Essays on behavioural perspectives on corporate decisions: A real options approach

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Finance

Faculty of Business
University of Alberta

Abstract

Essay 1 studies how managerial overconfidence, defined as a miscalibration bias, affects the timing and terms of mergers and acquisitions. Using a real options framework, I show that overconfident acquirers lead to earlier mergers in which the terms of the deal favour target firms. Acquirers' overconfidence results in positive (negative) announcement returns for the target (acquirer) and overall value destruction. When deals are hostile, announcement returns for both firms are higher, and overconfidence creates value. I present empirical evidence that strongly supports the model´s predictions.

Essay 2 studies how managerial overconfidence, defined as an overestimation of signal precision, affects the timing and terms of merger deals. Using a real options model that combines imperfect information and learning, I show that information-based overconfident managers overreact to information, delaying merger deals. Unlike other forms of overconfidence, firms benefit from this bias, with the terms of the deal being beneficial to firms with overconfident managers. Deals are characterized by positive pre-announcement returns for both firms and positive (negative) announcement returns for the biased (rational) firm.

Essay 3 studies how heterogeneity in beliefs affects investment decisions. I analyze a canonical real options investment problem from the perspective of a three-member group that must decide through majority voting. I show that when both the project's value and the investment costs are uncertain, belief heterogeneity becomes a key characteristic, as group's investment behaviour can not always be represented by any member or subset of the group.

Acknowledgements

I thank Professor Felipe Aguerrevere, my supervisor, for his guidance, advice, and mentorship throughout my Ph.D. studies. I sincerely appreciate his support and thoughtful feedback. I am also thankful to my supervisory committee members, Professor Masahiro Watanabe and Professor Sahil Raina, for all their advice and comments on my research.

I thank my external committee members, Professor Abel Cadenillas and Professor Lorenzo Garlappi, for their questions, comments and suggestions. I also thank Professor Aditya Kaul for his help as chair of my committee.

I appreciate the support of faculty members in the Finance Department, particularly Professor Efstathios Avdis, Professor Mark Huson, and Dean Vikas Mehrotra, for their thoughtful comments and discussion when preparing for the job market.

I am grateful to the Ph.D. office, Debbie Giesbrecht, Helen Wu, and Trish Reay, for all their kindness and willingness to help. I am also thankful to my fellow Ph.D. students, especially my cohort colleagues Joseph DeCoste and Yusuke Tsujimoto. I acknowledge the financial support provided by AIMCO, FGSR, and the Ph.D. office during my studies.

Last but not least, I am grateful to my family and friends. Particularly my wife, Carla and my mother, Maria Elena. This would not have been possible without their patience, support, encouragement, and unconditional love. I thank my son, Lucas, for being my greatest source of inspiration.

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Chapter 1

Introduction

This thesis investigates the effects of behavioural biases and heterogeneity in belief on corporate decisions. The idea that the personal characteristics of the individuals in charge of firms play an essential role in their success has gained considerable popularity as a result of the increased belief among both academics and practitioners that behavioural biases matter for corporate performance (Bertrand and Schoar 2003, Bloom and Van Reenen 2007).

In the first part of this thesis (Chapter 2 and 3), I investigate how overconfidence[1], by far the most studied behavioural bias in finance, affects mergers deals. The idea that overconfidence affects mergers is quite popular in the literature (see, for example, Roll 1986 and Malmendier and Tate 2008). Most of the previous research, however, has focused on only one aspect of this bias. My work adds to the literature by considering other types of overconfidence.

In Essay 1, **The role of overconfidence in M&A**, I explore how mergers and acquisitions are affected when managers in the acquiring firm think that projects under their control are less risky than they are. The model makes predictions for the performance of firms following a merger deal, as well as for overall value creation or destruction.

I show that overconfidence leads to early mergers in which the acquirer must con-

[1] De Bondt and Thaler 1995 state that the most robust finding in judgement theory is that people are overconfident.

cede a more significant fraction of the merged firm to convince the target to agree. As a result, announcement returns are negative (positive) for the acquirer (target), and overconfidence destroys value.

I test the model's predictions using a measure for miscalibration first developed in Huang et al. 2022. The empirical findings are highly supportive of my theory. Acquirer's overconfidence increases target's abnormal returns by 9% and reduces acquirer's announcement returns by 1%.

When extending the analysis to consider hostile deals, modelled as a Stackelberg leader-follower game in which the target firm has increased bargaining power due to hostile negotiations, I predict announcement performance to be higher for both firms and overconfidence to create value.

In essay 2, **Managerial overconfidence as a consequence of learning and its effect on M&As**, I explore how control deals are affected by a different aspect of overconfidence. In this case, overconfident managers are assumed to believe that the information they receive is more accurate than it is. In line with previous experimental research, I show that this aspect of overconfidence affects decision making in a completely different way.

In the model, merging firms learn from signals and form beliefs using the Kalman-Bucy filter method. Overconfidence leads managers to overreact to their private information, which delays merger deals.

Unlike merging firms, the market has access only to public information. This, combined with the effect of overconfidence, creates positive pre-announcement returns for both firms. Surprisingly, information-based overconfidence benefits the biased firm regarding announcement performance. Announcement returns are positive (negative) for the biased (rational) firm. This result implies that it is beneficial for the firm to have (information-based) overconfident managers. Finally, the combined effect for both firms is positive, however, all the value creation is realized as pre-announcement returns, with the announcement effect only being a transfer of wealth between firms.

The last part of this thesis investigates how disagreement between members of a decision-making group influences the group's behaviour as a whole. In essay 3, **Corporate Investment with heterogeneous beliefs**, I explore how a group's investment decision is affected by the different beliefs that members may have. I consider a three-member group that agrees to decide through majority voting and show that even with this simple decision rule, the group can not always be reduced to a representative member.

In a setting both the project's value and the investment cost are stochastic, members' beliefs can be such that their voting behaviour becomes non-standard: they vote to delay investment both when the value of the project is insufficiently above the investment cost, as well as when the value of the project exceeds the investment cost by too much.

Group heterogeneity becomes an essential characteristic when at least one group member has such voting behaviour. Interestingly, there are cases in which the group never invests despite all members being willing to invest if they had dictatorial decision power.

Chapter 2

The role of overconfidence in M&A

2.1 Introduction

How can we explain firm performance following a merger? This question has puzzled scholars in financial economics for decades. In this paper, I argue that one of the premier explanations, managerial overconfidence, has been missing a key element in its analysis. Specifically, I propose a theoretical framework in which the miscalibration bias, an aspect of overconfidence often ignored in the literature, explains the performance of both firms involved in the deal. Furthermore, I show empirical evidence that supports the predictions of my theory. Understanding exactly how managerial biases affect merger deals has important implications for CEO selection, managerial incentives[1], and our general understanding of corporate decisions[2].

Previous research has found that although mergers seem to create value, most of the gains are realized by target firms. Empirical studies show that following merger announcements, returns to shareholders in target firms are substantial and that returns for acquiring firms are low or even negative (Andrade, Mitchell, and Stafford 2001, Moeller, Schlingemann, and Stulz 2004). In line with previous evidence, I find that announcement returns for targets are, on average, 10% higher than for acquirers.

[1] Understanding the effect that miscalibration has on corporate decisions can help explain the seemingly inconsistent findings in Otto 2014 and Humphery-Jenner et al. 2016 about the effect that overconfidence has on CEO compensation packages.

[2] Mergers and acquisitions have a deep impact on the corporate environment as a whole. Netter, Stegemoller, and Wintoki 2011 document that 91.4% of all publicly listed firms in the US were involved in at least one control transaction deal.

The idea that decision-makers in acquiring firms pay too much for their targets as a result of overconfidence has its roots in Roll 1986 "hubris hypothesis", which predicts that (i) the combined value of the two firms should fall, (ii) the value of the bidding firm should decrease, and (iii) the value of the target should increase. In addition to confirming Roll's predictions, my framework is able to produce novel predictions regarding the mechanism through which overconfidence affects these deals and how overconfidence affects hostile mergers.

Overconfidence is a peculiar phenomenon as it can present itself in different ways[3]. As a result, it has been inconsistently studied in various disciplines. In an effort to reconcile the contradictory results found in the psychology literature, Moore and Healy 2008 find that the most common research mistake comes from confounding two aspects of overconfidence: overestimation and overprecision, and find that they are conceptually and empirically distinct. In finance, overestimation can be attributed to an upward bias in the mean, often called "optimism", while overprecision is defined as a downward bias in risk perceptions, often called "miscalibration". I associate overconfidence with a miscalibration bias that arises when an executive believes that projects under her control are less risky than they actually are. This leads to an underestimation of the volatility governing the evolution of profits, which alters the decision of when to execute the merger deal.

Previous literature has measured overconfidence almost exclusively[4] on its optimism dimension. The most prominent measure, initially developed in Malmendier and Tate 2005, links overconfidence with the decisions that the CEO or other executives make on their personal company stock options portfolios, arguing that a risk-averse manager is not likely to hold vested options that are deeper in-the-money than a certain threshold unless she is overconfident. As the authors point out, this

[3]Moore and Healy 2008 propose three different types of overconfidence: (i) overestimation of one's actual performance, (ii) over-placement of one's performance relative to others, and (iii) excessive precision in one's beliefs.

[4]Huang et al. 2022 is one of the first papers to explicitly investigate how the miscalibration bias affects corporate investments.

measure is intended to capture an optimism bias and is not well suited to capture the effect of executives that overestimate the precision of their beliefs, implying that the results obtained from option-based or similar measures can not be used to draw conclusions about the effect that a miscalibration bias has on corporate decisions.

Despite managerial miscalibration not receiving much attention as a key driver of corporate decision-making, empirical work has shown that firm executives are in fact, miscalibrated. In Ben-David, Graham, and Harvey 2013, the authors survey senior financial executives over a 10-year period and find that they, on average, produce confidence intervals that are too narrow. The apparent ubiquitousness of managerial miscalibration warrants a more profound understanding of how it affects corporate decisions.

Although much work has been done to understand how managerial optimism affects merger deals (Malmendier and Tate 2008,Ferris, Jayaraman, and Sabherwal 2013), the literature has been silent on exploring the miscalibration dimension of overconfidence. Understanding the effects that the miscalibration dimension of overconfidence has on mergers and acquisitions is important because miscalibration seems to be a more persistent effect than optimism. Moore and Healy 2008 find evidence that predicts that overprecision tends to be associated with less overestimation, implying that overprecision is the more important of the two biases.

I tackle the challenge of understanding how miscalibrated managers affect the merging process by developing a theoretical framework in which overconfidence drives the endogenously determined timing and terms of the merger deal. In the model, two firms with heterogeneous beliefs jointly make the irreversible decision of when to execute the merger and how to divide the combined firm. This decision is taken in two rounds: in the first round, each firm determines its optimal option exercise strategy, and in the second round, firms reach an equilibrium in which they jointly determine the timing and terms of the deal. To the best of my knowledge, I am the first to embed heterogeneous beliefs in a real options framework to study mergers and acquisitions.

The model predicts that overconfidence leads to early mergers in which the target obtains a higher ownership share of the combined firm. Because of the disagreement in beliefs, both firms are initially unable to agree on when to execute the deal. To settle this disagreement, the biased acquirer is willing to offer the target a higher percentage of the merged firm compared to what it would otherwise obtain. This result is consistent with the idea that acquirers pay too much for their targets.

To make predictions about returns following the merger announcements, I make three important assumptions: (i) the market is unbiased in its beliefs, (ii) the market is an outsider to the deal and therefore is not aware of managerial behavioural biases, and (iii) the market can forecast potential mergers in advance of any announcements. Consistent with Roll's hubris hypothesis, I predict positive (negative) abnormal returns for targets (acquirers) and that overconfidence destroys value in merger deals.

I point to the option-like nature of merger decisions and the disagreement on when to exercise this option as the main driver of why the acquirer overpays. This is an important distinction with what the optimism literature highlights as the key mechanism through which that bias affects mergers. Malmendier and Tate 2008 argue that an overestimation of deal synergies by the optimist acquirer is what drives the observed behaviour. In contrast, the results of my paper can be obtained independently of whether the acquirer overestimates, underestimates, or has unbiased estimates about merger synergies. By not relying on this overestimation of synergies, an argument based on managerial miscalibration is able to provide an explanation that is consistent with empirical findings that report an average underestimation of synergies by acquirers (Ismail and Mavis 2022), providing further evidence of the central importance that this aspect of overconfidence has in explaining merger deals.

I test the model's predictions by using a sample of mergers obtained from the Securities Data Corporation's (SDC) US M&A database. I test the effects that overconfident acquirers have on the announcement returns for both firms involved in the deal. I follow Huang et al. 2022 and classify CEOs as overconfident based on the precision bias of their earning forecasts. The empirical evidence is highly supportive of the model's predictions. Specifically, I find that acquirers' overconfidence is associated with an increase of up to 9% in targets' abnormal returns. At the same time, acquirers' announcement returns are 1% lower when they are classified as overconfident. Moreover, I find that managerial overconfidence can explain around 90 % of the difference in performance for both firms. Finally, I show partial evidence that supports the idea that the level of acquirer's overconfidence plays an important role in the magnitude of these effects.

Does managerial overconfidence lead to different outcomes based on how deals are negotiated? I explore this question by analyzing how managerial overconfidence can affect deals that are hostile in nature. I find that abnormal returns are higher for both firms when comparing them to friendly mergers. Surprisingly, I also find that overconfidence creates value when transactions are hostile. To the best of my knowledge, I am the first one to propose a behavioural explanation of both the higher returns that are usually observed in hostile takeover deals (Franks and Harris 1989, and Bouwman, Fuller, and Nain 2009) and the value generation in hostile deals (Bhagat et al. 2005,Sudarsanam and Mahate 2006, and Martynova and Renneboog 2011).

I further explore the validity of my model by relaxing the assumption that markets are complete. My results for both friendly and hostile deals are robust when considering an incomplete markets setting in which agent's risk preferences are in accordance with the CAPM. By studying an incomplete market setting, I am able to further analyze how different levels of overconfidence affect merger deals. Specifically, I decompose volatility and separately study miscalibration concerning the idiosyncratic and systematic components of risk. I find that overconfidence regarding the idiosyncratic component of risk has the same monotonic effect as overall overconfidence and is driven by the convexity effect that a decrease in volatility has on the option exercise threshold. Surprisingly, overconfidence regarding the systematic component of risk can, in some special conditions, lead to opposite results for sufficiently high levels of overconfidence. This occurs as a result of the additional effect that systematic risk has on the implied convenience yield.

This paper contributes to three strands of the literature. First, it contributes to the vast mergers and acquisitions literature (see Renneboog and Vansteenkiste 2019 for an updated literature review). My work is particularly related to the large body of research that uses real options to analyze mergers and acquisitions. Margrabe 1978 was the first author to model takeovers as exchange options. Among the previous papers that have studied mergers using real options, Lambrecht 2004 analyzes the endogenous timing of mergers motivated by economies of scale and shows that firms have incentives to merge in periods of economic expansion. Hackbarth and Morellec 2008 study the behaviour of stock returns in mergers and acquisitions, predicting a run-up in the beta of acquiring firms prior to the announcement, followed by a drop in beta at the announcement when the acquiring firm has a higher beta than the target prior to the announcement. Hackbarth and Miao 2012 develop a dynamic industry equilibrium and find that mergers are more likely in concentrated industries. I add to this literature by showing how overconfidence, understood as a miscalibration bias, affects the timing and terms of control transaction deals.

Second, I add to the literature on disagreements and differences in beliefs in finance. In one of the earliest papers in this extensive literature, Miller 1977 stated: "The very concept of uncertainty implies that reasonable men may differ in their forecasts." Previous research has studied the effects of disagreement on various corporate decisions, such as investments (Thakor and Whited 2011) and mergers Bargeron et al. 2014. The latter article looks at the effect of disagreement between managers and investors based on the information contained in bidder returns. I differentiate myself from these authors by analyzing the case when the source of disagreement is between merging firms.

Finally, this paper contributes to the literature on the role of behavioural biases in finance. My work is most aligned with research studying the role of these biases on the outcome of important corporate decisions, such as investments (Malmendier and Tate 2005), capital structure (Hackbarth 2008), CEO selection (Goel and Thakor 2008), and CEO turnover (Campbell et al. 2011). Previous work has also been done on mergers and acquisitions, notably by Malmendier and Tate 2008 and Shi and Chen 2019. Malmendier and Tate 2008 explore whether CEO optimism helps to explain merger decisions and find that the probability of a merger is 65% higher if the CEO is classified as overconfident. Shi and Chen 2019 examine the acquiring firm's CEO-CFO relative optimism and show that firms with high CEO-CFO relative optimism undertake more acquisitions. I am most aligned with the theoretical behavioural finance literature that focuses on managerial biases. Some notable examples are Hackbarth 2008 and Gervais, Heaton, and Odean 2011. The former studies how managerial biases affect the capital structure decisions of firms, while the latter focuses on how CEO biases affect their compensation.

The remainder of this paper proceeds as follows. Section 2.2 presents a simple model for mergers in which executives in the acquiring firm are overconfident. Section 2.3 presents empirical evidence in support of the idea that managerial miscalibration plays an important role in determining the performance of firms following a merger announcement. Section 2.4 extends the basic model to consider hostile takeovers. Section 2.5 relaxes the market completeness assumption. Finally, section 2.6 concludes.

2.2 Overconfidence in merger deals

In the following section, I study the effect that managerial overconfidence has on merger deals[5]. Throughout the model, I focus on a particular specification of overconfidence, commonly denoted as miscalibration. The model provides predictions for the timing and terms of merger deals, as well as for the behaviour of abnormal

[5] Appendix D contains numerical examples for all the results in this paper.

announcement returns.

2.2.1 Model setup

There are two infinitely lived firms that can form a combined firm. I denote the acquirer firm as "A", the target firm as "T", and the merged firm as "M". The roles for each firm are exogenously given, and therefore I do not consider strategic games in which acquirers and targets are endogenously assigned. Each firm's instantaneous profit function is defined as $\Pi_j X(t)$, where Π_j $(j = \{A, T, M\})$ is a deterministic component which is potentially different for each firm, and $X(t)$ is a stochastic variable. The stochastic shock that governs the profit function can be interpreted as shocks in output demand, output prices, production costs, or a combination of various sources of uncertainty to which firms are subject. For simplicity and to keep the model tractable, I assume that all firms are subject to the same shock $X(t)$, creating a setting that is most closely related to mergers between firms in similar industries. I am agnostic on the mechanism that governs Π_i, only assuming that $\Pi_M > \Pi_A + \Pi_T$, thus focusing on the type of deals that exploit synergies between merging firms. Synergistic mergers could be motivated by economies of scale (Lambrecht 2004) or by an increase in market power (Hackbarth and Miao 2012).

I follow Shleifer and Vishny 2003 and assume that firms can only grow through these types of deals, and not by internal investments. The shock $X(t)$ can be observed by all parties involved; however, the decision-makers in each firm have exogenously given heterogeneous beliefs about the behaviour of $X(t)$. Specifically, management in each firm thinks that $X(t)$ evolves following a geometric Brownian motion but disagree on their belief about the instantaneous volatility parameter. I assume that management in each firm does not update their beliefs after observing a realization of $X(t)$. This assumption reflects the idea that behavioural biases are persistent despite the existence of feedback (Huffman, Raymond, and Shvets 2022). This disagreement is driven by the acquirer's downward bias on the perception of risk, commonly known as miscalibration. All merging decisions are made in a context in which management in each firm maximizes shareholders' value.

$$dX(t) = \mu X(t)dt + \sigma_i X(t)dW_{t,i} \tag{2.1}$$

Equation (2.1) shows the dynamics of $X(t)$ according to i beliefs, where μ is the instantaneous growth rate of $X(t)$, $\sigma_i = \phi_i\sigma$ is the instantaneous volatility of $X(t)$ according to each firm's beliefs, and $W_{t,i}$ is a standard Wiener process under i beliefs. Overconfidence is assumed to be an underestimation of the variance in the stochastic shock. A manager that is afflicted by this bias believes that projects under her control are less risky than they really are. The degree of overconfidence is captured in the parameter ϕ, where $0 < \phi \leq 1$ takes the value of 1 for unbiased managers and decreases as overconfidence increases. Consistent with previous literature, I focus on the case in which only managers of the acquiring firm are considered to be overconfident.

I account for agent's preferences by introducing traded assets and requiring a valuation that is consistent with those existing assets. Let $K(t)$ denote the price of a riskless bond that follows the dynamics $dK(t) = rK(t)dt$, and let $S(t)$ be a market portfolio that spans all the risk underlying in $X(t)$. Given i beliefs, The dynamics of this market portfolio are given by $dS(t) = \alpha S(t)dt + \sigma S(t)dW_{t,i}$. Note that an overconfident acquirer does not have biased beliefs about the market portfolio, accentuating the idea that overconfidence is related to variables that the manager believes to be under her control. Given that the market is complete[6], there exists a unique risk-neutral measure Q that allows for the only valuation that is both consistent with agent's risk preferences and the traded assets. Under the risk-neutral measure[7], the

[6]The market is assumed to be complete from the perspective of each manager. Noting that the volatility for the acquirer is an affine function of the true constant volatility σ, the treatment of market completeness under heterogeneous beliefs is similar to previous literature (Basak 2000, Basak 2005). Adding options on $S(t)$ as a traded asset would allow for a more strict form of market completeness (Buraschi and Jiltsov 2006).

[7]The change of measure requires special considerations. As noted in Huang and Pages 1992, Revuz and Yor 1999 Section VIII.1, and Duffie 2002 Section 6.N, the construction of Girsanov's Theorem for infinite horizon models assumes that for any time t, the probability measures are

dynamics of $X(t)$ become:

$$dX(t) = (\mu + \phi_i(r - \alpha))X(t)dt + \sigma_i X(t)dW^Q_{t,i} \tag{2.2}$$

The model is completed by introducing a market, denoted by "m", which allows me to analyze how abnormal returns behave following the merger deal. Abnormal returns following a merger announcement have been consistently documented, leading to the conclusion that the market is not able to perfectly anticipate merger deals. To capture this phenomenon, I assume that the market has unbiased beliefs and acts as an outsider to the deal, unaware of the biases that each merging firm may have. This assumption is descriptive of settings where firms observe each other's biases in private meetings when negotiating the deal. Empirical evidence shows that the stock market forecasts probable targets in advance of any merger announcement (Asquith 1983). Consistently with this evidence, it can be inferred that the market imperfectly anticipates the timing and terms of the merger, giving rise to abnormal returns once the deal is announced. I assume that firms are not subject to any learning and thus do not change their beliefs during the negotiation process.

Following Dixit and Pindyck 1994, and assuming that the merger deal is at least partially irreversible, the value of firm j can be thought of as the sum of the value of assets in place plus the value of an option to merge.

The value of assets in place $H^i_j X(t))$ for firm j is defined as the expectation of the discounted value of profit, under $i = A, T, m$ beliefs and the risk-neutral measure Q.

$$H^i_j(X(t)) = E^Q_{i,t}[\int_t^\infty e^{-r(u-t)}\Pi_j X(u)\, du] = \frac{\Pi_j X(t)}{r(1-\phi_i) + (\phi_i\alpha - \mu)} \tag{2.3}$$

In equation (2.3), $E^Q_{i,t}[*]$ represents the expectation under the measure Q and beliefs i, conditional to the information available at time t. Equation (2.3) also denotes the value of the merged firm. To make sure the valuations are well defined, it is necessary

restricted to the filtration representing the information available at time t.

to assume that $r(1-\phi_i)+(\phi_i\alpha-\mu)>0$.

2.2.2 Timing and terms of the merger

At time $t>0$, firms can negotiate a merger deal. Since merger deals are costly, I assume a fixed lump-sum total cost λ, for which each firm pays in relation to their relative deterministic component of profit $\{\lambda_A=\frac{\Pi_A\lambda}{\Pi_A+\Pi_T},\lambda_T=\frac{\Pi_T\lambda}{\Pi_A+\Pi_T}\}$. The total cost λ can be thought of as the fees paid to investment bankers and lawyers, as well as the operational costs associated with integrating both firms.

The total surplus generated by merging both firms is equal to:

$$\frac{(\Pi_M-\Pi_A-\Pi_T)X(t)}{r(1-\phi_i)+(\phi_i\alpha-\mu)}-\lambda \tag{2.4}$$

The assumption that $\Pi_M>\Pi_A+\Pi_T$ ensures that benefits from the merger are always positive, allowing me to ignore the question about whether a merger will occur and instead focus on when and how the merger is going to take place. Firms' beliefs about the total surplus generated in the merger are dependent on the overconfidence variable ϕ_i, implying that managers disagree on the total benefits that the merger creates.

Proposition 2.1 *An overconfident acquirer underestimates synergies generated in the control transaction deal when $r>\alpha$, overestimates them when $r<\alpha$, and is unbiased in her synergies estimation when $r=\alpha$.*

Although the empirical literature often points to the overestimation of synergies as the main driver behind the effect of optimism in mergers (see Malmendier and Tate 2008), the model suggests that the incentives to merge for an overconfident (miscalibrated) and optimistic acquirer, often confounded in the literature, are not always aligned. This result highlights the importance of understanding the isolated effect of the miscalibration aspect of overconfidence.

Equation (2.4) highlights that it is not obvious whether an overconfident acquirer overestimates the synergies generated in the deal. If agents are risk averse ($\alpha > r$), an overconfident acquirer will overestimate the synergies of the deal, displaying a similar behaviour to an optimistic acquirer. When agents are risk neutral ($\alpha = r$), the overconfident acquirer will be unbiased in her estimation of merger synergies. Interestingly, when agents display risk-seeking preferences ($\alpha < r$), overconfident acquirers underestimate synergies, displaying the opposite behaviour to what the literature on optimism would suggest.

The analysis of synergies produces two important results. First, as the following sections will show, the model predictions can be obtained independently of the acquirer's biases in synergies estimation, implying that there is some other factor driving the effect of managerial overconfidence.

A second important result is that, unlike an optimism explanation, the miscalibration aspect of overconfidence can be consistent, under risk-seeking preferences, with empirical evidence (Ismail and Mavis 2022) documenting that, on average, synergies forecasts for acquirers are lower than realized synergies.

Although risk-seeking preferences are rarely considered in theoretical frameworks, there is evidence supporting the existence of local risk-seeking behaviour (Friedman and Savage 1948, Kahneman and Tversky 1979). Moreover, data shows that risk and return are negatively correlated across firms in most industries[8], which is consistent with decision-makers having risk-seeking preferences.

What drives then the merger decision when acquirers are overconfident? In what follows, I explore this question by studying how managerial overconfidence affects the endogenously negotiated timing and terms of the deal.

Before the merger takes place, the value of firm j according to i beliefs is denoted as $V_j^i(X(t))$.

[8]This paradoxical finding is known in the literature as Bowman's paradox (Bowman 1980, Bowman 1982)

$$V_j^i(X(t)) = \frac{\Pi_j X(t)}{r(1-\phi_i)+(\phi_i\alpha-\mu)} + OM_j^i(X(t)) \tag{2.5}$$

$OM_j^i(X(t))$ in Equation (2.5) represents the value of the merger option for firm j according to the beliefs of firm i and is obtained from the surplus generated in the merger. Assuming the post-merger ownership structure s_j, $i's$ beliefs about the merger surplus accruing to the shareholders in firm j is given by:

$$max(s_j H_M^i(X(t)) - H_j^i(X(t)) - \lambda_j, 0) \tag{2.6}$$

The payoff in (2.6) resembles a call option, implying that there exists for each firm a threshold x_i such that it is optimal to execute the merger option once X_t reaches x_i from below. Appendix A shows that the value of the option to merge can be written as:

$$OM_i^i(X(t)) = (\frac{(s_i\Pi_M - \Pi_i)x_i}{r(1-\phi_i)+(\phi_i\alpha-\mu)} - \lambda_i)(\frac{X(t)}{x_i})^{\beta_i} \ \ , \ \ \beta_i > 1 \tag{2.7}$$

Equation (2.7) has an intuitive interpretation: the first factor represents the surplus accruing to firm i at the time of the merger, and the second factor represents the probability of X_t ever hitting the merger threshold x_i. β_i is the positive root of the quadratic equation $\frac{1}{2}\phi_i^2\sigma^2\beta_i(\beta_i-1)+(\mu+\phi_i(r-\alpha))\beta_i - r = 0$.

I assume that negotiations take place in two stages. In the first stage, each firm individually chooses the threshold x_i that maximizes the value of their merger option. The second stage negotiation consists in jointly identifying the merger terms s_A, s_T such that both firms will exercise their merger options at the same threshold x^*.

The optimal threshold x_i selected by each firm satisfies the first-order condition

$$\frac{\partial OM_i^i(X_t)}{\partial x_i} = 0 \tag{2.8}$$

Solving equation (2.8) yields:

$$x_i^* = \frac{\beta_i}{\beta_i - 1}\lambda_i \frac{r(1-\phi_i)+(\phi_i\alpha-\mu)}{s_i\Pi_M - \Pi_i} \tag{2.9}$$

Equation (2.9) can be interpreted as NPV break-even point $\lambda_i \frac{r(1-\phi_i)+(\phi_i\alpha-\mu)}{s_i\Pi_M-\Pi_i}$, which is amplified by $\frac{\beta_i}{\beta_i-1} > 1$ reflecting the effect that uncertainty has on the timing decision. When analyzing the effect that overconfidence has on the timing chosen by firm i, it is clear that $\frac{\partial\beta_i}{\partial\phi} < 0$; therefore, as overconfidence increases, β_i decreases. Since $\frac{\partial x_i}{\partial\beta_i} < 0$, overconfidence decreases the threshold for a merger compared to an unbiased agent. This is in line with the notion that an overconfident manager underestimates risk, making decisions closer to the NPV break-even point. These results imply that an overconfident acquirer will always prefer an earlier merger relative to the target, and thus the bidding firm will have to offer a higher share than it otherwise would. The timing and terms of the merger are jointly negotiated by finding the shares $\{s_T, s_A, s_T + s_A = 1\}$ such that $x_T = x_A = x^*$.

Proposition 2.2 *The timing and terms of the merger deal, when the acquirer is overconfident, are given by:*

$$x^* = \frac{(((\beta_T-1)(r(1-\phi_A)+(\phi_A\alpha-\mu))\Pi_A+(\alpha-\mu)\Pi_T\beta_T)\beta_A-(\alpha-\mu)\Pi_T\beta_T)\lambda}{(\beta_T-1)(\beta_A-1)(\Pi_M-\Pi_A-\Pi_T)(\Pi_A+\Pi_T)} \tag{2.10}$$

$$s_T = \frac{\Pi_T}{\Pi_A+\Pi_T}\frac{(x^*(\Pi_A+\Pi_T)+\lambda(\alpha-\mu))\beta_T-x^*(\Pi_A+\Pi_T)}{\Pi_M x^*(\beta_T-1)} \tag{2.11}$$

From equations (2.10) and (2.11) is possible to check that $\frac{\partial x^*}{\partial\phi_A} > 0$ and $\frac{\partial s_T}{\partial\phi_A} < 0$. The intuition behind these results is that an overconfident acquirer has a higher incentive to merge, which is translated to a willingness to offer the target a higher share in exchange for an earlier merger. An early merger is independent of synergy forecasts and is driven by the effect that volatility has on option exercise. The model suggests that overconfidence is costly for acquirers and leads to earlier mergers. The threshold x^* being lowered as a consequence of an increase in acquirer's overconfidence has important implications for explaining merger waves. The model predicts that an increase in managerial overconfidence increases the likeliness of mergers and therefore points to a market-wide increase in overconfidence as a possible explanation for an overall increase in merger activity. Malmendier and Nagel 2011 show evidence that past individuals' experiences of macroeconomic shocks affect their decisions, pointing to a change in beliefs as a possible mechanism. Based on their evidence, cyclicality in shocks to the economy would imply cyclical distortions of decision makers' beliefs which in turn would be consistent with an increase in merger activity. I provide a behavioural explanation of merger waves that complements the hypothesis that shocks to the economy drive mergers (Mitchell and Mulherin 1996). I now turn to the effect that managerial overconfidence has on the returns following a merger announcement.

2.2.3 Market beliefs

Empirical evidence (Asquith 1983, Billett and Qian 2008) suggests that markets are able to predict merger deals in advance of any announcement. To this extent, I focus my analysis on the returns from the perspective of a market that makes forecasts under the assumption that (i) the market is an outsider to the deal and, therefore, unaware of any biases that either firm may have; and (ii) the market is assumed to be unbiased in its beliefs ($\phi_m = 1$).

The market acts as a social planner in forming its predictions, where the objective is to maximize the total surplus independently of where it is allocated. Since the market assumes both firms are identical in terms of their risk perceptions, Lambrecht 2004 shows that the global optimization approach taken by the market yields the same results as if both firms would negotiate under homogeneous beliefs.

Proposition 2.3 *The timing and terms of the merger predicted by the market are given by:*

$$x_m = \frac{\beta_m}{\beta_m - 1} \frac{\lambda(\alpha - \mu)}{\Pi_M - (\Pi_A + \Pi_T)} \tag{2.12}$$

$$s_T^m = \frac{\Pi_T}{\Pi_A + \Pi_T} \tag{2.13}$$

Equation (2.13) shows that under homogeneous beliefs, the share of the merged firms accruing to each firm's shareholders is the ratio of the deterministic component of profit. An important consequence of the result in equation (2.12) is that when the acquirer is overconfident, the market will always predict a merger that is later than the one given by equation (2.10), which follows directly from $\beta_A > \beta_m$. This late prediction by the market implies that it will never be able to update its information about the biases within the merging firms when the stochastic variable $X(t)$ reaches a new high point. This leads to all of the information being updated when the firms merge, and consequently, abnormal returns being fully realized exactly when $X(t)$ reaches x^*. Before the merger becomes public, the market values each firm's option to merge in a consistent manner with its unbiased predictions. I denote this valuation for the options to merge as $OM_j^{predicted}(X(t))$.

$$OM_j^{predicted}(X(t)) = (\frac{(\frac{\Pi_j}{\Pi_A+\Pi_T}\Pi_M - \Pi_j)x_m}{\alpha - \mu} - \frac{\lambda\Pi_j}{\Pi_A + \Pi_T})(\frac{X(t)}{x_m})^{\beta_m} \tag{2.14}$$

The first factor in Equation (2.14) represents the surplus that the market expects to be generated by firm i at the time it predicts the merger will occur; the second factor represents the probability of $X(t)$ ever hitting the predicted merger threshold.

2.2.4 Abnormal returns in mergers

One of the most striking and well-documented empirical facts about mergers and acquisitions is that bidding firms earn low or even negative returns at the deal announcement. In contrast, target firms tend to do significantly better (Jensen and Ruback 1983, Jarrell, Brickley, and Netter 1988,Andrade, Mitchell, and Stafford 2001). Consistent with the idea that behavioural biases affect decision-making, acquirers' optimism is believed to be an important explanation for the observed returns (Malmendier and Tate 2008), however, there is no evidence whether a more persistent and ubiquitous bias, managerial overconfidence, is also responsible for the observed returns. I try to answer this question by looking at the cumulative returns at the point of the merger and comparing what happens before and after the market updates its information regarding the actual terms and timing of the deal.

Before the merger is revealed, the market believes that x_m is the correct threshold for the deal. Following Hackbarth and Miao 2012, I write each firm's cumulative stock return at the time of the merger (x^*) as a fraction of the value of assets in place. The predicted cumulative return for each firm at the time of the merger (right before the market updates its information), denoted x^*_-, is given by:

$$R_j(x^*_-) = \frac{OM_j^{predicted}(x^*)}{E_j^m(t)} = \frac{\left(\frac{(\frac{\Pi_j}{\Pi_A+\Pi_T}\Pi_M-\Pi_j)x_m}{\alpha-\mu} - \frac{\lambda\Pi_j}{\Pi_A+\Pi_T}\right)\left(\frac{x^*}{x_m}\right)^{\beta_m}}{\frac{\Pi_j x^*}{\alpha-\mu}} \tag{2.15}$$

In obtaining the cumulative returns, the market values the merger options following the results in equations (2.12) and (2.13). When the merger occurs, the market proceeds to update its information about the timing (x^*) and terms (s_T), which thereby allows the market to update its valuation. The updated cumulative return for each firm at the time of the merger after the market has updated its information, denoted x^*_+, can also be expressed as a fraction of the value of assets in place, and is given by:

$$R_j(x^*_+) = \frac{OM_j^m(x^*)}{E_j^m(t)} = \frac{\left(s_j\frac{\Pi_M x^*}{\alpha-\mu} - \frac{\Pi_j x^*}{\alpha-\mu} - \frac{\lambda\Pi_j}{\Pi_A+\Pi_T}\right)}{\frac{\Pi_j x^*}{\alpha-\mu}} \tag{2.16}$$

Note that in Equation (2.16), the numerator represents the actual surplus generated at the time of the merger. The second term usually associated with merger options (of the form $\frac{X_t}{x}^{\beta}$) is 1, given that at this point, the merger has already been realized, hence the probability of X_t reaching the merger threshold is 1.

Cumulative abnormal returns AR_j at the time of the merger are computed as the difference between the cumulative returns after and before the realization by the market of the actual terms and timing of the merger deal. These abnormal returns are given by:

$$AR_j = R_j(x_+^*) - R_j(x_-^*) \tag{2.17}$$

The model predicts that when the acquirer is overconfident, abnormal returns at the time of the merger are positive for the target firm and negative for the acquiring firm. Additionally, the magnitude of these effects increases monotonically as the acquirer becomes more overconfident. These results suggest that overconfidence is an important driver of merger deals. The relative profitability of each firm, captured by the deterministic component of profit Π_j, plays a central role in determining the magnitude of each firm's abnormal returns. When both merging firms have similar profitability, the magnitude of the returns experienced due to overconfidence also tends to be similar. Existing literature supports the idea that acquiring firms are usually more productive than their targets (Morck, Shleifer, and Vishny 1990, Jovanovic and Rousseau 2002, Maksimovic, Phillips, and Yang 2013). A setting in which the acquirer is more profitable ($\Pi_A > \Pi_T$) is then consistent with these empirical findings and produces returns that are larger in magnitude for targets than for acquirers. An overconfident acquirer affects the outcome of merging decisions, taking the market by surprise. It is ultimately the interaction between behavioural biases from decision-makers and firm characteristics that determines the magnitude of these effects.

Because overconfidence generates opposite effects for acquirers and targets ($AR_A \leq 0$ and $AR_T \geq 0$), they pull in opposite directions for the overall value creation of the merger deal. It is then interesting to ask whether this bias creates an overall effect that is positive or negative. The model obtains its value creation predictions by computing the sum of the changes on the valuation of the merger options for both firms. The combined value of both firms falls monotonically as acquirers' overconfidence increases, and therefore managerial overconfidence destroys value in merger deals.

2.3 Empirical evidence

In this section, I test my predictions for the effect that managerial overconfidence has on returns. I find results that are highly supportive of my theory. Additionally, the empirical evidence shows that acquirer's overconfidence disproportionately affects targets, which is consistent with a setting in which $\Pi_A > \Pi_T$. I also find partial evidence that supports the idea that the magnitude of return surprises increases as the acquirer becomes more overconfident.

A description of the variables used for the empirical analysis can be found in Appendix B.

2.3.1 Data

Overconfidence measure

Measuring behavioural biases is particularly challenging due to the difficulty to observe and isolate their effects. While there is well-established literature that looks at the optimism dimension of overconfidence (Malmendier and Tate 2005, Malmendier and Tate 2008, Campbell et al. 2011), research on the miscalibration dimension is scarce, mainly relying on survey data to study its effect (Ben-David, Graham, and Harvey 2013). Huang et al. 2022 provide the first empirical measure for CEO miscalibration that can be directly computed from standard financial data. In this paper, I follow their procedure and use this measure to obtain novel results regarding the effect of CEO miscalibration on merger abnormal returns.

The overconfidence measure is obtained from annual earnings[9] forecasts made by CEOs. Forecast data is obtained from the IBES Guidance database for the period from 2000 to 2017. This period is chosen to be consistent with the data used to analyze merger deals. To be able to compute the precision in forecasts, observations that provide open-ended forecasts are excluded from the sample. Additionally, I

[9] Hribar and Yang 2016 argue that managerial overconfidence is most likely to be evidenced in annual earning forecasts.

limit the sample to forecasts made for the same fiscal year because there could be a substantial difference in the information available to managers for forecasts made in other fiscal years.

I merge the sample with Execucomp to obtain executive-level data. In my sample, each CEO is uniquely identified as a CEO-firm pair, which controls for the fact that a CEO may act differently when first moving to a new firm, for example, when the CEO moves to a new industry. I obtain firm-level control variables by matching the data to Compustat. Finally, I exclude regulated (SIC 6000-6999) and financial (SIC 6000-6999) firms. The final database consists of 23658 observations for earnings precision.

Table 2.1 reports summary statistics for the data I use to obtain the overconfidence measure. The precision variable is computed from the forecast interval as a fraction of the share price at the end of the previous fiscal year. The variable is then multiplied by a negative one for ease of interpretation. Notably, only 30% of the observations come from firms with acquisitions exceeding 5% of their total assets, meaning that the sample is not biased towards CEOs involved in acquisitions. Moreover, firms in the sample are rather large, with a median of 1.8 billion dollars in total assets.

Table 2.2 shows the correlations for the variables in the sample. Forecast precision generally has a low correlation with all the variables, with the highest being return on assets (0.139), change in earnings (0.103), and Loss (-0.136). All other correlations are generally low, with the highest correlations being between return on assets and Accruals (0.465), and loss (-0.573) respectively.

To construct the overconfidence measure, I follow Huang et al. 2022 and regress the forecast precision on five firm characteristics commonly used in the literature. Specifically, I use firm size (Firm Size), market-to-book ratio (MB), return on assets (ROA), change in earnings (Δ Earnings), and accounting accruals (Accruals) as independent variables. Additionally, I include variables that control for the volatility of firms' fundamentals, which affect the difficulty of making a forecast. These variables are earnings volatility (Earnings Volatility) and an indicator for firms that incur losses (Loss). All these variables are computed on the previous fiscal year.

Next, I add a second set of independent variables to control for managerial incentives and for the information set that CEOs have when making a forecast. First, to control for managerial incentives, I use an indicator variable for the total cost of acquisitions as a fraction of total assets (Acquisitions) and another one for net equity issuance (Net Equity Issuance) during the same fiscal year as the forecast announcement. Finally, to control for the information set available to the CEO, I use the time horizon (Forecast Horizon) between the announcement of the forecast and the end of the fiscal year.

I add year fixed effects to control for time-varying macroeconomic conditions, as well as industry fixed effects following the Fama-French 48 industries classification to control for characteristics of any particular industry. Table 2.3 shows the regression coefficient and t-stats. Almost all variables are highly significant (1% level). Only the market-to-book ratio and net equity issuance present non-significant coefficients(at least 10% level).

The result of interest is the residuals, which are interpreted as the precision bias. A CEO is considered to be more precision-biased the higher the residuals are. To reduce the noise of this measure, I aggregate at the CEO-firm level. I obtain a precision bias measure for 1515 unique CEO-firm observations.

A CEO is considered to be overconfident when the precision bias is in the top 25% of the sample. It is important to notice that this is a measure of relative overconfidence, and while it would be desirable to have an absolute measure of overconfidence, by for example, having access to interval forecasts for individual analysts, the measure used in this paper offers a valuable understanding of how overconfidence affects merger deals. I leave the development of an absolute measure of overconfidence for future work.

Merger deals

I identify merger deals using the SDC Mergers & Acquisitions database. The initial sample contains all reported transactions from January 1, 1999, to December 31, 2017. I filter the database by considering only completed transactions where both the acquirer and the target are U.S based firms listed on the Center for Research in Security Prices (CRSP) database. I further restrict the sample to transactions where the acquirer owns less than 50% of the target before the announcement and is planning to own more than 50% after the deal. Doing this allows me to focus the analysis on significant acquisitions. Additionally, I remove deals containing regulated (SICs 4900-4999) and financial (SIC 6000-6999) firms in order to avoid mergers governed by regulatory requirements.

Firm characteristics are obtained by matching the sample to Compustat[10]. Firm characteristics considered in the main analysis are (1) Firm size, (2) market-to-book ratio, (3) return on assets, and (4) Tobin's Q.

The sample is restricted to mergers in which abnormal returns can be obtained for both firms. Abnormal returns for acquirers and targets are obtained from CRSP by performing event studies around each merger announcement period. Cumulative abnormal returns (CAR) are the sum of daily abnormal returns that compare realized returns with a value-weighted market model. The estimation window is the 1-year period prior to the start of the event window.

Evidence for the creation or destruction of value surrounding mergers and acquisitions usually comes from short-term event studies (Bradley, Desai, and Kim 1988, Andrade, Mitchell, and Stafford 2001, Hackbarth and Morellec 2008). Consistently, I use the 3-day period window around the merger announcement, which is commonly used in the relevant literature. This 3-day window goes from 1 trading day before to 1 trading day after the announcement.

[10] I match Compustat to the SDC data using the mapping developed in Ewens, Peters, and Wang 2019

The model in section 2.2 is most descriptive of friendly deals. Consequently, I remove from the sample deals classified as hostile[11]. Finally, I remove deals for which the overconfidence measure obtained in Section 2.3.1 is not available for acquirers.

The final sample contains 379 deals. Table 2.4 shows summary statistics for the mergers in the sample. Notably, mergers in the sample are large, with a median deal value of 106 million dollars. Deals in the sample show a clear change in control: on average, acquirers take control of 99.8% of their target while only owning 1% prior to the announcement, likely toehold purchases.

It is interesting to note that while the overconfidence measure is constructed to capture the top 25% of all executives in the sample, only 18% of the acquirers are classified as overconfident.

Table 2.4 reports summary statistics for the control variables used in the analysis. I control for acquirer characteristics by considering (1) firm size, (2) market-to-book ratio, (3) return on assets, and (4) Tobin's Q. Additionally, I control for deal characteristics by considering (1) deal value, (2) the number of bidders, and (3) whether deals are made between firms in the same industry. Most deals have exactly one bidder, and only 34% of deals are made between firms in the same industry.

Cumulative abnormal returns for acquiring firms are close to 0, with an average of 0.5%. In contrast, they are (on average) substantially positive for target firms, reaching 11.3%. This large discrepancy between the return surprise for targets and acquirers is in line with evidence shown in previous literature, suggesting that this phenomenon is consistent over time. For example, the same pattern can be observed in Hackbarth and Morellec 2008, where the authors study the period between January 1, 1985, and June 30, 2002, and find abnormal returns of 18.21% and -0.52% for the target and acquirer firm respectively.

Table 2.5 shows pairwise correlations between the variables in the sample. Corre-

[11]Only eight deals are removed from the sample. The small amount of hostile takeovers makes it impossible to test this paper's predictions for hostile deals. I leave for future work testing these predictions once additional data is available.

lations are generally low. Notably, the correlation between the CAR for targets and the overconfidence variable is 0.091. Similarly, for the case of acquirer's CAR, the correlation with the overconfidence variable is -0.053.

2.3.2 Empirical results

In this section, I test whether managerial overconfidence, measured as in section 2.3.1, can explain the behaviour of abnormal returns. My theoretical results predict that a higher degree of acquirer's overconfidence prompts the acquirer to be willing to offer better terms to the target. This induces an earlier merger that is not correctly anticipated by the market. The combination of the terms and timing of the deal leads to abnormal returns for both firms at the time of the merger. My model predicts that acquirer's abnormal returns are negative, target's abnormal returns are positive, and that these effects are monotonically increasing in the overconfidence level. The empirical results presented in this section are highly supportive of the theory.

For the main results, presented in tables 2.6 and 2.7, specifications (3) and (4) control for deal characteristics. Additionally, specifications (5) and (6) consider firm characteristics. Year and industry fixed effects are included in specifications (2), (4), and (6).

Table 2.6 shows results for the effect that acquirer's overconfidence has on acquirer's CAR. The coefficients for the overconfidence variable are negative in all specifications and significant in specifications (1) to (4). For specifications (5) and (6), although the results are not statistically significant at the 10% level, the magnitudes align with the other results. The effect overconfidence has on the acquirer's abnormal returns is around -1% for the event window. Out of the control variables, only deal value shows significant coefficients.

Similarly, table 2.7 shows results for the effect that acquirer's overconfidence has on target's CAR. The coefficients for the overconfidence variable are positive and significant for all specifications. These effects are larger when compared to the previous results, at around 7% for the event window. In this case, deal value, the number of bidders, and the acquirer's firm size have significant coefficients.

These results are consistent with the predictions of my theory and support the idea that acquirer's overconfidence has a positive (negative) effect on target's (acquirer's) returns. Interestingly, these empirical findings also show the disproportionate effect that my theory predicts. In the model, this is driven by the deterministic component of profits, suggesting that the relative size of firms, or alternatively their profitability, is likely an important factor for the difference in magnitudes.

To test whether these results are driven by the event window, I do a robustness check and consider 5 additional specifications. I report the results for acquirer's and target's CARs in tables 2.8 and 2.9 respectively. Specifications (1) to (6) show results for the following event windows: (1) [-1,1], (2) [-1,2], (3) [-1,3], (4) [0,1], (5) [0,2], and (6) [0,3]. Both the magnitudes and t-statistics remain consistent for all specifications. Overall, results show that the effect that managerial overconfidence has on announcement returns is not driven by the selection of any specific event window.

Moving to the monotonic effect of overconfidence on abnormal returns, I present partial evidence in support of the theory. I analyze different levels of overconfidence by changing the threshold to classify CEOs as overconfident. I find that, in the case of targets, a higher level of acquirer's overconfidence has an increasing effect on abnormal returns. In table 2.10, I show results for the impact that different levels of acquirer's overconfidence have on target's CAR. In specification (2), I classify CEOs as overconfident when they are in the top 20% of the precision bias measure. For this case, the effect on abnormal returns increases to 13.7%. When increasing the threshold to the top 10% of the precision bias measure, specification (3) shows that managerial overconfidence increases target's abnormal returns by 23.2%.

My theory predicts that the difference between returns increases when the acquirer is overconfident. I find that managerial overconfidence accounts for around 90% of the average difference in abnormal returns, suggesting the primary role of overconfidence in explaining return surprises when mergers are announced. Table 2.11 shows the results of the regressions using the difference between CARs as the dependent variable. The coefficients for the overconfidence variable are positive and significant in all specifications. For example, in specification (6), when the acquirer is overconfident, the difference in abnormal returns increases by 10%. These results add additional supportive evidence to the validity of my theory.

Finally, adding to the supportive evidence for the monotonic effect of overconfidence on abnormal returns, analyzing the various overconfident thresholds on the difference between abnormal returns clearly shows this pattern. As table 2.12 shows, the coefficients increase from 10% to 23% as the threshold to classify the CEO increases. In unreported results, the monotonic effect for both target returns and the difference in returns persists when considering lower thresholds.

Collectively, the evidence presented in this section highly supports the effect that overconfidence, understood as a miscalibration bias, has in explaining the empirically observed pattern. Additionally, these results show the validity of my theory and suggest that we should pay closer attention to the effect of managerial miscalibration in corporate decisions.

In what follows, I expand my theory to get insight into some aspects that can not be tested empirically with the data I have available at this point. Specifically, I study deals in which the negotiations are hostile.

2.4 Hostile takeovers

The model presented so far considers a particular type of negotiation in which both firms simultaneously decide on their optimal timing threshold and subsequently negotiate the terms of the deal, being most descriptive of a friendly merger. Even when my results point to the importance of managerial overconfidence in shaping merger deals, it is not the case that all control transactions follow a similar negotiation scheme. It is interesting, then, to question whether the interaction between overconfidence and deal attitude could lead to different results. In this section, I extend the basic model to analyze mergers that are hostile in nature, and derive conclusions about the effect of acquirers' overconfidence in these types of transactions.

Before the takeover deal, the value of firm j according to i beliefs is the sum of assets in place plus the value of an option. I mow denote this takeover option as $OT_j^i(X(t))$.

$$V_j^i(X(t)) = \frac{\Pi_j X(t)}{r(1-\phi_i)+(\phi_i\alpha-\mu)} + OT_j^i(X(t)) \tag{2.18}$$

$$OT_j^i(X(t)) = ((\frac{(s_j\Pi_M-\Pi_j)x_i}{r(1-\phi_i)+(\phi_i\alpha-\mu)} - \lambda_i)(\frac{X(t)}{x_i})^{\beta_i} \ , \ \beta_i > 1 \tag{2.19}$$

Friendly and hostile mergers are not always easily distinguishable from each other because most of the initial negotiations are private. Deals publicly perceived as friendly can have early-stage negotiations that are hostile. Additionally, the distinction between each type of merger gets increasingly complex when considering that public announcements of takeover attempts are often part of a firm's negotiating strategy (Schwert 2000). I focus on how firms negotiate the terms and timing of the deal as the key distinction between friendly and hostile transactions. I assume that in a hostile deal, the target has an increased bargaining power[12], and can dictate the minimum terms required to accept the deal. Consequently, I follow Lambrecht 2004 and assume a Stackelberg leader-follower game in which the target first decides the terms of the deal, and then the acquiring firm decides on the timing. First, I obtain the acquirer's optimal threshold as a function of the target's share of the merger firm. The optimal threshold x_A selected by the acquirer satisfies the first-order condition:

$$\frac{\partial OT_A^A(X_t)}{\partial x_A} = 0 \tag{2.20}$$

[12]In appendix E, I analyze alternative negotiation assumptions for hostile takeovers in which acquirers have more bargaining power

$$x_A = \frac{\beta_A}{\beta_A - 1} \frac{\Pi_A \lambda (r(1-\phi_A) + (\phi_A \alpha - \mu))}{(\Pi_A + \Pi_T)((1-s_T)\Pi_M - \Pi_A)} \tag{2.21}$$

The target firm then sets the terms by taking the threshold in Equation (2.21) as a given. I obtain the target's optimal terms s_T from the following first-order condition:

$$\frac{\partial OT_T^T(X_t)}{\partial s_T} = 0 \tag{2.22}$$

Proposition 2.4 *The timing and terms of the hostile takeover, when the acquirer is overconfident, are given by:*

$$x^* = \frac{\beta_A \lambda (((r(1-\phi_A) + (\phi_A \alpha - \mu))\Pi_A + (\alpha - \mu)\Pi_T)\beta_A - (\alpha - \mu)\Pi_T)}{(\beta_T - 1)(\beta_A - 1)(\Pi_A + \Pi_T)(\Pi_M - (\Pi_A + \Pi_T))} \tag{2.23}$$

$$s_T = \frac{\beta_A((r-\alpha)\phi_A - r + \mu)\lambda \Pi_A}{x^*(\beta_A - 1)(\Pi_A + \Pi_T)\Pi_M} + \frac{\Pi_M - \Pi_A}{\Pi_M} \tag{2.24}$$

Overconfidence has a similar effect compared to friendly mergers. Acquirer's overconfidence leads to an earlier deal with a higher share of the combined firm going to the target. This can be proven by noting that $\frac{\partial x^*}{\partial \beta_A} < 0$ and $\frac{\partial s_T}{\partial \beta_A} > 0$. The model predicts that overconfidence increases the probability of deals independently on how they are negotiated, further supporting the idea that managerial overconfidence plays an important role in driving merger waves.

When comparing these results to friendly mergers, hostile takeovers are executed at a higher threshold. Moreover, the target obtains a higher share of the combined firm when negotiations are hostile in nature. My results are in line with the bargaining hypothesis for takeovers, which predicts that the increased share gained by the target firm comes from resisting initial offers as a bargaining strategy. Previous empirical literature supports this hypothesis and rejects the idea that the central role of takeovers is to perform a disciplinary function (Franks and Mayer 1996, Schwert 2000).

To form its predictions, the unbiased market solves the Stackelberg leader-follower game under homogeneous beliefs, obtaining the following timing and terms for the merger:

$$x_m = \frac{(\alpha-\mu))\lambda\beta_m((\Pi_A+\Pi_T)\beta_m-\Pi_T)}{(\beta_m-1)^2(\Pi_A+\Pi_T)(\Pi_M-(\Pi_A+\Pi_T)} \tag{2.25}$$

$$s_T^m = \frac{((\beta_m-1)\Pi_T+\Pi_A)\Pi_M-\Pi_A^2}{(\Pi_A\beta_m+(\beta_m-1)\Pi_T)\Pi_M} \tag{2.26}$$

The market predicts a higher takeover threshold, leading to all the uncertainty being resolved at once at the time of the takeover. To obtain the model's implications for announcement returns following a hostile takeover, I follow the same steps as in section 2.2.4. I first compute the cumulative returns at the time of the takeover ($RT_i(X(t))$ as a fraction of the value of assets in place. The predicted cumulative return for each firm at the time of the takeover, right before the market updates its information, is given by:

$$RT_i(x_-^*) = \frac{(s_i^m\frac{\Pi_M x_m}{(\alpha-\mu)}-\frac{\Pi_i x_m}{\alpha-\mu}-\lambda_i)(\frac{x^*}{x_m})^{\beta_m}}{\frac{\Pi_i x^*}{\alpha-\mu}} \tag{2.27}$$

The predicted cumulative return after the market updates its information about the real timing and terms of the takeover is given by:

$$RT_i(x_+^*) = \frac{(s_i\frac{\Pi_M x^*}{\alpha-\mu}-\frac{\Pi_i x^*}{\alpha-\mu}-\lambda_i)}{\frac{\Pi_i x^*}{\alpha-\mu}} \tag{2.28}$$

I then compute the abnormal returns as the difference between the cumulative returns after and before the realization by the market of the actual terms and timing of the takeover deal.

$$ART_i = RT_i(x_+^*) - RT_i(x_-^*) \tag{2.29}$$

Abnormal returns following a hostile takeover behave similarly to those in friendly mergers: they are positive for targets and negative for acquirers, and their magnitudes monotonically increase with overconfidence. Interestingly, I find that for equal levels of overconfidence, returns in hostile deals are always higher than those found in friendly deals. These results are driven by the increased bargaining power that the target exerts, which is positively interpreted by the market as it limits the effect of managerial overconfidence. My predictions are consistent with empirical findings showing that returns for both firms are generally higher in hostile deals (Franks and Harris 1989, Bouwman, Fuller, and Nain 2009). The idea that managerial overconfidence is responsible for the higher returns in hostile deals is novel to my paper.

Surprisingly, the relative increase in returns leads to value creation as a consequence of managerial overconfidence in hostile deals. Unlike the case for friendly mergers, the effect of overconfidence on value can be non-monotonic. This can happen when managers have risk averse preferences because overconfidence also increases the acquirer's instantaneous growth rate for the stochastic shock $X(t)$ (equation (2.2)), which ultimately has a downward effect on value. For sufficiently high levels of overconfidence, this negative effect can start dominating the previously mentioned increased returns, creating a concave effect of overconfidence in value. Interestingly, this concavity implies that there exists an optimal level of overconfidence for total value creation, which can help give a rational explanation for managerial overconfidence in acquiring firms.

Previous literature has already pointed out that hostile deals are associated with value creation (Bhagat et al. 2005, Sudarsanam and Mahate 2006, Martynova and Renneboog 2011). However, my paper is the first to link this increase in value with managerial overconfidence and, more generally, to show the central role overconfidence has as a driver for the outcome of different types of control transactions.

2.5 Incomplete markets

So far, the implications of acquirers' overconfidence for mergers and acquisitions have been derived under the assumption that markets are complete, which in the presence of no-arbitrage allows me to use traded assets to obtain the unique risk-neutral measure Q. Using standard arguments, the problem under risk aversion and real-world probabilities can be equivalently solved using this risk-neutral measure in a way that is consistent with both the market and risk preferences. Considering that the assumption that the stochastic variable $X(t)$ can be completely spanned by the market portfolio $S(t)$ is rather strong, in this section, I explore the validity of my model on a more realistic framework in which markets are incomplete. The dynamics of the traded portfolio are now given by:

$$dS(t) = \alpha S(t)dt + \sigma_s S(t)dB_{t,i} \tag{2.30}$$

By assuming that $dB_{t,i}$ is not perfectly correlated with $dW_{t,i}$, the risk underlying a firm's profit is not completely spanned by the traded portfolio, thus, the market is incomplete. Without loss of generality, and assuming that the Brownian motions are correlated with $-1 < \rho < 1$, $dW_{t,i}$ can be written as:

$$dW_{t,i} = \rho dB_{t,i} + \sqrt{1-\rho^2}dZ_{t,i} \tag{2.31}$$

With $Z_{t,i}$ being an additional Brownian motion that is by definition independent of $B_{t,i}$, $dZ_{t,i}dB_{t,i} = 0$. Using this change of variable, the stochastic shock underlying the profit of firms can be written as:

$$dX(t) = \mu X(t)dt + \sigma_i X(t)(\rho dB_{t,i} + \sqrt{1-\rho^2}dZ_{t,i}) \tag{2.32}$$

Under incomplete markets, there exists a plethora of martingale measures, so the question of how to perform valuations that take into account risk preferences is not a trivial one. I follow the approach of Ewald and Taub 2022 and assume that agents' attitudes towards risk are consistent with the CAPM. I focus on the only measure that is simultaneously consistent with risk aversion and the CAPM, commonly known in mathematical finance literature as the minimal martingale measure Q^{min} (see Föllmer, Schweizer, et al. 1990). The minimal martingale measure minimizes the relative entropy and as such, is the one that deviates the least from the physical probabilities. Under Q^{min}, the dynamics of the stochastic process $X(t)$ (Appendix C) are given by:

$$dX(t) = (\mu - \frac{\rho\sigma_i}{\sigma_s}(\alpha - r))X(t)dt + \sigma_i X(t)(\rho dB_{t,i}^{min} + \sqrt{1-\rho^2}dZ_{t,i}^{min}) \tag{2.33}$$

Using the dynamics of $X(t)$ under the minimal martingale measure Q^{min}, I solve the problems in Sections 2.2 and 2.4 and find that a setting with incomplete markets qualitatively maintains all the results previously obtained: overconfidence leads to early deals in which the target gets a higher share of the combined firm; abnormal returns are negative for acquirers, positive for targets, and higher in hostile takeovers when compared to friendly mergers; and overconfidence destroys value in friendly mergers while creating it in hostile takeovers.

The correlation term ρ directly affects all previous results by altering the implied convenience yield $r - \mu + \frac{\rho\sigma_i}{\sigma_s}(\alpha - r)$. The effect of ρ varies depending on the relationship of α and r. When $\alpha > r$, a decrease in ρ is associated with lower returns for acquirers and higher returns for targets, both in friendly mergers and hostile takeovers. This implies that as ρ becomes lower, overconfidence destroys more value in friendly mergers and creates less value in hostile takeovers. When $r > \alpha$, all these effects are reversed. Finally, results are invariant to ρ when $r = \alpha$.

The setting presented in this section allows me to explore further how different levels of acquirers' overconfidence affect deals by decomposing volatility into its idiosyncratic and systematic components. For $\rho > 0$, I assume that:

$$\sigma_i^2 = \sigma_{B,i}^2 + \sigma_{Z,i}^2 = (\phi_{B.i}\sigma_B)^2 + (\phi_{Z.i}\sigma_Z)^2 \tag{2.34}$$

$$\rho_i = \frac{(\phi_{B.i}\sigma_B)}{\sqrt{(\phi_{B.i}\sigma_B)^2 + (\phi_{Z.i}\sigma_Z)^2}} \tag{2.35}$$

$\sigma_{B,i}$ and $\sigma_{Z,i}$ represent firm i beliefs about systematic and idiosyncratic risk, respectively. Note that $\phi_{B.i}$ and $\phi_{Z.i}$ are both equal to 1 for an unbiased agent, and at least one of them is less than 1 for an overconfident acquirer. I can now study overconfidence independently by looking at the separate effects of $\phi_{B.i}$ and $\phi_{Z.i}$.

The implied convenience yield can be written as $r-\mu+\frac{\phi_{B.i}\sigma_B}{\sigma_s}(\alpha-r)$. Simple observation reveals that it is only affected by systematic risk. The effect of overconfidence with respect to the idiosyncratic component of volatility ($\phi_{Z.i} < 1$) is straightforward to analyze, as it only affects the overall volatility σ_i, thus leading to an earlier option exercise threshold and producing results in line with previous sections. On the contrary, overconfidence regarding the systematic component of volatility ($\phi_{B.i} < 1$) has a twofold effect. First, it reduces overall volatility leading to earlier option exercise. Second, it reduces the implied convenience yield, which leads to a later threshold. Which of the effects dominates depends on the specific parameters used, and therefore there are some conditions for which acquirers' overconfidence effect gets reversed.

In the following analysis, I explore the case for friendly mergers[13]. To see when the convenience yield effect dominates, it helps significantly to simplify notations by assuming that $r = 0$. The merger threshold selected by firm i in a friendly deal is given by:

$$x_i^* = \frac{\beta_i}{\beta_i - 1}\lambda_i \frac{-\mu + \frac{\phi_{B.i}\sigma_B}{\sigma_s}(\alpha)}{s_i\Pi_M - \Pi_i} \tag{2.36}$$

β_i solves $\beta_i(\mu - \frac{\phi_{B.i}\sigma_B}{\sigma_s}(\alpha)) + \frac{1}{2}(\beta_i(\beta_i - 1)((\phi_{B.i}\sigma_B)^2 + (\sigma_Z)^2) = 0$. I follow the procedure outlined in Section 2.2, and obtain the threshold x^* for which both firms agree on the terms of the deal:

$$x^* = \frac{(\alpha\sigma_B(\Pi_A\phi_{B.A} + \Pi_T) - ((\mu - \frac{\phi_{B.i}^2\sigma_B^2+\sigma_Z^2}{2})\Pi_A + (\mu - \frac{\sigma_B^2+\sigma_Z^2}{2})\Pi_T)\sigma_s)\lambda}{\sigma_s(\Pi_A + \Pi_T)(\Pi_M - \Pi A - \Pi_T)} \tag{2.37}$$

In contrast with the results in Section 2.2, the threshold x^* does not always decrease as the acquirer becomes more overconfident. There is a critical level for which the threshold starts increasing as overconfidence increases. This threshold is given

[13] Appendix D shows a numerical example for this case.

by $\frac{-\alpha}{\sigma_B \sigma_s}$. It is important to note that this critical level can only be attained when managers have risk-seeking preferences. The existence of this critical level implies a non-monotonic relation in the timing, terms, and returns in the deal. Moreover, it is possible for this reversal in effects to be such that there is a second critical point in which the timing of the mergers becomes later than market's expectations. This leads to opposite results for returns[14]: negative (positive) announcement returns for targets (acquirers). This surprising result suggests firms could benefit from having executives that are sufficiently overconfident and could help explain why senior executives hired by firms are consistently miscalibrated. Exploring the different ways in which corporate decisions are affected, depending on the level of executives' biases, offers exciting avenues for future research.

2.6 Conclusion

This paper studies how overconfidence, understood as a miscalibration bias, affects mergers and acquisitions. I find that this bias plays an important role in explaining firms' performance following a merger announcement.

I propose a theoretical model to study how managerial overconfidence affects merger deals. I develop a real options framework in which the endogenously negotiated timing and terms of a merger deal are determined by managerial overconfidence. When managers underestimate the risk of projects under their control, mergers are more probable, and targets obtain a higher fraction of the combined firm. When analyzing the market's expectations, I predict that overconfidence is associated with positive returns for targets and negative returns for acquirers. My model's predictions are consistent with the observed behaviour of merger deals. The model shows that the combined effect for merging firms leads to value destruction as a result of acquirers' overconfidence.

[14] Given that the threshold is later than market's expectations, the market gradually updates the information. In this case, surprises in returns are realized over time.

I test my model's predictions using a sample of 379 deals obtained from the SDC Mergers & Acquisitions database. The empirical findings are highly supportive of my theory. My evidence shows that the effect that overconfidence has on the acquirer's abnormal returns is around -1% for a three-day event window. Simultaneously, I find that the effect for the target is 7% for the same period. My empirical analysis also reveals that managerial overconfidence is responsible for 90% of the gap in firms' performance when the deal is announced.

To understand how deal characteristics play a role in control transactions in the context of overconfidence, I extend the basic model to consider hostile takeovers. I predict that when there is an overconfident acquirer, returns for both firms are higher in hostile deals when compared to friendly mergers. I also find that overconfidence creates value when deals are hostile in nature. My paper is the first to link the increased announcement returns and value creation observed in hostile deals with managerial overconfidence.

Finally, I show that opposite results can be obtained in special circumstances when acquirers are overconfident about the systematic component of risk, suggesting that acquiring firms may benefit from having sufficiently overconfident managers.

	N	Mean	Median	St. dev.
Precision	23658	-0.005	-0.002	0.021
Firm Size	23697	7.530	7.491	1.488
MB	23648	4.086	2.833	29.036
ROA	23697	0.064	0.062	0.079
Δ Earnings	23637	-0.000	0.006	0.136
Accruals	23692	-0.514	-0.046	0.069
Loss	23706	0.083	0	0.276
Acquisitions	23706	0.309	0	0.462
Net Equity Issuance	23706	0.084	0	0.278
Earnings Volatility	22712	0.006	0.000	0.069
Forecast Horizon	23706	200.566	218	98.980

Table 2.1: **Summary statistics overconfidence measure**. This table presents summary statistics for the variables used to estimate the overconfidence measure. The construction of this sample is discussed in section 2.3.1. I report the number of observations, arithmetic mean, median, and standard deviation.

	Precision	Firm Size	MB	ROA	Δ Earnings	Accruals	Loss	Acquisitions	Net Equity Issuance	Earnings Volatility	Forecast Horizon
Precision	1										
Firm Size	0.022	1									
MB	0.015	0.030	1								
ROA	0.139	-0.046	0.075	1							
Δ Earnings	0.103	-0.012	0.008	0.359	1						
Accruals	0.056	0.102	0.016	0.465	0.363	1					
Loss	-0.136	-0.069	-0.018	-0.573	-0.249	-0.339	1				
Acquisitions	0.039	0.006	-0.012	0.062	0.034	0.031	-0.069	1			
Net Equity Issuance	-0.022	-0.104	0.003	-0.099	0.002	0.001	0.047	0.055	1		
Earnings Volatility	-0.017	-0.074	-0.001	0.006	0.008	0.023	0.039	-0.001	0.011	1	
Forecast Horizon	-0.042	0.008	-0.008	0.004	-0.004	-0.009	-0.001	-0.008	-0.004	-0.001	1

Table 2.2: **Correlations for overconfidence measure**. This table reports pairwise correlations for the variables used to obtain the overconfidence measure presented in section 2.3.1.

	Precision
Firm Size	0.000***
	(2.58)
MB	0.000
	(0.74)
ROA	0.025***
	(10.55)
Δ Earnings	0.009***
	(8.87)
Accruals	-0.012***
	(-5.58)
Loss	-0.006***
	(-9.81)
Acquisitions	0.000*
	(1.75)
Net Equity Issuance	-0.001
	(-1.5)
Earnings Volatility	-0.004**
	(-1.5)
Forecast Horizon	-0.000***
	(-6.11)
Constant	-0.005*
	(-1.82)
Year Fixed Effects	Yes
Industry Fixed Effects	Yes
Observations	22705
R^2	0.09

Table 2.3: **Precision bias estimation**. This table reports the results from an OLS regression where the dependent variable is the earnings forecast precision. Control variables include Firm Size, MB, ROA, Δ Earnings, Accruals, Loss, Acquisitions, Net Equity Issuance, Earnings Volatility, and Forecast Horizon. Fama French 48 Industries and year-fixed effects are included. t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	N	Mean	Median	St. dev.
Overconfident	379	0.177	0	0.382
Deal Value	379	691.228	106.833	2072.203
Shares Owned Before	379	0.869	0	6.139
Shares Owned After	379	99.837	100	2.077
Number of Bidders	379	1.029	1	0.183
Firm Size	379	8.271	8.0467	1.828
MB	376	3.908	2.963	7.169
ROA	379	0.058	0.059	0.074
Tobin's Q	376	2.151	1.860	1.164
Same Industry	379	0.340	0	0.474
CAR Acquirer	379	0.005	0.003	0.052
CAR Target	379	0.113	0.017	0.227

Table 2.4: **Summary statistics mergers data**. This table presents summary statistics for the variables used in the analysis of merger deals. The construction of this sample is discussed in section 2.3.1. I report the number of observations, arithmetic mean, median, and standard deviation.

	Overconfident	Deal Value	Number of Bidders	Firm Size	MB	ROA	Tobin's Q	Same Industry	CAR Acquirer	CAR Target
Overconfident	1									
Deal Value	0.004	1								
Number of Bidders	-0.005	0.169	1							
Firm Size	-0.103	0.216	0.022	1						
MB	-0.114	-0.071	-0.047	0.000	1					
ROA	-0.222	0.077	0.032	0.089	0.346	1				
Tobin's Q	-0.058	0.019	0.049	-0.124	0.436	0.362	1			
Same Industry	0.069	0.023	-0.031	-0.189	-0.018	-0.135	-0.049	1		
CAR Acquirer	-0.053	-0.057	0.001	-0.061	0.085	0.065	-0.005	0.026	1	
CAR Target	0.091	0.126	0.108	0.244	0.017	0.008	0.0155	0.003	-0.097	1

Table 2.5: **Correlations in merger variables**. This table reports pairwise correlations for the variables used in the analysis of mergers.

	CAR [-1 , 1]					
	(1)	(2)	(3)	(4)	(5)	(6)
Overconfident	-0.012*	-0.014*	-0.012*	-0.015*	-0.009	-0.010
	(-1.65)	(-1.77)	(-1.68)	(-1.86)	(-1.23)	(-1.22)
Deal Value			-0.000	-0.000**	-0.000	-0.000**
			(-1.33)	(-2.54)	(-0.99)	(-2.28)
Number of Bidders			0.003	0.003	0.004	0.004
			(0.19)	(0.21)	(0.29)	(0.25)
Same Industry			0.003	0.001	0.002	0.001
			(0.57)	(0.13)	(0.42)	(0.24)
Firm Size					-0.002	-0.001
					(-1.16)	(-0.44)
MB					0.001	0.001
					(1.45)	(1.15)
ROA					0.044	0.065
					(1.04)	(1.49)
Tobin's Q					-0.003	-0.003
					(-1.12)	(-0.88)
Constant	0.007**	0.073	0.005	0.070	0.019	0.076
	(2.46)	(1.30)	(0.29)	(1.21)	(0.89)	(1.23)
Year Fixed Effects	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	No	Yes	No	Yes	No	Yes
Observations	379	379	379	379	376	376
R^2	0.005	0.04	0.002	0.05	0.004	0.05

Table 2.6: **Acquirer abnormal returns**. This table reports the effect that managerial overconfidence has on acquirer's abnormal returns. I show OLS regressions where the dependent variable is the cumulative abnormal returns for the acquirer, considering an event window from 1 trading day before to 1 trading day after the merger announcement. The main independent variable in the analysis is Overconfident. In specifications (3) and (4), I control for Deal Value, Number of Bidders, and Same Industry. For specifications (5) and (6), I add Firm Size, MB, ROA, and Tobin's Q as controls. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	CAR [-1 , 1]					
	(1)	(2)	(3)	(4)	(5)	(6)
Overconfident	0.054*	0.072**	0.057*	0.077**	0.067**	0.089**
	(1.77)	(2.02)	(1.87)	(2.20)	(2.19)	(2.44)
Deal Value			0.000**	0.000***	0.000	0.000*
			(2.06)	(2.76)	(0.93)	(1.71)
Number of Bidders			0.131**	0.139**	0.133**	0.141**
			(2.04)	(2.1)	(2.12)	(2.16)
Same Industry			0.001	0.005	0.026	0.030
			(0.02)	(0.19)	(1.04)	(1.13)
Firm Size					0.033***	0.029***
					(4.95)	(4.15)
MB					0.001	0.001
					(0.41)	(0.63)
ROA					-0.034	0.016
					(-0.19)	(0.08)
Tobin's Q					0.009	0.004
					(0.8)	(0.31)
Constant	0.103***	-0.018	-0.04	-0.147	-0.339***	-0.454*
	(8.06)	(-0.07)	(-0.59)	(-0.59)	(-3.76)	(-1.74)
Year Fixed Effects	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	No	Yes	No	Yes	No	Yes
Observations	379	379	379	379	376	376
R^2	0.006	0.018	0.024	0.054	0.07	0.09

Table 2.7: **Target abnormal returns**. This table reports the effect that managerial overconfidence has on targets's abnormal returns. I show OLS regressions where the dependent variable is the cumulative abnormal returns for the target, considering an event window from 1 trading day before to 1 trading day after the merger announcement. The main independent variable in the analysis is Overconfident. In specifications (3) and (4), I control for Deal Value, Number of Bidders, and Same Industry. For specifications (5) and (6), I add Firm Size, MB, ROA, and Tobin's Q as controls. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	CAR					
	(1)	(2)	(3)	(4)	(5)	(6)
Overconfident	-0.010	-0.009	-0.009	-0.005	-0.007	-0.006
	(-1.22)	(-1.06)	(-0.87)	(-0.54)	(-0.81)	(-0.68)
Deal Value	-0.000**	-0.000**	-0.000	-0.000	-0.000**	-0.000**
	(-2.28)	(-2.39)	(-1.46)	(-1.32)	(-2.13)	(-2.16)
Number of Bidders	0.004	-0.003	-0.006	0.003	0.012	0.004
	(0.25)	(-0.25)	(-0.33)	(0.16)	(0.83)	(0.28)
Same Industry	0.001	0.000	0.002	0.003	0.002	0.001
	(0.24)	(0.07)	(0.33)	(0.45)	(0.34)	(0.15)
Firm Size	-0.001	-0.001	-0.002	-0.002	-0.001	-0.002
	(-0.44)	(-0.68)	(-0.99)	(-1.19)	(-0.65)	(-0.97)
MB	0.001	0.001*	0.001**	0.001**	0.000	0.001*
	(1.15)	(1.80)	(2.04)	(2.16)	(1.25)	(1.93)
ROA	0.065	0.119***	0.056	0.033	0.042	0.094**
	(1.49)	(2.66)	(1.10)	(0.67)	(1.00)	(2.17)
Tobin's Q	-0.003	-0.005*	-0.006*	-0.005	-0.002	-0.004
	(-0.88)	(-1.69)	(-1.67)	(-1.48)	(-0.63)	(-1.48)
Constant	0.076	0.102	0.136*	0.134*	0.074	0.101
	(1.23)	(1.60)	(1.90)	(1.91)	(1.23)	(1.61)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	376	376	376	376	376	376
R^2	0.05	0.08	0.02	0.02	0.05	0.07

Table 2.8: **Acquirer abnormal returns, multiple windows**. This table reports the effect that managerial overconfidence has on acquirer's abnormal returns. I show OLS regressions where the dependent variable is the cumulative abnormal returns for the acquirer, considering multiple event windows. The event windows are: (1) [-1,1], (2) [-1,2], (3) [-1,3], (4) [0,1], (5) [0,2], and (6) [0,3]. The main independent variable in the analysis is Overconfident. I include Deal Value, Number of Bidders, Same Industry, Firm Size, MB, ROA, and Tobin's Q as controls in all specifications. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	CAR					
	(1)	(2)	(3)	(4)	(5)	(6)
Overconfident	0.089**	0.091**	0.091**	0.086**	0.084**	0.086**
	(2.44)	(2.45)	(2.47)	(2.36)	(2.34)	(2.34)
Deal Value	0.000*	0.000	0.000*	0.000	0.000	0.000
	(1.71)	(1.54)	(1.78)	(1.53)	(1.46)	(1.28)
Number of Bidders	0.141**	0.147**	0.148**	0.157**	0.150**	0.157**
	(2.16)	(2.22)	(2.25)	(2.43)	(2.34)	(2.40)
Same Industry	0.030	0.033	0.029	0.024	0.025	0.028
	(1.13)	(1.21)	(1.07)	(0.89)	(0.94)	(1.04)
Firm Size	0.029***	0.029***	0.029***	0.028***	0.028***	0.028***
	(4.15)	(4.08)	(4.09)	(4.01)	(4.09)	(4.01)
MB	0.001	0.001	0.001	0.001	0.001	0.001
	(0.63)	(0.71)	(0.70)	(0.58)	(0.52)	(0.59)
ROA	0.016	0.017	0.040	0.011	-0.004	-0.011
	(0.08)	(0.09)	(0.21)	(0.06)	(-0.02)	(-0.06)
Tobin's Q	0.004	0.002	0.003	0.004	0.005	0.004
	(0.31)	(0.17)	(0.22)	(0.36)	(0.43)	(0.30)
Constant	-0.454*	-0.459*	-0.438*	-0.464*	-0.479*	-0.485*
	(-1.74)	(-1.73)	(-1.66)	(-1.78)	(-1.86)	(-1.85)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	376	376	376	376	376	376
R^2	0.09	0.09	0.09	0.09	0.09	0.09

Table 2.9: **Target abnormal returns, multiple windows**. This table reports the effect that managerial overconfidence has on target's abnormal returns. I show OLS regressions where the dependent variable is the cumulative abnormal returns for the target, considering multiple event windows. The event windows are: (1) [-1,1], (2) [-1,2], (3) [-1,3], (4) [0,1], (5) [0,2], and (6) [0,3]. The main independent variable in the analysis is Overconfident. I include Deal Value, Number of Bidders, Same Industry, Firm Size, MB, ROA, and Tobin's Q as controls in all specifications. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	CAR [-1,1]		
	(1)	(2)	(3)
Overconfident	0.089**		
	(2.44)		
Overconfident 80		0.137***	
		(3.10)	
Overconfident 90			0.232***
			(4.09)
Deal Value	0.000*	0.000	0.000
	(1.71)	(1.63)	(1.62)
Number of Bidders	0.141**	0.147**	0.147**
	(2.16)	(2.28)	(2.29)
Same Industry	0.030	0.036	0.032
	(1.13)	(1.33)	(1.23)
Firm Size	0.029***	0.039***	0.027***
	(4.15)	(4.20)	(3.90)
MB	0.001	0.001	0.001
	(0.63)	(0.55)	(0.44)
ROA	0.016	0.009	0.023
	(0.08)	(0.05)	(0.13)
Tobin's Q	0.004	0.004	0.004
	(0.31)	(0.35)	(0.31)
Constant	-0.454*	-0.444*	-0.421
	(-1.74)	(-1.71)	(-1.64)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	376	376	376
R^2	0.09	0.10	0.12

Table 2.10: **Target abnormal returns, multiple overconfidence levels**. This table reports the effect that managerial overconfidence has on target's abnormal returns. I show OLS regressions where the dependent variable is the cumulative abnormal returns for the target, considering an event window from 1 trading day before to 1 trading day after the merger announcement. The main independent variable in specification (1) is Overconfident. The main independent variable in specification (2) is Overconfident 80. The main independent variable in specification (3) is Overconfident 90. I include Deal Value, Number of Bidders, Same Industry, Firm Size, MB, ROA, and Tobin's Q as controls in all specifications. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	CAR [-1,1]					
	(1)	(2)	(3)	(4)	(5)	(6)
Overconfident	0.066**	0.087**	0.068**	0.092**	0.076**	0.100***
	(2.05)	(2.32)	(2.15)	(2.52)	(2.37)	(2.62)
Deal Value			0.000**	0.000***	0.000	0.000**
			(2.26)	(3.21)	(1.12)	(2.16)
Number of Bidders			0.128*	0.136**	0.129*	0.137**
			(1.90)	(1.96)	(1.95)	(2.01)
Same Industry			-0.003	0.004	0.023	0.028
			(-0.11)	(0.16)	(0.9)	(1.03)
Firm Size					0.034***	0.030***
					(4.99)	(4.08)
MB					0.000	0.000
					(0.06)	(0.34)
ROA					-0.077	-0.049
					(-0.42)	(-0.26)
Tobin's Q					0.012	0.006
					(1.02)	(0.49)
Constant	0.096***	-0.091	-0.045	-0.217	-0.358***	-0.530*
	(7.14)	(-0.35)	(-0.63)	(-0.84)	(-3.79)	(-1.95)
Year Fixed Effects	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	No	Yes	No	Yes	No	Yes
Observations	379	379	379	379	376	376
R^2	0.01	0.03	0.03	0.07	0.08	0.10

Table 2.11: **Difference in abnormal returns**. This table reports the effect that managerial overconfidence has on the difference in abnormal returns. I show OLS regressions where the dependent variable is the difference in cumulative abnormal returns, considering an event window from 1 trading day before to 1 trading day after the merger announcement. The main independent variable in the analysis is Overconfident. In specifications (3) and (4), I control for Deal Value, Number of Bidders, and Same Industry. For specifications (5) and (6), I add Firm Size, MB, ROA, and Tobin's Q as controls. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

	CAR [-1,1]		
	(1)	(2)	(3)
Overconfident	0.100***		
	(2.62)		
Overconfident 80		0.140***	
		(3.04)	
Overconfident 90			0.224***
			(3.76)
Deal Value	0.000**	0.000**	0.000**
	(2.16)	(2.07)	(2.07)
Number of Bidders	0.137**	0.143**	0.142**
	(2.01)	(2.12)	(2.12)
Same Industry	0.028	0.034	0.030
	(1.03)	(1.22)	(1.10)
Firm Size	0.030***	0.030***	0.028***
	(4.08)	(4.11)	(3.82)
MB	0.000	0.000	0.000
	(0.34)	(0.25)	(0.14)
ROA	-0.049	-0.067	-0.059
	(-0.26)	(-0.35)	(-0.31)
Tobin's Q	0.006	0.007	0.007
	(0.49)	(0.56)	(0.53)
Constant	-0.530*	-0.520*	-0.497*
	(-1.95)	(-1.91)	(-1.84)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	376	376	376
R^2	0.10	0.1	0.12

Table 2.12: **Difference in abnormal returns, multiple overconfidence levels**. This table reports the effect that managerial overconfidence has on on the difference in abnormal returns. I show OLS regressions where the dependent variable is the difference in cumulative abnormal returns, considering an event window from 1 trading day before to 1 trading day after the merger announcement. The main independent variable in specification (1) is Overconfident. The main independent variable in specification (2) is Overconfident 80. The main independent variable in specification (3) is Overconfident 90. I include Deal Value, Number of Bidders, Same Industry, Firm Size, MB, ROA, and Tobin's Q as controls in all specifications. Fama French 48 Industries and year-fixed effects are included in specifications (2), (4), and (6). t-statistics are reported in parenthesis under the coefficients. ***,**, and * indicate significance at 1%, 5%, and 10% level respectively.

Chapter 3

Managerial overconfidence as a consequence of learning and its effect on M&As

3.1 Introduction

Since Roll 1986 introduced the concept of managerial overconfidence to corporate finance, the idea that merger deals are affected by this behavioural bias has become a primary way to explain the observed performance of firms following a merger announcement (Andrade, Mitchell, and Stafford 2001, Moeller, Schlingemann, and Stulz 2004). The problem with the analysis of overconfidence in the context of merger deals is that the literature has almost exclusively focused on one aspect of this complex behavioural bias, that is, managerial optimism, leaving out other aspects that also influence the outcome of merger deals. In order to understand the real implications of decision-makers beliefs on merger deals, the overconfidence theory for mergers and acquisitions warrants an analysis of how all its different dimensions affect them.

In this paper, I extend the analysis of Chapter 2 and continue exploring how biased beliefs about uncertainty influence merger deals. In the model, two firms must jointly decide when to execute the real option to merge. While one firm is managed rationally, the other has a biased manager. Overconfidence is assumed to be an overestimation of the precision of the signals received during the negotiation process about the profitability of the merged firm. I refer to this aspect of overconfidence as information-based overconfidence. I assume that both firms have access to public and private information and use it to form beliefs about the profit that the combined firm will have once the merger occurs. Beliefs are created by solving a linear filtering problem. The biased manager overestimates the precision of the private signal, which causes her to overreact to the private information compared to the rational manager. This increases the real option's exercise threshold, thus delaying the merger deal.

Contrary to the standard notion, I show that overconfidence can be beneficial for the biased firm. In the model, the biased firm obtains a higher share of the merged firm. Moreover, returns for the biased firm increase with overconfidence. My results are consistent with previous research highlighting the positive effects of information-based managerial overconfidence (Gervais, Heaton, and Odean 2011).

I make three predictions for the effect of information-based overconfidence on the performance of M&As. First, the model shows that merger returns start to be realized as run-ups (Keown and Pinkerton 1981) before the deal is made public. This pre-announcement effect is positive for both firms and is driven by both the relative quality of private information and overconfidence. Second, the market reacts positively to the firm with biased managers at the moment of the announcement. Third, when looking at the combined effect for both firms overconfidence creates value, however, this value is completely realized before the merger is announced.

Although both the miscalibration aspect of overconfidence studied in Chapter 2 and the information-based overconfidence studied in this paper refer to biases about uncertainty, the opposing predictions from both models suggest that they are not the same phenomenon, and that is important to study them separately, making a clear distinction[1] between overestimating the precision of information and the precision of knowledge, the latter being associated with the miscalibration effect of Chapter 2.

[1] Previous research, for example, Glaser and Weber 2007, has tested models that use information-based overconfidence by using a measure of miscalibration, not being able to find the results implied by the models.

Experimental research (Fellner and Krügel 2012) supports the idea that overconfidence in the form of narrow confidence intervals as a result of miscalibration, and overconfidence in the perception of signals are unrelated.

When assuming, as most of the literature does, that managers in the acquiring firm are biased, the type of overconfidence studied in this paper does not explain the general behaviour of merger returns. However, it may help explain cases that do not follow the general pattern. Previous research has found that when targets are privately held firms, returns to acquirers tend to be much higher (Chang 1998). In these cases, it would be reasonable to assume that there is less prior knowledge about the target, thus overconfidence being much more likely to appear in the form of an overestimation of the precision of new information. Acquirer overconfidence could also help explain recent evidence showing that mergers driven by shocks to productivity lead to higher (lower) acquirer (target) announcement returns (Wang 2018) and that in unanticipated deals, acquirers gain significantly from mergers (Tunyi 2021).

Alternatively, assuming that the target firm has biased managers makes the predictions of this paper consistent with what is considered stylized facts. Virtually all previous literature has exclusively focused on acquirers' behavioural biases as the sole way in which they can affect mergers and acquisitions. However, management in target firms can also be susceptible to overconfidence, which certainly would influence the control transaction process. In general, managers are believed to be prone to overconfidence (Moore 1977), so it stands to reason that one would be as likely to find overconfident managers in target firms as in acquiring firms. My results offer a new explanation for how target's overconfidence can affect merger deals.

In addition to contributing to the vast mergers and acquisitions literature by exploring how overconfident managers interpret and learn from information regarding the unobservable performance of the merged firm, my research advances two distinct areas of research.

First, I add to the real options literature. My work is most aligned with research that incorporates learning into settings of imperfect information. In most of the literature, learning occurs by observing actions (exercise of the real option). Notable papers that adopt this approach include Grenadier 1999,Bernardo and Chowdhry 2002, Lambrecht and Perraudin 2003, Grenadier and Wang 2005, Morellec and Schürhoff 2011, Grenadier and Malenko 2011, and Gorno and Iachan 2020. In the context of merger deals, Morellec and Zhdanov 2005 presents a model where outsider investors update their information by observing whether participating firms exercise or not the option to merge. The authors predict a run-ups of stock prices before the merger announcement, and that combined returns should be positive.

Unlike these papers, my work relates to the less common case in which learning does not occur as a result of exercising the real option but from the observation of the stochastic process itself. An example of previous work that utilizes this approach is Grenadier and Malenko 2010, in which the authors study how uncertainty related to the persistence of past shocks, in a setting with Bayesian updating, affects investment decisions. They find that in addition to the standard option to wait, the firm has an incentive to learn more about past shocks.

Second, I contribute to the behavioural finance literature. Specifically to theoretical models that study overconfidence as an overestimation of informational precision. This aspect of overconfidence has been used to explain various characteristics of financial markets, for example, trading volume (Odean 1998, Daniel, Hirshleifer, and Subrahmanyam 2001), return comovements (Peng and Xiong 2006), price bubbles (Scheinkman and Xiong 2003), and market efficiency (Ko and Huang 2007).

Previous theoretical corporate finance research has also analyzed the effects of information-based overconfidence. Gervais, Heaton, and Odean 2002 study investment policies and show that overconfident managers can make decisions that are more aligned with shareholders' interests. In Goel and Thakor 2008, the authors show that overconfident managers are more likely to be promoted to CEO and that managerial overconfidence can increase the firm's value. Gervais, Heaton, and Odean

2011 study the contractual implications of managerial overconfidence, showing that both the firm and the manager can gain from this bias.

The remainder of this paper proceeds as follows. Section 3.2 presents a model for mergers in which one of the firms overestimates the precision of private information. Section 3.3 presents a numerical analysis of the model. Finally, Section 3.4 concludes.

3.2 A model for M&As driven by information-based overconfidence

3.2.1 Model setup

In this section, I study the effect that managerial overconfidence has on merger deals. I focus on the information-based aspect of overconfidence. The way overconfidence is modelled in this paper is most similar to Scheinkman and Xiong 2003. The model provides predictions for the timing and terms of the merger deal, as well as for the behaviour of merger returns.

There are two firms that are negotiating a merger. Under the assumption that one of these firms has a manager that can be overconfident, I denote firms as Rational (R) and Biased (B). Each firm's instantaneous profit function is assumed to be deterministic and equal to Π_i. This greatly simplifies the analysis while still being able to study the effect of overconfidence. The combined firm (M) has an instantaneous profit function $\Pi_M f(t)$ that depends on the unobservable stochastic process $f(t)$, which represents all the combined sources of uncertainty that affect profits following the deal. The previous assumptions can be interpreted as an analysis of the shocks to profits added as a result of the control transaction, normalizing by any pre-merger shocks. Since merging firms are not subject to different shocks, the model is most descriptive of deals for firms within the same industry.

Each firm forms beliefs $X(t)$ about the variable $f(t)$ using all available information. There are two sources of information: a public signal $P(t)$, and a private signal $S(t)$.

Both the public and private signals are commonly observed by the firms.

The public signal can be thought of as the combination of the true variable and a noise term with volatility σ_P.

$$dP(t) = f(t)dt + \sigma_P dZ_t^P \tag{3.1}$$

Similarly, the private signal is the combination of the true variable and a noise term, however, this signal is subject to an overconfidence bias. When executives in the biased firm are overconfident, they believe that the private signal they observe is less noisy than it really is ($0 < \phi_B \leq 1$). Executives in the rational firm always assume correctly that $\phi_R = 1$. The private signal follows:

$$dS(t) = f(t)dt + \phi_i \sigma_S dZ_t^S \tag{3.2}$$

The stochastic shock governing the profit function after firms merge follows an arithmetic mean reverting process. This functional form is chosen to obtain analytical solutions for the conditional beliefs of each firm.

$$df(t) = -\kappa(f(t) - \overline{f})dt + \sigma_f dZ_t^f \tag{3.3}$$

κ is the speed of mean reversion, $\overline{f}$ is the long-term mean of the shock, and $\{dZ_t^P, dZ_t^S, dZ_t^f\}$ are mutually independent standard Brownian motions.

The model is completed by adding a market, denoted by "m", which is unbiased in its beliefs and can only observe public information. The market is unaware that the biased firm can have overconfident managers, assuming that $\phi_B = \phi_R = 1$. There are no merging costs, all agents are risk neutral, and there exists a risk-free asset yielding a constant interest rate $r > 0$.

3.2.2 Beliefs about shocks to profit

The evolution of the conditional mean of beliefs is obtained by solving a linear filtering problem (see Liptser and Shiriaev 1977). I follow the standard practice of focusing on the stationary solution for the variance of beliefs.

Proposition 3.1 *The conditional mean of beliefs for managers in firm i follows:*

$$dX(t) = -\kappa(X(t) - \overline{f})dt + \frac{\gamma_i}{\sigma_P} dB_t^P + \frac{\gamma_i}{\phi_i \sigma_S} dB_t^S \tag{3.4}$$

Additionally, the variance of the stationary solution γ_i solves:

$$0 = -2\kappa\gamma_i + \sigma_f^2 - (\frac{\gamma_i^2}{\sigma_P^2} + \frac{\gamma_i^2}{\phi_i^2 \sigma_S^2}) \tag{3.5}$$

In Equation (3.4), $dB_t^P = \frac{1}{\sigma_P}(dZ_t^P - X(t)dt)$ and $dB_t^S = \frac{1}{\phi_i \sigma_S}(dZ_t^s - X(t)dt)$ are mutually independent Brownian motions for managers in firm i.

The variance term $\sigma_{\phi_i}^2 = \frac{\gamma_i^2}{\sigma_P^2} + \frac{\gamma_i^2}{\phi_i^2 \sigma_S^2}$ directly affects the exercise threshold of the option (see Equation (3.8)). Because γ_i decreases with ϕ_i, an increase in overconfidence increases the variance $\sigma_{\phi_i}^2$ leading to a later exercise or the option to merge.

3.2.3 Timing and terms of the deal

The value of assets in place $H_i(t)$ for firm i is equal to $\frac{\Pi_i}{r}$. Based on their own beliefs, the value of firm i before the merger can be thought of as the sum of the value of assets in place plus the value of an option to merge $OM_i(X(t))$.

The value of the option to merge is obtained from the merger surplus for firm i, given by:

$$max(s_i * H_M - \frac{\Pi_i}{r}, 0) \tag{3.6}$$

s_i represents the share of the combined firm that firm i receives. The value of the combined firm E_M is equal to the expectation of the sum of discounted future profit.

$$H_M = \Pi_M(\frac{X(t)}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}) \tag{3.7}$$

Given that the surplus in Equation (3.6) resembles a call option, real options theory (see for example Dixit and Pindyck 1994) shows that a threshold (x_i^*) exists such that it is optimal for each firm to execute the merger. Using standard methods, it can be shown (see Appendix F) that the value of the option to merge, before the option is executed, is described by the following differential equation:

$$\frac{\partial OM_i(X(t))}{\partial X(t)}(\kappa(\overline{f} - X(t))) + \frac{1}{2}\frac{\partial^2 OM_i(X(t))}{\partial X^2(t)}\sigma_{\phi_i}^2 = rOM_i(X(t)) \tag{3.8}$$

The general solution for this equation is:

$$OM_i(X(t)) = \begin{cases} \beta_i h_i(X(t)) & X(t) < x_i^* \\ s_i \Pi_M(\frac{X(t)}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}) - \frac{\Pi_i}{r} & X(t) \geq x_i^* \end{cases} \tag{3.9}$$

Where the function $h_i(X(t))$ is a combination of the Kummer functions U and M (see Abramowitz and Stegun 1964).

$$h_i(X(t)) = \begin{cases} U(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma_{\phi_i}^2}) & X(t) \leq \overline{f} \\ (\frac{2\pi}{\Gamma(\frac{1}{2}+\frac{r}{2\kappa})\Gamma(\frac{1}{2})}M(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma_{\phi_i}^2}) - U(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma_{\phi_i}^2})) & X(t) \geq \overline{f} \end{cases} \tag{3.10}$$

The constant β_i and the threshold x_i^* are obtained from two boundary conditions that ensure that each firm chooses the merger timing optimally. Because both firms find their optimal timing and subsequently negotiate the terms of the deal, the model is most descriptive of friendly deals. The first condition, commonly known as "value matching", equates the value of the option at the threshold with the surplus obtained at the time of the merger:

$$\beta_i h_i(x_i^*) = s_i \Pi_M(\frac{x_i^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}) - \frac{\Pi_i}{r} \tag{3.11}$$

The second boundary condition, "smooth pasting", equates the derivative of OM_i with the derivative of the surplus obtained at the time of the merger.

$$\beta_i h_i'(x_i^*) = \frac{s_i \Pi_M}{r+\kappa} \tag{3.12}$$

The timing and terms of the merger can be numerically obtained by finding $\{x^*, s_R^*, s_B^*\}$ that solves the system of equations given by (3.11) and (3.12) for both firms simultaneously.

3.2.4 Merger returns

Merger returns are obtained from the perspective of the market, which forms beliefs about the dynamics of profits by observing the public signal. The conditional belief $X(t)$ from the perspective of the market is:

$$dX(t) = -\kappa(X(t) - \overline{f})dt + \frac{\gamma_m}{\sigma_P} dB_t^P \tag{3.13}$$

With the variance of the stationary solution γ_m equating to:

$$0 = -2\kappa\gamma_m + \sigma_f^2 - \frac{\gamma^2}{\sigma_P^2} \tag{3.14}$$

Based on this belief, the market predicts the timing x_m^*. Since the market is unaware of the behavioural biases in one of the merging firms, it predicts that $s_i = \frac{\Pi_i}{\Pi_R + \Pi_B}$. by comparing $\sigma_m^2 = \frac{\gamma^2}{\sigma_P^2}$ with $\sigma_{\phi_i}^2$, it is straightforward to note that $\sigma_{\phi_i}^2 > \sigma_m^2$. This implies that the market predicts that the merger will occur earlier than it actually happens. Consequently, pre-announcement returns arise as the market updates its information every time $X(t)$ reaches a new highest point. In addition to the pre-announcement returns, not being able to anticipate how managerial overconfidence affects the terms of the deal implies that there are also announcement returns.

Total merger returns for firm i (R_i) can be written (following Morellec and Zhdanov 2005,Hackbarth and Miao 2012) as a fraction of assets in place $\frac{\Pi_i}{r}$:

$$R_i = \frac{(s_i^* \Pi_M(\frac{x^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}) - \frac{\Pi_i}{r}) - (\frac{\Pi_i}{\Pi_R+\Pi_B}\Pi_M(\frac{x_m^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}) - \frac{\Pi_i}{r})}{\frac{\Pi_i}{r}} \tag{3.15}$$

The expression in equation (3.15) can be decomposed into pre-announcement (PAR_i) and announcement (AR_i) returns by considering the market's expectations just before the merger is announced.

$$R_i = PAR_i + AR_i \tag{3.16}$$

$$PAR_i = \frac{\frac{\Pi_i}{\Pi_R+\Pi_B}\Pi_M(\frac{x^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)})) - (\frac{\Pi_i}{\Pi_R+\Pi_B}\Pi_M(\frac{x_m^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}))}{\frac{\Pi_i}{r}} \tag{3.17}$$

$$AR_i = \frac{(s_i^* \Pi_M(\frac{x^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)})) - (\frac{\Pi_i}{\Pi_R+\Pi_B}\Pi_M(\frac{x^*}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}))}{\frac{\Pi_i}{r}} \tag{3.18}$$

Pre-announcement returns are positive ($x^* - x_m^* > 0$) for both firms. It is well documented in the M&A literature that targets firms have positive pre-announcement returns (Keown and Pinkerton 1981, Schwert 1996). Interestingly, this result is also consistent with recent research showing that in unanticipated deals, acquirers have positive pre-announcement returns (Wang 2018, Tunyi 2021).

Whether firm i has positive or negative announcement returns depends on the sign of $s_i^* - \frac{\Pi_i}{\Pi_R+\Pi_B}$. As section 3.3 shows, the biased firm benefits from having an overconfident manager: overconfidence increases the share of the combined firm it gets leading to positive announcement returns. Notably, if both firms have a rational manager($\phi_B = 1$), there are no announcement surprises for either firm.

3.3 Numerical analysis

I present numerical results for the model derived in section 3.2. The parameters used for the analysis are: $r = 0.08$, $\kappa = 0.5$, $\sigma_f = 0.2$, $\sigma_P = 0.5$,$\sigma_S = 0.15$, $\overline{f} = 1$, $\Pi_R = 10$, $\Pi_B = 10$, $\Pi_M = 25$. The parameters chosen are most descriptive of a merger between similar firms ($\Pi_R = \Pi_B$). Additionally, $\sigma_P > \sigma_S$ implies that private signals are more precise than the ones available to the public. Finally, the parameters describe deals that are synergistic ($\Pi_M > \Pi_R + \Pi_M$).

3.3.1 Timing and terms of the deal

The model predicts that managerial overconfidence concerning the precision of private signals delays mergers. As figure 3.1 shows, a decrease in ϕ_B leads to an increase in the merger threshold x^*. This result is driven by an overestimation effect on the variance $\sigma^2_{\phi_B}$. Contrary to the effect of knowledge based-overconfidence (miscalibration effect), a manager that overestimates the precision of signals will over-react to the information contained in them, which will, in turn, cause her to overestimate the volatility of the uncertain variable, delaying the exercise of the option due to the standard convexity effect of volatility in real options.

Figure 3.1 also illustrates that the market will predict an earlier merger compared to the one that is privately negotiated by both firms. Every time $X(t)$ reaches a new highest point, and no merger has occurred, the market will update its valuation, leading to pre-merger run-ups.

In addition to the role that managerial overconfidence plays in determining the difference between the market´s prediction and the actual merger ($x^* - x^*_m$), even when $\phi_B = 1$ the merger is realized later than what the market predicts. This second factor is attributed to the informational asymmetry as a result of not observing the private signal. An increase in the public signal's precision (decrease of σ_P) reduces the effect of this factor.

Turning to how the combined firm is divided in friendly negotiations, the model predicts that an increase in information-based overconfidence leads to a larger share of the firm being allocated to the biased firm. Information-based overconfidence is beneficial during negotiations because it causes firms to disagree on when it is optimal to merge. Since the rational firm always wants to merge earlier, it must offer a higher share of the combined firm to convince managers in the biased firm. The effect of overconfidence on the terms of the deal is relatively small. Figure 3.2 shows the terms of the biased firm increasing from 50% when $\phi_B = 1$ up to 51%.

3.3.2 Merger returns

As evident from equation (3.17) combined with the result that $x^* - x_m^* > 0$, pre-announcement returns are positive and equal for both firms. Although pre-announcement returns are driven mainly by the informational advantage that merging firms have, my research shows that managerial overconfidence also explains this empirically observed phenomenon. In the model, merger delays caused by overconfidence positively affect pre-merger run-ups. Figure 3.3 shows pre-announcement returns increasing from 1.16% to 1.52% as managerial overconfidence increases. Another critical factor affecting pre-merger run-ups is the synergies in the deal. An increase in Π_M shifts pre-announcement returns upwards.

When the merger is announced, the market observes the actual terms of the deal. Since merger terms are different from the market's predictions, the surprise leads to an announcement effect for both firms. I find that announcement returns are positive (negative) for the biased (rational) firm. Additionally, overconfidence has a monotonic impact on the magnitude of returns. As figure 3.4 shows, returns are 0% when $\phi_B = 1$ and evolve monotonically up to 2.4% (-2.4%) for the biased (rational) firm. Contrary to the adverse effect usually associated with overconfidence in merger deals, this surprising result shows that information-based overconfidence has a positive effect. In line with my results, previous research has supported the idea that information-based overconfidence can be beneficial for firms (see Gervais, Heaton, and Odean 2002, Gervais, Heaton, and Odean 2011). The magnitude of announcement returns is also influenced by other parameters in the model, notably, the post-merger deterministic component of profits (Π_M), the relative size of the firms, and the relative informativeness of the public and private signal.

The model's predictions have important implications for our understanding of how overconfidence as a whole affects merger deals. First, under the assumption that the biased firm is the acquirer, my results predict an opposite outcome compared to the other aspects of overconfidence studied in the financial literature, optimism (Malmendier and Tate 2008), and miscalibration (Chapter 2 of this thesis). When taking into account the results of this paper, an overconfidence explanation is consistent with the different outcomes observed in merger deals. A prime example of cases in which information-based overconfidence in acquirers may drive merger deals is the acquisition of private firms. Due to the nature of these firms, especially their disclosure requirements, there is less available information when compared to public firms. An acquirer is more likely to express this bias due to the information she obtains during the negotiation process.

A second implication of the model comes from assuming managerial overconfidence in target firms. Among the few papers that have studied target's overconfidence, John, Liu, and Taffler 2010 find that the market's adverse reaction to overconfident acquirers is further increased when target management is also overconfident. My theory gives an explanation for the channel through which target's overconfidence affects deals.

When analyzing the combined returns as a way to understand the model's implications for the creation of value, the model predicts that the combined returns should be positive and increase in overconfidence. Previous research has indicated that mergers create wealth in the short run (Morellec and Zhdanov 2005) in a setting of imperfect information. However, my paper is the first to link value creation to information-based overconfidence. The model further predicts that all value is created before the merger is announced, with the announcement effect being only a transfer of wealth between merging firms.

3.4 Conclusion

This paper develops a real options model for mergers and acquisitions in which managerial overconfidence, understood as an overestimation of the precision of information, affects the endogenously determined timing and terms of the deal. The model combines asymmetric information, learning, and behavioural biases to obtain implications for returns around merger announcements. Overconfidence causes the biased manager to overreact to information, delaying deals and leading to beneficial terms for the biased firm.

The model obtains important predictions for merger returns. First, the model predicts that there are positive pre-announcement returns that are increasing in overconfidence. Second, announcement returns for the biased firm are positive and increasing in managerial overconfidence. Finally, when analyzing the combined effect for both firms, the model predicts that information-based overconfidence creates value, however, this value is fully realized before the merger is announced.

Empirically measuring and testing how information-based overconfidence affects merger deals represents an exciting and novel avenue for future research, as it can further our understanding of how the personal characteristics of managers shape corporate decisions.

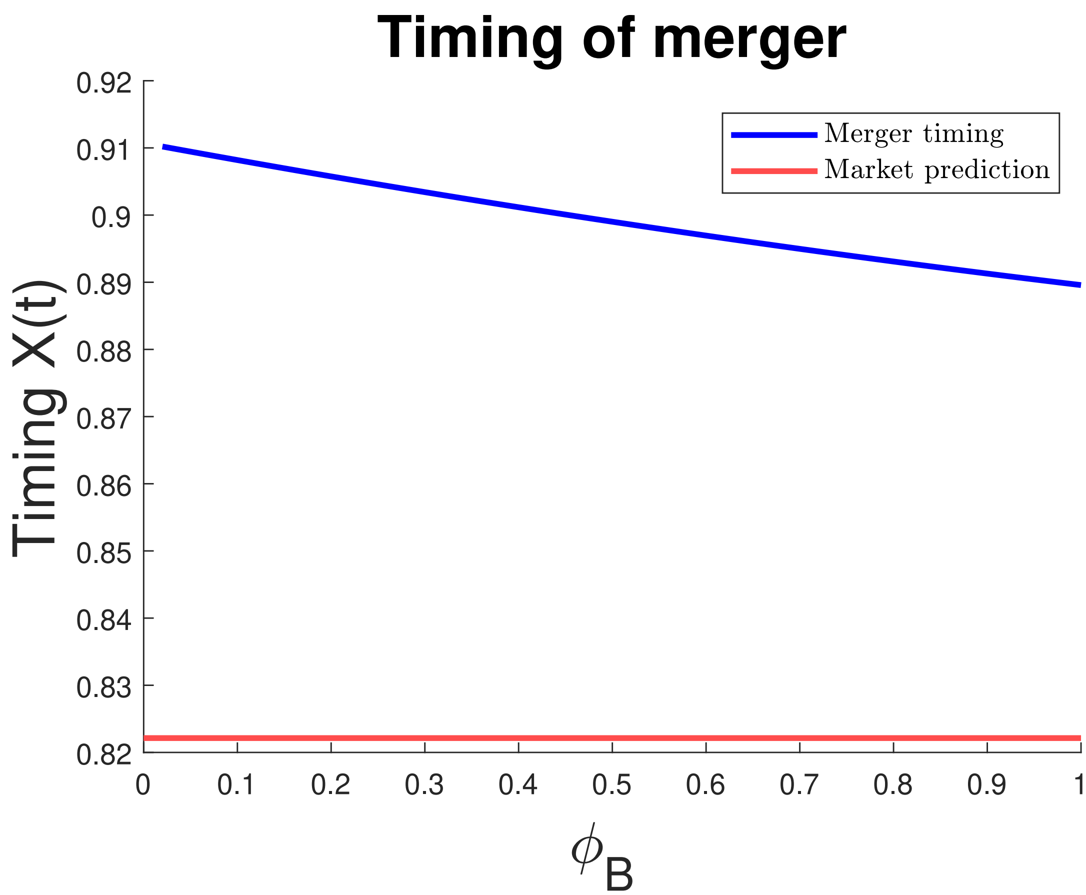

Figure 3.1: **Timing in a merger: Information-based overconfidence**. This figure plots the effect that the degree of information-based overconfidence (measured by ϕ_B) has on the friendly merger's threshold x^* (blue). This figure also plots the market's prediction (red). The parameters used are: $r = 0.08$, $\kappa = 0.5$, $\sigma_f = 0.2$, $\sigma_P = 0.5$, $\sigma_S = 0.15$, $\overline{f} = 1$, $\Pi_R = 10$, $\Pi_B = 10$, and $\Pi_M = 25$.

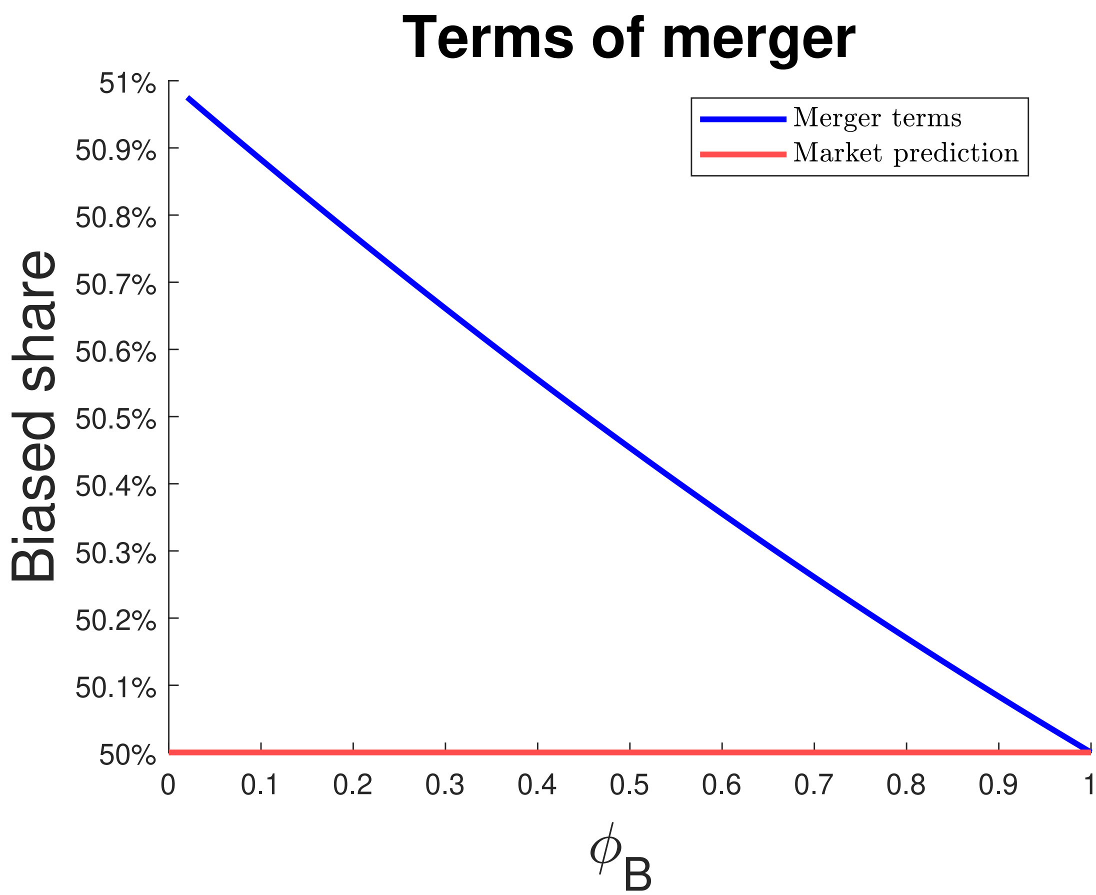

Figure 3.2: **Terms in a merger: Information-based overconfidence**. This figure plots the effect that the degree of information-based overconfidence (measured by ϕ_B) has on the biased firm's ownership share s_T (blue). This figure also plots the market's prediction (red). The parameters used are: $r = 0.08$, $\kappa = 0.5$, $\sigma_f = 0.2$, $\sigma_P = 0.5$, $\sigma_S = 0.15$, $\overline{f} = 1$, $\Pi_R = 10$, $\Pi_B = 10$, and $\Pi_M = 25$.

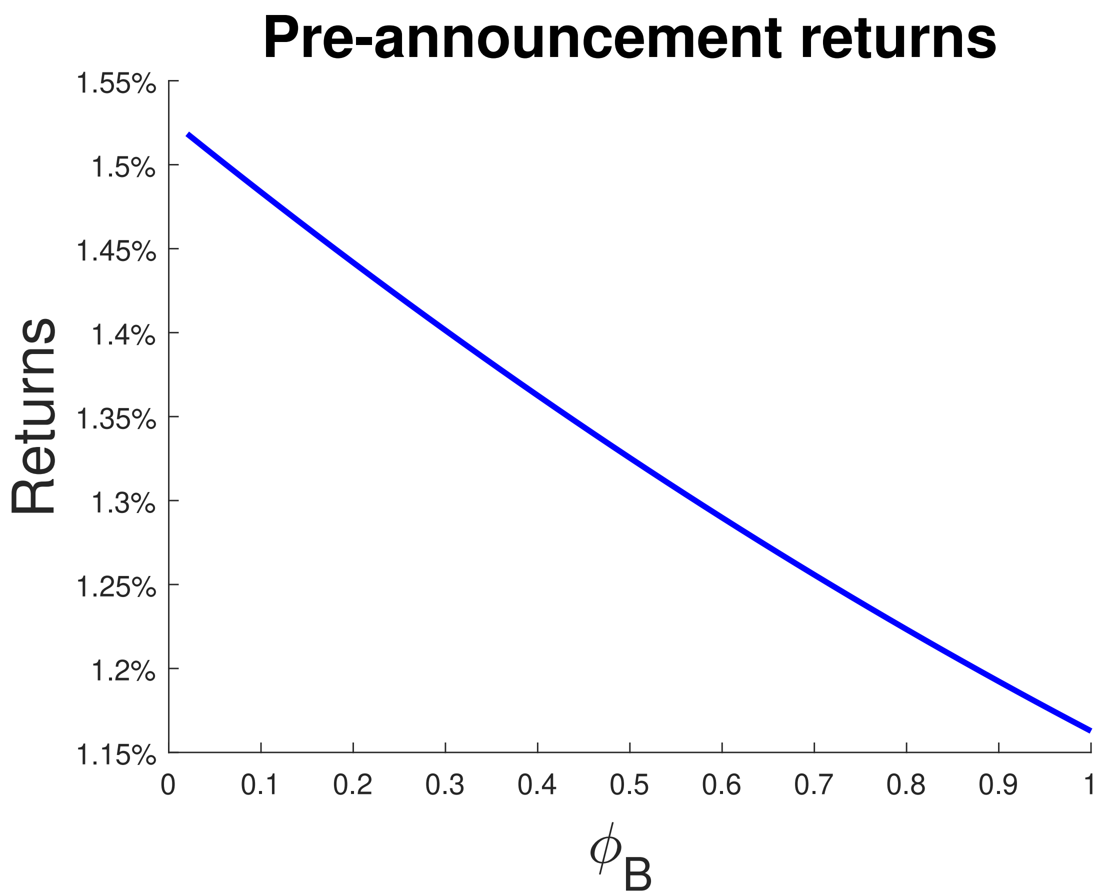

Figure 3.3: **Pre-announcement returns: Information-based overconfidence**. This figure plots the effect that the degree of information-based overconfidence (measured by ϕ_B) has on pre-announcement returns. The figure plots returns for the biased (red) and rational (blue) firms. The parameters used are: $r = 0.08$, $\kappa = 0.5$, $\sigma_f = 0.2$, $\sigma_P = 0.5$, $\sigma_S = 0.15$, $\overline{f} = 1$, $\Pi_R = 10$, $\Pi_B = 10$, and $\Pi_M = 25$.

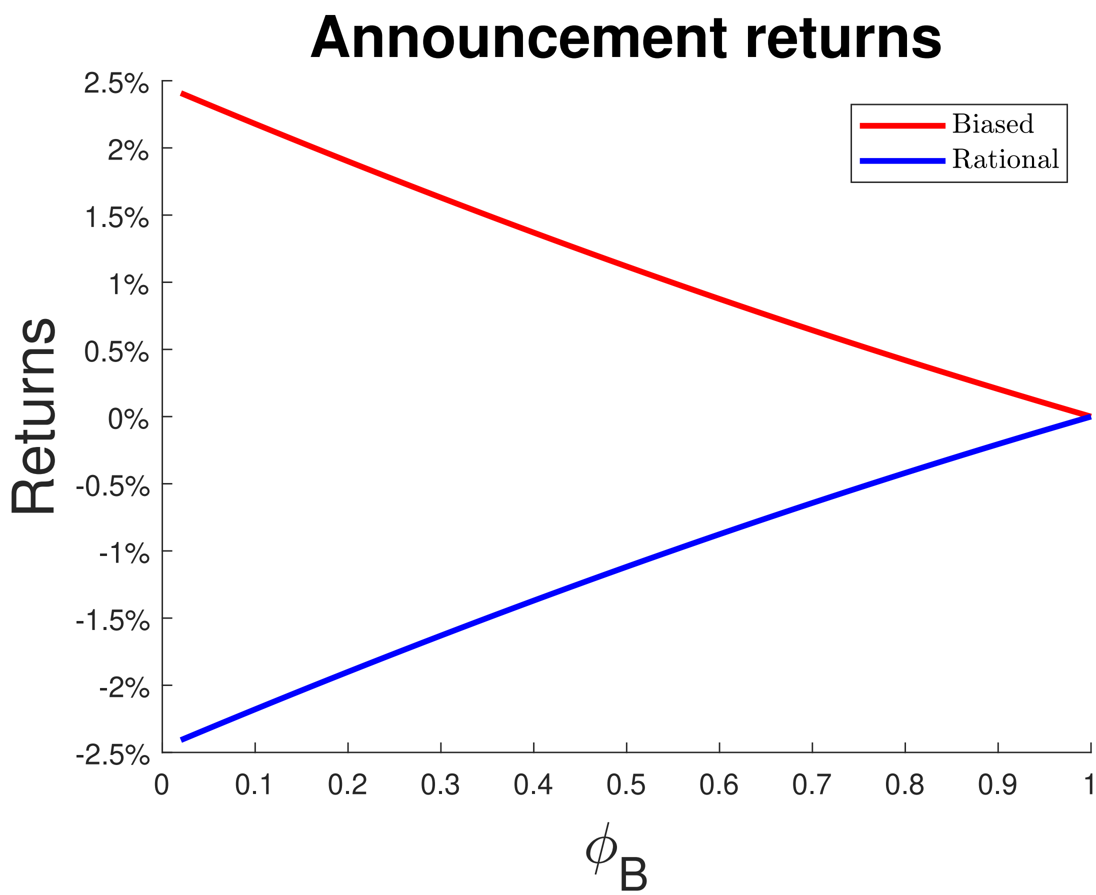

Figure 3.4: **Announcement returns: Information-based overconfidence**. This figure plots the effect that the degree of information-based overconfidence (measured by ϕ_B) has on announcement returns. The figure plots returns for the biased (red) and rational (blue) firms. The parameters used are: $r = 0.08$, $\kappa = 0.5$, $\sigma_f = 0.2$, $\sigma_P = 0.5$, $\sigma_S = 0.15$, $\overline{f} = 1$, $\Pi_R = 10$, $\Pi_B = 10$, and $\Pi_M = 25$.

Chapter 4

Corporate Investment with heterogeneous beliefs

4.1 Introduction

Can group heterogeneity affect investment decisions? This question has important implications for the way we analyze and model corporate events. Despite corporate decision-making being among the most studied topics in finance, little to no attention has been drawn to perhaps the single elements all decisions have in common: most, if not all, are made to some extent by groups. Instead, most models forgo groups by resorting to a representative agent. It is important then to ask whether and under what conditions a group can correctly be represented by a single decision-maker and when, to the contrary, group heterogeneity must be taken into account.

In this paper, I study a canonical real options investment problem. I depart from the standard framework by analyzing a 3-member group with heterogeneous beliefs that must decide when to invest in a project. Although the problem of investment under uncertainty has been extensively studied in the real options literature, it has rarely been studied from a group's perspective. My paper shows that when both the project's value and the investment costs are uncertain, belief heterogeneity becomes a key characteristic of the group. In these cases, the group's investment behaviour can not be represented by any single member or subset of the group. Moreover, members' beliefs can lead to underinvestment (Garlappi, Giammarino, and Lazrak

2017; Garlappi, Giammarino, and Lazrak 2022); that is, the group never invests despite all members being willing to invest if they had dictatorial decision power.

My results call into question the use of a representative agent to model and study corporate decisions. Additionally, they are in line with the behaviour of real-world groups. For example, experimental psychology literature (Stoner 1968) suggests that when groups make decisions under risk, the outcome of those decisions is significantly different from the average of the initial decision from each member.

I rely on three important assumptions: (i) the group decides by majority voting, (ii) decisions are (at least partially) irreversible, and (ii) even though decision-makers have perfect information, they do not change their beliefs. Assumption (i) allows me to abstract from the complexities of social choice and model the process of resolving disagreements in the simplest possible way.

Assumption (ii) is standard in the literature: investment irreversibility leads to members finding value in delaying investment when faced with uncertainty. Each member's investment problem is analyzed as a perpetual American option, in which their voting behaviour is characterized by a "continuation region" where it is optimal for them to vote to delay investment and an "immediate investment region" that leads them to vote "yes" to executing the project.

Assumption (iii) implies that members of the group can be thought of as behavioural investors. This assumption captures the observation that managers are prone to display behavioural biases[1]. Moreover, The idea that members do not learn from each other or when they observe new information is also supported by the finding that managers tend not to learn from repeated feedback Huffman, Raymond, and Shvets 2022.

In the benchmark case (constant investment cost), each member's voting behaviour is always defined by a single threshold. Members vote for immediate investment

[1]Some examples of managerial biases are optimism Malmendier and Tate 2005, overconfidence Ben-David, Graham, and Harvey 2013, and risk tolerance Graham, Harvey, and Puri 2013

when they think that the project's value is sufficiently above the investment cost. This implies that the immediate investment region of any member is a subset of the investment region of all members with a lower threshold. When ordering group members by their investment threshold, the group can always be reduced to the median member, making group heterogeneity irrelevant. This result is in line with previous research from social choice theory (Black et al. 1958), which predicts that the outcome of a decision with disagreeing members is the same as the decisions of the member with median preferences. Whenever this median voter theorem holds, using a representative member perfectly captures the behaviour of the group.

When both the project's value and the investment costs follow a stochastic process, Battauz, Donno, and Sbuelz 2012 show that a double continuation region can characterize the option's value associated with the investment problem. When this happens, investment is delayed when the value of the project is insufficiently above the investment cost, as well as when the value of the project exceeds the investment cost by too much. The double continuation region can only arise (depending on the other parameters of the model) when the growth rate of the investment cost is greater than the one for the project's value, which in turn is greater than the discount rate.

When one or more members have non-standard beliefs that give rise to the double continuation region, heterogeneity becomes a key characteristic of the group. Using numerical examples, I show the various patterns for the group behaviour. First, in cases where a representative member still exists, this member is not always the one with median preferences. Second, it is possible that none of the members that are part of the majority can represent the group's behaviour. Third, multiple investment regions can arise where each region is obtained with votes from different members. In this case, the group cannot be represented by any subset of members. Finally, a majority may never be attained, leading to underinvestment.

The conditions necessary for the double continuation region to appear can be descriptive of real-world investment decisions. Take, for example, a mining project. It is well known that legal, social, and environmental factors (Dupuy 2014, Badakhshan et al. 2023) affect investment costs in mining operations. The uncertain nature of these factors makes it reasonable to assume a positive growth rate for investment costs. Further, a mining's project value depends on forecasts for the mineral's price. A scenario in which the mineral's price is expected to grow substantially, such as lithium (Martin et al. 2017) amid the electric car revolution, that coincides with a period associated with intense social and political pressure against operations seen as damaging for the environment, makes it perfectly possible for the growth rate of both variables to be larger than the risk-free rate. In this scenario is also plausible for an investor to believe that, over the long run, increases in the investment cost would be greater than increases in the project's present value. Such an investor could (depending on her beliefs about volatility) have a voting pattern consistent with the one explored in this paper.

The effect of heterogeneity in beliefs on a voting group in the context of real options has been previously studied in Garlappi, Giammarino, and Lazrak 2022. The authors focus on sequential timing decisions (licensing, investment, and abandonment) and find that heterogeneity is relevant because the deciding voter changes from one decision to another. My paper builds on their work and extends it by showing that heterogeneity is also relevant for decisions involving one optimal timing problem. My focus on individual decisions is guided by the belief that real decision-makers do not act entirely rationally (see Camerer 1998). Thus they may not, unconsciously or deliberately, consider subsequent decisions that should be considered. Previous research has shown that managers display "short-termism" (Narayanan 1985, Laverty 1996), in which they pursue short-term gains, sacrificing the long-term interests of shareholders. For example, consider a project that, once invested, takes a long time to be implemented. By the time subsequent decisions can be operationalized, the managers that made the initial decision may no longer be involved in the project. In this case, they may be incentivized only to consider the initial investment in their analysis.

My research contributes to the real options literature. I am most aligned with research studying investment decisions. Brennan and Schwartz 1985, McDonald and Siegel 1986 are the first to study investment decisions as real options. Following these initial papers, the problem of investment under uncertainty has been extended in numerous ways. Grenadier and Wang 2005 introduce agency conflicts between owners and managers in a setting with information asymmetries, showing that agency conflicts delay investment. Grenadier and Wang 2007 extend the standard framework of investment under uncertainty to consider time-inconsistent preferences and show that the investor's degree of awareness about their future behaviour alters their investment decisions. In more recent work, Lambrecht and Myers 2017 study how investment, financing, and payout decisions interact, finding that risk-averse managers invest less than what a value-maximizer would. Kumar and Yerramilli 2018 research the joint decision of capacity investment and financial leverage, finding that capacity and financial leverage are substitutes. I contribute to this extensive literature by exploring how a non-standard option value characterized by a double continuation region (Battauz, Donno, and Sbuelz 2012) affects a group's optimal investment problem.

This paper also contributes to the literature that relates to dynamic decisions by groups[2]. I am most aligned with research studying heterogeneity in beliefs. In Garlappi, Giammarino, and Lazrak 2017, group members update their beliefs after observing a public signal and use a utilitarian governance rule. The authors show that under-investment can occur in this setting. In Donaldson, Malenko, and Piacentino 2019, corporate board heterogeneity can lead to the inefficient selection of CEOs. Garlappi, Giammarino, and Lazrak 2022 are the first ones to model dynamic decisions by a voting group as a real option. Unlike their focus on sequential decisions, I show that even in a single investment decision, heterogeneity plays a vital role in determining the decision behaviour of the group.

[2]Group decisions have been studied in a general context, for example, Marshall 2010, Dass, Nanda, and Wang 2013, and Agrawal and Chen 2017

The remainder of this paper proceeds as follows. Section 4.2 presents a benchmark model for an investment decision made by a 3-member group with heterogeneous beliefs. Section 4.3 extends the base model to consider stochastic investment costs. Finally, Section 4.4 concludes.

4.2 Investment decision under heterogeneous beliefs

4.2.1 Model setup

A group of three members must collectively decide on investing in a new project with a fixed investment cost of I. Group members have exogenously given heterogeneous beliefs about the evolution of the project's value. Specifically, all members believe that the project's present value evolves following a geometric Brownian motion, however, they disagree on the parameters of the stochastic process. Specifically, member n's beliefs are given by the pair (μ_n, σ_n), which completely characterize their beliefs about X_t.

$$dX_t = \mu_n X_t dt + \sigma_n X_t dW_{t,n} \tag{4.1}$$

Equation (4.1) shows the dynamics of the project's present value X_t according to member n. μ_n is the instantaneous growth rate, σ_n is the instantaneous volatility, and $W_{t,n}$ is a standard Wiener process under n's beliefs. I assume that individual beliefs are known to all members of the group. Additionally, all members are risk neutral, and there exists a risk-free rate $r > 0$.

Each member's beliefs are maintained through time; they do not learn from each other or with every new observation of X_t. This assumption is most descriptive of situations in which either learning about the true parameters of the process may take a long time or cases in which the present value of a new project can not be perfectly observed before investing in it. Moreover, this setting also describes behavioural decision-makers and captures the idea that behavioural biases present in managers are persistent even after repeated feedback (Huffman, Raymond, and Shvets 2022).

Consistent with the primary purpose of this paper, I assume that the group solely focuses on the investment decision and that their analysis is not guided by any possible future decision contingent on investing in the project, such as abandonment of the project or potential growth opportunities. This assumption captures relevant scenarios, such as managerial short-termism (Narayanan 1985).

4.2.2 Individual investment decisions

In this section, I study each member's investment choice as if they have complete control over the investment decision. Under the assumption that the investment decision is irreversible, there is an incentive to wait before investing. This problem can be interpreted as a perpetual call option to invest in the project with a strike price equal to the investment cost. The option is executed when member n thinks that the present value of the project is sufficiently above the investment cost I. Formally, the value of the perpetual option is given by:

$$\sup_{\tau \geq 0} \mathbb{E}_n[e^{-r\tau} \max(X_\tau - I, 0) | X_0 = x] \tag{4.2}$$

Member n's value for the option to invest can be written as:

$$O^n(x, x_n) = \begin{cases} (x_n - I)(\frac{x}{x_n})^{\nu_n}, & x < x_n \\ (x - I), & x \geq x_n \end{cases} \tag{4.3}$$

with

$$\nu_n = \sqrt{(\frac{1}{2} - \frac{\mu_n}{\sigma_n^2})^2 + \frac{2r}{\sigma_n^2}} + \frac{1}{2} - \frac{\mu_n}{\sigma_n^2} > 1 \tag{4.4}$$

ν_n is the positive root of the characteristic equation $\frac{\sigma_n^2}{2}\nu(\nu - 1) + (\mu_n)\nu - r = 0$. To ensure that results are correctly defined, it is necessary to impose that $max(\mu_n) < r$.

For cases where $\mu_n > r$, both the value of the option and stopping time τ go to infinity.

The value of the option presented in equation (4.3) is standard in the real options literature (see Appendix G) and has an intuitive interpretation. For cases where the current present value of the project is already above the required threshold x_n, the investment opportunity is taken immediately, resulting in a net payoff $x - I$. If the value of the project has not yet reached the required threshold, the option's value has two factors. The first one represents the payoff at the time of investment. The second term is a discount factor that can be interpreted as the probability of X_t ever hitting the threshold x_n. The required threshold x_n is directly linked to the stopping time τ in equation (4.2), which is defined as the first time X(t) reaches x_n from below:

$$\tau = \inf\{t \geq 0 : X_t \geq x_n\} \tag{4.5}$$

Member n chooses the optimal investment threshold x_n^*, such that it maximizes the option in equation 4.3. The resulting optimal investment threshold is given by:

$$x_n^* = \frac{\nu_n}{\nu_n - 1} I \tag{4.6}$$

Member n would choose to invest at time τ^*, which is the earliest time that $X(t)$ reaches x_n^*. The investing timing τ^* obtains the supremum in equation (4.2).

Assuming that the heterogeneity in (μ_n, σ_n) is such that different members would choose a different investment time, I classify members of the group as Early (E), Median (M), and late (L) investors.

4.2.3 Group decision

For a three-member group, a majority voting rule requires that two of the three members agree on their votes. Given that $x_E^* < x_M^* < x_L^*$, and that all members know each other's beliefs, the sequential nature of individual choices imply that everyone in the group recognizes that the median investor M casts the deciding vote.

Proposition 4.1 *After the problem of investment under heterogeneous beliefs is resolved by majority voting, the group invests at the threshold* x_M^*.

Proposition 4.1 implies that the solution to a dynamic investment problem consisting of a single decision made by majority voting is the same as one made by the member with median preferences. This implication is not new and follows the median voter theorem (Black et al. 1958).

This result shows that heterogeneity in beliefs is irrelevant because the group can always be correctly reduced to its representative investor, whose identity is always the median investor. Additionally, there is no underinvestment due to heterogeneity in beliefs: no project that is individually accepted by all group members gets ever rejected by the group.

The analysis in this section can be straightforwardly extended to larger groups and for different voting rules. For any group of size N, a voting rule requiring $0 < k \leq N$ members to agree comes to the same conclusion as the individual decision made by the k^{th} member (ranking their investment timing decisions in ascending order).

In the next section, I extend the model to consider stochastic investment costs. Under this assumption, an interesting case arises where the group cannot be represented by the median member.

4.3 Stochastic investment and the double continuation region

Consider now that the three-member group must collectively decide on investing in a project where the investment cost I_t is stochastic with dynamics:

$$dI_t = \mu_{I,n} I_t dt + \sigma_{I,n} I_t dB_{t,n} \tag{4.7}$$

To simplify the analysis, I assume that members agree on their beliefs about the dynamics of the investment cost. Particularly, I assume that $\mu_{I,n} = \mu_I$ and $\sigma_{I,n} = \sigma_I$

for all members.

Without loss of generality, the dynamics for the present value of the project can be written as a function of the two independent Brownian motions $B_{t,n}$ and $Z_{t,n}$.

$$dX_t = \mu_n X_t dt + \sigma_{B,n} X_t dB_{t,n} + \sigma_{Z,n} X_t dZ_{t,n} \tag{4.8}$$

Each member's beliefs are now fully characterized by the trio $(\mu_n, \sigma_{B,n}, \sigma_{Z,n})$.

4.3.1 individual investment decisions

Similar to the analysis in section 4.2.2, the investment problem for each member acting independently can be interpreted as a perpetual option. The value of the perpetual option is given by:

$$\sup_{\tau \geq 0} \mathbb{E}_n[e^{-r\tau} \max(X_\tau - I_\tau, 0) | X_0 = x, I_0 = I] \tag{4.9}$$

A standard technique is to reduce the dimensionality of the problem by rewriting it in terms of the cost-to-value ratio A_t:

$$A_t = \frac{I_t}{X_t} \tag{4.10}$$

Using $X_t e^{-(\mu_n - r)t}$ as a numeraire allows me to change to the probability measure $\mathbb{A}$ for which the problem in equation (4.9) is equivalent to:

$$x * \sup_{\tau \geq 0} \mathbb{E}_n^{\mathbb{A}}[e^{(\mu_n - r)\tau} \max(1 - A_\tau, 0) | A_0 = \frac{I}{x}] \tag{4.11}$$

The problem is now interpreted as a perpetual put option with a strike price of 1. Under the probability measure $\mathbb{A}$, the dynamics for A_t are given by:

$$dA_t = (\mu_I - \mu_n) A_t dt + (\sigma_I - \sigma_{B,n}) A_t dB_{t,n}^{\mathbb{A}} - \sigma_{Z,n} A_t dZ_{t,n}^{\mathbb{A}} \tag{4.12}$$

$(\sigma_I - \sigma_{B,n}) dB_{t,n}^{\mathbb{A}} - \sigma_{Z,n} dZ_{t,n}^{\mathbb{A}}$ can be written using the Brownian motion $Q_{t,n}^{\mathbb{A}}$, such that:

$$\sqrt{(\sigma_I - \sigma_{B,n})^2 + \sigma_{Z,n}^2} dQ^{\mathbb{A}}_{t,n} = (\sigma_I - \sigma_{B,n}) dB^{\mathbb{A}}_{t,n} - \sigma_{Z,n} dZ^{\mathbb{A}}_{t,n} \tag{4.13}$$

This leads to the following expression for A_t:

$$dA_t = (\mu_I - \mu_n) A_t dt + \sqrt{(\sigma_I - \sigma_{B,n})^2 + \sigma_{Z,n}^2} A_t dQ^{\mathbb{A}}_{t,n} \tag{4.14}$$

If I assume that $r \geq \mu_n$, the problem in equation (4.11) becomes a standard real options problem that delivers the same conclusions as those highlighted in section 4.2. Here, member n delays investment until the project's present value is sufficiently higher than the investment cost. Notably, heterogeneous beliefs are irrelevant to the investment decision when $r \geq \mu_n$ for all members.

Unlike in section 4.2, the stopping time does not necessarily explode to infinity when $r < \mu_n$. As Battauz, Donno, and Sbuelz 2012 first show, a non-standard solution arises under certain conditions, such that the optimal stopping time is a finite interval and a double continuation region appears. Under these conditions, member n would decide to delay investment when the value of the project is insufficiently above the investment cost, as well as when the value of the project exceeds the investment cost by too much. The intuition behind delaying investment when the value of the project is well above the investment cost is that member n would expect that over the short term, increases in the project's present value would be greater than increases in the investment cost, finding it optimal to delay investment. The double continuation region appears when:

$$\mu_I - \mu_n - \frac{(\sigma_I - \sigma_{B,n})^2 + \sigma_{Z,n}^2}{2} - \sqrt{2((\sigma_I - \sigma_{B,n})^2 + \sigma_{Z,n}^2)(\mu_n - r)} \geq 0 \tag{4.15}$$

Notably, this can only happen when the growth rate of the investment cost μ_I is greater than member's n beliefs about the growth rate μ_n. Under these conditions, member n's value for the option to invest can be written as:

$$O^n(x, I, a_{n,1}, a_{n,2}) = \begin{cases} x(1-a_{n,1})(\frac{A_0}{a_{n,1}})^{\beta_{n,1}}, & A_0 < a_{n,1} \\ (x-I), & a_{n,1} \leq A_0 \leq a_{n,2} \\ x(1-a_{n,2})(\frac{A_0}{a_{n,2}})^{\beta_{n,2}}, & A_0 > a_{n,2} \end{cases} \tag{4.16}$$

with $\beta_{n,1} \geq \beta_{n,2}$ the negative roots of the characteristic equation:

$$\frac{(\sigma_I - \sigma_{B,n})^2 + \sigma_{Z,n}^2}{2}\beta(\beta-1) + (\mu_I - \mu_n)\beta + (\mu_n - r) = 0 \tag{4.17}$$

It is important to note that when the expression in equation (4.15) is precisely equal to 0, there is only one negative root for equation (4.17), and therefore $\beta_{n,1} = \beta_{n,2} = \beta_n$.

Member n chooses $a_{n,1}$ and $a_{n,2}$ to maximize the option in equation (4.16). The resulting optimal investment thresholds are given by:

$$a_{n,1} = \frac{\beta_{n,1}}{\beta_{n,1} - 1} \tag{4.18}$$

$$a_{n,2} = \frac{\beta_{n,2}}{\beta_{n,2} - 1} \tag{4.19}$$

The optimal stopping time τ^* is now given by the interval between $a_{n,1}$ and $a_{n,2}$.

$$\tau^* = \inf\{t \geq 0 : a_{n,1} \leq A_t \leq a_{n,2}\} \tag{4.20}$$

Following this stopping time, member n would delay investment until the cost-to-value ratio is within this interval. When there is a unique negative root for equation (4.17), $a_{n,1} = a_{n,2} = a_n$. Additionally, member n delays investment until the cost-to-value ratio is exactly $a_n = \frac{\beta_n}{\beta_n - 1}$. The associated optimal stopping time is now given by:

$$\tau^* = \inf\{t \geq 0 : A_t = a_n\} \tag{4.21}$$

The non-standard investment behaviour presented in this section leads to interesting results for the group's investment decision.

4.3.2 Group decision

In this section, I use numerical examples to explore how heterogeneity in beliefs can affect group decisions. My analysis shows that when not restricting beliefs like in section 4.2, the group may not be able to be reduced to a representative member. Moreover, I find that heterogeneous beliefs can lead to underinvestment in which the group never accepts a project that would be accepted by all members individually.

I classify members as Low (L), Median (M), and High (H) based on their initial threshold, that is, the highest cost-to-value ratio for which they start voting "yes" to immediate investment. In the numerical examples, each member has beliefs as defined in table 4.1. Additionally, $r = 5\%$, $\mu_I = 15\%$, and $\sigma_I = 20\%$.

When the group decides by majority voting and at least one member has beliefs that lead to the non-standard individual choice behaviour, the results implied by Proposition 4.1 do not necessarily hold.

The intuition for this is simple: Since the immediate investment region for some members is no longer defined by a single threshold, a member voting to invest does not necessarily imply that members that have supported investment in the past will continue to do so. The effects of heterogeneous beliefs on the group's decision are summarized in the following examples.

First, in cases where a representative member exists, it is not always the same (Median) member. As example 1 (Panel A) shows, the group decides to invest only when L and M support investment. Since member L's investment region ($A_t \leq 0.36$) is a subset of M's ($A_t \leq 0.42$), the group can be correctly represented by investor L.

Example 2 (Panel B) shows that differences in beliefs can be such that no member can be considered representative of the group. Similar to the previous case, a majority is only attained with votes from L and M. In this case, however, the group's investment region ($0.75 \leq A_t \leq 0.77$) is neither represented by L ($A_t \leq 0.75$) nor M ($0.72 \leq A_t \leq 0.77$). In this case, the subset {L,M} can fully represent the group and beliefs from both members affect the group's investment decision.

Example 3 (Panel C) illustrates a case where multiple investment regions can arise. A majority can be attained with votes from M and L or votes from H and M. In this case, no subset of members can represent the group's investment region ($A_t \leq 0.36 \cup 0.42 \leq A_t \leq 0.45$). Beliefs from all members are needed to characterize the group fully.

Finally, example 4 (Panel D) highlights an important economic implication of heterogeneous beliefs: underinvestment. Even when all members would invest in the project if acting on their own at different levels for the cost-to-value ratio, there is never a level where the required majority can be achieved, thus the project is never executed.

4.4 Conclusion

I study a canonical real options investment problem in which a three-member group with heterogeneous beliefs must decide via majority voting on when to invest in a project. When considering the realistic assumption that investment costs are also stochastic, I show that, depending on the degree of disagreement, the group´s behaviour cannot be represented by any single member or subgroup.

Group heterogeneity becomes a relevant characteristic when members' beliefs lead to a voting pattern characterized by a double continuation region: they vote to delay investment when the project's value is either insufficiently above the investment cost or when it surpasses the investment cost by too much. In this latter case, their beliefs about the short-term behaviour of both variables make them think that it is optimal to wait.

Although real-world endeavours entail multiple decisions that are often connected, it is essential to understand whether group heterogeneity can affect every individual decision, especially when considering that managers do not act in an entirely rational way and may wrongfully consider each decision separately.

My paper shows that it is important to consider group heterogeneity when studying and modelling investment problems, as the investment can be altered or even cancelled as a result of differences in beliefs.

Panel A					
Member	μ	σ_B	σ_Z	Immediate investment	Group decision
L	3%	40%	40%	$A_t \leq 0.36$	
M	4%	35%	35%	$A_t \leq 0.42$	$A_t \leq 0.36$
H	8.5%	30%	15%	$0.54 \leq A_t \leq 0.64$	
Panel B					
Member	μ	σ_B	σ_Z	Immediate investment	Group decision
L	3%	20%	25%	$A_t \leq 0.75$	
M	10.6%	15%	10%	$0.72 \leq A_t \leq 0.77$	$0.75 \leq A_t \leq 0.77$
H	12%	15%	5%	$0.8 \leq A_t \leq 0.88$	
Panel C					
Member	μ	σ_B	σ_Z	Immediate investment	Group decision
L	3%	40%	40%	$A_t \leq 0.36$	
M	3.5%	35%	35%	$A_t \leq 0.45$	$A_t \leq 0.36 \cup 0.42 \leq A_t \leq 0.45$
H	8%	30%	15%	$0.42 \leq A_t \leq 0.72$	
Panel D					
Member	μ	σ_B	σ_Z	Immediate investment	Group decision
L	4.5%	25%	25%	$A_t \leq 0.71$	
M	10.6%	15%	10%	$0.72 \leq A_t \leq 0.77$	$\emptyset$
H	12%	15%	5%	$0.8 \leq A_t \leq 0.88$	

Table 4.1: **Numerical Analysis**. This table shows the investment decision for a three-member group with heterogeneous beliefs. Panels A to D shows variables for the examples used in section 4.3.2. In each panel, I show members' beliefs $(\mu_n, \sigma_{B,n}, \sigma_{Z,n})$, their immediate investment region and the group's investment region.

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Appendix A: Propositions

A.1 Essay 1

Proposition 2.1. The total synergies generated by the merger are given by equation (2.4). Taking the derivative with respect to ϕ_i gives:

$$\frac{(\Pi_M - \Pi_A - \Pi_T)X(t)(r-\alpha)}{((r-\alpha)\phi_i - r + \mu)^2} \tag{A.1}$$

It is straightforward to see that the sign of equation (A.1) is driven by the relation between r and α. Because ϕ_i decreases as overconfidence increase, an overconfident acquirer underestimates synergies generated in the control transaction deal when $r > \alpha$, overestimates them when $r < \alpha$, and is unbiased in her synergies estimation when $r = \alpha$. $\square$

Propositions 2.2 and 2.3. Let $OM(X(t))^i_j$ be the value of the option to merge for firm j under $i's$ beliefs. Assuming that $OM(X(t))^i_j$ is twice differentiable function of $X(t)$ in equation (2.2), Ito's lemma gives:

$$dOM(X(t))^i_j = \frac{dOM^i_j(X(t))}{dX(t)}dX(t) + \frac{1}{2}\frac{d^2OM^i_j(X(t))}{dX^2(t)}dX^2(t) \tag{A.2}$$

The value of the option to merge must satisfy the following no-arbitrage condition that is obtained by equating the expectation of $dOM(X(t))^i_j$ to $rOM(X(t))^i_j dt$:

$$rOM(X(t))^i_j = \frac{dOM^i_j(X(t))}{dX(t)}(\mu + \phi_i(r-\alpha))X(t) + \frac{1}{2}\frac{d^2OM^i_j(X(t))}{dX^2(t)}\phi_i^2\sigma^2X^2(t) \tag{A.3}$$

The general solution of the differential Equation (A.3) is given by:

$$OM(X(t))_j^i = A_1 X(t)^{\beta_i} + A_2 X(t)^{\nu_i}, \beta_i > 1 \; and \; \nu_i < 0 \tag{A.4}$$

With $\nu_i < 0$ and $\beta_i > 1$ solutions for p_i in the quadratic equation $(\mu + \phi_i(r - \alpha))p_i + 0.5\sigma_i^2 p_i(p_i - 1) - r = 0$. By imposing the boundary condition (no-bubbles condition) $lim_{X \to 0} OM(X(t))_j^i = 0$, I obtain the general form for the value of the option to merge $OM(X(t))_j^i = A_1 X(t)^{\beta_i}$.

To obtain A_1, I impose one additional condition, usually called "value matching". Assuming that the option is executed at $X = x_i$, the option's value at exercise must equal the surplus accruing to the firm.

$$A_1(x_i)^{\beta_i} = s_j H_M^i(x_i) - H_j^i(x_i) - \lambda_j \tag{A.5}$$

Solving for A_1 and plugging it back to $OM(X(t))_j^i = A_1 X(t)^{\beta_i}$ gives equation (2.7). On a friendly merger, both firms independently choose their optimal merger threshold, Equation (2.9), as the solution to the first order condition in equation (2.8). The timing and terms of the merger are obtained by solving the system given by each firm's merger threshold function and the condition that $S_A + S_T = 1$. The solution to this problem is given by equations (2.10) and (2.11).

The market solves the same problem when making its predictions, however, it assumes that $\phi_A = \phi_T = 1$. The solution to this problem is given by equations (2.12) and (2.13). $\square$

Proposition 2.4. In a hostile takeover, both firms follow a Stackelberg leader-follower game. The acquirer chooses the optimal merger threshold as a function of the target's share of the combined firm. This optimal threshold is the solution to the first order condition (2.20). The target then takes Equation (2.21) as given and obtains the terms of the deal by solving the first order condition in Equation (2.22). The solution to this problem is given by equations (2.24) and (2.23). $\square$

A.2 Essay 2

Proposition 3.1. Let the unobservable variable $f(t)$ and the system of observable signals $\xi(t) = (P(t), S(t))'$ be described by the following processes:

$$df(t) = -\kappa(f(t) - \overline{f})dt + \sigma_f dZ_t^f \tag{A.6}$$

$$d\xi(t) = \begin{bmatrix} 1 \\ 1 \end{bmatrix} f(t)dt + \begin{bmatrix} \sigma_P & 0 \\ 0 & \phi_i \sigma_S \end{bmatrix} \begin{bmatrix} dZ_t^P \\ dZ_t^S \end{bmatrix} \tag{A.7}$$

Using a Kalman-Bucy method (Liptser and Shiriaev 1977 Theorem 10.3), the evolution of the conditional mean of beliefs $(X(t))$ follows:

$$dX(t) = -\kappa(X(t) - \overline{f})dt + \begin{bmatrix} 1 & 1 \end{bmatrix} \gamma_i(t) \begin{bmatrix} \frac{1}{\sigma_P^2} & 0 \\ 0 & \frac{1}{\phi_i^2 \sigma_S^2} \end{bmatrix} \begin{bmatrix} dZ_t^P - X(t)dt \\ dZ_t^S - X(t)dt \end{bmatrix} \tag{A.8}$$

and the variance $\gamma_i(t)$ is given by:

$$\gamma_i'(t) = -2\kappa\gamma_i(t) + \sigma_f^2 - \begin{bmatrix} \gamma_i(t) & \gamma_i(t) \end{bmatrix} \begin{bmatrix} \frac{1}{\sigma_P^2} & 0 \\ 0 & \frac{1}{\phi_i^2 \sigma_S^2} \end{bmatrix} \begin{bmatrix} \gamma_i(t) \\ \gamma_i(t) \end{bmatrix} \tag{A.9}$$

By focusing on the stationary solution $\gamma_i'(t) = 0$, equations (A.8) and (A.9) are equal to (3.4) and (3.5) respectively. The (positive) solution to equation (3.5) is given by:

$$\gamma_i = \frac{(-\kappa\sigma_P\sigma_S + \sqrt{(\phi_i^2\sigma_S^2 + \sigma_P^2)\sigma_f^2 + \kappa^2\phi_i^2\sigma_P^2\sigma_S^2})\phi_i\sigma_S\sigma_P}{\phi_i^2\sigma_S^2 + \sigma_P^2} \tag{A.10}$$

Is straightforward to check the $\frac{\partial\gamma_i}{\partial\phi_i} > 0$ and that $\frac{\partial\sigma_{\phi_i}^2}{\partial\phi_i} < 0$ □

A.3 Essay 3

Proposition 4.1. Members {E,M,L} are defined such that $x_E^* < x_M^* < x_L^*$, with x_n^* defined in equation (4.6). Since the immediate investment region for each member is the closed interval $[x_n^*, \infty)$, member's n vote to invest necessarily implies that members that have voted to invest before will continue to do so, therefore the threshold x_M^* always attains the majority. $\square$

Appendix B: Variables

Δ **Earnings** Change in earnings, computed as the difference in income before extraordinary items, divided by share price times common shares outstanding.

Accrual Difference between income before extraordinary items and net cash flow for operating activities, divided by total assets.

Acquisitions Binary variable that takes the value of 1 if acquisitions divided by total assets is greater than 5%.

CAR Cumulative abnormal returns a the time of the merger announcement. Computed as the difference between realized returns and returns predicted by a market model.

Deal value Deal value in USD millions.

Earnings Volatility 5-year volatility of return on assets.

Firm size Natural logarithm of total assets.

Forecast horizon Difference between the forecast announcement date and the end of the fiscal year.

Loss Binary variable that takes the value of 1 the income before extraordinary items is less than 0.

MB Market to book ratio, computed as share price times common shares outstanding, divided by total equity.

Net Equity Issuance Binary variable that takes the value of 1 if the difference between sales and purchases of stocks, divided by total assets, is greater than 5%.

Number of Bidders Number of bidders in the deal.

Overconfident Binary variable that takes the value of 1 if the CEO is classified as overconfident by being in the top 25% of the precision bias.

Overconfident 80 Binary variable that takes the value of 1 if the CEO is classified as overconfident by being in the top 20% of the precision bias.

Overconfident 90 Binary variable that takes the value of 1 if the CEO is classified as overconfident by being in the top 10% of the precision bias.

Precision Interval of CEO Earning forecasts divided by the share price. The variable is multiplied by negative 1 for ease of interpretation.

ROA Return on assets, computed as income before extraordinary items divided by total assets.

Same industry Binary variable that takes the value of 1 if the acquirer and target share the same primary SIC code.

Shares Owned After Percentage of shares owned by acquirer after the deal.

Shares Owned Before Percentage of shares owned by acquirer before the deal.

Tobin's Q Total assets plus share price times common shares outstanding minus total equity, divided by total assets.

Appendix C: Minimal martingale measure

This appendix derives the dynamics of $X(t)$ under the minimal martingale measure Q^{min}. I closely follow the derivation presented in Ewald and Taub 2022.

For any measure Q^*, the Radon-Nikodym derivative is given by:

$$\frac{\partial Q^*}{\partial P} = e^{-(\int_0^t \theta_B dB_s + \int_0^t \theta_Z dZ_s) - \frac{1}{2}\int_0^t (\theta_B^2 + \theta_Z^2) ds} \tag{C.1}$$

Assuming that $dB^{Q^*} dZ^{Q^*} = 0$, the processes $B^{Q^*} = B + \int_0^t \theta_B ds$ and $Z^{Q^*} = Z + \int_0^t \theta_Z ds$ are Brownian motions. Consequently, the dynamics of X(t) under Q^* are given by:

$$dX(t) = (\mu - \rho\sigma_i\theta_B - \sqrt{1-\rho^2}\sigma_i\theta_Z)X(t)dt + \sigma_i X(t)(\rho dB^{Q^*} + \sqrt{1-\rho^2} dZ^{Q^*}) \tag{C.2}$$

Under the minimal martingale measure Q^{min}, pricing is consistent with both agents preferences and the CAPM. For this measure to be consistent with risk preferences, $e^{-rt}S(t)$ must be a martingale and therefore the only possible value for θ_B is:

$$\theta_B = \frac{\alpha - r}{\sigma_s} \tag{C.3}$$

A contingent claim $V(t)$ can be written as a function of t,$S(t)$,and $X(t)$. Application of Itô's lemma shows that the expectation of dV under Q^* is given by:

$$E^{Q^*}[dV] = [V_t + V_X X(t)(\mu - \rho\frac{\alpha - r}{\sigma_s}\sigma_i - \sqrt{1-\rho^2}\sigma_i\theta_Z) + V_S S(t) r + \frac{1}{2}V_{XX}X^2(t)\sigma_i^2 + \frac{1}{2}V_{SS}S^2(t)\sigma_s^2 + V_{XS}X(t)S(t)\sigma_i\sigma_s\rho]dt \tag{C.4}$$

Where the sub-indexes of V represent partial derivatives. Similarly, the expectation of dV under the physical measure is given by:

$$E[dV] = [V_t + V_X X(t)\mu + V_S S(t)\alpha + \frac{1}{2}V_{XX}X^2(t)\sigma_i^2 + \frac{1}{2}V_{SS}S^2(t)\sigma_s^2 + V_{XS}X(t)S(t)\sigma_i\sigma_s\rho]dt \tag{C.5}$$

Plugging the expectation under Q^* into Equation (C.5) gives:

$$E[dV] = [E^{Q^*}[dV] + V_X X(t)(\rho\frac{\alpha - r}{\sigma_s}\sigma_i + \sqrt{1-\rho^2}\sigma_i\theta_Z) + V_S S(t)(\alpha - r)]dt \tag{C.6}$$

Noting that $E^{Q^*}[dV]$ must be equal to $rVdt$, the return of V is:

$$\frac{E[\frac{dV}{V}]}{dt} = r + \zeta(\alpha - r) + \frac{V_X}{V}X(t)(\sqrt{1-\rho^2}\sigma_i\theta_Z) \tag{C.7}$$

The term ζ is the correlation between the returns of V and S.

$$\zeta = \frac{E[\frac{dV}{V}\frac{dS}{S}]}{E[(\frac{dS}{S})^2]} = \frac{V_X}{X}X(t)\frac{\sigma_i\rho}{\sigma_s} + \frac{V_s}{V}S(t) \tag{C.8}$$

The minimal martingale measure requires the return of V in Equation (C.7) to be consistent with the CAPM, thus θ_Z must be equal to 0. Under this minimal martingale measure, the dynamics for X(t) are given by Equation (2.33).

Appendix D: Numerical examples

This Appendix shows numerical examples that illustrate the predictions of the theory presented in Chapter 2. The parameters values are: $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$. I consider a case in which the acquirer is larger than the target ($\Pi_A > \Pi_T$), and that Π_M is 20% more than $\Pi_A + \Pi_T$. Additionally, I assume that agents are risk averse and that $\alpha = 0.09$.

D.1 Base model

Starting with the analysis of the deal's timing, figure D.1 shows how an increase in acquirer's overconfidence decreases the threshold required for the merger to occur. Additionally, it is shown how this threshold always comes earlier than market predictions. As a result, the market is surprised, leading to abnormal returns.

Moving to the effect on terms of the deal, figure D.2 shows that as overconfidence increases, the target's share of the combined firm increases from 28.5% to 30.9%. This can be interpreted as the extra cost that the acquirer pays for being overconfident. This seemingly small change has important implications for each firm's performance.

In Figure D.3, I illustrate the effect that managerial overconfidence has on abnormal returns and show each firm's performance when the merger occurs. In the figure, overconfidence creates positive abnormal returns for targets, with abnormal returns going up to 7.5% depending on the degree of overconfidence. Similarly, the effects for acquirers are negative, decreasing to -6.5%. Interestingly, a setting in which ($\Pi_A > \Pi_T$) captures the disproportional effect that overconfidence has for both firms.

Looking at the combined effect, figure D.4 clearly shows how managerial overconfidence destroys value. In the example, combined returns drop up to -2.5%. Notably, this effect is monotonic in overconfidence level, meaning that more value is destroyed as overconfidence increases.

D.2 Hostile deals

In hostile deals, overconfidence has a similar effect on both the timing and terms of the deal. As overconfidence increases, deals occur earlier, with terms that are increasingly in favour of targets. That being said, some key differences arise. First, hostile deals occur at a higher threshold for all overconfidence levels. Using the base parameters, figure D.5 shows that a deal in which the acquirer is not overconfident occurs when the stochastic variable reaches 0.023, compared to 0.016 in the base model. Second, hostile deals give more bargaining power to the target. Comparing the numerical results, figure D.6 shows that the base terms go from 28.5% in friendly deals to 32.2% in hostile takeovers.

In line with the base model, I predict that for hostile deals, abnormal returns are negative (positive) for acquirers (targets). Figure D.7 shows that in hostile deals, returns for both firms are higher than those in friendly mergers. For example, for an overconfidence level of $\phi_A = 0.5$, returns for the target increase from 4.8% to 10%. Similarly, acquirer returns increase from -3.3% to -2.1% when comparing friendly and hostile deals, respectively.

Despite returns following the same general pattern, the target's increased bargaining power leads to entirely different implications for overall value creation. As figure D.4 illustrates, overconfidence creates value when deals are hostile. In the example, an increase in overconfidence creates up to 1.4% in value for both firms combined.

Figure D.8 also shows that the effect of overconfidence is not monotonic. While value increases for low levels of overconfidence, it starts to decrease for higher levels. This non-monotonic effect implies that in hostile takeovers, there is an optimal level of overconfidence from a societal point of view. In the example, optimal value creation is obtained when the acquirer has an overconfidence level associated with $\phi_A = 0.5$. At this level of overconfidence, overall value creation is 1.38%.

D.3 Incomplete markets: Special case

I now illustrate the special case discussed in section 2.5. In this setting, the acquirer is overconfident about the systematic component of volatility ($\phi_{B,A}$). Additionally, under the simplification imposed by assuming that $r = 0$, the parameters are selected such that $\alpha < -\phi_{B,A}\sigma_B\sigma_S$ for some values of $\phi_{B,A} \in (0, 1)$. The parameters used in this case are: $\sigma_Z = \sigma_B = \sigma_s = 0.2$, $\lambda = 0.1$, $\mu = \alpha = -0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

An important difference in this special case is that the effects for both firms are reversed for sufficiently high levels of overconfidence. This reversal starts at the critical value $\phi_{B,A} = \frac{-\alpha}{\sigma_B\sigma_S}$, corresponding to $\phi_{B,A} = 0.7$ in this example. For values of $\phi_{B,A}$ below this level, increases in overconfidence start delaying the merger and favouring the acquirer. Figures D.9 and D.10 illustrate the effect of both the timing and terms of the merger, respectively.

For some parameters, there exists a second critical point ($\phi_{B,A} = 0.41$) for which overconfidence has no effect on the mergers. This means that both the timing and terms coincide with market's expectations and that there are no abnormal returns or value implications. Overconfidence levels part this point lead to positive (negative) abnormal returns for acquirers (targets). Figure D.11 illustrates the effects on abnormal returns. For high levels of overconfidence, returns for acquirers (targets) can increase (decrease) up to 0.8% (-2%).

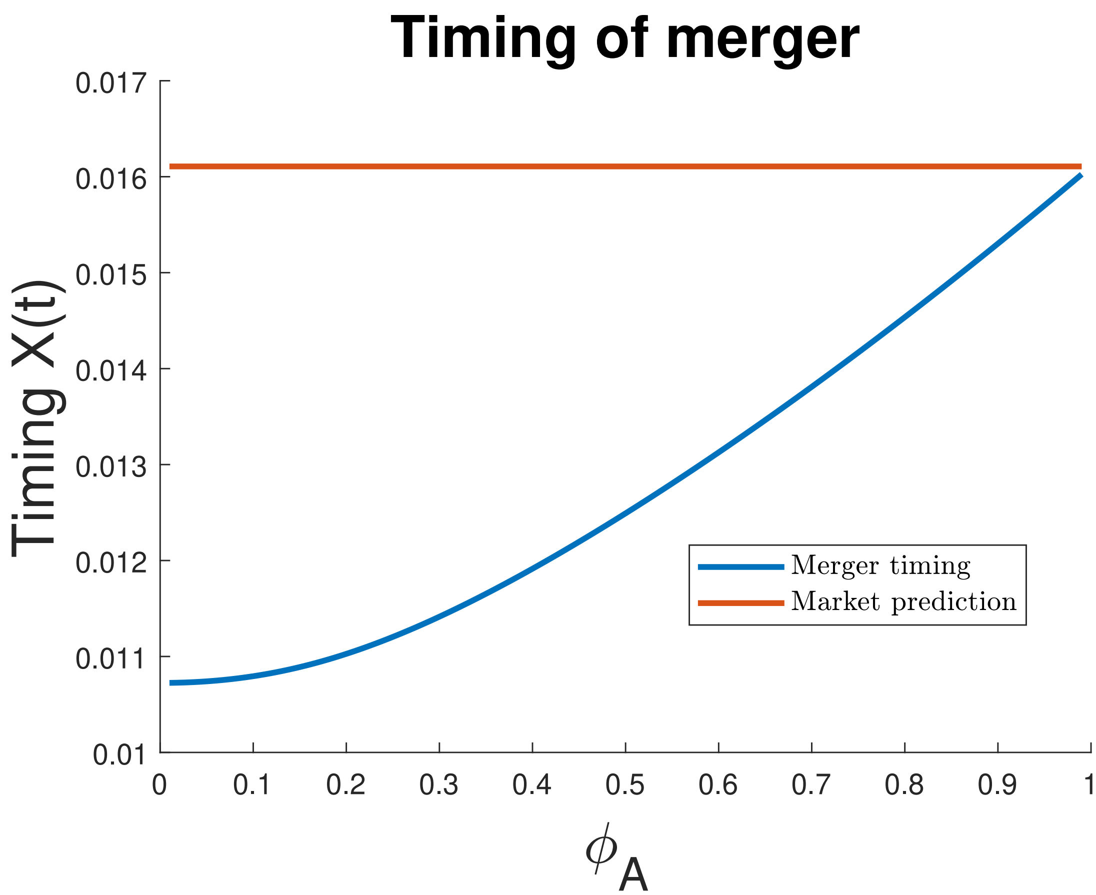

Figure D.1: **Timing in a friendly merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on the friendly merger's threshold x^* (blue). This figure also plots the market's prediction (red). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

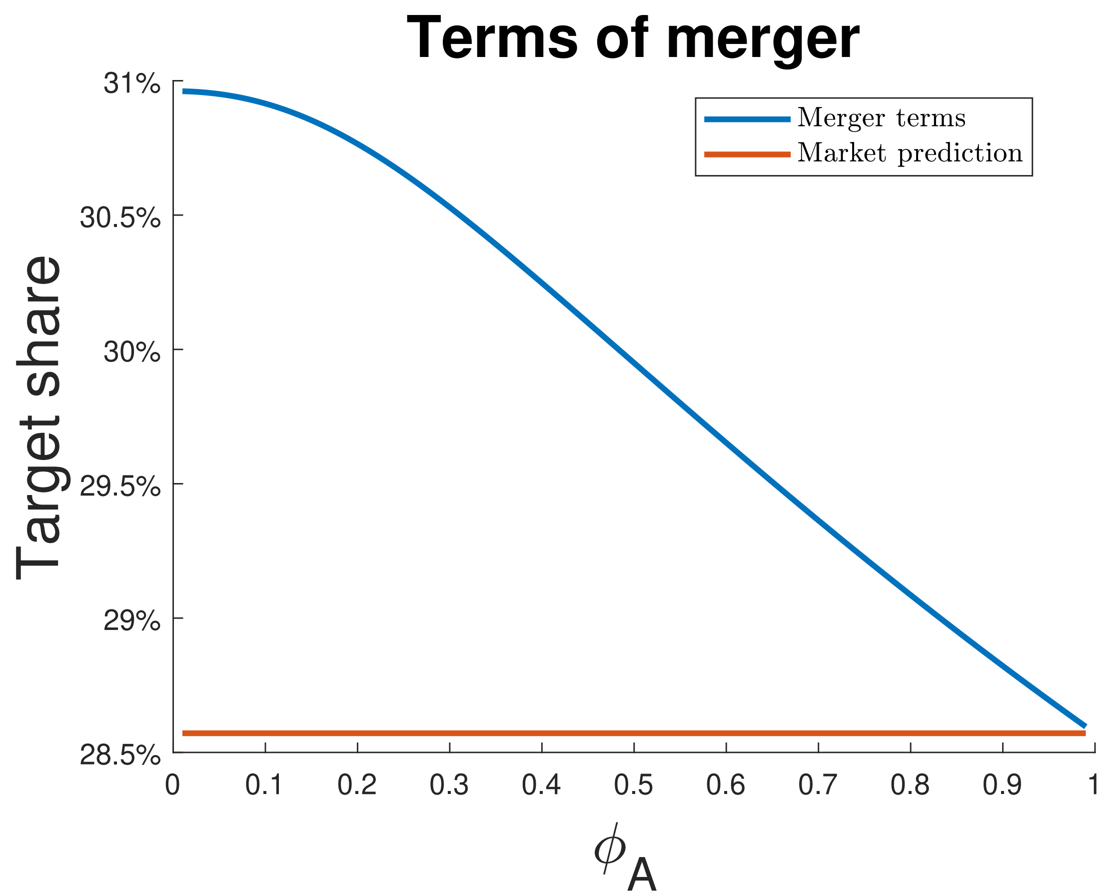

Figure D.2: **Terms in a friendly merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on the target's ownership share s_T (blue). This figure also plots the market's prediction (red). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

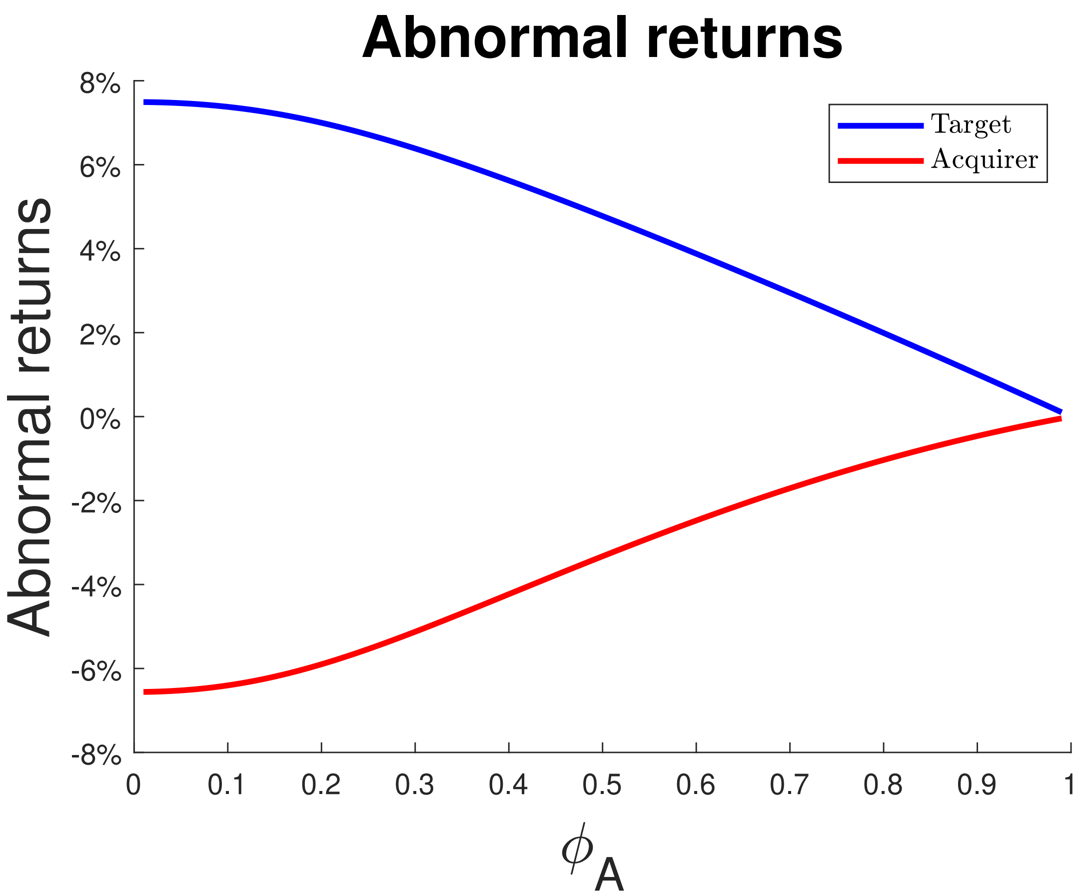

Figure D.3: **Abnormal returns in a friendly merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on return surprises. The figure plots acquirer's (red) and target's (blue) abnormal returns. The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

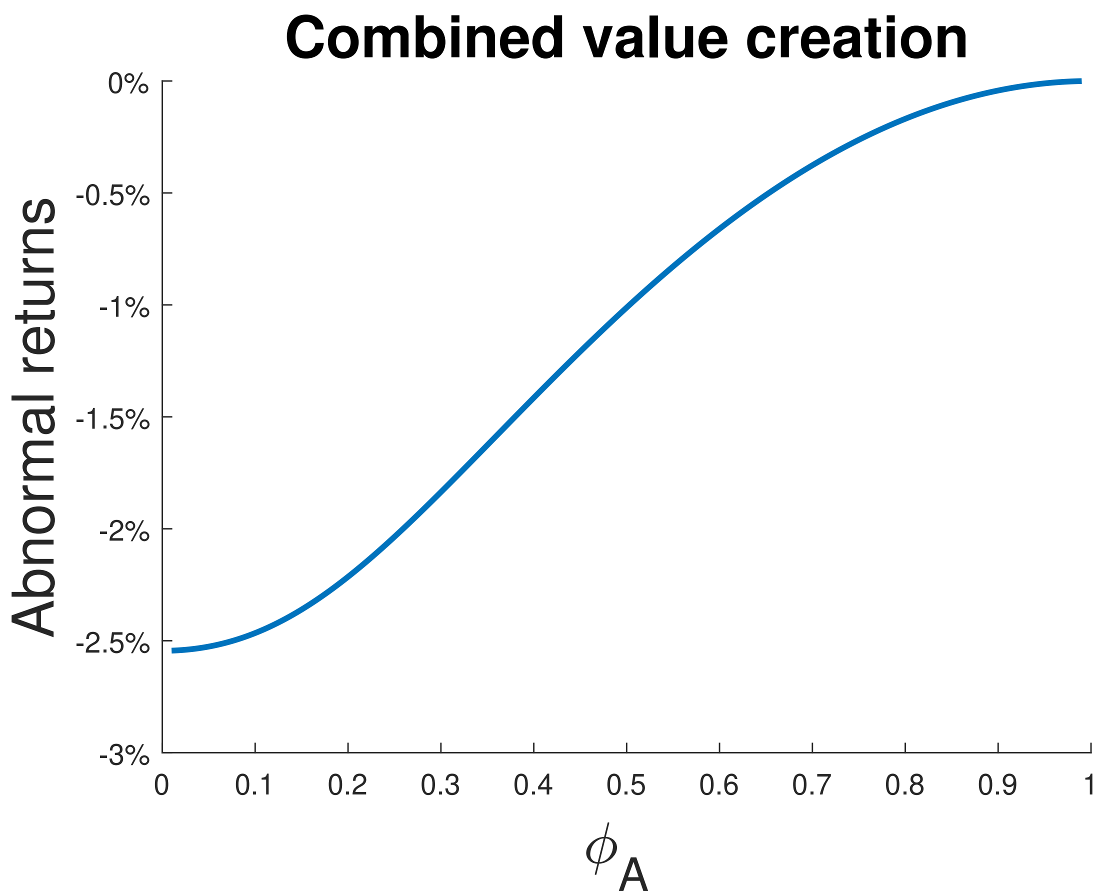

Figure D.4: **Value in a friendly merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on value creation. The figure plots combined abnormal returns (blue). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

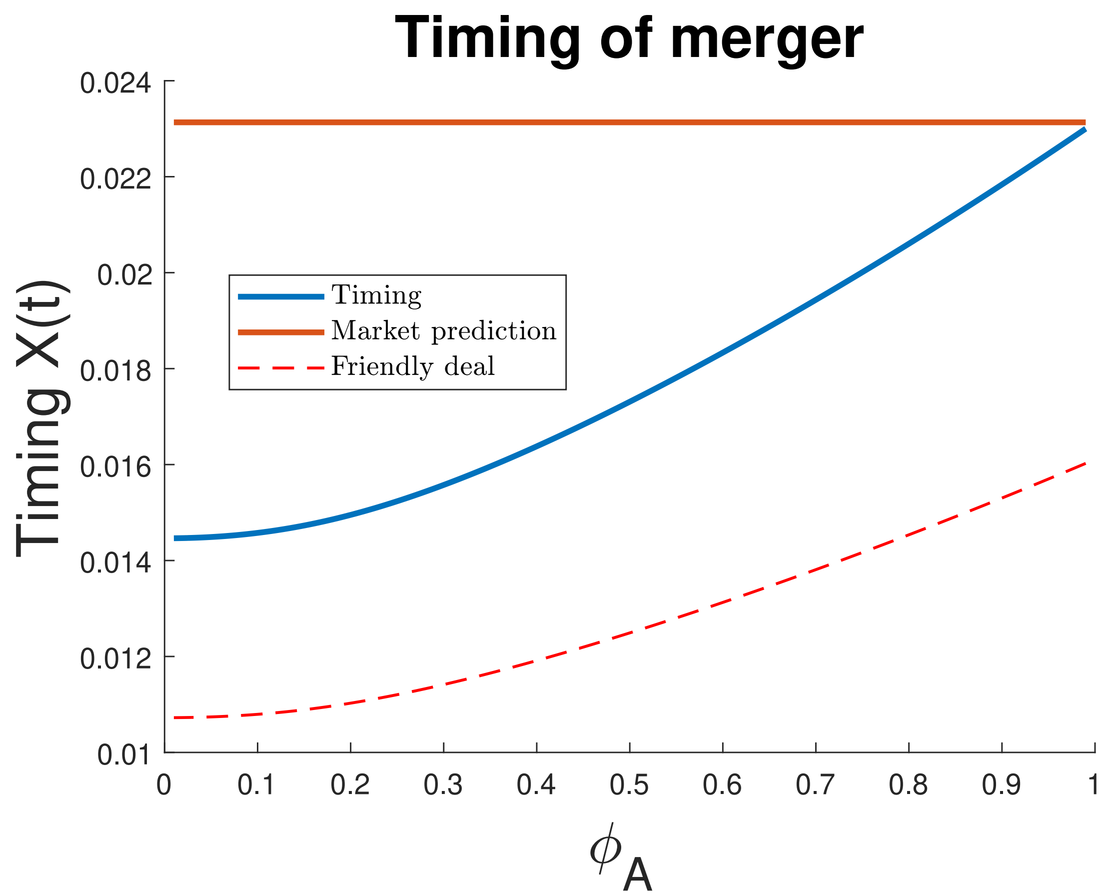

Figure D.5: **Timing in a hostile merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on the hostile merger's threshold x^* (blue). This figure also plots the market's prediction (red) and the friendly merger's threshold (dotted line). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

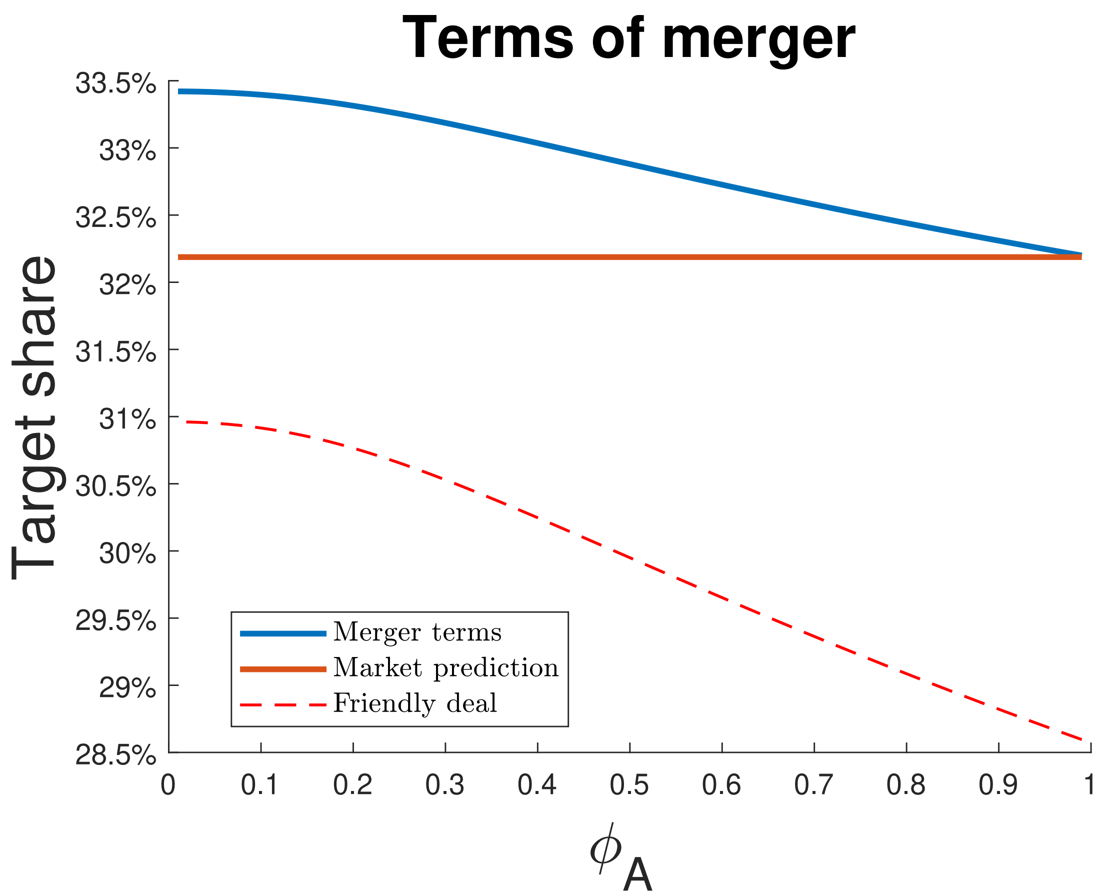

Figure D.6: **Terms in a hostile merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on the target's ownership share s_T (blue). This figure also plots the market's prediction (red) and the friendly merger's terms (dotted line). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

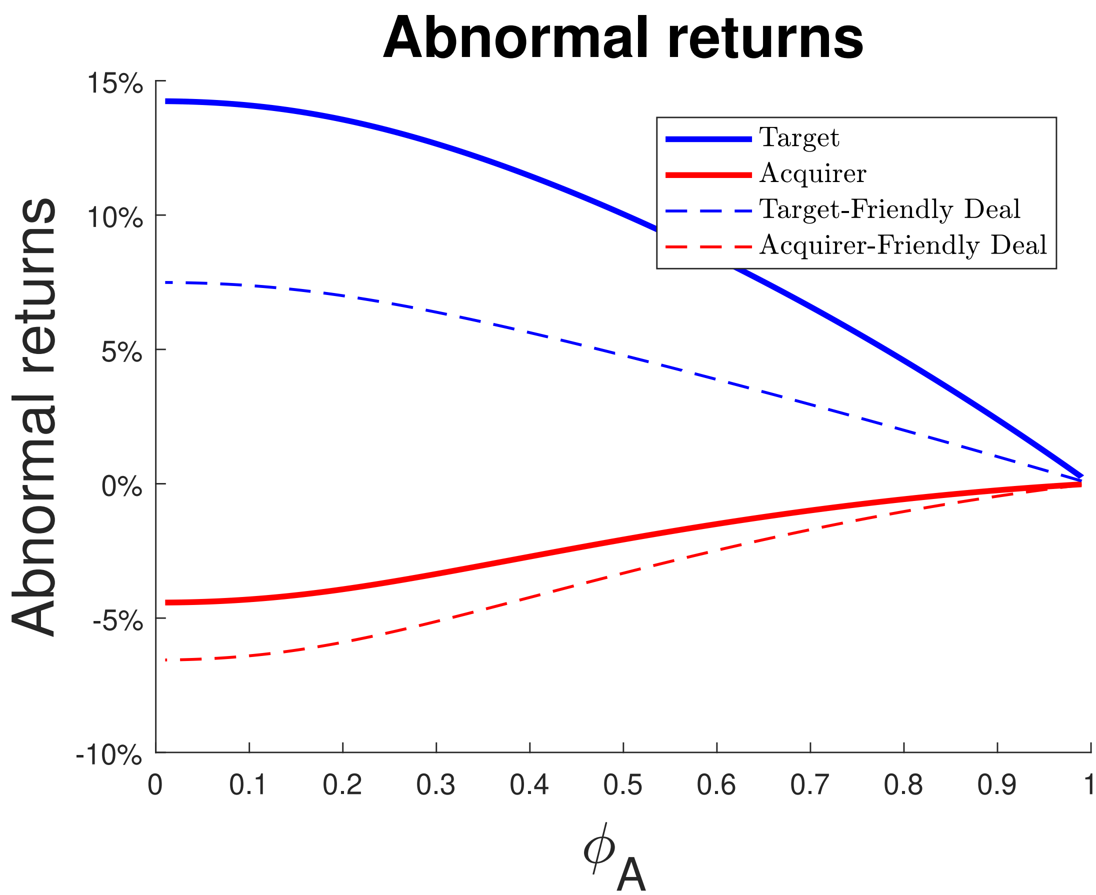

Figure D.7: **Abnormal returns in a hostile merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on return surprises. The figure plots acquirer's (red) and target's (blue) abnormal returns. Returns for friendly mergers are also shown (dotted line). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

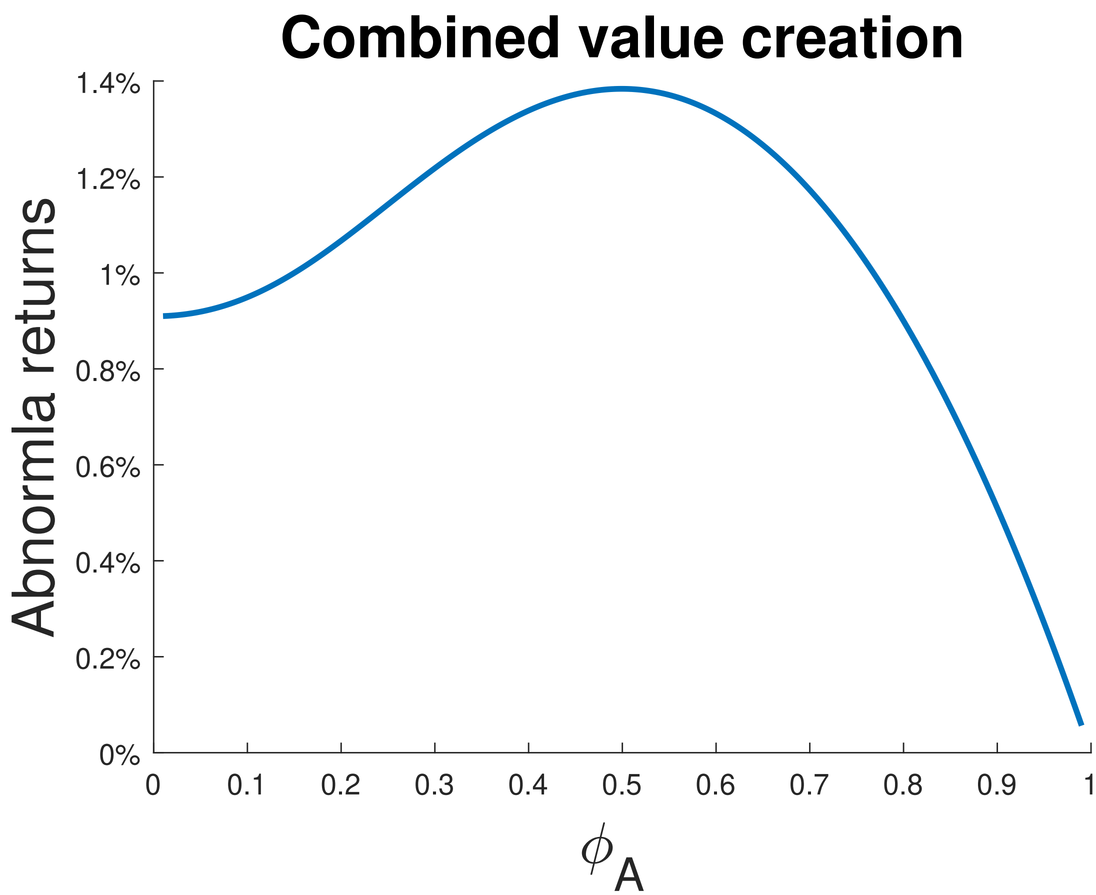

Figure D.8: **Value in a hostile merger**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on value creation. The figure plots combined abnormal returns (blue). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

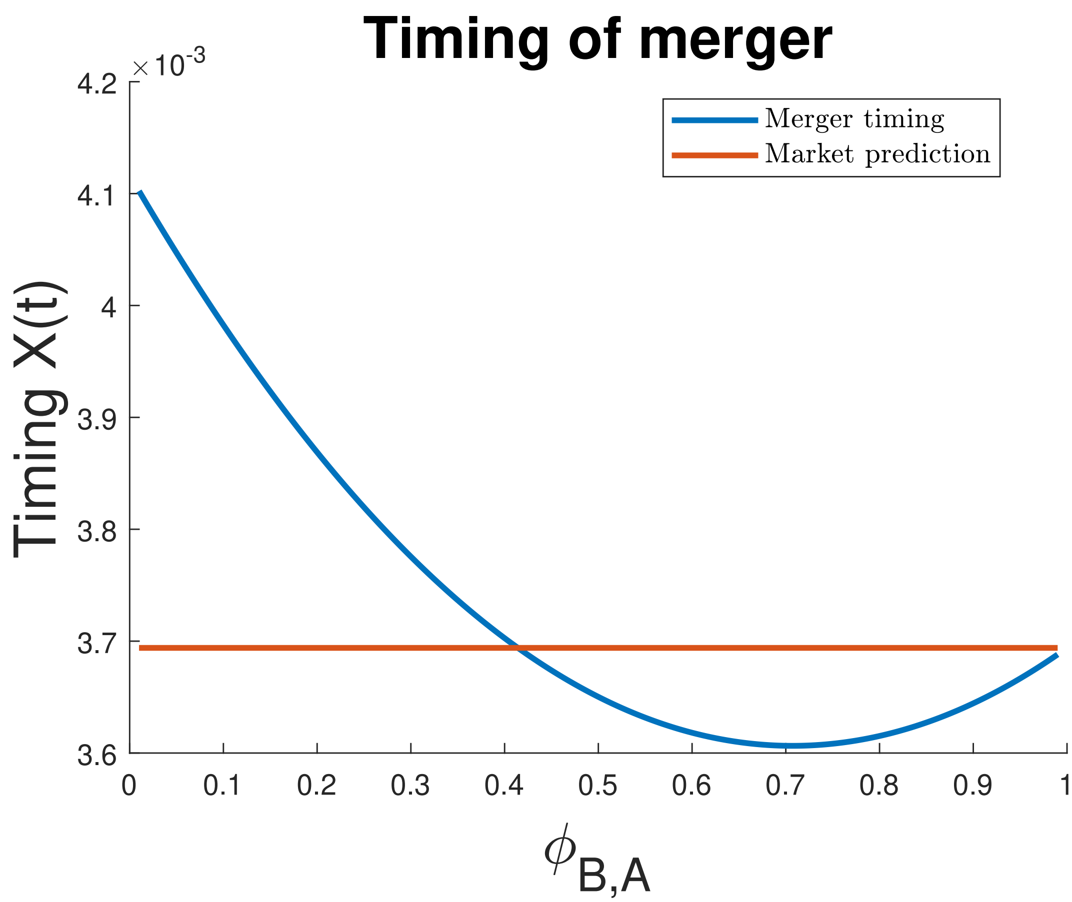

Figure D.9: **Timing in a friendly merger: Incomplete market**. This figure plots the effect that the acquirer's degree of overconfidence regarding the systematic component of volatility (measured by $\phi_{B,A}$) has on the friendly merger's threshold x^* (blue). This figure also plots the market's prediction (red). The parameters used are: $\sigma_Z = \sigma_B = \sigma_s = 0.2$, $\lambda = 0.1$, $\mu = \alpha = -0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, $\Pi_M = 4.2$

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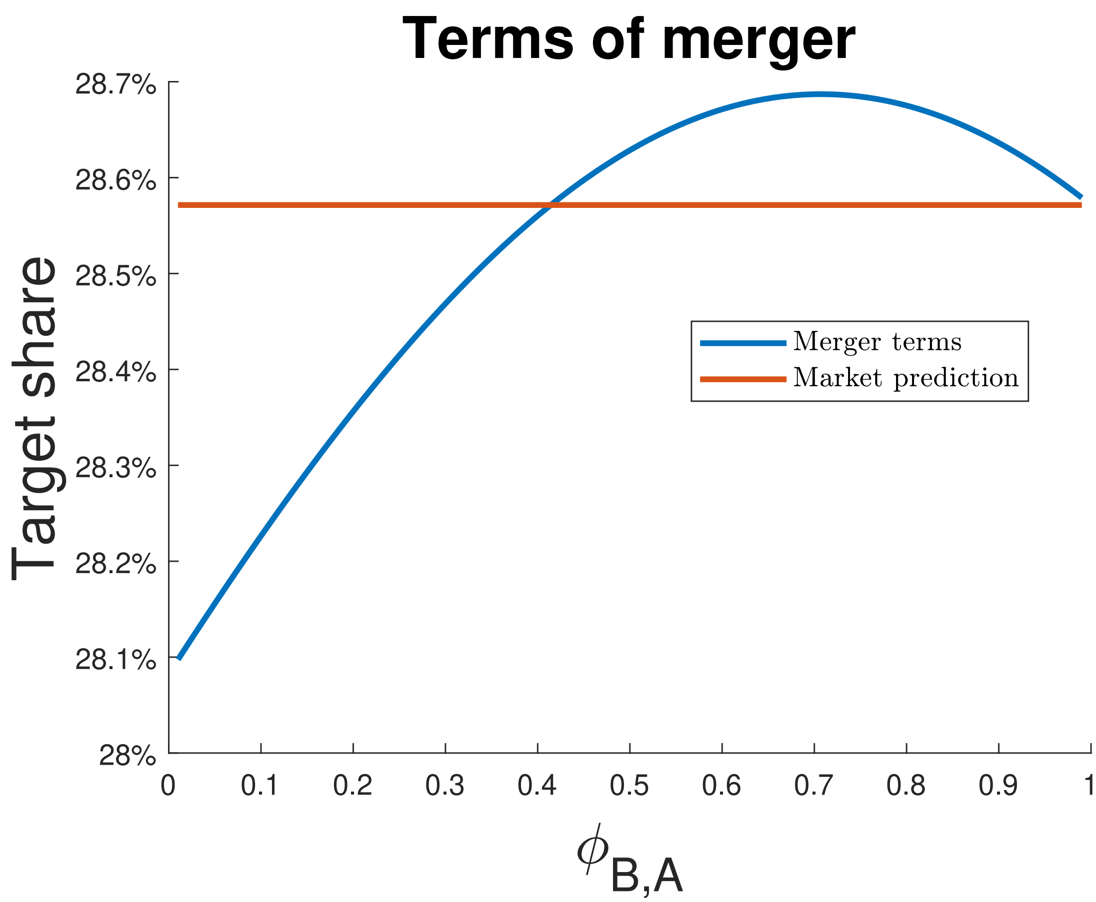

Figure D.10: **Terms in a friendly merger: Incomplete market**. This figure plots the effect that the acquirer's degree of overconfidence regarding the systematic component of volatility (measured by $\phi_{B,A}$) has on the target's ownership share s_T (blue). This figure also plots the market's prediction (red). The parameters used are: $\sigma_Z = \sigma_B = \sigma_s = 0.2$, $\lambda = 0.1$, $\mu = \alpha = -0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, $\Pi_M = 4.2$
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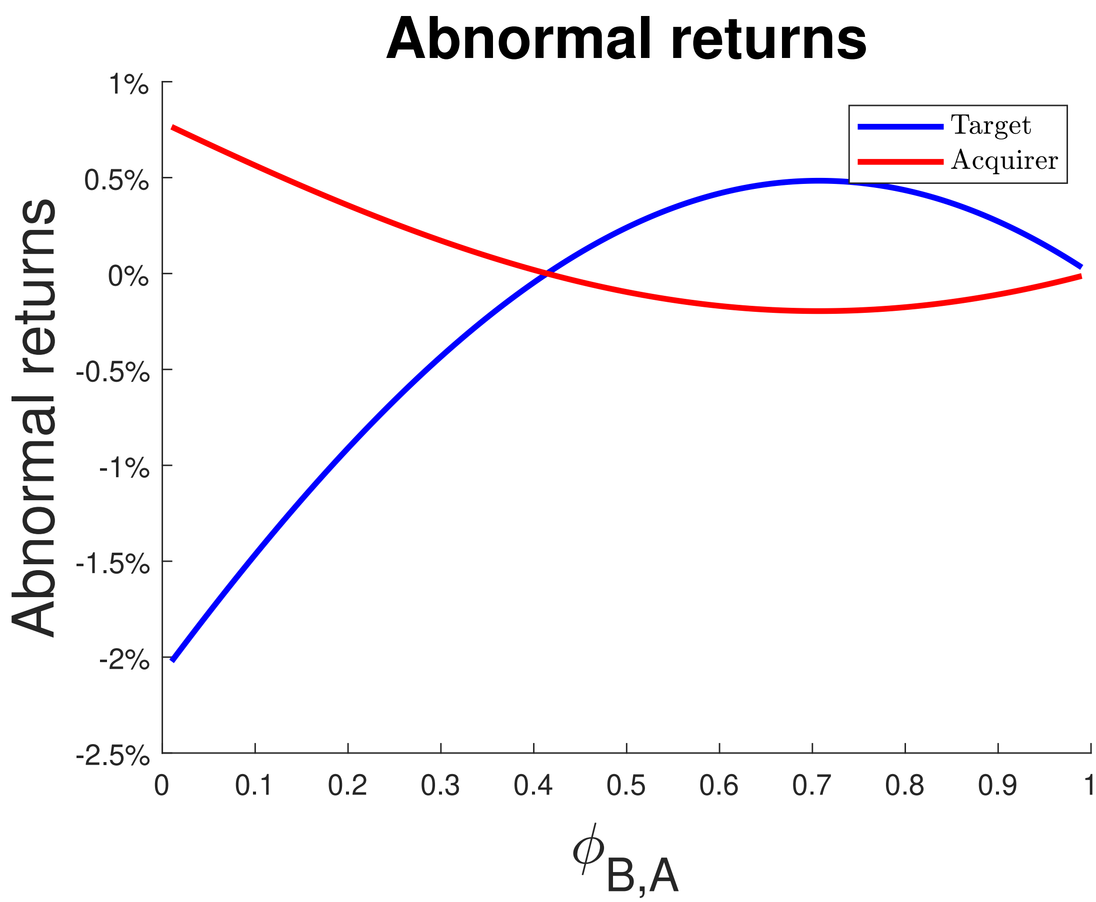

Figure D.11: **Abnormal returns in a friendly merger: Incomplete market**. This figure plots the effect that the acquirer's degree of overconfidence regarding the systematic component of volatility (measured by $\phi_{B,A}$) has on return surprises. The figure plots acquirer's (red) and target's (blue) abnormal returns. The parameters used are:$\sigma_Z = \sigma_B = \sigma_s = 0.2$, $\lambda = 0.1$, $\mu = \alpha = -0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, $\Pi_M = 4.2$
.

Appendix E: Alternative hostile negotiations

Section 2.4 assumes a negotiation strategy that increases the target's bargaining power. While this may be the case in situations where there are either strong takeover defense mechanisms or the target has credible outside options, such as multiple bidders competing for the target; there are other situations in which acquirers may, in fact, gain bargaining power as a result of hostile negotiations. Ahern 2012 explores one of these situations and shows that product market dependence between suppliers and customers plays an important role in establishing bargaining power in vertical deals. For example, an acquiring consumer could have high bargaining power when it can credibly threaten to stop purchasing the supplier's product if negotiations are unsuccessful.

In what follows, I explore the model's predictions for deals in which hostility increases the acquirer's bargaining power.

The value of each firm's takeover option follows equation (2.19). In this case, I assume a Stackelberg leader-follower game in which the acquirer now decides on the deal's term, and the target then decides on the timing. First, I obtain the target's optimal threshold by satisfying the following first-order condition:

$$\frac{\partial OT_T^T(X_t)}{\partial x_T} = 0 \tag{E.1}$$

The acquirer sets the terms of the deal by taking the threshold in equation (E.1) as a given. I obtain the target's optimal terms from the following first-order condition:

$$\frac{\partial OT_A^A(X_t)}{\partial s_A} = 0 \tag{E.2}$$

The timing and terms of this hostile takeover are given by:

$$x^* = \frac{\beta_A \lambda((\beta_T - 1)((r - \alpha)\phi - r + \mu)\Pi_A + \Pi_T \beta_T(\mu - \alpha))}{(\beta_A - 1)(\Pi_A - \Pi_M + \Pi_T)(\beta_T - 1)(\Pi_A + \Pi_T)} \tag{E.3}$$

$$s_T = \frac{(x^* * (\Pi_A + \Pi_T) - \lambda(\mu - \alpha))\beta_T - x^*(\Pi_A + \Pi_T))\Pi_T}{\Pi_M x^*(\beta_T - 1)(\Pi_A + \Pi_T)} \tag{E.4}$$

The key difference for this type of hostile deal is that targets obtain a lower share of the merged firm for all levels of overconfidence compared to friendly mergers. This relative increase in the acquirer's bargaining power leads to predictions that can differ substantially from the ones presented in section 2.4.

Qualitative predictions for the effect of overconfidence on this type of hostile negotiation are highly dependent on the numerical values used for the parameters, especially on managers' risk preferences. While most cases behave in concordance with section 2.4, it is possible to observe a convex effect on both the timing and terms of the deal. This leads to a non-monotonic effect on abnormal returns, the possibility for these returns to be lower than in friendly mergers, and value destruction for sufficiently high levels of overconfidence. In what follows, I present an example for risk-averse managers. The parameters used in this example[1] are $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

The first notable difference is that both the timing and terms of the deal do not vary monotonically with overconfidence. As figure E.1 shows, higher levels of overconfidence ($\phi_A \leq 0.14$) start delaying the merger. The terms of the deal are affected similarly, with figure E.2 showing that increases in overconfidence past $\phi_A = 0.14$ start decreasing the target´s share of the combined firm. An exciting implication

[1]For ease of comparison, I use the same parameters as appendix D.

of this convexity is that, for the target, there exists a non-trivial optimal level of acquirer´s overconfidence.

The convexity in the deal's terms and timing directly affect how abnormal returns behave. Even though returns are still negative (positive) for acquirers (targets), figure E.3 illustrates how, for high levels of overconfidence ($\phi_A \leq 0.14$), the effect on returns is reversed, and overconfidence starts increasing acquirer's returns while decreasing them for targets. This coincides with the reversal in both timing and terms. A notable difference with hostile takeovers modelled as in section 2.4 is that returns are not necessarily higher than the ones in a friendly merger. In this case, target returns are always lower than in a friendly lead.

Turning to value, illustrated in figure E.4, the effect overconfidence has on the acquirer's instantaneous growth rate for the stochastic shock X(t) gets amplified as a result of the increase in bargaining power, eventually leading to value destruction. For low levels of overconfidence ($\phi_A > 0.73$), value creation is observed. For levels $0.14 < \phi_A \leq 0.73$, the negative effect on the growth rate starts dominating, therefore, value starts to decrease due to overconfidence. This effect is strong enough to cause value destruction for $\phi_A \leq 0.47$. Finally, the reversal in the effects of both the timing and terms of the deal causes an increase in value as overconfidence increases for $\phi_A \leq 0.14$.

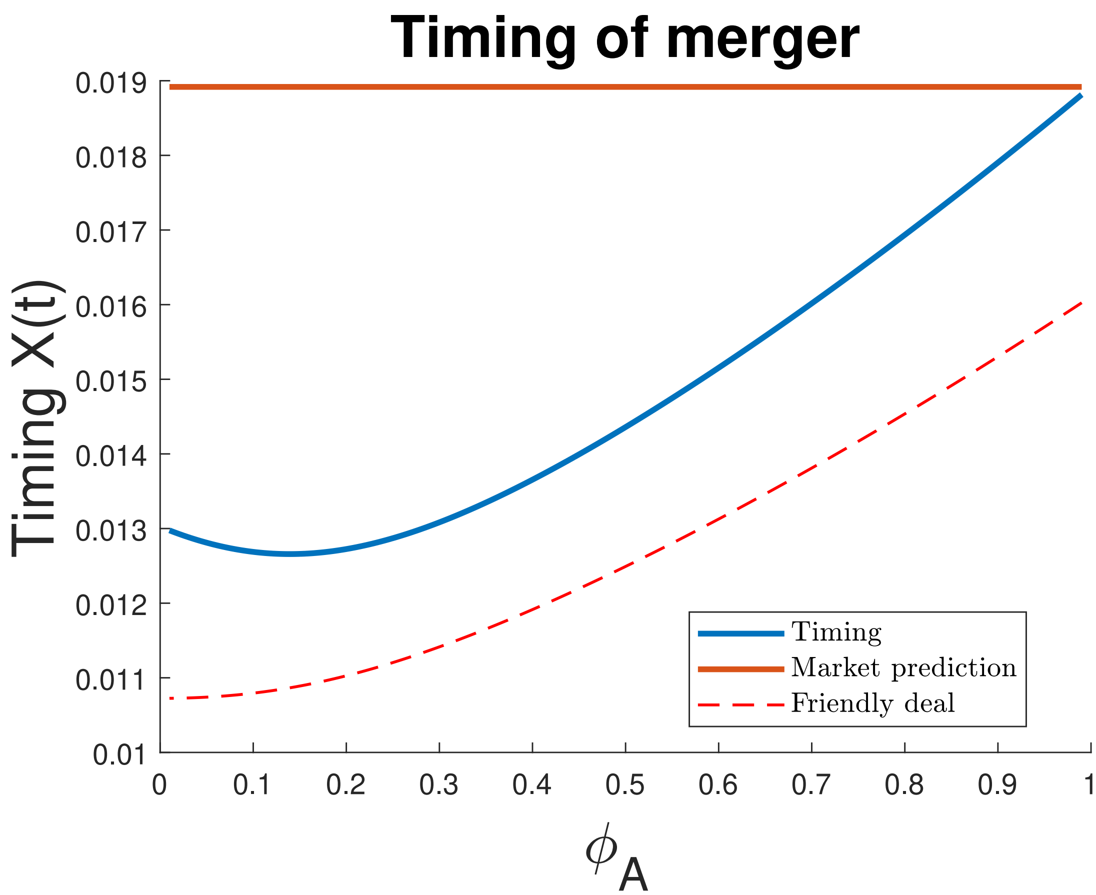

Figure E.1: **Timing in a hostile merger: alternative negotiations**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on the hostile merger's threshold x^* (blue). This figure also plots the market's prediction (red), and the friendly merger's threshold (dotted line). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

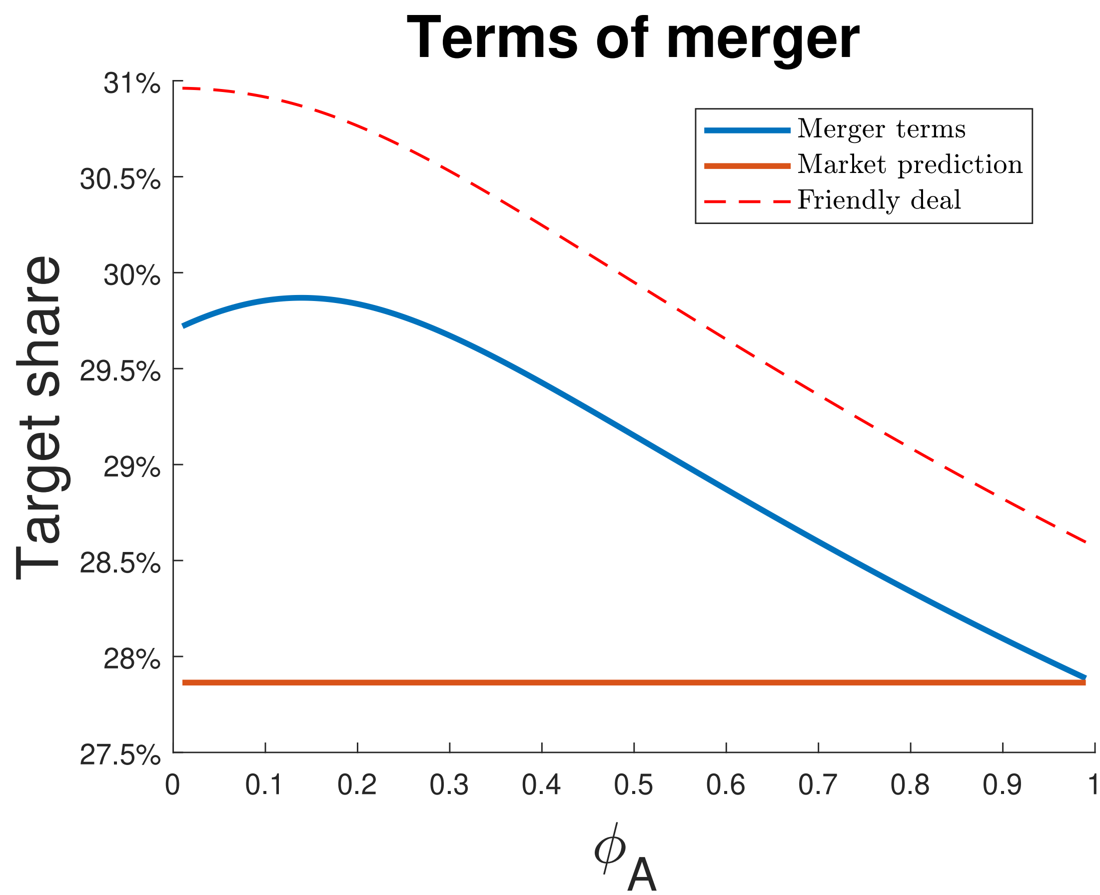

Figure E.2: **Terms in a hostile merger: alternative negotiations**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on the target's ownership share s_T (blue). This figure also plots the market's prediction (red), and the friendly merger's terms (dotted line). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

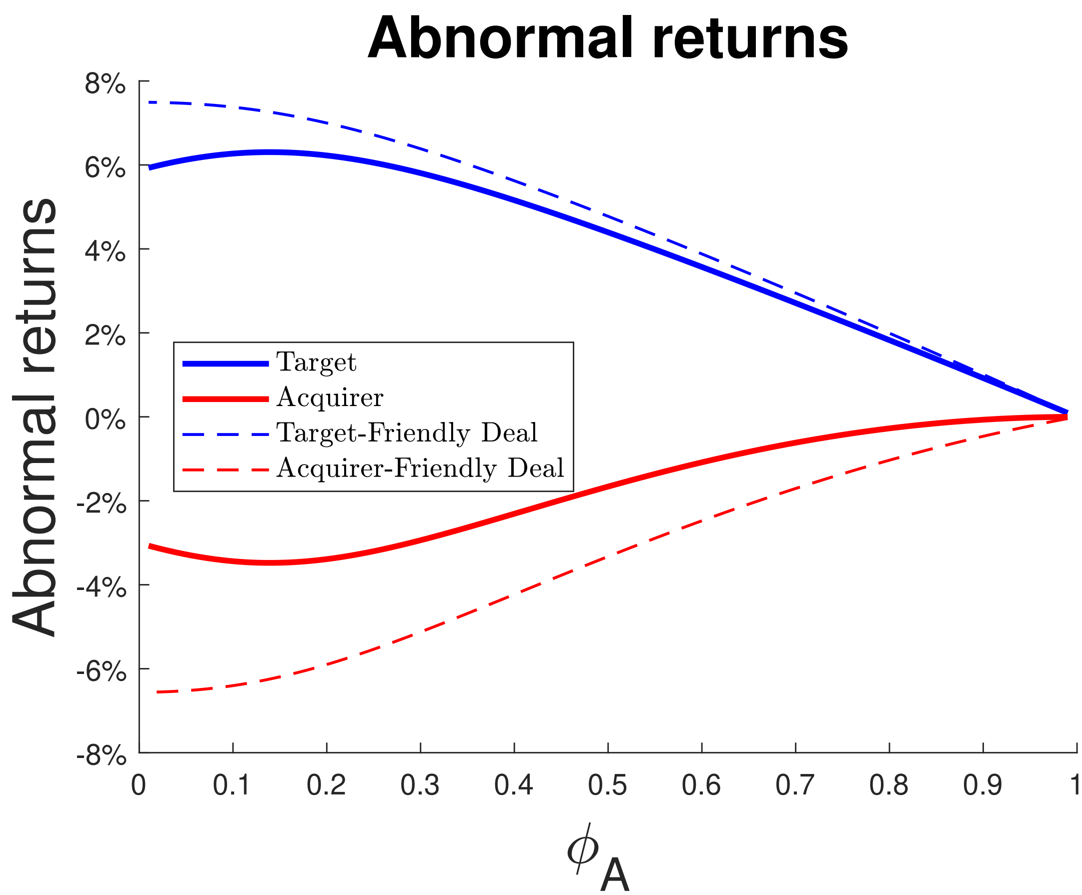

Figure E.3: **Abnormal returns in a hostile merger: alternative negotiations**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on return surprises. The figure plots acquirer's (red) and target's (blue) abnormal returns. Returns for friendly mergers are also shown (dotted line). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

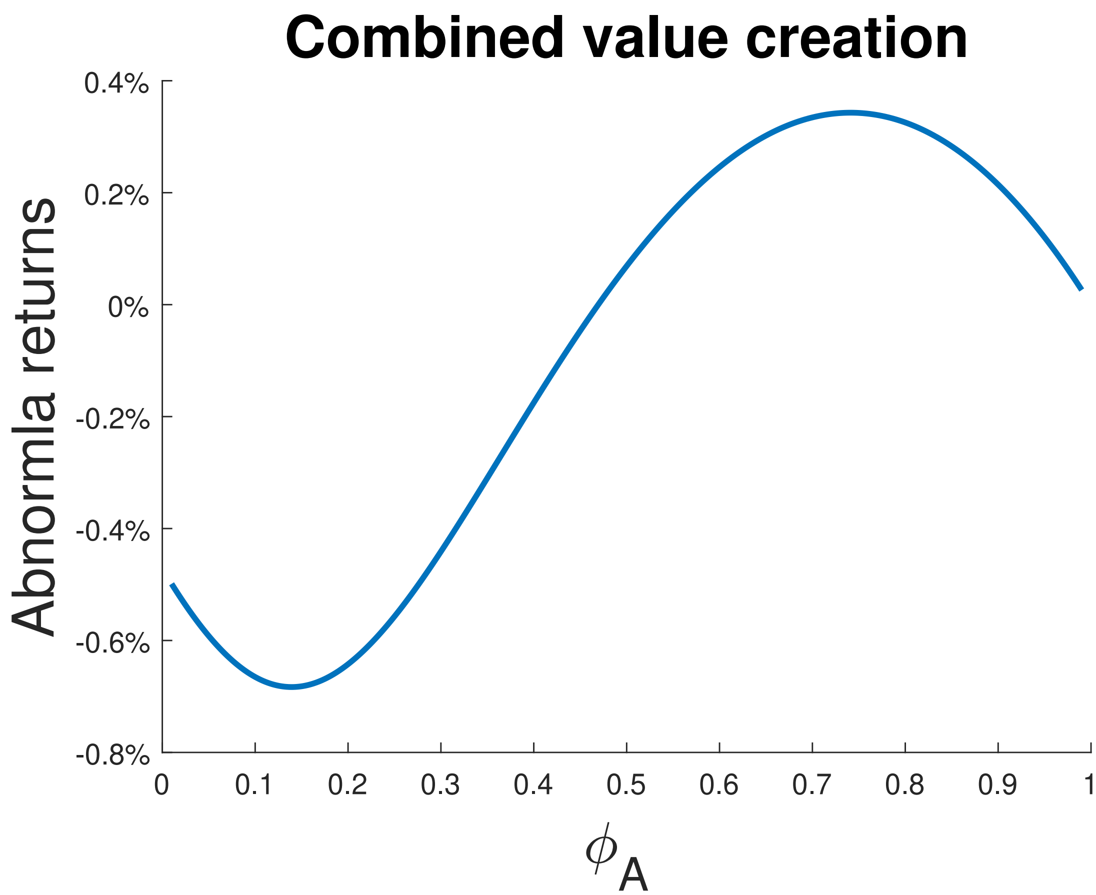

Figure E.4: **Value in a hostile merger: alternative negotiations**. This figure plots the effect that the acquirer's degree of overconfidence (measured by ϕ_A) has on value creation. The figure plots combined abnormal returns (blue). The parameters used are: $\alpha = 0.09$, $r = 0.06$, $\sigma = 0.2$, $\lambda = 0.1$, $\mu = 0.02$, $\Pi_A = 2.5$, $\Pi_T = 1$, and $\Pi_M = 4.2$.

Appendix F: Value of the option to merge: mean-reverting process

This appendix derives the value for the option to merge used in Chapter 3. I closely follow the derivation in (Scheinkman and Xiong 2003).

Let the value of the option to merge be $OM_i(X(t))$. Ito's lemma shows that $OM_i(X(t))$ satisfies the following equation:

$$dOM_i = \frac{dOM_i}{dX(t)} dX(t) + \frac{1}{2} \frac{d^2 OM_i}{dX(t)^2} (dX(t))^2 \tag{F.1}$$

Given the stochastic process in equation (3.4), equation (F.1) can be written as:

$$dOM_i = \frac{dOM_i}{dX(t)} (-\kappa(X(t) - \overline{f})dt + \frac{\gamma_i}{\sigma_P} dB_t^P + \frac{\gamma_i}{\phi_i \sigma_S} dB_t^S) + \frac{1}{2} \frac{d^2 OM_i}{dX(t)^2} ((\frac{\gamma_i}{\sigma_P})^2 + (\frac{\gamma_i}{\phi_i \sigma_S})^2) dt \tag{F.2}$$

The value of the option to merge must satisfy the following no-arbitrage condition:

$$rOM_i(X(t)) = \frac{dOM_i}{dX(t)} (-\kappa(X(t) - \overline{f})) + \frac{1}{2} \frac{d^2 OM_i}{dX(t)^2} ((\frac{\gamma_i}{\sigma_P})^2 + (\frac{\gamma_i}{\phi_i \sigma_S})^2) \tag{F.3}$$

replacing $\sigma_{\phi_i}^2 = (\frac{\gamma_i}{\sigma_P})^2 + (\frac{\gamma_i}{\phi_i \sigma_S})^2$ gives equation (3.8).

Under the following transformation:

$$Y(t) = \kappa \frac{(\overline{f} - X(t))^2}{\sigma_{\phi_i}^2} \tag{F.4}$$

It is straightforward to verify that $OM_i(X(t)) = g(Y(t))$ solves the following equation:

$$Y(t) * g''(Y(t)) + (\frac{1}{2} - Y(t))g'(Y(t)) - \frac{r}{2\kappa}g(Y(t)) = 0 \tag{F.5}$$

Equation (F.9) is known as Kummer's equation, which has two independent solutions (see Abramowitz and Stegun 1964):

$$M(\frac{r}{2\kappa}, \frac{1}{2}, Y(t)) = 1 + \frac{\frac{r}{2\kappa}Y(t)}{\frac{1}{2}} + \frac{(\frac{r}{2\kappa})_2 Y^2(t)}{(\frac{1}{2})_2 2!} + ... + \frac{(\frac{r}{2\kappa})_n Y^n(t)}{(\frac{1}{2})_n n!} + ... \tag{F.6}$$

$$U(\frac{r}{2\kappa}, \frac{1}{2}, Y(t)) = \frac{\pi}{sin(\frac{\pi}{2})}\{\frac{M(\frac{r}{2\kappa}, \frac{1}{2}, Y(t))}{\Gamma(1 + \frac{r}{2\kappa} - \frac{1}{2})\Gamma(\frac{1}{2})} - Y(t)^{\frac{1}{2}}\frac{M(1 + \frac{r}{2\kappa} - \frac{1}{2}, \frac{3}{2}, Y(t))}{\Gamma(\frac{r}{2\kappa})\Gamma(\frac{3}{2})}\} \tag{F.7}$$

Where $(c)_n$ in equation (F.6) is defined as:

$$(c)_n = c(c+1)(c+2)...(c+n-1), (c)_0 = 1 \tag{F.8}$$

A general solution for equation (F.9) can be written as

$$g(Y(t)) = \alpha M(\frac{r}{2\kappa}, \frac{1}{2}, Y(t)) + \beta U(\frac{r}{2\kappa}, \frac{1}{2}, Y(t)) \tag{F.9}$$

Given that the transformation in equation (F.4) maps only to positive values for Y, it is necessary to construct two solutions for $OM_i(X(t))$:

$$OM_i(X(t)) = \begin{cases} \alpha_1 M(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma^2_{\phi_i}}) + \beta_1 U(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma^2_{\phi_i}}) & X(t) \leq \overline{f} \\ \alpha_2 M(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma^2_{\phi_i}}) + \beta_2 U(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma^2_{\phi_i}}) & X(t) > \overline{f} \end{cases} \tag{F.10}$$

The constants $(\alpha_1, \alpha_2, \beta_1, \beta_2)$ are obtained as follows. First, given that $OM_i(X(t))$ must be positive and increasing for $X(t) \leq \overline{f}$, and that $M(\frac{r}{2\kappa}, \frac{1}{2}, \kappa\frac{(\overline{f}-X(t))^2}{\sigma^2_{\phi_i}})$ is decreasing in $X(t)$ for $X(t) \leq \overline{f}$, α_1 must be equal to 0.

Second, the function and its derivative must be continuous at the point $X(t) = \overline{f}$, which leads to the following values:

$$\alpha_2 = \beta_1 \frac{2\pi}{\Gamma(\frac{1}{2} + \frac{r}{2\kappa})\Gamma(\frac{1}{2})}, \quad \beta_2 = -\beta_1 \tag{F.11}$$

Equation (F.10) represents the value of the option to merge before the merger occurs ($X(t) < x_i^*$). In the main document, and for ease of notation, I factor out $\beta_1 = \beta_i$ such that:

$$OM_i(X(t)) = \beta_i h_i(X(t)), \quad X(t) < x_i^* \tag{F.12}$$

with $h_i(X(t))$ as in equation (3.10). At the point of the merger, the value of the option to merge must be equal to the payoff in equation (3.6).

$$OM_i(X(t)) = s_i \Pi_M (\frac{X(t)}{r+\kappa} + \frac{\kappa \overline{f}}{r(r+\kappa)}) - \frac{\Pi_i}{r}, \quad X(t) \geq x_i^* \tag{F.13}$$

Combining (F.12) and (F.13) gives equation (3.9).

Appendix G: Value of the option to invest

Let $F(X)$ be the value of an option to invest (for ease of notation, I omit time dependency of X_t). Using Ito's Lemma:

$$dF = \frac{dF}{dX}dX + 0.5\frac{d^2F}{dX^2}dX^2 \tag{G.1}$$

By substituting X from equation (4.1), the expected value of dF is equal to:

$$E[dF] = \mu_n \frac{dF}{dX}Xdt + 0.5\frac{d^2F}{dX^2}\sigma_n^2 X^2 dt \tag{G.2}$$

Using the fact that the total expected return of the investment opportunity over a dt time interval is equal to $rFdt$, I can rewrite (G.2) as:

$$\mu_n \frac{dF}{dX}X + 0.5\frac{d^2F}{dX^2}\sigma_n^2 X^2 - rF = 0 \tag{G.3}$$

The differential equation (G.3) has a general solution of the form $F(X) = aX^{\gamma_n} + bX^{\nu_n}$, with $\gamma_n < 0$ and $\nu_n > 1$ solutions for p_n in the quadratic equation $(\mu_n)p_n + 0.5\sigma_n^2 p_n(p_n - 1) - r = 0$. By imposing the boundary condition $lim_{X \to 0}F(X) = 0$, I obtain the general form for the value of the option to invest $F(X) = bX^{\nu_n}$.

To obtain b, I impose one additional condition, usually called "value matching". Assuming that the option is executed at $X = x_n$, the option's value when executed must be equal to the present value of the project minus the investment cost I.

$$bx_n^{\nu_1} = x_n - I \tag{G.4}$$

Solving for b and plugging it back to $F(X)$ gives[1]:

$$F(X) = \begin{cases} (x_n - I)(\frac{X}{x_n})^{\nu_n}, & X < x_n \\ (X - I), & X \geq x_n \end{cases} \tag{G.5}$$

To obtain the optimal investment timing x_n^*, a "smooth pasting" condition requires that at the point it is executed, the derivative of $F(X)$ must be equal to the derivative of the project's payoff $X - I$.

$$\nu_n b(x_n^*)^{\nu_n - 1} = 1 \tag{G.6}$$

solving for x_n^* gives the optimal investment time in equation (4.6).

$$x_n^* = \frac{\nu_n}{\nu_n - 1} I \tag{G.7}$$

[1]Since the option is executed at x_n, for all $X > x_n$ the value of the options must be equal to its payoff.