares, leading to higher (or lower) prices than the value of a firm. This explanation assumes expectations are irrational, and implies that the difference between market value and fundamental value is not related to the value of the firm, and has no economic justification.

The previous chapters have shown that it is hard to find unambiguous evidence for one case or the other. One of the major problems in empirical work is the fact that the value of a firm to investors is unobserved. Moreover, while prices are generally available to the public and fairly unambiguous, the notion of "value" is evasive and may vary over time and between individuals. From the viewpoint of a "buyer" (whether he is an individual shareholder, an institutional investor, or an acquirer firm), firm value at any point in time depends not only on current firm performance, but also on the buyer's unique history, experience and sentiment that shape his/her expectations about future value.

The results above show that the rational expectations hypothesis holds in some cases but is violated in others, and describe investors that may be smart but are not without error. In Chapter 2, we show that the pricing residual has statistical properties that are similar (and behaves analogously) to a portfolio of real options. In Chapter 3, however, we have seen that this does not imply that the value residual can be interpreted as the value of growth opportunities. The measure is noisy and does not lead to reliable estimates that are consistent between firms, sectors and countries. Furthermore, in Chapter 4, we found that market frictions and investor psychology may cause share prices to deviate from fundamental value without economic justification, which hints at more problems than just measurement error.

The assumption of rational behavior allows us to simplify subtle and complicated issues, and economists have historically been fascinated by revealing hidden logic that shapes and changes the world that we observe. As demonstrated in chapters 2 and 5, even an oversimplified rational view can be helpful to detect unexpected implications, to uncover inconsistencies in a line of reasoning, and to test ideas against empirical evidence. But as we have seen in chapter 3, some ways of simplifying do not provide more insight than is destroyed. An important implication that follows from these studies is therefore the lack of conclusion in the field, and the joint validity of rational and irrational expectations as explanations for the price–value divergency. This perspective has found empirical support in chapter 4.

Considering the two co-existing explanations, an interesting question that immediately arises is *why* there are two reasons for such divergencies, and what causes them. This is left largely unexplored in this dissertation, so I will now loosely discuss some recent developments in which different views on the world co-exist. For instance, a potential explanation could be the existence of two groups of investors, where each investor trades according to fundamentals-based or market-based decision rules. Research on heterogeneous agent models has found that this setup explains many empirical observations that have previously puzzled researchers. The interested reader is referred to Hommes (2006) for an introduction to this literature.

Heterogeneous agents can take different decisions at different points in time, and a noteworthy study in a similar context is John List's (2003) work on the *endowment effect* (Thaler 1980). Thaler observed that individuals require much more to give up a good than they would pay to acquire it. This seems irrational, and has been explained by people who prefer avoiding losses over acquiring gains (Tversky and Kahneman 1981) or by people's preference to maintain the status quo (Samuelson and Zeckhauser 1988). By examining trading patterns of sports memorabilia and collector pins in an actual marketplace, List shows that experienced traders are more likely to trade goods than inexperienced traders, and are therefore less susceptible to the endowment effect. This suggests the existence of two different groups of investors, similar to the bidding firm's shareholders and its managers in Chapter 4. In both situations, it is likely that one group is better informed, more familiarized, and/or better skilled than the other.

Lack of experience not only explains why irrational expectations exist; it also allows rational behavior and psychological mistakes to co-exist and interact. On the one hand, the endowment effect exists and has a substantial effect on individuals. On the other, however, it doesn't influence more experienced traders. Heterogeneous agent models build on the existence of two distinct groups, and List (2003) provides a psychological explanation for how these groups come about. Or as Financial Times columnist Tim Harford put it in his 2009 book "*The Logic of Life*": heterogeneous groups will emerge as long as people are taken out of their comfort zone.

Clearly, experience is just one of many (non-)psychological mechanisms that may lead to heterogeneity, and heterogeneity can take many more forms than the one described here. However, this example illustrates that the difference between price and value can be plausible at times and questionable at others. This leaves the truth to lie somewhere in the middle.

# Chapter 8

# Bibliography


Ang, A., R.J. Hodrick, Y. Xing, and X. Zhang, 2006. The cross-section of volatility and expected returns. *Journal of Finance* **61** 259–299.

Ang, A., R.J. Hodrick, Y. Xing, and X. Zhang, 2009. High idiosyncratic volatility and low returns: International and further US evidence. *Journal of Financial Economics* **91** 1–23.

Arellano, M. and Bond, S., 1991. Some tests of specication for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58, 277–297.

Arellano, M., and Bover, O., 1995. Another look at the instrumental variables estimation of error components models. *Journal of Econometric*s, 68, 29–51.

Anderson, C. W., L. Garcia-Feijoo,, 2006. Empirical evidence on capital investment, growth options, and security returns. *Journal of Finance* **61** 171–194.

Andrade, G., M. Mitchell, E. Stafford, 2001. New evidence and perspectives on mergers. *Journal of Economic Perspectives* **15** 103–120.

Baker, M. P., R. S. Ruback, J. A. Wurgler, 2007. Behavioral corporate finance: A survey. *Handbook in Corporate Finance: Empirical Corporate Finance*, Amsterdam, Netherlands: Elsevier.

Baker, M., J. Wurgler, 2002. Market timing and capital structure. *Journal of Finance* **57** 1–32.

Barberis, N., R. Thaler, 2003. A survey of behavioral finance. *Handbook of the Economics of Finance*, Amsterdam, Netherlands: Elsevier.

Barberis, N., M. Huang, 2001. Mental accounting, loss aversion and individual stock returns. *Journal of Finance* **56** 1247–1292.

Barth, M.E., W.H. Beaver, W.R. Landsman, 2001. The relevance of the value-relevance literature for financial accounting standard setting: Another view. *Journal of Accounting and Economics* **31** 77–104.

Ben-Horim, M. and Callen, J., 1989. The Cost of Capital, McCaulay's Duration, and Tobin's q. *Journal of Financial Research* **12** 143.

Berger, P., Ofek, E., and Swary, I., 1996. Investor valuation of the abandonment option. *Journal of Financial Economics* **42** 257–287.

Berk, J., Green, R., and Naik, V., 1999. Optimal investment, growth options, and security returns. *Journal of Finance* **54** 1553–1607.

Berk, J., Green, R., and Naik, V., 2004. Valuation and return dynamics of new ventures. *Review of Financial Studies* **17** 1–35.

Bettis, R., and M. Hitt, 1995. The new competitive landscape. *Strategic Management Journal* **16** 7–19.

Black, F., Scholes, M., 1973. The pricing of options on corporate liabilities. *Journal of Political Economy* **81** 637–659.

Blume, M., 1975. Betas and their regression tendencies. *Journal of Finance* **30** 785–795.

Blundell, R., and Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics* **87** 115–143.

Blundell, R., and Bond, S., 2000. GMM estimation with persistent panel data: An application to production functions. *Econometric Reviews*, **19**, 321–340.

Bowman, E.H. and Hurry, D., 1993. Strategy through the option lens: an integrated view of resource investments and incremental-choice process. *Academy of Management Review* **18** 760–782.

Brosch, R., 2001. Portfolio Aspects in Real Options Management. F&A Working Paper Series, J. W. Goethe-Universität, No. 66

Cao, C., Simin, T., and Zhao, J., 2006. Can growth options explain the trend in idiosyncratic risk? *Review of Financial Studies* **21** 2599–2633.

Carlson, M., Fisher, A., and Giammarino, R., 2004. Corporate investment and asset price dynamics: Implications for the cross-section of returns. *Journal of Finance* **59** 2577–2603.

Cassimon, D., Engelen, P.J., Thomassen, L., Van Wouwe, M., 2004. The valuation of a NDA using a 6-fold compound option. *Research Policy* **33** 41–51.

Chan, L., Lakonishok, J., and Sougiannis, T., 2001. The stock market valuation of research and development expenditures. *Journal of Finance* **56** 2431–2456.

Chen, K., Cheng, D., and Hite, G., 1986. Systematic Risk and Market Power: An Application of Tobins q. *Quarterly Review of Economics and Business* **26** 58–72.

Chien, C-F., 2002. A Portfolio-Evaluation Framework For Selecting R&D Projects. *R&D Management* **32** 359–368.

Childs, P.D., S. H. Ott, A. J. Triantis, 1998. Capital budgeting for interrelated projects: A real options approach. *Journal of Financial and Quantitative Analysis* **33** 305–34.

Chung, K. and Charoenwong, C., 1991. Investment options, assets in place, and the risk of stocks. *Financial Management* **20** 21–33.

Chung, K., Li, M., and Yu, L., 2005. Assets in place, growth opportunities, and IPO returns. *Financial Management* **34** 65–88.

Copeland, T., V. Antikarov, 2001. *Real Options.* New York, NY.

Corrado, C., Hulten, C. and Sichel, D., 2005. Measuring Capital and Technology: An Expanded Framework. In: *Measuring Capital in the New Economy*, C. Corrado, J. Haltiwanger, and D. Sichel, eds., *Studies in Income and Wealth*, Vol. 65. Chicago: The University of Chicago Press, 11-41.

Corrado, C., Hulten, C. and Sichel, D. 2006. Intangible Capital and Economic Growth. National Bureau of Economic Research, Working Paper 11948

Craine, R., 1989. Risky business: The allocation of capital. *Journal of Monetary Economics* **23** 201–218.

Cummins, J., 2004. A New Approach to the Valuation of Intangible Capital. Unpublished Working Paper, Division of Research and Statistics, Board of Governors of the Federal Reserve System

Coval J. and T. Shumway, 2001. Expected option returns. *Journal of Finance* **56** 983–1009.

Damodaran, A., 2002. *Investment Valuation.* New York, NY.

Daniel, K. D., D. Hirshleifer, A. Subrahmanyam, 2001. Overconfidence, arbitrage, and equilibrium asset pricing. *Journal of Finance* **56** 921–965.

Dixit, A. K., R. S. Pindyck, 1994. *Investment Under Uncertainty.* Princeton, NJ: Princeton University Press.

Dong, M., D. Hirshleifer, S. H. Teoh, S. Richardson, 2006. Does investor misvaluation drive the takeover market? *Journal of Finance* **61** 725–762.

Engwall, M., 2003. No Project is an Island: Linking Projects to History and Context. *Research Policy,* **32** 789–808

Erb. C., Harvey, C. and Viskanta, T., 1996. Expected returns and volatility in 135 Countries. *Journal of Portfolio Management* **22** 46–58

Fama, E. F., J. D. MacBeth, 1973. Risk, return, and equilibrium: empirical tests. *Journal of Political Economy* **81** 607–636.

Fama, E.F. and K.R. French, 1992. The cross-section of expected stock returns. *Journal of Finance* **47** 427–465.

Fama, E.F. and K.R. French, 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics* **33** 3–56.

Francis, J., K. Schipper, 1999. Have financial statements lost their relevance? *Journal of Accounting Research* **37** 319–352.

Fukao, K., Hamagata, S., Miyagawa, T. and Tonogi, K., 2007. Intangible Investment in Japan: Measurement and Contribution to Economic Growth. RIETI Discussion Papers Series, May

Galai, D. and Masulis, R., 1976. The option pricing model and the risk factor of stock. *Journal of Financial Economics* **3** 53–81.

Griliches, Z., 1981. Market value, R&D, and patents. *Economic Letters* **7** 183–187.

Grullon, G., E. Lyandres, and A. Zhdanov, 2008. Real Options, Volatility, and Stock Returns. Working Paper (Rice University).

Hall, B., 2001. The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995. *RAND Journal of Economics* **32** 101–128

Hall, B., A. Jaffe and M. Trajtenberg, 2005. Market Value and Patent Citations. *RAND Journal of Economics* **36** 16–38

Hall, B. and Oriani, R., 2005. Does the Market Value R&D Investment by european Firms? Evidence from a Panel of Manufacturing firms in France, Germany and Italy. *International Journal of Industrial Organization*, 1–23

Hao, J., Manole, V. and Van Ark, B., 2008. Intangible Assets in France and Germany. The Conference Board, Unpublished Working Paper.

Hand, J. and Lev, B., 2003. *Intangible assets: value, measures and risks.* Oxford: Oxford University Press.

Hansen, L., 1982. Large sample properties of generalized method of moments estimators, *Econometrica* **50** 1029-1054.

Hartmann, M. and Hassan, A., 2006. Application of real options analysis for pharmaceutical R&D project valuation–Empirical results from a survey. *Research Policy* **35** 343–354

Harvey, C. and Siddique, A., 2000. Conditional skewness in asset pricing tests. *Journal of Finance* **55** 1263–1295.

Hevert, K., McLaughlin, R., and Taggart Jr, R., 1998. Growth options and equity duration. *Journal of Portfolio Management* **25** 43–50.

Himmelberg, C.; R. Hubbard, and D. Palia, 1999. Understanding the determinants of managerial ownership and the link between ownership and performance. *Journal of Financial Economics* **53** 353–384.

Holmstrom, B., S. Kaplan, 2001. Corporate governance and merger activity in the U.S.: Making sense of the 80's and the 90's. *Journal of Economic Perspectives* **15** 121–144.

Hull, J. C., 2006, Options, Futures and Other Derivatives, 6th ed., Prentice Hall of India, Pearson Education

Hulten, C. and Hao, J., 2008. Intangible Capital and the Market to Book Value Puzzle. The Conference Board Economic Working Paper EPWP #08 – 02

Jacquier, E., Titman, S., Yalcin, A., and Yolu, R., 2001. Growth opportunities and assets in place: implications for equity betas. Technical report, Working Paper (Boston College).

Jenter, D., 2004. Market timing and managerial portfolio decisions. *Journal of Finance* **60** 1903–1949.

Kaplan, S. and Ruback, R., 1995. The valuation of cash ow forecasts: An empirical analysis. *Journal of Finance* **50** 1059–1093.

Kellogg, D., Charnes, J. M., 2000. Real-options valuation for a biotechnology company. *Financial Analysts Journal* **56** 76–85

Kester, W.C., 1984. Today's options for tomorrow's growth. *Harvard Business Review* **62** 153–160.

Knez, P. and Ready, M., 1997. On the robustness of size and book-to-market in cross-sectional regressions. *Journal of Finance* **52** 1355–1382.

Kothari, S., Shanken, J., and Sloan, R., 1995. Another look at the cross-section of expected stock returns. *Journal of Finance* **50** 185–224.

Lakonishok, J., A. Shleifer, and R.W. Vishny, 1994. Contrarian investment, extrapolation, and risk. *Journal of Finance* **49** 1541–1578.

Lambrecht, B. M., 2004. The timing and terms of mergers motivated by economies of scale. *Journal of Financial Economics* **72** 41–62.

Larwood, L., W. Whittaker, 1977. Managerial myopia: Self-serving biases in organizational planning. *Journal of Applied Psychology* **62** 194–198.

Lee, J. and Paxson, D.A., 2001. Valuation of R&D real American sequential exchange options. *R&D Management* **31** 191–201.

Lev, B. 2001. Intangibles: Management, Measurement, and Reporting. The Brookings Institution.

Lev, B. and Radhakrishnan, S., 2005. The Valuation of Organization Capital, in Corrado, Haltiwanger, and Sichel, eds., *Measuring Capital in a New Economy*, National Bureau of Economic Research and University of Chicago Press, 73–99.

Linton, J. D., Walsh, S. T. and Morabito, J., 2002. Analysis, Ranking and Selection of R&D Projects in a Portfolio. *R&D Management* **32** 139–148.

List, J. A., 2003. Does Market Experience Eliminate Market Anomalies? *Quarterly Journal of Economics* **118** 41–71

Loch, C.H. and Bode-Greuel, K., 2001. Evaluating growth options as sources of value for pharmaceutical research projects. *R&D Management* **31** 231–248.

Long, M., Wald, J., and Zhang, J., 2005. A cross-sectional analysis of growth options. In: *Innovation, Organization, and Strategy: New Developments and Applications in Real Options*, Oxford University Press.

Longstaff, F. A., E. S. Schwartz, 2001. Valuing american options by simulation: A simple least-squares approach. *Review of Financial Studies* **14** 113–147.

Loughran, T., J. Ritter, 1995. The new issues puzzle. *Journal of Finance* **50** 23–51.

Malmendier, U., G. Tate, 2005. CEO overconfidence and corporate investment. *Journal of Finance* **60** 2261–2700.

March, J. G., Z. Shapira, 1987. Managerial perspectives on risk and risk taking. *Management Science* **33** 1404–1418.

Margrabe, W., 1978. The value of an option to exchange one asset for another. *Journal of Finance* **33** 177–186.

Markowitz, H., 1952. Portfolio selection. *Journal of Finance* **7** 77-91.

Marrano, M. and Haskel, J., 2006. How Much Does the U.K. Invest in Intangible Assets? Working Paper.

Marrano, M., Haskel, J. and Wallis, G., 2007. What happened to the knowledge economy? ICT, Intangible Investment and Britain's Productivity Record Revisited. Queen Mary University of London Working Paper 603

Martino, J. P., 1995. R&D Project selection, Wiley InterScience, New York

Merton, R., 1998. Applications of option-pricing theory: twenty-ve years later. *American Economic Review* **88** 323–349.

Miller, K. D., T. B. Folta, 2002. Option value and entry timing. *Strategic Management Journal* **23** 655–665.

Miller, M. H., F. Modigliani, 1961. Dividend policy, growth, and the valuation of shares. *Journal of Business* **34** 235–64.

Mitchell, M., J. H. Mulherrin, 1996 The impact of industry shocks on takeover and restructuring activity. *Journal of Financial Economics* **41** 193–229.

Morck, R., A. Shleifer, R. W. Vishny, 1990. Do managerial objectives drive bad acquisitions? *Journal of Finance* **45** 31–48.

Morellec, E., A. Zhdanov, 2005. The dynamics of mergers and acquisitions. *Journal of Financial Economics* **77** 649–672.

Muelbroek, L., 1992. An empirical analysis of illegal insider trading. *Journal of Finance* **47** 1661–1699.

Myers, S. C., 1976. *Modern Developments in Financial Management,* New York, NY: Praeger.

Myers, S. C., 1977. Determinants of Corporate Borrowing. Journal of Financial Economics, 5, 147-175.

Nickell, S., 1981. Biases in dynamic models with fixed effects. *Econometrica*, Vol. 49, pp. 1417–1426.

Nordhaus, W.D., 1989. Comment, Brookings Papers on Economic Activity. Microeconomics, 320–325.

Pakes, A., 1985. On Patents, R & D, and the Stock Market Rate of Return. *Journal of Political Economy*, 93, 2, 390

Penman, S., 1998. Combining earnings and book value in equity valuation. *Contemporary Accounting Research* **15** 291–324.

Pindyck, R., 1988. Irreversible investment, capacity choice, and the value of the rm. *American Economic Review*, 78, 969–985.

Prencipe, A., Tell, F. 2001. Inter-Project Learning: Processes and Outcomes of Knowledge Codification in Project-Based Firms. *Research Policy* **30** 1373–1394

Rhodes-Kropf, M., D. T. Robinson, S. Viswanathan, 2005. Valuation Waves and merger activity: The empirical evidence. *Journal of Financial Economics* **77** 561–603.

Rhodes-Kropf, M., S. Viswanathan, 2004. Market valuation and merger waves. *Journal of Finance* **59** 2685–2718.

Ringuest, J. L., Graves, S. B., Case, R. H., 2004. Mean-Gini analysis in R&D portfolio selection. European Journal of Operational Research **154** 157–169.

Ritter, J. R., 1991. The long-run performance of initial public offerings. *Journal of Finance* **46** 3–27.

Roll, R., 1986. The hubris hypothesis of corporate takeovers. *Journal of Business* **59** 197–216.

Roodman, D., 2006. How to do XTABOND2. Working Paper 103, Center for Global Development Working Paper.

Roodman, D., 2009. A Note On the Theme of Too Many Instruments. *Oxford Bulletin of Economics and Statistics*, 71, 1, 135–158.

Samuelson, W. and R Zeckhauser, 1988. Status Quo Bias in Decision Making. *Journal of Risk and Uncertainty*, 1, 7-59.

Sargan, J., 1958. The estimation of economic relationships using instrumental variables. *Econometrica*, 26, 393–415.

Satterthwaite, F. E. 1946. An approximate distribution of estimates of variance components. *Biometrics Bulletin* **2** 110–114.

Scherer, F. M. and Harhoff, D., 2000. Technology policy for a world of skew-distributed outcomes. *Research Policy* **29** 559–566

Seyhun, H. N., 1992. Why does aggregate insider trading predict future stock returns? *Quarterly Journal of Economics* **107** 1303–31.

Shiller, R. J., 2000. *Irrational Exuberance.* Princeton, NJ: Princeton University Press.

Shleifer, A., 2000. *Inefficient Markets: An Introduction to Behavioral Finance.* Oxford, U.K.: Oxford University Press.

Shleifer, A., R. W. Vishny, 2003. Stock market driven acquisitions. *Journal of Financial Economics* **70** 295–311.

Smit H. T. J., 1999. Option characteristics of stock in high-tech industries. Working Paper.

Smit, H., 2000. Option Characteristics of Stocks in High Tech Industries. Technical report, Working paper (Erasmus University).

Smit, H. T. J., 2001. Acquisition strategies as option games. *Journal of Applied Corporate Finance* **14** 79–89.

Smith, J. L. and Thompson, R., 2003. Managing a Portfolio of Real Options: Sequential Exploration of dependent Prospects. MIT center for Energy and Environmental Policy Research, Working paper no. 04-003WP

______, 2005. Diversification and the Value of Exploration Portfolios. Southern Methodist University, Working Paper.

Smith, W. S. and A. J. Triantis, 1995. The value of options in strategic acquisitions. In L. Trigeorgis (Ed.), *Real options in capital investment:* 135–149. Westport, CT: Greenwood Publishing Group, Praeger.

Spiegel, M. I. and X. Wang, 2006. Cross-sectional variation in stock returns: Liquidity and idiosyncratic risk. Working Paper (Yale School of Management).

Thaler, R., 1980. Toward a Positive Theory of Consumer Choice. *Journal of Economic Behavior & Organization*, **1**, 39–60

Thijssen, J., 2008. Optimal and strategic timing of mergers and acquisitions motivated by synergies and risk diversification. *Journal of Economic Dynamics and Control* **32** 1701–1720.

Thomke, S. H., 1997. The Role of Flexibility in the Development of New Products: an Empirical Study. *Research Policy* **26** 105–119

Tong, T. and Reuer, J., 2007. Real options in multinational corporations: Organizational challenges and risk implications. *Journal of International Business Studies* **38** 215–230.

Tong, T. W., T. M. Alessandri, J., J. Reuer, A. Chintakanda, 2008. How much does country matter? An analysis of firms' growth options. *Journal of International Business Studies* **29** 387–405.

Tong, T. W., J., J. Reuer, M. W. Peng, 2008. International joint ventures and the value of growth options. *Academy of Management Journal* **51** 1014–1029.

Trigeorgis, L. 1996. *Real Options: Managerial Flexibility and Strategy in Resource Allocation.* Cambridge, MA: MIT Press.

Trigeorgis, L. and Lambertides, N., 2006. The Role of Growth Options in Explaining Stock Returns. Is Book-to-Market Dead. Technical report, Working paper (Columbia University).

Tversky, A., and Kahneman, D., 1981. The Framing of Decisions and the Psychology of Choice. *Science* **211** 453–458

Van Ark, B. and Hulten, C., 2007. Innovation, Intangibles and Economic Growth: Towards A Comprehensive Accounting of the Knowledge Economy. The Conference Board Economic Working Paper EPWP #07 – 02

Van Rooijen-Horsten, M., Van Den Bergen, D. and Tanriseven, M., 2008. Intangible Capital in the Netherlands: A Benchmark. Statistics Netherlands Discussion Paper 08001

Vassalou, M. and Apedjinou, K., 2004. Corporate innovation, price momentum, and equity returns. Technical report, Working Paper (Columbia University). Columbia University.

Windmeijer, F., 2005. A finite sample correction for the variance of linear ecient two-step

GMM estimators. *Journal of Econometrics* **126** 25–51.

Wörner, S.D., Racheva-Iotova, B. and Stoyanov, S., 2002. Calibrating A Basket Option Applied To Company Valuation. Mathematical models in Operations research, SME 2001, Klagenfurth, Austria, pp 242–244.

Wörner, S. D., Grupp, H., 2003. The Derivation of R&D Return Indicators Within A Real Options framework. *R&D Management* **33** 313–325.

Xu, J., 2007. Price convexity and skewness. *Journal of Finance* **62** 2521–2552.

# Curriculum Vitae

### Graduate Education

| | |
|---|---|
| **Ph.D. Economics** | Tinbergen Institute Rotterdam (September 2010) |
| **M.Phil. (Finance track)** | Erasmus University Rotterdam (August 2007) |
| **M.Sc. B.A. (Cum Laude)** | Erasmus University Rotterdam (August 2006) |

### Honors and Awards

- Niels Stensen Post-Doc Grant (Niels Stensen Foundation)

- Robert H. McGuckin III Grant (The Conference Board)

- Research Honours Class 2005 (Erasmus University Rotterdam)

### Publications

- "A Real Options Perspective on Portfolio Diversification," (with Enrico Pennings and Han Smit): ***Research Policy*** *(38) 2009, pp. 1150 – 1158 ;* M.Phil. dissertation.

- "Buy Smart, Time Smart: Are Takeovers Driven by Growth Options or Investor Euphoria?," (with Han Smit and Enrico Pennings): ***Financial Management*** (conditionally accepted).

### Professional Experience

**- NYU Stern** New York, U.S.**:** Visiting Scholar in Finance (January 2010 – current).

**- Erasmus School of Economics,** Rotterdam, Netherlands**:** Researcher in Economics (September 2006 – current).

- **Tridata,** The Hague, Netherlands**:** Consultant statistical and quantitative economic analysis (November 2008 – current).

- **The Conference Board**, New York, United States: Research fellow at Economic Research Department (July – October 2008).

- **Science & Business,** Ede, Netherlands: Consultant valuation modeling for technology transfers **(**March 2007 – October 2008).

## Teaching Experience

- **Seminar Advanced Corporate Finance** (with Prof. Han Smit (graduate level, 2007 – 2009)): Average personal score of 86% on student evaluations for lecturing competence.

- **Real Options and Private Equity** (with Prof. Han Smit (graduate level, 2007)): No student evaluations.

- **Supervisor** of 18 B.S. and 16 M.S. dissertations (2008 – current).

## Additional Information

- Educational Board member, Erasmus School of Economics, 2008 – 2009.

- Human Languages: Dutch (native), English (fluent; Cambridge CPE certificate), Spanish (working knowledge).

- Computer Languages: Gauss/Matlab/Ox, Stata, Excel/VBA, LyX/TeX.

## References (in alphabetical order):

- Prof. Enrico Pennings, Professor in Applied Economics, Erasmus University, Rotterdam, Netherlands: pennings@ese.eur.nl; tel. +31 10-4082166.

- Prof. Han Smit, Professor in Finance, Erasmus University, Rotterdam, Netherlands: jsmit@ese.eur.nl; tel. +31 10-4082623.

- Prof. David Yermack, Albert Fingerhut Professor of Finance and Business Transformation, New York University, New York, U.S. dyermack@stern.nyu.edu; tel +1 212-998-0357.

# Tinbergen Institute Research Series

The Tinbergen Institute is the Institute for Economic Research, which was founded in 1987 by the Faculties of Economics and Econometrics of the Erasmus University Rotterdam, University of Amsterdam and VU University Amsterdam. The Institute is named after the late Professor Jan Tinbergen, Dutch Nobel Prize laureate in economics in 1969. The Tinbergen Institute is located in Amsterdam and Rotterdam. The following books recently appeared in the Tinbergen Institute Research Series:

435. A.V.P.B. MONTEIRO, *The Dynamics of Corporate Credit Risk: An Intensity-based Econometric Analysis.*

436. S.T. TRAUTMANN, *Uncertainty in Individual and Social Decisions: Theory and Experiments.*

437. R. LORD, *Efficient pricing algorithms for exotic derivatives.*

438. R.P. WOLTHOFF, *Essays on Simultaneous Search Equilibrium.*

439. Y.-Y. TSENG, *Valuation of travel time reliability in passenger transport.*

440. M.C. NON, *Essays on Consumer Search and Interlocking Directorates.*

441. M. DE HAAN, *Family Background and Children's Schooling Outcomes.*

442. T. ZAVADIL, *Dynamic Econometric Analysis of Insurance Markets with Imperfect Information.*

443. I.A. MAZZA, *Essays on endogenous economic policy.*

444. R. HAIJEMA, *Solving large structured Markov Decision Problems for perishable-inventory management and traffic control.*

445. A.S.K. WONG, *Derivatives in Dynamic Markets.*

446. R. SEGERS, *Advances in Monitoring the Economy.*

447. F.M. VIEIDER, *Social Influences on Individual Decision Making Processes.*

448. L. PAN, *Poverty, Risk and Insurance: Evidence from Ethiopia and Yemen.*

449. B. TIEBEN, *The concept of equilibrium in different economic traditions: A Historical Investigation.*

450. P. HEEMEIJER, *Expectation Formation in Dynamic Market Experiments.*

451. A.S. BOOIJ, *Essays on the Measurement Sensitivity of Risk Aversion and Causal Effects in Education.*

452. M.I. LÓPEZ YURDA, *Four Essays on Applied Micro econometrics.*

453. S. MEENTS, *The Influence of Sellers and the Intermediary on Buyers' Trust in C2C Electronic Marketplaces.*

454. S. VUJIĆ, *Econometric Studies to the Economic and Social Factors of Crime.*

455. F. HEUKELOM, *Kahneman and Tversky and the Making of Behavioral Economics.*

456. G. BUDAI-BALKE, *Operations Research Models for Scheduling Railway Infrastructure Maintenance.*

457. T.R. DANIËLS, *Rationalised Panics: The Consequences of Strategic Uncertainty during Financial Crises.*

458. A. VAN DIJK, *Essays on Finite Mixture Models.*

459. C.P.B.J. VAN KLAVEREN, *The Intra-household Allocation of Time.*

460. O.E. JONKEREN, *Adaptation to Climate Change in Inland Waterway Transport.*

461. S.C. GO, *Marine Insurance in the Netherlands 1600-1870, A Comparative Institutional Approach.*

462. J. NIEMCZYK, *Consequences and Detection of Invalid Exogeneity Conditions.*

463. I. BOS, *Incomplete Cartels and Antitrust Policy: Incidence and Detection*

464. M. KRAWCZYK, *Affect and risk in social interactions and individual decision-making.*

465. T.C. LIN, *Three Essays on Empirical Asset Pricing.*

466. J.A. BOLHAAR, *Health Insurance: Selection, Incentives and Search.*

467. T. FARENHORST-YUAN, *Efficient Simulation Algorithms for Optimization of Discrete Event Based on Measure Valued Differentiation.*

468. M.I. OCHEA, *Essays on Nonlinear Evolutionary Game Dynamics.*

469. J.L.W. KIPPERSLUIS, *Understanding Socioeconomic Differences in Health An Economic Approach.*

470. A. AL-IBRAHIM, *Dynamic Delay Management at Railways: A Semi-Markovian Decision Approach.*

471. R.P. FABER, *Prices and Price Setting.*

472. J. HUANG, *Education and Social Capital: Empirical Evidences from Microeconomic Analyses.*

473. J.W. VAN DER STRAATEN, *Essays on Urban Amenities and Location Choice.*

474. K.M. LEE, *Filtering Non Linear State Space Models: Methods and Economic Applications.*

475. M.J. REINDERS, *Managing Consumer Resistance to Innovations.*

476. A. PARAKHONYAK, *Essays on Consumer Search, Dynamic Competition and Regulation.*

477. S. GUPTA, *The Study of Impact of Early Life Conditions on Later Life Events: A Look Across the Individual's Life Course.*

478. J. LIU, *Breaking the Ice between Government and Business: From IT Enabled Control Procedure Redesign to Trusted Relationship Building.*

479. D. RUSINOVA, *Economic Development and Growth in Transition Countries.*

480. H. WU, *Essays on Top Management and corporate behavior.*

481. X. LUI, *Three Essays on Real Estate Finance*

482. E.L.W. JONGEN, *Modelling the Impact of Labour Market Policies in the Netherlands*

483. M.J. SMIT, *Agglomeration and Innovations: Evidence from Dutch Microdata*