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Applications of Strategic Real Options in Finance

by

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Thesis

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Declarations

I declare that any material contained in this thesis has not been submitted for a degree to any other university. I further declare that Chapters 2 and 3 of this thesis are co-authored with A. Elizabeth Whalley.

Zhou Zhang February, 2020

Abstract

This thesis consists of three essays. In the first essay (Chapter 2) co-authored with A. Elizabeth Whalley, we incorporate optimism about future growth prospects into a real-options duopolistic setting. We show that optimism can change entry order: a more optimistic firm may enter first even if its competitor has higher profitability. Becoming a leader directly generates monopoly profits as extra benefit but potentially at a cost of losing some value of waiting. Furthermore, in contrast to the impact of optimism in non-competitive settings where optimism accelerates investment, a leader's optimism in duopolistic competition when it needs to enter pre-emptively could delay investment. Since optimism shortens the rival's monopoly period, it alleviates the pre-emption pressure from its rival which enables the firm to capture greater option value. Optimism can thus increase the firm's value even from a rational perspective.

The second essay (Chapter 3) is also co-authored with A. Elizabeth Whalley. In a duopoly entry game, we consider a delegated management problem where rational shareholders can hire managers with particular levels of optimism. We find that in equilibrium at most one firm (i.e. the leader) would wish to hire an optimistic manager and that optimism is benefial to the leader only when the two firms are close competitors. Defining a firm's first-mover advantage as its monopolistic profitability relative to duopolistic profitability, we find that the firm with relatively lower first-mover advantage compared to its rival would hire an optimistic manager and thus become the leader in equilibrium. Lower first-mover advantage implies the firm's monopoly profits account for a smaller portion of its value of being the leader. Therefore, its rival's optimism is less effective in discouraging the firm by reducing its leader's value.

The third essay (Chapter 4) is solo-authored which investigates the role of investment reversibility in determining the relation between product market competition and stock returns. We develop a unified real-option framework involving corporate investment and disinvestment decisions in a continuous-time Cournot-Nash equilibrium. The model predicts that stock returns are more negatively correlated with the level of competition when investment is more reversible. We use asset redeployability as a measure of investment reversibility and find robust empirical evidence supporting our theoretical prediction. This paper provides a new perspective (i.e. investment reversibility) to understand the competition-return relation which has mixed evidence in the existing literature.

Chapter 1

Introduction

The thesis consists of three essays with applications of strategic real options in Finance. Chapter 2 studies the effects of entrepreneurial optimism on firms' investment timing and values under the setting of duopoly. As an extension, Chapter 3 further investigates the equilibrium levels of managerial optimism if rational shareholders could hire managers with particular levels of optimism. Chapter 4 shows that investment reversibility can help explain the relationship between competition and stock returns both theoretically and empirically.

Empirical studies show that entrepreneurs are optimistic rather than realistic as widely assumed in existing models [Puri and Robinson, 2013; Cooper et al., 1988; Landier and Thesmar, 2008]. This personality trait is found to be inherent as entrepreneurs already have such behavioural bias before they become self-employed [Dawson and Henley, 2013]. In the absence of competition, optimism accelerates investment since optimistic entrepreneurs overestimate the present value of cash flows generated by the new project [Hackbarth, 2009].

In Chapter 2, we further incorporate duopolistic competition and consider a strategic entry game between two firms. Specifically, the firm which enters first is the leader and temporarily monopolises the market until the other firm (follower) enters. Investment timing decisions are made by entrepreneurs. They maximise their perceived net present value of the investment by taking into account the other firm's best response. Assuming one entrepreneur is optimistic and the other entrepreneur is rational ¹, we examine the effects of optimism by comparing it with the benchmark case where both entrepreneurs are rational. We also assume that the two firms could have different investment costs and profitabilities as a monopolist or a duopolist.

We first analyse the symmetric case where the two firms are identical except for entrepreneurial optimism. We find that the firm run by an optimistic entrepreneur will enter earlier than the firm run by a rational entrepreneur but at a higher threshold than if neither firm were optimistic. This is in contrast to the results that optimism decreases investment thresholds in the non-competitive setting. Then we consider asymmetric firms with different combinations of monopolistic and duopolistic profitabilities. In general, it is more likely for the optimist to be the leader which implies that optimism can compensate for a competitive disadvantage in costs and revenues in determining the entry order. Entrepreneurial optimism can also be value-enhancing to rational outside investors in two scenarios. One scenario is when optimism makes the firm become the leader from being the follower as long as monopoly profits outweights the lost value of waiting. The other scenario is when optimism defers the rival's pre-emption which enables the firm to realise more real options value as leader. In addition, we also consider the case when both entrepreneurs are optimistic. Compared with identical positive optimism case, further increases in one entrepreneur's optimism can be beneficial to its rival when the two firms are close competitors. Although a higher level of optimism makes the rival lose the opportunity to be the leader, the rival can retain more value of waiting as follower.

Nowadays, management is separated from ownership in large corporations. Therefore, in most cases, investment decisions are made by more skilled and experienced managers instead of entrepreneurs/shareholders. Given the potential benefits

¹The two entrepreneurs have perfect information on each other's beliefs (i.e. levels of optimism).

of optimism we find in Chapter 2, shareholders may consider increasing a firm's competitive advantage by hiring an optimistic manager. We aim to find out the desired levels of optimism in equilibrium in Chapter 3. This has important implications for explaining the wide prevalence of optimistic managers. Our results may suggest a new angle (i.e. a strategic aspect) to understand this phenomenon. Further, by considering asymmetric firms, we may draw conclusions for which types of firms are most likely to end up with optimistic managers.

Based on the model in Chapter 2, we assume that shareholders are realistic but can hire optimistic managers. Both firms are able to choose from a pool of managers with different levels of optimism. We also assume there is no information asymmetry on managers' optimism between shareholders and managers. Shareholders maximise the firms' values from their point of view (i.e. from rational perpectives).

We use numerical iteration to find the equilibrium levels of optimism. We show that in equilibrium the firm which enters the market second always prefers a rational manager. This implies that at most one firm (the leader) is likely to hire an optimistic manager. Optimism is beneficial to the leader only when the two firms are close competitors. Moreover, we find that the weak firm in terms of overall profitability can finally become the leader by hiring an optimistic manager whereas the strong firm can never fight back by doing so. We define the firstmover advantage (FMA) as the instantaneous monopolistic profit of the firm over its duopolistic profit. We prove that optimism has a stronger effect in threatening the rival and thus reducing the rival's pre-emptive incentive if the rival has a relatively higher FMA. The reason is that monopoly profits constitutes an important part of total profits if the firm's FMA is high. The firm's value of being the leader thus significantly depends on the length of the period over which it can be a temporary monopolist. Therefore, the firm with relatively lower FMA which is less sensitive to the rival's optimism could eventually win and become the leader by hiring an optimistic manager.

In Chapter 4, we study how the effect of competition on stock returns depends on investment reversibility. The relationship between product market competition and stock returns constantly receives attention in the literature. However, mixed evidence has been found². Our paper provides more thorough understanding of this relation by taking into account investment reversibility.

We develop a real options model with Cournot competition to analyse firms' systematic risk. We assume that the investment cost can be partially recovered which suggests firms own disinvestment options in addition to investment options. Since competition accelerates investment but delays disinvestment under uncertainty regarding market demand, the associated expansion (contraction) option values are lower (higher) for firms in industries with more intense competition. Generally, expansion (contraction) options increase (decrease) firms' riskiness and these effects are stronger when the options are more valuable. Thus, firms' risk decreases with the level of competition if we consider only the expansion and contraction options held by firms (the *real option effect*). Notably, as market demand declines, contraction options become more important which predicts a negative relation between competition and firms' risk. This is in contrast to Aguerrevere [2009].

On the other hand, we also incorporate firms' assets in place. By introducing production costs, we define a firm's operating leverage as the present value of production costs over the total value of the firm as in Aguerrevere [2009]. As competition reduces profit margins, operating leverage would be higher for firms in more competitive industries. Note that firms' risk also increases with their operating leverage (the *operating leverage effect*) which works in the opposite direction to the real option effect. If investment reversibility is higher, the firm is more likely to adjust its capacity according to the market demand and thus is less sensitive to the

 $^{^{2}}$ Hou and Robinson [2006] find a positive relation whereas Bustamante and Donangelo [2017] show that the competition-return should be negative. We also find insignicant effect of competition on stock returns in our sample.

risk arising from assets in place. In this case, the operating leverage effect corresponding to assets in place has been weakened and the real option effect dominates. Therefore, we predict that stock returns are more negatively correlated with the level of competition when investment is more reversible.

Then we empirically test our model's prediction. Using asset redeployability³ as the measure of investment reversibility, we find a significantly negative interaction effect between competition and investment reversibility on stock returns. This is consistent with our theory. Our results are also robust to alternative measures of competition and investment reversibility. To sum up, this paper highlights the role of investment reversibility in determining the competition-return relation.

 $^{^{3}}$ This measure is developed by Kim and Kung [2016] who use it as an inverse measure of investment irreversibility and also link it to real options theory.

Chapter 2

Optimism, Investment Timing and Valuation in Duopoly

2.1 Introduction

Empirical studies have consistently found that entrepreneurs are more optimistic than the general population [Puri and Robinson, 2013; Cooper et al., 1988; Landier and Thesmar, 2008] and that they were so even before they became self-employed [Dawson and Henley, 2013], consistent with the idea that optimism is an inherent trait. Existing studies of the impact of decision-makers' inherent optimism on investment decisions such as Hackbarth [2009] show optimism decreases investment thresholds, bringing forward investment, because of the greater perceived present value of future cash flows arising from the project. In this chapter we take into account strategic interactions between firms and use real options analysis to investigate the impact of entrepreneurial inherent optimism on the entry order, investment thresholds and its option values in a duopoly setting.

We start by considering otherwise identical firms (with the same entry costs and revenues after entry, both as temporary monopolists and as duopolists in the long run) and show that if one firm is run by an optimistic entrepreneur and the other by a non-optimisitc (realistic) entrepreneur, then the optimist will enter first and thus enjoy temporarily higher monopolistic profits. Moreover, if he enters in order to pre-empt the realist (which will be the case if the entrepreneur's optimism level is not too great), the optimist will enter at a higher threshold than an equivalent firm run by a non-optimistic entrepreneur, in stark contrast to the results in a noncompetitive setting.

We then generalise to consider competition between two asymmetric firms which may have different levels of profitability, both as monopolist and duopolist, and different investment costs for entering the market initially. Here we show that an entrepreneur's optimism can move him earlier in the entry order. As shown by Kong and Kwok [2007], in the absence of optimism, which firm enters first depends on the firms' relative advantages in both monopoly and duopoly settings. Considering two firms, A and B, if one firm (B) dominates in both duopoly and monopoly market entry, this firm will enter first; however a sufficiently strong advantage as a duopolist can outweigh a disadvantage as a monopolist, and vice versa. We show that optimism can change the entry order when the relative competitive strengths of the two firms are similar (*i.e.* the thresholds at which each firm is willing to preempt its competitor in order to enter the market as leader are close). If the weaker firm (A) is run by an optimistic entrepreneur, this optimism can compensate for the firm's competitive disadvantage in profitability. The firm run by a realist (B)can be stronger as both a monopolist and in duopoly and yet will still not enter the market first.

The reason for this is that Firm A's optimism discourages pre-emption by its realistic rival. Firm A's optimism inflates its estimates of future value; this is why it enters at a lower threshold in the absence of competitive pressure [Hackbarth, 2009]. In a duopoly setting, this result remains true when the optimist is the follower: the more optimistic an entrepreneur is about future revenue growth, the earlier it enters as second mover. However, this earlier entry by the optimistic entrepreneur (A) reduces the time over which a realistic first entrant would enjoy higher monopoly profits and thus decreases the realistic competitor (B)'s value of entering the market as leader. The threshold at which the realist B will be willing to pre-empt and enter as first mover thus *increases* with Firm A's optimism. On the other hand, a greater level of optimism reduces the optimist's pre-emption threshold. Thus A's optimism decreases A's and increases B's thresholds. In this case, even if the realistic firm has a competitive advantage in profitability (i.e. B's pre-emptive threshold would be lower than A's pre-emptive threshold if A and B were both realistic), optimism is likely to reverse the exercise order: an optimistic A may be willing and able to pre-empt B and enter the market first. Moreover, as long as B's pre-emption threat is still effective¹, the optimistic A will only enter the market just before demand hits B's pre-emption threshold. Therefore, increases in A's optimism can delay A's pre-emptive entry.

Given the difference that optimism could make in investment timing, we further explore the effects on the firms' valuation. Entrepreneurs maximise their perceived values while making decisions. In fact, this could be detrimental to the firms if entrepreneurs have behavioural biases. For example, in the absence of competition, an optimistic entrepreneur always makes sub-optimal investment decisions which reduce the firm's value from a rational perspective. This generates important implications for how outside investors would value the firm if outside investors are assumed to be rational. Outside equity holders care about whether they should pay more or less for their holdings if this firm run by an optimistic entrepreneur. Under the competitive setting, outside equity holders may also consider the rival's optimism level. To show the effects of optimism on both firms, we compare the rational values when one entrepreneur is optimistic with the benchmark where both entrepreneurs are rational. We show that, in duopoly, optimism can increase the

¹If B completely loses its incentive to be the leader due to A's optimism or B's pre-emptive threshold is even higher than A's optimal leader threshold, then A can enter at its perceived optimal leader threshold which decreases with A's optimism. This is discussed in greater detail in Section 2.3.

firm's rational value by deferring the rival's pre-emption. One scenario for why this occurs is that A, the firm which would be the follower if both entrepreneurs were rational, becomes the leader as A's optimism increases. This is because A can earn extra monopoly profits. However, becoming the leader is not beneficial for rational outside investors in all cases. If pre-empting its rival is too costly (e.g. entering at an extremely low threshold in order to be the first mover), the lost value of waiting outweighs the additional monopoly profits. The other scenario is that A is able to delay its investment as leader. Intuitively, even if A is stronger in terms of overall profitability in monopoly and duopoly, as long as A and B are close competitors (i.e. B creates pre-emptive pressure on A), A cannot wait until its optimal leader threshold to invest but will just pre-empt B. This implies that A's investment timing is constrained by B's pre-emptive threshold and thus A loses part of its option value of waiting. To some extent, A's optimism relieves the pressure from B's pre-emption, which enables A to capture a greater value of waiting.

In addition, we also investigate the effects of differential optimism (i.e. when both entrepreneurs are optimistic but A is more optimistic than B) on the two firms' values. Compared with the case where A and B have the same level of optimism, we find that increases in A's optimism can also be beneficial to B from a rational perspective. This happens when the two firms are close competitors and B successfully enters first if both entrepreneurs have the same level of optimism. Less option value can be retained for closer competitors as the pre-emptive pressure from the rival is stronger. Specifically, the leader has to pre-empt its rival at a very low threshold. Optimism leads to even lower pre-emptive thresholds which suggests earlier entry for the leader (B). This destroys most of the option value. As Abecomes more optimistic, the entry order switches. Even though B then becomes the follower, it is still value-enhancing for B. This case shows that being more optimistic also could have positive externalities.

Our work extends the real options literature. A number of papers (e.g.

Dixit and Pindyck [1994]) have investigated strategic interactions between firms in asymmetric duopoly [Pawlina and Kort, 2006; Kong and Kwok, 2007]. Pawlina and Kort [2006] examine the effects of asymmetric investment costs on the entry timing and the values of the two firms under uncertainty. They find that the firms invest simultaneously if both the cost asymmetry and first-mover advantage are small. When first-mover advantage is sufficiently large, the low-cost firm pre-empts the high-cost firm. When the cost asymmetry is significant, it leads to sequential investment. For a certain range of the asymmetry level, an increase in the investment cost of the disadvantaged firm can enhance this firm's own value. Kong and Kwok [2007] find the entry order is affected by firms' relative advantages in both monopoly and duopoly. If one firm dominates both as first entrant and in duopoly, they will enter the market first. More generally there is a trade-off: relative strength as first entrant can offset weakness in the duopoly market to 'win' the pre-emption game and enter first. We introduce another type of potential asymmetry between rival entrepreneurial firms: differences in the entrepreneurs' perceived growth rates, or optimism levels, and show optimism acts as a source of pre-emptive advantage which can offset competitive weaknesses to secure entry as leader, particularly for firms which have a relative advantage in duopoly (but not as monopolist) but where product market competition reduces overall profits significantly in duopoly, and when volatility is low.

Whilst the assertion of managerial overconfidence and/or optimism has been investigated empirically in the Finance literature (see e.g. Malmendier and Tate [2005]), there are nevertheless relatively few papers which consider the implications of these biases on investment decisions under uncertainty. Hackbarth [2009] shows optimism decreases exercise thresholds for investment options and goes on to consider impacts on firm leverage (see also Hackbarth [2008], Kamoto [2014]). More recently Smit and Matawlie [2017] model the effects of optimism about growth rates on the choice between direct acquisition and via a toehold strategy. They argue that optimistic bidders are more likely to pursue direct acquisitions rather than toehold acquisition strategies and find supporting empirical evidence. Their rationale builds on Hackbarth [2009]'s result that investment thresholds decrease as a decision-maker's optimism increases. However, none of these papers consider the impact of optimism on strategic incentives in a competitive setting, where we find the opposite comparative static result can hold.

A number of studies have suggested reasons why inherent or dispositional optimism or overconfidence may provide advantages in competitive settings. Goel and Thakor [2008] argue that overconfidence can increase the likelyhood of promotion to CEO. Kyle and Wang [1997] show that overconfidence induces traders to trade more agressively (or equivalently have higher capacity in a Cournot duopoly model), which causes realistic rivals to trade less (select lower quantities) (See also Odean [1998]) In contrast, our model does not rely on differences in the choice of capacity or size by optimists. Instead our results show that, even in the absence of such capacity impacts, differences in optimists' timing of entry can discourage pre-emption by rivals. Adding in these features would only strengthen our results, and we leave this for future work.

Key to our results is the premise that optimism is a trait inherent to an individual which thus cannot be changed, rather than a choice variable. Sharot et al. [2011] suggest a mechanistic explanation for the persistence of unrealistic optimism. They found evidence supporting the existence of systematic selective updating of beliefs whereby negative information was less likely to be incorporated, leading to overoptimistic expectations relating to future events. Furthermore, the magnitude of the difference in coding of positive and negative updates as measured by activity in different parts of the brain was larger for individuals exhibiting greater optimism. Dispositional optimism in young adults has also been found to be predicted by heredity explaining 25% ([Plomin et al., 1992]), early childhood reported temperament [Heinonen et al., 2005] and family socio-economic status [Heinonen et al., 2006].

The inherent nature of optimism is also supported by De Meza et al. [2019] who found financial optimism to be positively correlated with both divorce and smoking, suggesting the existence of a psychological trait. Furthermore Kaniel et al. [2010] and Matthews et al. [2004] amongst others have found persistence, i.e. high correlation of measured optimism levels over time. Dawson and Henley [2013] found individuals who become self-employed were more optimistic before switching, consistent with an optimistic disposition pre-dating the decision to become self-employed. although being self-employed also increased measured optimism. The correlation between optimism and self-employment is well documented (Puri and Robinson [2013], Cooper et al. [1988], Landier and Thesmar [2008]) and extends to events outside the entrepreneur's locus of control. Koudstaal et al. [2015] find entrepreneurs are more optimistic (have both greater "dispositional optimism" and "more optimistic attributional style when bad events occur") than managers. Bengtsson and Ekeblom [2014] find Swedish entrepreneurs have more optimistic (but also more accurate) beliefs than the general population about future economic conditions. We assume optimistic entrepreneurs have higher expectations about future growth rates of demand for their firm's products.

Details of the model and solution are found in Section 2.2. Section 2.3 presents the results and Section 2.4 concludes.

2.2 Model

2.2.1 General setting

Consider two entrepreneurs A and B who have the same investment opportunity to set up a new project and will compete in the same market. The subscripts for all the variables in this chapter denote entrepreneurs. Once the entrepreneur pays the lump-sum cost I_i with $i \in \{A, B\}$, he will receive instantaneous revenue cash flows $\pi(X_t) = DX_t$ each period indefinitely. Here D is deterministic and can take one of four different values $D \in \{D_A^m, D_B^m, D_A^d, D_B^d\}$. The superscript 'm' denotes monopolistic profit and 'd' denotes duopolistic profit. We assume that monopolistic profit is greater than duopolistic profit for each entrepreneur (i.e. $D_A^m > D_A^d$ and $D_B^m > D_B^d$). The entrepreneur who enters first is the leader and enjoys monopoly profits until the other entrepreneur (i.e. follower) enters. After both entrepreneurs have entered the market, each receives a lower duopolistic profit which may differ between the entrepreneurs. Market demand is represented by X_t which follows the stochastic process under risk-neutral measure:

$$dX_t = \nu X_t dt + \eta X_t dB_t \tag{2.1}$$

where ν and η are constants corresponding to drift rate and volatility respectively. The two entrepreneurs may have different subjective beliefs about the future growth rate of market demand, ν , and thus denote each entrepreneur's subjective belief by ν_A and ν_B . The opportunity cost of forgone cash flows δ , defined by $\delta = r - \nu$ may thus also differ between the entrepreneurs ($\delta_A \neq \delta_B$). If the drift rate and opportunity cost of foregone cash flows under non-optimistic beliefs are ν_0 , $\delta_0 = r - \nu_0$ respectively and the entrepreneur's optimism level is denoted by α , entrepreneur A's belief in the growth rate is $\nu_A = \nu_0 + \alpha_A$ and thus the corresponding opportunity cost of foregone cash flows $\delta_A = \delta_0 - \alpha_A$.²

Entry order (i.e. who is the leader and who is the follower) is endogenously determined in the model. Both entrepreneurs choose their leader and follower thresholds (what level of market demand) optimally, i.e. to maximise their expected perceived value given their competitors' best responses. We solve the resulting strategic game backwards in time, by firstly finding each entrepreneur's follower threshold

²Note that δ_A represents an opportunity cost of delaying the investment so that $\delta_A > 0$ (see Dixit and Pindyck [1994, p.149]). This puts a natural upper bound on the optimism levels considered in this chapter. As only optimism and realism are considered, we require α_A and α_B to be nonnegative. Hence we have $0 \le \alpha_A < \delta_0$ and $0 \le \alpha_B < \delta_0$.

(which takes account of his own subjective beliefs, i.e. optimism), secondly finding each entrepreneur's value of entering as leader, and hence the pre-emptive threshold above which he is willing to pre-empt his competitor in order to enter the market as first mover. This pre-emptive threshold may not exist for some scenarios since the value of waiting to be the follower can dominate the value of immediate investment (being the leader). This happens when the difference in profitability between being the monopolist and being the duopolist is not sufficiently big. Or the uncertainty associated with profit flows is high which implies greater value of waiting. Moreover, each entrepreneur's pre-emptive threshold depends not only on their own optimism, but also on the subjective beliefs of their competitor, since the latter affects the threshold at which they downgrade their monopoly profit to duopoly profit. We also find each entrepreneur's optimal leader's threshold by assuming that there is no pre-emption pressure from his competitor. Finally we compare both entrepreneurs' pre-emption thresholds to determine which firm enters first (the one with the lower pre-emptive threshold) and find the actual threshold at which the leader will enter, which depends on the relationship between the leader's optimal threshold and their rival's pre-emptive threshold.

2.2.2 Follower's value function and investment threshold

First suppose that one entrepreneur (leader) has already invested. The other entrepreneur (follower) only has to consider the optimal time to enter the market as part of a duopoly. Since the follower is last to invest, the decision of the follower is equivalent to a stand-alone investment option problem.

Let $x = X_t$. We assume that $V_A^F(x)$ denotes entrepreneur A's perceived value if A were a follower and \bar{x}_A^F denotes A's perceived optimal follower threshold. After investment, A will receive infinite profit flows and the instantaneous profit is $D_A^m x$. If immediate investment is optimal to entrepreneur A, the follower value is calculated as the discounted profit flows less investment cost (i.e., $V_A^F(x) = \frac{D_A^d x}{\delta_0 - \alpha_A} - I_A$). To solve for A's follower value when it is optimal to delay investment, we can apply the standard dynamic programming method in continuous time to obtain the differential equation given by

$$rV_A^F(x) = \left[r - (\delta_0 - \alpha_A)\right] x \frac{\partial V_A^F(x)}{\partial x} + \frac{1}{2}\eta^2 x^2 \frac{\partial^2 V_A^F(x)}{\partial x^2}$$
(2.2)

with boundary conditions

$$V_A^F(0) = 0 (2.3)$$

$$V_A^F(\bar{x}_A^F) = \frac{D_A^d \bar{x}_A^F}{\delta_0 - \alpha_A} - I_A \tag{2.4}$$

$$\frac{\partial V_A^F(x)}{\partial x}\bigg|_{x=\bar{x}_A^F} = \frac{D_A^d}{\delta_0 - \alpha_A}$$
(2.5)

The first two conditions are value-matching conditions and the last one is the smooth-pasting condition. Solving (2.2) - (2.5) yields the follower's value function

$$V_A^F(x) = \begin{cases} \left(\frac{D_A^d \bar{x}_A^F}{\delta_0 - \alpha_A} - I_A\right) \left(\frac{x}{\bar{x}_A^F}\right)^{\beta_A} &, x < \bar{x}_A^F \\ \\ \\ \frac{D_A^d x}{\delta_0 - \alpha_A} - I_A &, x \ge \bar{x}_A^F \end{cases}$$
(2.6)

and optimal follower's threshold \bar{x}^F_A which is given by

$$\bar{x}_A^F = \frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)I_A}{D_A^d} \tag{2.7}$$

where β_A equals

$$\beta_A = \frac{1}{2} - \frac{r + \alpha_A - \delta_0}{\eta^2} + \sqrt{\left(\frac{r + \alpha_A - \delta_0}{\eta^2} - \frac{1}{2}\right)^2 + \frac{2r}{\eta^2}} > 1$$
(2.8)

We can follow the same steps to obtain the follower's value function of entrepreneur B and also his optimal follower threshold. Note each entrepreneur's value functions

before and after investment as follower depend on their own subjective beliefs but are independent of their rival's level of optimism.

Proposition 2.1. Optimism accelerates the investment of the follower, i.e. the optimal follower's threshold \bar{x}_A^F is a strictly decreasing function of the optimism level α_A .

Proof. See Appendix 2.A.

Proposition 2.1 states that an optimistic entrepreneur tends to enter the market earlier than an equivalent rational one (i.e. with identical duopoly profits and identical investment costs) as the follower. Furthermore, the more optimistic the follower is, the earlier his entry. This arises because the optimistic entrepreneur overestimates the growth trend (drift rate) of future profits. A higher expected growth rate induces entrepreneurs to exercise investment options earlier whilst higher volatility causes them to delay: the optimal threshold is the result of a trade-off between them. Optimism plays a role in "increasing" the optimistic entrepreneur's anticipated growth rate, thereby accelerating investment for the follower problem which is actually same as a stand-alone investment option. This implies that, in the absence of competition, entrepreneurial optimism brings investment timing forward.

2.2.3 Leader's value function and investment threshold

We now consider each entrepreneur's optimisation problem for entering as a leader, taking account of their rival's behaviour as follower (i.e. his competitor's optimal follower threshold). Intuitively, the leader's value is defined as the value to the entrepreneur if he invests immediately to secure being the first mover. As the leader, he is able to enjoy monopoly profits at the beginning. However, the leader's profits will fail to the duopoly level once the follower (the other entrepreneur) enters. The leader's value takes account of the follower's later entry. This is also how strategic interaction between two entrepreneurs arises in the model. We can derive the leader's value function, e.g. for entrepreneur A, which satisfies

$$rV_A^L(x) = D_A^m x + \left[r - (\delta_0 - \alpha_A)\right] x \frac{\partial V_A^L(x)}{\partial x} + \frac{1}{2}\eta^2 x^2 \frac{\partial^2 V_A^L(x)}{\partial x^2}$$
(2.9)

with boundary conditions

$$V_A^L(0) = -I_A (2.10)$$

$$V_A^L(\bar{x}_B^F) = \frac{D_A^d \bar{x}_B^F}{\delta_0 - \alpha_A} - I_A \tag{2.11}$$

where \bar{x}_B^F is B's follower threshold. Hence, the leader's value equals

$$V_A^L(x) = \begin{cases} \frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \bar{x}_B^F \left(\frac{x}{\bar{x}_B^F}\right)^{\beta_A} + \frac{D_A^m}{\delta_0 - \alpha_A} x - I_A & , x < \bar{x}_B^F \\ \\ \frac{D_A^d x}{\delta_0 - \alpha_A} - I_A & , x \ge \bar{x}_B^F \end{cases}$$
(2.12)

When market demand x is above the optimal follower threshold of B (i.e. $x \ge \bar{x}_B^F$), Note that $V_A^L(x)$ is only the leader's value function upon investment. Letting \bar{x}_A^E denote the actual entry point of entrepreneur A as leader, his leader's value function before his investment, $V_A^{LB}(x)$, satisfies the following equation

$$rV_A^{LB}(x) = \left[r - (\delta_0 - \alpha_A)\right] x \frac{\partial V_A^{LB}(x)}{\partial x} + \frac{1}{2}\eta^2 x^2 \frac{\partial^2 V_A^{LB}(x)}{\partial x^2}$$
(2.13)

with boundary conditions

$$V_A^{LB}(0) = 0 (2.14)$$

$$V_A^{LB}(\bar{x}_A^E) = V_A^L(\bar{x}_A^E) \tag{2.15}$$

Solving the above equations gives

$$V_A^{LB}(x) = \frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \bar{x}_B^F \left(\frac{x}{\bar{x}_B^F}\right)^{\beta_A} + \left(\frac{D_A^m}{\delta_0 - \alpha_A} \bar{x}_A^E - I_A\right) \left(\frac{x}{\bar{x}_A^E}\right)^{\beta_A}$$
(2.16)

If entrepreneur A can enter at his optimal leader threshold \bar{x}_A^L , i.e. $\bar{x}_A^E = \bar{x}_A^L$, which satisfies the smooth-pasting condition

$$\frac{\partial V_A^{LB}(x)}{\partial x}\bigg|_{x=\bar{x}_A^L} = \frac{\partial V_A^L(x)}{\partial x}\bigg|_{x=\bar{x}_A^L}$$
(2.17)

Note that the optimal leader threshold \bar{x}_A^L should be less than \bar{x}_B^F . After taking Equation (2.12) and (2.16) and substituting $x = \bar{x}_A^L$, we have

$$\frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \beta_A \left(\frac{\bar{x}_A^L}{\bar{x}_B^F}\right)^{\beta_A - 1} + \left(\frac{D_A^m}{\delta_0 - \alpha_A} \bar{x}_A^L - I_A\right) \frac{\beta_A}{\bar{x}_A^L} = \frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \beta_A \left(\frac{\bar{x}_A^L}{\bar{x}_B^F}\right)^{\beta_A - 1} + \frac{D_A^m}{\delta_0 - \alpha_A} (2.18)$$

Thus, the optimal leader's threshold \bar{x}_A^L is given by

$$\bar{x}_A^L = \frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)I_A}{D_A^m}$$
(2.19)

We can see that the optimal leader's threshold \bar{x}_A^L has the same form as the optimal investment threshold of a monopolist when there are no other competitors and the deterministic part of instantaneous monopoly profit is D_A^m . However, the value function of a monopolist is different from $V_A^{LB}(x)$ here even though they have the same optimal threshold (i.e. \bar{x}_A^L).

As mentioned before, the optimal leader's threshold \bar{x}_A^L is not always achievable because of competition. Both entrepreneurs are willing to give up some option value as long as they can capture enough monopolistic profit by pre-empting their rival. Intuitively, an entrepreneur will have an incentive to pre-empt as soon as the value of becoming the leader exceeds the value of waiting to be the follower (i.e. $V_A^L(x) \ge V_A^F(x)$). When demand level is very low (e.g x is close to zero), the leader's value is negative as profits are too low to cover the sunk investment cost. Since becoming the follower can fully realise option value that is always non-negative, the follower's value is greater than the leader's value if both are evaluated at a low x. As x increases, the leader's value is growing faster than the follower's value because we assume the deterministic part of monopolistic profit is greater than that of duopolistic profit. We define each entrepreneur's pre-emptive threshold (e.g. \bar{x}_A^P for A's pre-emptive threshold) as the lowest value of x for which an entrepreneur's follower's value equals their leader's value as the *pre-emptive threshold*. This solves

$$\bar{x}_A^P = \inf\{x : V_A^L(x) = V_A^F(x)\}$$
(2.20)

or

$$\bar{x}_A^P = \inf\left\{x: \frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \bar{x}_B^F \left(\frac{x}{\bar{x}_B^F}\right)^{\beta_A} + \frac{D_A^m}{\delta_0 - \alpha_A} x - I_A = \left(\frac{D_A^d \bar{x}_A^F}{\delta_0 - \alpha_A} - I_A\right) \left(\frac{x}{\bar{x}_A^F}\right)^{\beta_A}\right\}$$
(2.21)

If entrepreneur A perceived leader's value is less than his follower's value for any $x < \bar{x}_B^F$, then \bar{x}_A^P does not exist. In this case, entrepreneur A is willing to be the follower and has no incentive to pre-empt firm B. Entrepreneur B's pre-emptive threshold \bar{x}_B^P can be calculated similarly. If \bar{x}_A^P and \bar{x}_B^P both exist, then the entrepreneur with the lower pre-emptive threshold will be the leader. For example, if $\bar{x}_A^P < \bar{x}_B^P$, entrepreneur A will be first to enter the market. As long as B's willingness to pre-empt is still effective, A can never enter at his perceived optimal leader threshold \bar{x}_A^P . In other words, A's entry timing is constrained by B's pre-emptive threshold \bar{x}_B^P . Therefore, the actual entry threshold for A is $\bar{x}_A^E = \min{\{\bar{x}_A^L, \bar{x}_B^P\}}$.

If $\bar{x}_A^E = \bar{x}_B^P$, this signifies *pre-emptive investment*. In this case, A invests just before their competitor's pre-emption threshold in order to obtain the leader value. Differentiating $V_A^{LB}(x)$ with respect to the entry threshold \bar{x}_A^E :

$$\frac{\partial V_A^{LB}(x)}{\partial \bar{x}_A^E} = -\beta_A \left(\frac{D^m}{\delta_0 - \alpha_A} - \frac{I_A}{\bar{x}_A^E} \right) \left(\frac{x}{\bar{x}_A^E} \right)^{\beta_A} + \frac{D^m}{\delta_0 - \alpha_A} \left(\frac{x}{\bar{x}_A^E} \right)^{\beta_A} \\ = \left((1 - \beta_A) \frac{D^m}{\delta_0 - \alpha_A} + \beta_A \frac{I_A}{\bar{x}_A^E} \right) \left(\frac{x}{\bar{x}_A^E} \right)^{\beta_A} > 0 \text{ if } \bar{x}_A^E < \bar{x}_A^L$$

shows that as long as $\bar{x}_A^E < \bar{x}_A^L$, the leader's value function increases with \bar{x}_A^E , i.e.

the leader prefers to enter as late as possible in order to capture as much of the option value of waiting as possible. However, if they delay investment so $x > \bar{x}_B^P$, B will pre-empt, so $\bar{x}_A^E \leq \bar{x}_B^P$ is a binding constraint for A to enter the market first.

Alternatively, if $\bar{x}_A^L < \bar{x}_B^P$, or if *B*'s pre-emptive threshold does not exist, entrepreneur *B* will never have an incentive to pre-empt *A*, and thus entrepreneur *A* becomes the dominant leader. This leads to *sequential investment*. In this case, the first entrant, e.g. *A*, can enter at his own optimal leader threshold (i.e. $\bar{x}_A^E = \bar{x}_A^L$).

The following proposition illustrates how one entrepreneur's (e.g. B's) preemptive incentive can be affected by entrepreneur A's optimism.

Proposition 2.2. Entrepreneur B's pre-emptive threshold \bar{x}_B^P increases with entrepreneur A's optimism level α_A if entrepreneur B is rational and \bar{x}_B^P exists.

Proof. See Appendix 2.A.

Proposition 2.2 implies that, as long as the (more) optimistic entrepreneur enters in order to pre-empt his realistic (less optimistic) rival (i.e. at *B*'s preemptive threshold), then the threshold at which the optimistic entrepreneur enters as leader increases as his level of optimism increases. This is in contrast to the monopolistic case (e.g. Hackbarth [2009]) that investment thresholds decrease as optimism increases. The reason is that *A*'s threshold is determined by his rival $(\bar{x}_A^E = \bar{x}_B^P)$ and increased optimism decreases *A*'s follower's threshold which reduces *B*'s leader value. This in turn increases *B*'s pre-emptive threshold and hence *A*'s entry threshold as leader as long as *B*'s pre-emptive threat is real (i.e. $\bar{x}_B^P < \bar{x}_A^L$).

2.3 Results

Our goal is to illustrate the effect of entrepreneurial optimism in a general setting for two firms with asymmetric costs of entry, monopolistic and duopolistic profitability, and run by entrepreneurs with different levels of optimism. We start by considering the case where the two firms have identical costs and revenues but the entrepreneurs have different levels of optimism. Then we generalise to incorporate asymmetry in both profitability and subjective beliefs (optimism levels). Apart from the effect on investment timing, we also explore the implications for firms' valuation from a rational perspective.

2.3.1 Symmetric duopoly

We consider two entrepreneurs running identical firms, i.e. net income in monopoly and duopoly are identical as are the initial entry costs. To examine the effect of one entrepreneur's optimism, we compare the case where entrepreneur A is optimistic whereas entrepreneur B is realistic with the case where both entrepreneurs are realistic.

Figure 2.1 plots entrepreneur A (or B) perceived follower's and leader's values. The solid convex (concave) curves represent follower's (leader's) values. The corresponding optimal follower threshold and pre-emptive threshold are also shown in each subfigure. Figure 2.1a and Figure 2.1b are for firm A and B respectively when the two entrepreneurs have symmetric realistic beliefs (i.e. in the absence of optimism). The first intersection of the two solid curves is the pre-emptive threshold and the second intersection is its competitor's optimal follower threshold. Since the two firms are symmetric in every aspect, they have the same follower and pre-emptive thresholds.

Next, we let entrepreneur A become optimistic and entrepreneur B remain realistic. Figure 2.1c and Figure 2.1d show the changes in value curves for firm A and B respectively. The grey solid curves are the original ones when neither entrepreneur is optimistic (i.e. same as the black solid curves in Figure 2.1a and Figure 2.1b). From Figure 2.1c, we see both value curves for firm A shift up (from grey curves to red curves) and A's pre-emptive threshold decreases. An optimistic entrepreneur is more willing to invest as he inflates the growth prospect of revenue flows. However, this does not necessarily mean that entrepreneur A would accelerate



Figure 2.1: The Effects of Entrepreneur A's Optimism on Two Identical Firms' Thresholds. Figures 2.1a and 2.1b represent the benchmark case when both entrepreneurs are rational. Figures 2.1c and 2.1d represent the case when B is rational whereas A is optimistic. Parameter values: r = 0.05, $\delta_0 = 0.04$, $\eta = 0.15$, $\alpha_B = 0$, $D_A^m = D_B^m = 2$, $D_A^d = D_B^d = 1$ and $I_A = I_B = 100$.

investment as first mover. As long as entrepreneur B's pre-emptive incentive works as a constraint to A (i.e. $\bar{x}_B^P < \bar{x}_A^L$), entrepreneur A prefers to delay until \bar{x}_B^P and just pre-empt B. Entrepreneur B's pre-emptive threshold is shown in Figure 2.1d. The leader's value of B decreases (from grey concave curve to blue concave curve) as A's follower threshold decreases. Consistent with Proposition 2.1, A's optimism brings forward its follower's threshold. As a result, this shortens the expected monopoly period for B and thus discourages B from being the first mover. In contrast to the non-competitive setting, increases in A's optimism enable A to delay by lowering B's incentive to pre-empt.



Figure 2.2: The Continuous Effect of A's Optimism on Two Identical Firms' Thresholds. Parameter values: r = 0.05, $\delta_0 = 0.04$, $\eta = 0.15$, $\alpha_B = 0$, $D_A^m = D_B^m = 2$, $D_A^d = D_B^d = 1$ and $I_A = I_B = 100$.

Figure 2.2 shows how their follower thresholds and more importantly preemptive thresholds change as A's optimism increases continuously. In terms of the optimal follower threshold, an entrepreneur's optimism can only affect his own threshold, so we observe that \bar{x}_B^F remains the same no matter how optimistic Ais. However, A's follower threshold \bar{x}_A^F decreases as we increase entrepreneur A's optimism level, consistent with Proposition 2.1.

In Figure 2.2b, we note that two pre-emptive thresholds diverge correspond-

ingly. To be specific, the pre-emptive threshold for entrepreneur B increases with A's optimism while the pre-emptive threshold for entrepreneur A follows a downward trend. Since the entrepreneur who has the smaller pre-emptive threshold will be the leader, this shows that optimism increases the likelihood of being the leader. In this case of symmetric firms, if both firms are run by "realistic" entrepreneurs, their pre-emptive thresholds would co-incide. Using a mixed strategy as in Thijssen et al. [2012] would result in equal probabilities of either firm becoming the leader at the pre-emptive threshold. A's optimism breaks this symmetry: the more optimistic entrepreneur now enters the market first for sure.

Figure 2.2b also shows that the threshold at which the more optimistic entrepreneur will enter the market is higher than if he were rational even though his own pre-emptive threshold becomes smaller. This is because the winner of the preemption game will wait until just before his rival's pre-emptive threshold (as long as this is below his optimal leader's threshold). In the absence of competition, entrepreneurs would like to wait until the optimal leader's threshold before investing as this maximises the option value. The threat of pre-emption by his competitor limits how long the eventual leader can wait before investing. However the optimistic entrepreneur can wait longer than his realistic counterpart because his rival's pre-emptive threshold is higher.

The impact of changes in optimism levels on an optimistic entrepreneur's pre-emptive entry thresholds thus relies on the impact the entrepreneur's optimism has on his rival's incentives to pre-empt. By lowering the threshold at which he will enter as second mover, an increase in optimism reduces the rival's benefit of entering as leader by reducing the expected duration of her initial monopoly.

To see the underlying intuition why the two pre-emptive thresholds diverge, recall the pre-emptive threshold is defined as the first intersection of the entrepreneur's follower value and leader value. The pre-emptive threshold increases with the follower value whereas it decreases with the leader value. Increasing A's optimism has no effect on B's value as a follower, since A has already entered the market. However, the impact A's optimism has in lowering its follower threshold has a negative effect on B's leader value, because it reduces the length of time B expects to earn the higher monopoly profits. Since B has less incentive to enter as leader, its pre-emptive threshold increases.

On the other hand, A's optimism about future product market growth increases the value he places on entering the market, both as a leader and as a follower. The increase in the leader value acts to decrease A's pre-emption threshold whereas the increase in the follower value acts in the opposite direction. By implementing numerical simulations for different sets of parameter values, we always find that the impact on the leader's value dominates. That is, the pre-emptive threshold for an optimistic entrepreneur decreases with his own optimism.

2.3.2 Asymmetric duopoly

Next we consider more general cases where the two firms have different competitive advantages. For example, one firm might be more profitable than the other if they were monopolists. After both firms invest, they will compete for market share at the same time. We could see that one firm is superior than the other or the market is actually equally divided. In this section, we will examine the effects of entrepreneurial (asymmetric) optimism on investment timing and firms' valuation.

Following Kong and Kwok [2007], we are able to identify different combinations of asymmetric payoffs and costs in an effective way.

We first define two important terms DAR and MAR as B's relative duopolistic advantage to A (i.e. $\frac{I_A D_B^d}{I_B D_A^d}$) and B's relative monopolistic advantage to A (i.e. $\frac{I_A D_B^m}{I_B D_A^m}$) respectively. Then we use the DAR-MAR plane to identify entry order and different investment equilibria (i.e. pre-emptive investment or sequential investment). Let regions A^* , A, B and B^* denote {A is dominant leader}, {A is pre-emptive leader}, {B is pre-emptive leader} and {B is dominant leader} respec-


Figure 2.3: Entry Order and Different Investment Equilibria. "Duopolistic Advantage Ratio B/A" (DAR) is defined as $\frac{I_A D_B^d}{I_B D_A^d}$ and "Monopolistic Advantage Ratio B/A" (MAR) is defined as $\frac{I_A D_B^m}{I_B D_A^m}$. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$, $I_A = I_B = 100$ and FMA_A = $D_A^m/D_A^d = 1.2$.

tively. Mathematically, they correspond to cases where {only \bar{x}_A^P exists}, { $\bar{x}_A^P < \bar{x}_B^P$ }, $\{\bar{x}_B^P < \bar{x}_A^P\}$ and {only \bar{x}_B^P exists} respectively.

Define D_A^m/D_A^d as firm A's first-mover advantage (FMA_A). Figure 2.3 shows the location of these regions for a fixed value of FMA_A, as in Kong and Kwok [2007]. *B* becomes leader when it has a competitive advantage as a monopolist (high MAR) and as a duopolist (high DAR) whereas *A* becomes leader when *B*'s relative advantage as a monopolist (MAR) or as a duopolist (DAR) is low. The separating curve (bold solid curve) represents the situation when two entrepreneurs have the same pre-emptive thresholds even though their costs and payoffs are different. Intuitively, the separating curve is downward-sloping since one entrepreneur cannot dominate the other in any dimension: as DAR decreases, MAR has to increase to compensate if two entrepreneurs end up with identical pre-emptive thresholds. An increase in *B*'s competitive advantage over *A* as a leader (increase in MAR) decreases *B*'s pre-emptive threshold and hence increases the range of parameter values, including DAR, for which B becomes leader.

Effects on investment timing

To illustrate the main effect of optimism for asymmetric entrepreneurs, we plot the separating curve and boundaries between equilibria as first shown in Figure 2.3 again but increase entrepreneur A's optimism level. By keeping all the other parameters the same, we can compare how these curves will shift and how the regions will change as one entrepreneur (A) becomes more optimistic.



Figure 2.4: The Effect of A's Optimism on Entry Order and Investment Equilibria in Asymmetric Duopolies. Blue curves represent boundaries when both entrepreneurs are rational. Red curves represent boundaries when A becomes more optimistic. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and FMA_A = $D_A^m/D_A^d = 1.2$.

In Figure 2.4, we use blue curves to represent original boundaries as in Figure 2.3. The red curves represent new boundaries when entrepreneur A is optimistic whilist B remains rational. As shown in Figure 2.4, all the boundaries shift up and to the right. This implies A's optimism increases the range of product market characteristics for which A enters as leader (regions A and A^*). Effectively A's optimism provides an additional source of pre-emptive advantage. In other words, a firm run by an optimistic entrepreneur (A) can enter first or become a dominant

leader even if firm B has higher pre-emptive advantage in terms of costs and payoffs.



Figure 2.5: The Effect of A's Optimism on Entry Order and Timing in Asymmetric Duopolies. Grey shaded area represents the cases where the entry order changes. Red shaded area represents the cases where entrepreneur A could delay investment as leader. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and FMA_A = $D_A^m/D_A^d = 1.2$.

To further show the effects on investment timing, Figure 2.5 highlights two regions with shaded areas. The grey shaded area (between the bold solid separating curves) is the region where the entry order changes. In this region, when both entrepreneurs are realistic B has a pre-emptive advantage and thus enters first; however when A is optimistic B's pre-emptive threshold decreases whilst A's increases sufficiently that the order of the two entrepreneurs' pre-emptive thresholds switches. Entrepreneur A remains to be leader or follower outside this region. Interestingly, by taking into account strategic interaction between two entrepreneurs, increases in A's optimism can delay her investment as in the symmetric duopoly (see Section 2.3.1). For more general cases of asymmetric duopolies, we also find a region (red shaded area) where an optimistic entrepreneur A can enter at a higher threshold as leader. The reason is similar to the symmetric case. A's optimism reduces B's incentives to pre-empt, by reducing the expected duration of the period over which she can earn monopolistic profits. In turn this is due to A's earlier entry as follower due to his inherent optimism.

Comparative statics

We now consider under which circumstances optimism has the strongest effect on entry order investment timing. Specifically, we consider the same change of A's optimism (i.e. α_A increases from 0 to 0.018) whilst letting entrepreneur B remain rational. Then we investigate how the effects of A's optimism documented in the last session depend on other parameter values (e.g. volatility and FMA_A).



Figure 2.6: The Effect of A's Optimism for Different Volatilities. Parameter values: r = 0.05, $\delta_0 = 0.03$ and FMA_A = $D_A^m/D_A^d = 1.2$.

We first investigate the effects of optimism for different levels of volatility. As shown in Figure 2.6, the entry order switching region between two bold solid curves (i.e. grey shaded area) is larger for low volatility. This is because investment timing involves a trade-off between the expected growth rate and uncertainty (volatility). If volatility increases, the desire to delay the investment will be stronger. In this case, the same increment in the expected growth rate of market demand (i.e. same level of optimism) makes a smaller difference to the entry order. The red shaded area is similar for both low and high levels of volatility.



Figure 2.7: The Effect of A's Optimism for Different Values of FMA_A. Parameter values: r = 0.05, $\delta_0 = 0.03$ and $\eta = 0.3$.

We also investigate how the effects of optimism vary for different levels of FMA_A (See Figure 2.7). A higher value of FMA_A means A's monopolistic profit is proportionately greater than A's duopolistic profit, or, in other words, A's profit decreases by a greater proportion on entry by his competitor. Figure 2.7 shows the impact of optimism for low and high levels of first-mover advantage for A respectively.

By comparing Figure 2.7a and 2.7b, we notice that the size of the grey shaded area is similar. However, the size of the red shaded area (where entrepreneur A is able to delay investment as leader) expands significantly when A's first-mover advantage is higher. This is because the region {A is pre-emptive leader} (i.e. region A in Figure 2.3) is larger for higher value of FMA_A.

To further understand why the region A expands as FMA_A increases, we note that \bar{x}_A^P , \bar{x}_A^L and \bar{x}_A^F would be very close together if FMA_A is sufficiently small³.

³Imagine the extreme case when A's monopolistic profit equals its duopolistic profit (i.e. $D_A^m/D_A^d = 1$). Then it follows $\bar{x}_A^P = \bar{x}_A^L = \bar{x}_A^F$ since the monopolistic profit is the same as the duopolistic profit which means the decision of being the leader is the same as that of being the follower.

However, as long as \bar{x}_B^P exists, the inequality $\bar{x}_B^P < \bar{x}_A^F$ must hold: *B*'s incentive to be the leader is only valid before *A*'s entry. If \bar{x}_A^P and \bar{x}_A^L are only marginally smaller than \bar{x}_A^F , then \bar{x}_B^P is less likely to be between \bar{x}_A^P and \bar{x}_A^F . Thus, the case when $\bar{x}_B^P < \bar{x}_A^P$ is more likely to happen. On the other hand, \bar{x}_A^P can be much smaller than \bar{x}_A^F if FMA_A = D_A^m/D_A^d is sufficiently large. Intuitively, *A*'s pre-emptive incentive is stronger if monopoly profits are significantly higher than its duopoly profits. This implies a smaller value of \bar{x}_A^P . Hence the range of DAR and MAR for which \bar{x}_B^P is located between \bar{x}_A^P and \bar{x}_A^F would be relatively larger. In this case, *A*'s optimism can discourage pre-emptive entry by *B* and thus entrepreneur *A* has a chance to delay investment as leader.

The effect of optimism on entry order is thus greater for entrepreneurs in less volatile markets. An entrepreneur's optimism can delay their own investment as leader for a wider range of cashflow-based competitive advantages when their firstmover advantage (ratio of instantaneous monopoly profit relative to instantaneous duopoly profit) is higher⁴.

Effects on values

Our findings in the previous section suggest that optimism can provide another preemptive advantage and can also delay investment by discouraging the competitor. In this section, we will explore the impact of optimism on the two firms' values. We try to answer the question that whether optimism increases (reduces) the firm's (the competitor's) value under the strategic setting. Note that the values that we consider are not from the optimistic entrepreneur's perspective since their decisions definitely maximise their own firm's value from their point of view. It is interesting to consider the values perceived by outside rational equity holders (i.e. rational values)⁵. This analysis provides implications for whether outside equity holders

⁴We also re-examine the effect for different levels of the opportunity cost of forgone cashflows, δ_0 , but find little impact on entry order and investment timing.

⁵This chapter does not incorporate the entrepreneurial decisions on how much equity for outside investors to be issued.



Figure 2.8: The Effect of A's Optimism on Values from a Rational Perspective. Solid curves are the boundaries when both investors are rational and dashed curves are the boundaries when B is rational but A becomes optimistic. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and FMA_A = $D_A^m/D_A^d = 1.35^6$.

would pay more or less for a holding in a firm run by an optimistic entrepreneur than in an identical firm run by a rational entrepreneur.

Denoting $\hat{V}_A^F(x)$ as the rational value of the follower (e.g. firm A) before entry, we have

$$\hat{V}_A^F(x) = \left(\frac{D_A^d \bar{x}_A^F}{\delta_0} - I_A\right) \left(\frac{x}{\bar{x}_A^F}\right)^{\beta_0} \tag{2.22}$$

where β_0 equals

$$\beta_0 = \frac{1}{2} - \frac{r - \delta_0}{\eta^2} + \sqrt{\left(\frac{r - \delta_0}{\eta^2} - \frac{1}{2}\right)^2 + \frac{2r}{\eta^2}}$$
(2.23)

The follower threshold \bar{x}_A^F is chosen by the entrepreneur whereas other parameters $(\beta_0 \text{ and } \delta_0)$ related to valuation are set to be independent of A's optimism. If firm A were the leader, its rational value before entry is thus given by

$$\hat{V}_A^{LB}(x) = \left(\frac{D_A^m}{\delta_0}\bar{x}_A^E - I_A\right) \left(\frac{x}{\bar{x}_A^E}\right)^{\beta_0} + \frac{D_A^d - D_A^m}{\delta_0}\bar{x}_B^F \left(\frac{x}{\bar{x}_B^F}\right)^{\beta_0}$$
(2.24)

where \bar{x}_A^E is the actual entry point of A which equals $\bar{x}_A^E = \min\{\bar{x}_B^P, \bar{x}_A^L\}$ (see details

⁶In order to show different regions clearly, we use $\text{FMA}_A = D_A^m / D_A^d = 1.35$ instead of $\text{FMA}_A = D_A^m / D_A^d = 1.2$ for contour plots.

in Section 2.2). In order to make sure option values have been considered, we evaluate the values of both firms at a fixed value of x before either firm enters.

Since we focus on the change of rational values, we define the value ratio as the rational value when only A is optimistic over the value when both entrepreneurs are rational. If the value ratio is greater than 1, then optimism is value-enhancing to the firm. In Figure 2.8, we use coloured contour plots to present the value ratios for firm A and B respectively. The green area represents that the value ratio equals 1 suggesting that the value is unchanged. All the grey (warm colour) areas represent that the value ratio is less (greater) than 1. Darker colour indicates the effect on the rational value is greater.

Figure 2.8a shows the effect of A's optimism on firm B's value. B's value ratios are equal to or less than 1 for all the possible cases on the MAR-DAR plane. The green area where B is unaffected by A's optimism corresponds to the region for which $\{B \text{ is always the follower}\}$. Entrepreneur B chooses his perceived optimal follower threshold as long as it is worthwhile being the follower. As B's optimal follower threshold does not depend on A's optimism, B's investment timing is the same as that when both entrepreneurs are rational. Thus, B's option value can be fully realised. Except for this scenario, A's optimism reduces B's rational value, especially for low DAR and high MAR (the darkest area in the upper left corner). This area is located in the entry order switching region where B becomes the follower from being the leader due to A's increased optimism. Firm B loses all its monopoly profits. Moreover, if MAR is high and DAR is low, firm B is more profitable being a monopolist compared to being a duopolist. Therefore, losing its monopoly profits is a huge loss to firm B. As a conclusion, A's optimism can reduce B's value and this negative effect is most evident when B loses the opportunity to be the leader (or a monopolist over a period) and B's period of monopoly profits account for the major part of its total value.

Then we show how entrepreneur A's optimism influences her own firm's value

(see Figure 2.8b). Firm A is worse off for most cases given that a large area is in colour grey. If firm A's investment timing has never been constrainted by firm B's pre-emption incentive, then A's optimism always accelerates investment and destroys the option value of waiting for a rational outside investor. This occurs when A is always the follower or the dominant leader. The area in warm colours appears around the original solid curve on which the two firms have the same preemptive advantage in terms of costs and payoffs. Hence entrepreneur's optimism can be value-enhancing to the firm itself only when the two firms are close competitors. By comparing Figure 2.8b with Figure 2.7b, we notice that part of this area belongs to the entry order switching region. If A's optimism can make A become the leader, then A could earn monopoly profits as an extra benefit (warm-coloured area in the entry order swithcing region). However becoming the leader does not necessarily increase value as it is at the cost of losing some value of waiting. Once the additional monopoly profits are not enough to cover this cost, firm A's value decreases as entrepreneur A becomes more optimistic (grey area in the entry order switching region). The rest of warm-coloured area coincides with the red area in Figure 2.7b. This implies that A can also benefit from delaying B investment due to increases in the A's optimism. By successfully discouraging B from pre-empting, firm A can thus realise more option value of waiting.

Next we consider three special cases of asymmetric duopolies to illustrate the effect of continuous changes in optimism. Figure 2.9 plots the value ratios of the two firms against A's optimism level. For comparasion purposes, we fix DAR equal to 1 and vary MAR to generate asymmetric cases.

Figure 2.9a shows the case when A becomes the dominant leader from being the pre-emptive leader. Note that B's value ratio always equals 1. This is because B invests at his own perceived optimal follower threshold which is independent of A's optimism. As for firm A, its value ratio first increases to above 1 and then falls gradually down below 1 as A's optimism increases. The initial upward trend



Figure 2.9: (Special Cases) The Continuous Effect of A's Optimism on Values. Value ratios are defined in Figure 2.8. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.2$.

is when A is still the pre-emptive leader (i.e. when A's entry timing is constraint by B's pre-emptive threshold). Increases in A's optimism defer B's pre-emption so A can realise more option value by delaying investment. Once B completely loses pre-emptive incentive, A will invest at her perceived optimal leader threshold which decreases with A's optimism. A high level of optimism leads to entering the market prematurely and thus losing option value of waiting.

Figure 2.9b illustrates a case when A is able to become the leader as A's optimism increases. In region (1), when A's optimism is relatively low, A is still the follower so its value decreases with optimism⁷. As A's optimism increases, \bar{x}_B^P will increase and \bar{x}_A^P will decrease simultaneously. Once \bar{x}_B^P exceeds \bar{x}_A^P , the two firms switch roles suggesting that A becomes the leader. At this moment, A's optimism is just enough to compensate for firm A's disadvantage in costs and payoffs. This implies that their pre-emptive thresholds are very close to each other. In other words, the pre-emption pressure from the competitor is very strong. Hence A loses most of its option value even though extra monopoly profits can be earned. That is why there is a sharp decrease in the value ratio of firm A from region (1) to (2). In region (2), A is a pre-emptive leader and A's optimism helps retain option value by discouraging B's pre-emption. In region (3), when A's optimism is relatively high, A becomes the dominant leader. Then the rational value of firm A decreases with A's optimism and the reason is similar to the explanation for the downward trending in Figure 2.9a.

In Figure 2.9c, A's value ratio monotonically decreases with A's optimism level. This corresponds to the case when A is always the follower. As the follower, A's optimism accelerates investment (Proposition 2.1), which makes the investment timing deviate from the optimal follower threshold. Therefore, entrepreneur's optimism is not beneficial to her own firm if the firm can only be the follower. Note that B's value ratio decreases more compared to A's. Even if A's optimism is not

⁷In Figure 2.9b, region (1) is similar to the case shown in Figure 2.9c. More explanation follows in the next paragraph.



Figure 2.10: The Effect of Differential Optimism on Values from a Rational Perspective. Solid curves are the boundaries when $\alpha_A = \alpha_B = 0.01$ and dashed curves are the boundaries when $\alpha_A = 0.028$ and $\alpha_B = 0.01$. The value change of a firm (e.g. firm A) is defined as $\Delta \hat{V}_A = \hat{V}_A|_{\alpha_A=0.028,\alpha_B=0.01} - \hat{V}_A|_{\alpha_A=0.01,\alpha_B=0.01}^8$. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.35$.

enough to switch roles (i.e. making A become the leader), its threat to firm B is still effective. To be specific, in order to pre-empt A, firm B has to enter at a lower threshold as A becomes more optimistic. Consequently, B loses more of its option value.

In the previous analysis for valuation, we assume that entrepreneur B is always rational. Next we consider the case when both entrepreneurs are optimistic while one entrepreneur (e.g. A) is more optimistic than the other. To uncover the effect of differential optimism, we compare this case with the case when the two entrepreneurs have the same level of optimism ($\alpha_A = \alpha_B$). Meanwhile, we keep the optimism difference $\alpha_A - \alpha_B = 0.018$ the same as in Figure 2.8. Note that we consider rational values instead of entrepreneurs' perceived values. Figure 2.10a and 2.10b are the contour plots for firm B and A respectively. Similarly as in Figure 2.8, the green area represents the value change is 0; the warm-coloured (grey) area represents the value change is positive (negative).

In Figure 2.10a, notably there is a yellow area (warm colour area). This

⁸Since the values may flip sign if α_A increases from 0.01 to 0.028, we use value change rather than value ratio.

yellow area implies that B can benefit from his competitor's increased optimism. Within this area, B is the leader when the two entrepreneurs are of the same optimism whereas B is the follower when A is more optimistic (i.e. $\alpha_A = 0.028$ and $\alpha_B = 0.01$). From a rational perspective, optimistic entrepreneur B always makes sub-optimal decisions regardless of B's role (leader or follower). We see an increase in the rational value of B because being the follower is less worse than being the leader for this scenario. This vellow area appears near the original separating curve suggesting that the two firms have similar pre-emptive advantage when $\alpha_A = \alpha_B$. In this case, even if B could enter the market first, the preemption pressure from Ais strong so that B's investment timing is severely constrainted by A's pre-emptive threshold. As a result, B has to give up a significant part of its option value to pre-empt A. If A is more optimistic than B, B can only be the follower. Compared with the case of identical optimism, B loses the monopoly profits but retains more option value. As long as the increased option value outweighs the monopoly profits, B's rational value can be higher for a higher level of A's optimism. As for A's value change, we find little difference between Figure 2.10b and 2.8b.

We also examine the continuous effect of differential optimism for when both entrepreneurs are optimistic as shown in Figure 2.11. When A becomes the dominant leader from being the pre-emptive leader (see Figure 2.11a), the effects on both values are similar to those in Figure 2.9a. We investigate two interesting cases where B's value has increased due to A's increased optimism (see Figure 2.11b and 2.11c). In each figure, there are three regions corresponding to the cases when B is the pre-emptive leader, when A is the pre-emptive leader, and when A is the dominant leader respectively. Note that B's value experiences a substantial increase when A just successfully pre-empts B from region (1) to (2). The reason is that B becomes the follower and more of the option value can be realised⁹. Comparing Figure 2.11b with 2.11c, we find that B's rational value can be increased even more

⁹The more detailed explanation is provided in the last paragraph for Figure 2.10.



Figure 2.11: (Special Cases When Both Entrepreneurs Are Optimistic) The Continuous Effect of Differential Optimism on Values. The value ratio is defined as the rational value when $\alpha_A = 0.028$, $\alpha_B = 0.01$ over the rational value when $\alpha_A = \alpha_B = 0.01$. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.2$.

if the two firms are closer competitors in terms of costs and payoffs (DAR = 1 and MAR = 1.01). One reason is that B's monopoly profits are lower for a lower MAR. This implies that B gives up a smaller amount of total profits by no longer being the leader. The other reason is that closer competitors indicates fiercer competition in terms of the two firms' pre-emptive advantage. The cost of pre-empting the other firm is higher. Therefore, being the follower would rather be preferred from a rational outside equity holder's point of view.

2.4 Conclusion

Entrepreneurial optimism is a widespread trait whereas little attention has been received on its implications in the strategic investment games. In this chapter we investigate the impact of entrepreneurial optimism on the investment timing and firms' values from a rational perspective in a duopoly setting. We assume one entrepreneur is more optimistic than the other and compare it with the case when both entrepreneurs are rational or have the same level of optimism.

We start by considering an identical case where two firms have the same profitability. We show that an entrepreneur's investment threshold can *increase* with her optimism, if she is entering to pre-empt her rival: the opposite of the standard investment result in the monopoly setting [Hackbarth, 2008]. Optimism works as a threat to the competitor since it would shorten the expected period over which the competitor could be the monopolist.

For more general settings of asymmetric duopolies, we find that optimism could provide a pre-emptive advantage, allowing a more optimistic entrepreneur to enter the market first even if their rival has a competitive advantage in terms of monopoly and duopoly profits. Furthermore the range of competitive advantages that could be offset is greater for firms in less volatile markets. The range of competitive advantages where the (more) optimistic entrepreneur could delay investment is greater for a higher ratio of first-mover advantage which is defined as monopoly profit over duopoly profit.

We proceed by examining the effects on the firms' values. Entrepreneurial optimism is shown to be value-enhancing to her own firm under some circumstances even from a rational perspective. One scenario is that optimism helps the firm become the leader and thus earn monopoly profits as an extra source of value. The other scenario is when an entrepreneur can further delay investment due to her threat to the competitor. In addition, when both entrepreneurs have the same optimism, we show that one firm can even benefit from its competitor's increased optimism. This effect is stronger for close competitors in terms of pre-emptive advantage. In this case, we show a positive externality that increases in an entrepreneur's optimism could have under the setting of competition.

Based on these findings, in Chapter 2, we will deepen our understanding on entrepreneural or managerial optimism by analysing what levels of managerial optimism would be desired by rational shareholders in equilibrium.

Appendix 2.A Technical Proofs

Proof of Proposition 2.1

Considering the functional form for β_A given by Equation (2.8), we can rewrite

$$\frac{\beta_A}{\beta_A - 1} = \frac{1}{2} \frac{\eta^2}{(\delta_0 - \alpha_A)} \left[\sqrt{\left(\frac{r + \alpha_A - \delta_0}{\eta^2} - \frac{1}{2}\right)^2 + \frac{2r}{\eta^2}} - \left(\frac{r + \alpha_A - \delta_0}{\eta^2} - \frac{1}{2}\right) + \frac{2r}{\eta^2} \right]$$
(A2.1)

thus \bar{x}^F_A equals

$$\bar{x}_{A}^{F} = \frac{\eta^{2} I_{A}}{2D_{A}^{d}} \left[\sqrt{\left(\frac{r+\alpha_{A}-\delta_{0}}{\eta^{2}}-\frac{1}{2}\right)^{2}+\frac{2r}{\eta^{2}}} - \left(\frac{r+\alpha_{A}-\delta_{0}}{\eta^{2}}-\frac{1}{2}\right) + \frac{2r}{\eta^{2}} \right]$$
(A2.2)

Take the first partial derivative w.r.t. α_A to give

$$\frac{\partial \bar{x}_{A}^{F}}{\partial \alpha_{A}} = \frac{I_{A}}{2D_{A}^{d}} \left[\frac{\frac{r + \alpha_{A} - \delta_{0}}{\eta^{2}} - \frac{1}{2}}{\sqrt{\left(\frac{r + \alpha_{A} - \delta_{0}}{\eta^{2}} - \frac{1}{2}\right)^{2} + \frac{2r}{\eta^{2}}} - 1 \right]$$
(A2.3)

If $\frac{r+\alpha_A-\delta_0}{\eta^2}-\frac{1}{2} \leq 0$, then $\frac{\partial \bar{x}_A^F}{\partial \alpha_A} < 0$. Otherwise, if $\frac{r+\alpha_A-\delta_0}{\eta^2}-\frac{1}{2} > 0$, then

$$\frac{\frac{r+\alpha_A-\delta_0}{\eta^2}-\frac{1}{2}}{\sqrt{\left(\frac{r+\alpha_A-\delta_0}{\eta^2}-\frac{1}{2}\right)^2+\frac{2r}{\eta^2}}} = \frac{\sqrt{\left(\frac{r+\alpha_A-\delta_0}{\eta^2}-\frac{1}{2}\right)^2}}{\sqrt{\left(\frac{r+\alpha_A-\delta_0}{\eta^2}-\frac{1}{2}\right)^2+\frac{2r}{\eta^2}}} < 1 \qquad (A2.4)$$

since $\frac{2r}{\eta^2} > 0$. Thus, we still have $\frac{\partial \bar{x}_A^F}{\partial \alpha_A} < 0$. Therefore \bar{x}_A^F is strictly decreasing as α_A increases.

Proof of Proposition 2.2

Define $f(x, \alpha_A) = V_B^L(x, \alpha_A) - V_B^F(x)$ where only the leader's value of firm *B* is a function of α_A but the follower's value of firm *B* is unaffected by α_A . Given \bar{x}_B^P does exist, \bar{x}_B^P solves $f(\bar{x}_B^P, \alpha_A) = 0$, so we have

$$\frac{d\bar{x}_B^P}{d\alpha_A} = -\frac{\partial f(\bar{x}_B^P, \alpha_A)}{\partial \alpha_A} \middle/ \frac{\partial f(\bar{x}_B^P, \alpha_A)}{\partial x}$$
(A2.5)

where $\frac{\partial f(\bar{x}_B^P, \alpha_A)}{\partial \alpha_A} = \frac{D_B^d - D_B^m}{\delta_0 - \alpha_B} (1 - \beta_B) \left(\frac{\bar{x}_B^P}{\bar{x}_A^F}\right)^{\beta_B} \frac{d\bar{x}_A^F}{d\alpha_A} < 0 \text{ since } \frac{D_B^d - D_B^m}{\delta_0 - \alpha_B} < 0,$ $1 - \beta_B < 0, \left(\frac{\bar{x}_B^P}{\bar{x}_A^F}\right)^{\beta_B} > 0 \text{ and } \frac{d\bar{x}_A^F}{d\alpha_A} < 0. \text{ Then consider}$ $\frac{\partial f}{\partial x} = \beta_B \left[\frac{D_B^d - D_B^m}{\delta_0 - \alpha_B} \left(\frac{1}{\bar{x}_A^F}\right)^{\beta_B - 1} - \left(\frac{D_B^d \bar{x}_B^F}{\delta_0 - \alpha_B} - I_A\right) \left(\frac{1}{\bar{x}_B^F}\right)^{\beta_B}\right] x^{\beta_B - 1} + \frac{D_B^m}{\delta_0 - \alpha_B} (A2.6)$

$$\frac{\partial^2 f}{\partial x^2} = \beta_B(\beta_B - 1) \left[\frac{D_B^d - D_B^m}{\delta_0 - \alpha_B} \left(\frac{1}{\bar{x}_A^F} \right)^{\beta_B - 1} - \frac{I}{\beta_B - 1} \left(\frac{1}{\bar{x}_B^F} \right)^{\beta_B} \right] x^{\beta_B - 2} < 0 \quad (A2.7)$$

Thus, $f(x, \alpha_A)$ is a concave function of x. Let x_B^* denote the turning point of $f(x, \alpha_A)$. Recall the definition of \bar{x}_B^P , i.e. $\bar{x}_B^P = \inf \{x : f(x, \alpha_A) = 0\}$. If \bar{x}_B^P does exist, we will always have $f(x_B^*, \alpha_A) > 0$ and $\frac{\partial f(\bar{x}_B^P, \alpha_A)}{\partial x} > 0$. Combining with $\frac{\partial f(\bar{x}_B^P, \alpha_A)}{\partial \alpha_A} < 0$, we prove that $\frac{d\bar{x}_B^P}{d\alpha_A} > 0$.

Chapter 3

The Equilibrium Levels of Managerial Optimism in Duopoly

3.1 Introduction

In Chapter 2, it has been shown that optimism can provide a pre-emptive advantage which could be beneficial to the firm even from a rational perspective in a duopoly setting. In modern society, the separation of ownership and management widely exists in most large corporations. One advantage is to enable the company to utilize managerial professional skills and experience. In this chapter, we show that managerial characteristics, such as inherent optimism, can also provide a competitive advantage. We address an important issue that has long been questioned yet underexplored: why can we continue to see optimistic managers?

In the presence of duopolistic competition, we investigate whether it is worthwhile for each firm to hire an optimistic manager in equilibrium from the perspective of a rational shareholder. If a large number of managers with different levels of optimism are available in the labour market, we further analyse what particular levels of optimism are desired by the rational shareholders of different firms. Moreover, we show that how the results depend on product market characteristics. This enables us to understand under what circumstances managerial optimism can provide more of a competitive advantage.

We start by considering some special cases where the two firms have different combinations of monopolistic and duopolistic advantages. We solve for the equilibrium levels of optimism using a numerical iteration method. We find that, in equilibrium, the firm which enters the market as the follower prefers a rational manager. This is because an optimistic manager always destroys firm value by sub-optimally accelerating investment from a rational shareholder's perspective.

The other firm, as the leader, prefers an optimistic manager when the two firms are close competitors in terms of their pre-emptive thresholds. The benefit of hiring an optimistic manager is to defer the pre-emption by the other firm. If the two firms are not close competitors, this implicitly means that one firm significantly dominates the other. The weak firm may even have no incentive to pre-empt the strong firm and thus the strong firm will become the leader. In the meanwhile, from the leader's perspective, hiring an optimistic manager is unnecessary as there is no pre-emptive pressure from the other firm if a great disparity between the two firms exists. In addition, once the leader's entry threshold is no longer constrained by the other firm's pre-emptive threshold, the leader will enter at its manager perceived optimal leader threshold. This threshold decreases with the firm's own manager's optimism level, which destroys the leader's value of waiting. Therefore, an optimistic manager is preferred by the leading firm only when the two firms have similar preemptive thresholds.

In the absence of optimism, the entry order is determined by firms' relative advantage in the monopoly and duopoly markets. Interestingly, there are some cases where the "advantaged" firm (i.e., the firm with stronger pre-emptive incentive) may lose the opportunity to enter the market first whereas the "disadvantaged" firm can finally win this entry game by hiring an optimistic manager. This outcome sustains in equilibrium which means it is not worthwhile for the "advantaged" firm to fight back by hiring a more optimistic manager. For illustration purposes, we define the firm's first-mover advantage (FMA) as the ratio of instantaneous monopoly profit to duopoly profit. A higher value of FMA implies that the monopolistic profitability is significantly higher than the duopolistic profitability. Meanwhile, it also measures how much profit a firm could lose from being a monopolist to a duopolist. In this sense, this advantage could also be viewed as one kind of disadvantage. In a strategic entry game, the rival's optimism reduces the firm's value of being the leader by shortening the period over which the firm can be a temporary monopolist. For higher FMA, the firm's monopoly profits contribute a significant portion of overall profits (the expected value of being the leader). Then the rival's optimism is more of a threat to the firm. This implies that one firm's pre-emptive incentive is more negatively affected by the rival's optimism if the firm has a higher FMA.

Next we generalise our study to more asymmetric cases and show some comparative statics results. We find that increases in volatility of profit flows can reduce the regions where the "disadvantaged" firm becomes the leader. In addition, these regions shrink as the firm's own FMA increases. Finally, we show that one firm's ability to reverse a competitive disadvantage by hiring an optimistic manager depends on both its own FMA and its rival's FMA. The firm with relatively lower FMA is more likely to become the leader in equilibrium.

This paper contributes to the growing literature on the analysis of managerial optimism. A number of papers have shown that managerial optimism can play a significant role in corporate investment decisions (Heaton [2002], and Malmendier and Tate [2005]), capital structure (Hackbarth [2008], and Malmendier et al. [2011]), manager's compensation contract (Giat et al. [2009], and Gervais et al. [2011]), etc.

In contrast to these existing papers, we focus on the likelihood of the longrun survival of optimism taking into account its impact on the firm's valuation. There are a few papers relevant to ours in this aspect. Goel and Thakor [2008] and Bernardo and Welch [2001] both develop theories to explain why overconfident CEOs who sometimes make value-destroying investments are still widely found. Goel and Thakor [2008] show that an overconfident manager has a higher probability of being promoted to CEO than a rational manager by taking more risk. Higher risk-taking is associated with higher expected returns which may differentiate overconfident individuals from the rational counterparts. Bernardo and Welch [2001] explain it as overconfident entrepreneurs are more likely to broadcast valuable private information to the group whereas rational individuals would just follow the herd. By considering different risk attitudes (i.e. managers are risk-averse whereas shareholders are risk-neutral), Campbell et al. [2011] provide a theoretical explanation that moderate managerial optimism can align the interest of a risk-averse executive with that of rational shareholders since managerial optimism works as an opposite force to risk aversion. It is consistent with their empirical evidence that moderately optimistic managers face lower probability of forced turnover. Our paper is different from them in that we consider industry competition as a strategic reason for why rational shareholders want to hire optimistic managers. Our results also suggest that it is not always optimal to have optimistic managers whereas they find general benefits of optimism.

In terms of competition, there are some static models incorporating optimism/overconfidence in a Cournot duopoly (Kyle and Wang [1997], Englmaier [2010], and Persson and Seiler [2018]). Although Kyle and Wang [1997] develop a trading model of informed speculation which is different from corporate investment problems, it features Cournot competition and also implies a strategic channel through which overconfidence can be beneficial in equilibrium. Generally speaking, these papers analyse the effects of optimism/overconfidence on capacity choice and expected profit. Optimistic/overconfident managers tend to trade/invest more aggressively, leaving less incentive for their competitors to engage in trading/investment. In a Cournot game, the trader/investor's reaction function is decreasing in the competitor's capacity choice, the equilibrium price per unit would fall given the optimistic/overconfident competitor increases its capacity. Distinct from their models, our duopoly model does not involve capacity choice but considers the investment timing under uncertainty. The survival of optimism in our model can be attributed to the fact that it can deter the competitor's entry and thus lengthen the period of being a monopolist.

The rest of Chapter 3 is organized as follows. Section 3.2 introduces the numerical iteration method applied in solving for equilibrium results. Section 3.3 shows our main results and comparative statics. Section 3.4 concludes.

3.2 Setup and Method

The model setup is similar to Chapter 2. We also consider an entry game in the duopoly setting. Time is continuous and infinite. The firm which enters first becomes the leader as a temporary monopolist. The other firm will enter later as the follower and then share the market with the leader. Firms are required to pay lump-sum costs to enter the market. Each firm can receive different profit flows as a monopolist or a duopolist. The instantaneous profit flow is denoted by Dx where the deterministic part D and the stochastic part x are defined in section 2.2. The entry order is endogenously determined.

In the previous chapter, we assume the decisions are made by entrepreneurs. Now we consider a problem of delegation in management. To be specific, shareholders can hire managers and investment decisions are instead made by their managers. We assume that all the shareholders are realistic but that managers can have behavioural biases such as inherent optimism. Here α_A and α_B denotes the optimism levels of the managers hired by firm A and B respectively. Since we show that optimism can provide a pre-emptive advantage and increase the rational value of the firm in the duopoly setting (see Chapter 2), rational shareholders have incentives to hire optimistic managers for strategic reasons. We assume shareholders of both firms have the flexibility and ability to hire managers with different levels of optimism¹. Furthermore, our model features a one-off game which means the manager can never be fired once he is hired².

We aim to find out the desired levels of managerial optimism (denoted by α_A^* and α_B^*) from rational shareholders' perspective in equilibrium. We calculate the equilibrium levels of optimism by iteration. We iterate from the case where both managers are rational (i.e. $\alpha_A = 0$ and $\alpha_B = 0$) until convergence (i.e. when α_A^* and α_B^* remain unchanged).

At each iteration, we search for a level of managerial optimism that maximises the firm value to its rational shareholders given the rival's optimism level from the previous iteration. The maximisation problem is more complex when there is the possibility that the follower may become the leader for the feasible set of managerial optimism levels. To deal with this, we first derive local optima, i.e. the optimal levels of optimism which maximise the rational firm value as follower and leader respectively. Then we compare the two local maximum firm values and thus find out the global optimum. The following propositions summarise the properties of follower's and leader's rational values as a function of its own manager's optimism level respectively.

Proposition 3.1. The follower's value (before entry) to a rational shareholder \hat{V}_A^F decreases with α_A and thus is maximised at $\alpha_A = 0$.

Proof. See Appendix 3.A.

From a rational shareholder's point of view, the only optimal follower thresh-

¹To ensure each firm can hire its ideal manager, we assume that there are enough manager candidates in the labor market and there is no information asymmetry on degrees of optimism between shareholders and manager candidates.

²This assumption is reasonable as CEO turnover is found to be relatively low. On average, 2% of CEOs at public U.S. companies are fired every year (see Kaplan and Minton [2006], Huson et al. [2001] and Taylor [2010].)

old is the rational threshold denoted by \hat{x}_A^F and entering at any point earlier or later results in a sub-optimal investment decision. In general, optimism leads to early investment which means the firm would lose some value of waiting. As α_A increases, manager A tends to invest at an even lower threshold compared to the rational threshold \hat{x}_A^F and thus destroys firm's value even more. As long as the firm will surely be the follower, a rational shareholder would always hire a rational manager instead of an optimistic one.

Proposition 3.2. The leader's value (before entry) to a rational shareholder \hat{V}_A^{LB} increases with α_A when firm A just pre-empts firm B (i.e. $\bar{x}_B^P < \bar{x}_A^L$) and decreases with α_A when firm A is able to enter at the manager's perceived optimal leader threshold \bar{x}_A^L (i.e. $\bar{x}_B^P > \bar{x}_A^L$). Therefore, \hat{V}_A^{LB} is maximised at $\alpha_A(\bar{x}_B^P = \bar{x}_A^L)^3$.

Proof. See Appendix 3.A.

Suppose firm A is the leader for all feasible α_A . Note that leader's value (before entry) is a non-monotonic function of manager's optimism. This is because there are two opposing effects of optimism on the leader's value. On one hand, optimism could act as a "threat" to its rival under the strategic game, discouraging its rival from pre-emption (i.e. \bar{x}_B^P increases with α_A). On the other hand, managerial optimism might lead to early entry from the perspective of rational shareholders (i.e. \bar{x}_A^L decreases with α_A and the inequality $\bar{x}_A^L < \hat{x}_A^L$ always holds for positive α_A) and thus be detrimental to the firm's value if the manager is able to invest at his perceived threshold \bar{x}_A^L .

When α_A is relatively low, firm A can only pre-empt firm B. The threshold at which firm A enters as leader is constrained by firm B's pre-emptive threshold \bar{x}_B^P , which is delayed due to the "threat" caused by manager A's optimism. This enables firm A to realise more option value of waiting. This scenario documents the positive effect of manager A's optimism in pre-emptive equilibrium. The "threat" to firm B becomes stronger as manager A's optimism increases. The negative effect emerges

³This is the level of optimism α_A such that $\bar{x}_B^P = \bar{x}_A^L$

when it is possible for firm A to enter the market at \bar{x}_A^L regardless of firm B's preemption (i.e. when $\bar{x}_B^P > \bar{x}_A^L$). In this scenario, the positive effect of manager A's optimism disappears since \bar{x}_B^P no longer acts as a constraint, i.e. manager A would not delay investment until \bar{x}_B^P . Thus, the optimal α_A that maximises firm A's value as leader is the optimism level which just sets $\bar{x}_B^P = \bar{x}_A^L$.

In fact, the feasible sets of α_A and α_B are constrained by dividend yield δ_0 because the conditions $\delta_A = \delta_0 - \alpha_A > 0$ and $\delta_B = \delta_0 - \alpha_B > 0$ must be satisfied to ensure the thresholds to be infinite. For example, given manager *B*'s optimism level α_B , firm *A* can hire a manager with the optimism level $\alpha_A \in [0, \delta_0^-]$. Thus, the local optimum $\alpha_A(\bar{x}_B^P = \bar{x}_A^L)$ maximising leader's value is not always achievable. In the case where firm *A* can never enter at \bar{x}_A^L , firm *A*'s value as leader would monotonically increase with α_A . Then the local optimum of the leader's value should be δ_0^- .

Since one of the firms must be the follower, it is optimal for at least one firm to have a rational manager. Let α_A^* and α_B^* denote the optimism levels in equilibrium for manager A and B respectively. Therefore, in equilibrium, the solution for two managers' optimism levels belongs to $\{(\alpha_A^*, 0), (0, \alpha_B^*), (0, 0)\}$ where $\alpha_A^* > 0$ and $\alpha_B^* > 0$. Note that the firm with an optimistic manager must be the leader in equilibrium otherwise it is not worthwhile hiring an optimistic manager.

3.3 Results

We find that the equilibirum level of optimism (α_A^*, α_B^*) depends on which firm has the right to choose its manager (i.e. the optimal level of optimism) first. Hence, the analysis for 'firm A chooses first' and 'firm B chooses first' will be shown respectively. We use the subscript A or B to distinguish between these two cases. For example, $(\alpha_A^*, \alpha_B^*)_A$ is the equilibrium levels of α_A and α_B respectively if 'firm A chooses first'.

3.3.1 Special Cases

We will consider more general cases with different combinations of competitive advantages in monopoly and duopoly on the MAR-DAR plane. For illustration purposes, we first present some special cases shown in Figure 3.1, 3.2 and 3.3 respectively. We plot the value ratio from a rational shareholder's perspective against the manager's optimism level for each iteration. The value ratio is defined as the rational firm's value if shareholders choose a manager with optimism level α_A over the firm's value with a rational manager for a given α_B . Mathematically, the value ratio of firm A can be written as

$$VR_A(\alpha_A|\alpha_B) = \frac{\hat{V}_A(\alpha_A|\alpha_B)}{\hat{V}_A(\alpha_A = 0|\alpha_B)}$$
(3.1)

If manager A is rational, firm A's value ratio is equal to 1 (i.e. $VR_A(\alpha_A = 0|\alpha_B) =$ 1). We use red and blue solid lines to represent the value ratios for firm A and B respectively. The red shaded area stands for the region where firm A is the leader and blue shaded area stands for the region where firm B leads. The superscripts for α_A and α_B indicate the number of iterations that have been taken. For example, α_A^0 denotes the initial level of A's optimism.

Figure 3.1 illustrates the case where the two firms are identical. In equilibrium, the firm which has the right to choose first would be the leader by hiring an optimistic manager whereas the other firm would rather hire a rational manager. In Figure 3.1a Iteration 1 where 'firm A chooses first', given firm B's manager is initially rational (i.e. $\alpha_B^0 = 0$), a positive level of optimism α_A^1 maximises the firm A's value from a rational shareholder's view. The value ratio $VR_A(\alpha_A | \alpha_B^0 = 0)$ increases first and then declines. According to Proposition 3.2, the value ratio would peak at the level of A's optimism when firm A is just able to enter at its optimal leader threshold \bar{x}_A^L , even though \bar{x}_A^L is not the optimal leader threshold perceived by the rational shareholder \hat{x}_A^L and $\bar{x}_A^L < \hat{x}_A^L$. Entering at the threshold \bar{x}_A^L enables



(b) Firm B chooses first

Figure 3.1: (Identical Firms: DAR = 1, MAR = 1) The equilibrium levels of optimism vary for 'firm A chooses first' and 'firm B chooses first', i.e. $(\alpha_A^*, \alpha_B^*)_A \neq$ $(\alpha_A^*, \alpha_B^*)_B$. In equilibrium, $(\alpha_A^*, \alpha_B^*)_A = (0.014, 0)$ or $(\alpha_A^*, \alpha_B^*)_B = (0, 0.014)$. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.2$.

A to realise the highest option value of waiting if firm A were the leader. Given that firm A chooses a manager with a positive optimism level $(\alpha_A^1 > 0)$ and becomes the leader, firm B could respond by hiring a more optimistic manager. However, it turns out to be not worthwhile for firm B to be the leader compared to be the follower. As shown in Figure 3.1a Iteration 2, the value ratio of firm B (i.e. $VR_B(\alpha_B|\alpha_A^1)$ represented by the blue curve) reaches its highest level at $\alpha_B^2 = 0$, which is in the red shaded area where firm B is still the follower. It means that the extra benefit from being the leader rather than follower cannot exceed the cost of losing option value of waiting.

Figure 3.1b where 'firm B chooses first' shows the same pattern but is in different colours since both firms are identical in terms of all aspects.

Next we consider an asymmetric case where DAR = 0.6 and MAR = 1.3(see Figure 3.2). Since DAR < 1 and MAR > 1, firm B has a lower duopolistic advantage but a greater monopolistic advantage compared to firm A. Thus, firm B is the pre-emptive leader when both managers are rational. This can be confirmed by checking Iteration 1 in both Figure 3.2a and 3.2b which begin with the blue shaded area. When 'firm A chooses first', A will hire an optimistic manager and become the leader. This result makes intuitive sense as firm A has the right to choose first. More surprisingly, when 'firm B chooses first', firm A is also able to lock the role of leader from iteration 2 and firm B could never regain leadership after that. After iteration 2, firm A becomes the leader by choosing an optimistic manager. When it is firm B's turn to fight back in iteration 3, we notice that firm B chooses a rational manager as the rational follower's value is even greater than the maximum rational leader's value. The reason is as follows. As α_B increases, \bar{x}_B^P would decrease and \bar{x}_A^P would increase. The change of identity would happen when $\bar{x}_B^P = \bar{x}_A^P$. Here firm A's pre-emptive threshold \bar{x}_A^P is only associated with the change in firm A's leader value given that its follower value is independent of α_B . Since firm A has relatively lower monopolistic advantage and greater duopolistic advantage, being a temporary



(b) Firm B chooses first

Figure 3.2: (DAR = 0.6, MAR = 1.3) The equilibrium levels of optimism are the same for 'firm A chooses first' and 'firm B chooses first', i.e. $(\alpha_A^*, \alpha_B^*)_A = (\alpha_A^*, \alpha_B^*)_B = (0.01, 0)$. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.2$.



(b) Firm B chooses first

Figure 3.3: (DAR = 1.05, MAR = 0.92) The equilibrium levels of optimism are the same for 'firm A chooses first' and 'firm B chooses first', i.e. $(\alpha_A^*, \alpha_B^*)_A = (\alpha_A^*, \alpha_B^*)_B = (0, 0.008)$. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.2$.

monopolist cannot add a significant amount of monopoly profits as extra benefit to A. The duration of this monopolistic period has a relatively small effect on firm A's leader value. In other words, firm A's leader value has low sensitivity to the threshold at which the second mover (B) enters. Thus, B's optimism has limited influence on A's leader value. In contrast, firm B which has greater monopolistic advantage, the effect of α_A on \bar{x}_B^P is much stronger.

In Figure 3.3 with DAR = 1.05 and MAR = 0.92, firm *B* is the one which always ends up with an optimistic manager and firm *A* hires a rational manager in equilibrium. Even though firm *A* has a chance to reverse (see Iteration 3 in Figure 3.3a), the maximum leader value of firm *A* is even lower than its follower value with a rational manager. Here we have DAR > 1 and MAR < 1 suggesting that firm *B* has greater duopolistic advantage whereas firm *A* has greater leader advantage. Consistent with our analysis for Figure 3.2, leader's value can be affected more by its rival's optimism if the firm relies more on its monopolistic advantage rather than duopolistic advantage. Higher profitability in duopoly makes the firm (e.g. firm *B*) stronger against the rival (e.g. firm *A*)'s "threat" due to the rival's optimism.

From these two special cases, we find that an optimistic manager would be chosen by rational shareholders when the firm has a relatively greater duopolistic advantage compared to monopolistic advantage. The ratio of monopolistic advantage to duopolistic advantage is defined as the firm's first-mover advantage. The following proposition summarises and analytically proves our findings.

Proposition 3.3. The pre-emptive threshold of one firm (e.g. \bar{x}_A^P) would be more sensitive to changes in the competitor's optimism (α_B) if the firm's first-mover advantage (i.e. $FMA_A = D_A^m/D_A^d$) is higher.

Proof. See Appendix 3.A.

In sum, whether equilibrium levels of optimism will be independent of which firm choosing first depends on whether FMA_A is sufficiently different from FMA_B . For example, if we assume $\text{FMA}_A < \text{FMA}_B$, then it is more likely for firm A to undercut firm B's leader value given the higher sensitivity of firm B's leader value to A's optimism. On the contrary, manager B's optimism is less of a "threat" to firm A. Therefore, firm A could become the leader by hiring an optimistic manager in equilibrium.



3.3.2 General Cases

Figure 3.4: (Benchmark) The Equilibrium Levels of Optimism. Parameter values: r = 0.05, $\delta_0 = 0.03$, $\eta = 0.3$ and $D_A^m/D_A^d = 1.2$.

Figure 3.4 shows the equilibrium levels of managers' optimism for different asymmetric cases. All the boundaries are the same as the ones in Figure 2.3 in the absence of optimism. We use different colours to represent different scenarios. Note that it is always optimal for the follower to remain rational (see Proposition 2.1), so at least one of the two firms which finally becomes the follower in equilibrium would hire a rational manager. The white area is when rational managers are preferred by both firms (i.e. $\alpha_A^* = 0$ and $\alpha_B^* = 0$). The non-white area corresponds to the cases

when one manager is optimistic and the other manager is rational. In general, the non-white area surrounds the indifference curve (the solid curve), suggesting that it is optimal to hire an optimistic manager only when the pre-emptive thresholds of two firms are sufficiently close. If the overall asymmetry in costs and profits is too large to be compensated by managerial optimism, neither firm would hire an optimistic manager in equilibrium. When both firms have similar profitability in both monopoly and duopoly (i.e. the values of DAR and MAR are around 1 within the vellow area), the firm that would become the leader by hiring an optimistic manager is the one which chooses first. The red area represents cases where firm Ahires an optimistic manager and the blue area represents cases where firm B hires an optimistic manager in equilibrium. The dark red or blue area indicates that the two firms can switch roles in equilibrium and the disadvantaged firm in terms of costs and profits can eventually become the leader by hiring an optimistic manager. For example, in the dark red area, when the two managers are rational, firm B is the pre-emptive leader. However, firm B's pre-emption advantage mainly comes from its monopolistic advantage given firm B's duopolistic advantage is less than firm A's (i.e. DAR < 1). Similar to the case in Figure 3.2, the "threat" from manager A is strong since firm B's overall advantage relies primarily on monopoly profits which would be negatively affected by firm A's follower entry timing.

3.3.3 Comparative Statics

In this session, we perform some comparative statics to see how the effects would vary for different levels of volatility and A's first-mover advantage (FMA_A) respectively.

In Figure 3.5, holding other parameters fixed, we compare our benchmark case where $\eta = 0.3$ with the case where $\eta = 0.6$. As we increase the volatility of the demand shock, the dark red or blue areas shrink which implies that firms are less likely to switch roles by hiring optimistic managers. Since higher volatility increases the relative importance of uncertainty, inflating the growth rate of revenue flows (the



Figure 3.5: (Different Levels of Volatility) The Equilibrium Levels of Optimism. Parameter values: r = 0.05, $\delta_0 = 0.03$ and $D_A^m/D_A^d = 1.2$.

definition of optimism in our model) is less effective in changing the entry order. This finding is consistent with our previous finding as in Figure 2.6.

Figure 3.6 illustrates the equilibrium levels of optimism for different levels of firm A's first-mover advantage FMA_A measured by D_A^m/D_A^d . Note that the light blue area expands while the dark red area shrinks as FMA_A increases. Firm B is more likely to become the leader in equilibrium by hiring an optimistic manager. For high FMA_A, firm A's monopoly profits are significantly higher its duopoly profits and thus manager B's optimism can reduce firm A's leader value more effectively.

We are particularly interested in the dark regions where the two firms can switch roles in equilibrium. Within these regions, the firm which used to have preemptive advantage eventually becomes the follower due to its competitor's optimism. Since we find that this effect is closely related to the firm's first-mover advantage, we next explore how the relative magnitude of the two firms' first-mover advantage determines this entry order switching region in equilibrium.

In Figure 3.7, we plot the entry order switching regions on the FMA_A-FMA_B plane. The dashed line in the middle represents the cases where FMA_A equals FMA_B. In region A, firm A will eventually become the leader by hiring an optimistic



Figure 3.6: (Different Levels of Firm A's FMA) The Equilibrium Levels of Optimism. Parameter values: r = 0.05, $\delta_0 = 0.03$ and $\eta = 0.3$.

manager to overcome its initial competitive disadvantage. Region A features low FMA_A and high FMA_B. Similarly, we find that region B features low FMA_B and high FMA_A. The red boundary of region A is the minimum level of FMA_B required to ensure firm A switch the role to be the leader for a given level of FMA_A. Note that this boundary is always above the dashed line, which implies that FMA_B needs to be higher than FMA_A to be in the region A. In addition, the minimum required FMA_B increases dramatically with FMA_A. The means that it is difficult for firm A to become the leader by hiring an optimistic manager if firm A's own FMA is high. Region A and region B are symmetric about the dashed line. It makes sense as the


Figure 3.7: Regions Where One Firm Can Surely Be the Leader by Hiring an Optimistic Manager. The upper left region with red boundary is where firm A wins and the lower right region with blue boundary is where firm B wins. FMA_B is equal to FMA_A on the dashed line. Parameter values: r = 0.05, $\delta_0 = 0.03$ and $\eta = 0.3$.

feasible sets of FMA_A and FMA_B are the same. If FMA_B is treated as given, we would observe the similar pattern for the minimum required FMA_A to compensate for competitive disadvantage, as shown by the blue boundary. Through this analysis, we conclude that one firm's ability to switch roles by hiring an optimistic manager decreases with its own first-mover advantage and increases with its competitor's first-mover advantage.

3.4 Conclusion

This paper studies the equilibrium levels of managerial optimism in asymmetric duopoly. As an extension to Chapter 2, we consider delegated management instead of owner management and assume that rational shareholders can hire optimistic managers. We aim to analyse the interaction between managerial characteristics (optimism) with product market characteristics. In particular, we investigate which firms have incentives to hire optimistic managers and what types of managers (i.e. levels of optimism) are desired in equilibrium under the setting of duopoly.

We find the equilibrium levels of two managers' optimism by applying numerical iteration. By considering different combinations of competitive advantages in monopoly and duopoly respectively, we find that an optimistic manager is beneficial to the firm from a rational shareholder's perspective only when the two firms are close competitors. Otherwise, optimism is not sufficient to compensate for asymmetry in profitability.

We also find that at most one firm (leader) prefers an optimistic manager whereas the other firm (follower) still prefers a rational manager in equilibrium. An optimistic manager is detrimental to the follower by sub-optimally decreasing the investment threshold, which is similar to the non-competitive setting. The firm which could eventually be the leader has incentive to hire an optimistic manager because of the effective threat to its rival. Optimism can not only make the firm become the leader but also relieve the pre-emption pressure from the rival.

One interesting finding is that the disadvantaged firm can become the leader by hiring an optimistic manager and the other firm has no incentive to fight back. Managerial optimism is more effective in threatening the rival (i.e. discouraging the rival from pre-emption) when his own firm has relatively greater advantage in duopoly instead of monopoly. By defining a firm's first-mover advantage (FMA) as its monopolistic profitability over duopolistic profitability, we conclude that the firm with relatively lower FMA is more likely to hire an optimistic manager in equilibrium.

This chapter provides a rationale for the existence of managerial optimism by considering a strategic aspect. Our model also has some empirical implications. Managerial optimism is more likely to survive in industries where firms have similar pre-emptive advantage. Moreover, an optimistic manager is preferred by rational shareholders especially when the firm has relatively lower FMA compared to other firms in the same industry.

Appendix 3.A Technical Proofs

Proof of Proposition 3.1

Consider

$$\hat{V}_A^F(x) = \left(\frac{D_A^d \bar{x}_A^F}{\delta_0} - I_A\right) \left(\frac{x}{\bar{x}_A^F}\right)^{\beta_0} \tag{A3.1}$$

where $\bar{x}_A^F = \frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)I_A}{D_A^d}$ and β_A is a function of α_A given by equation (2.8). Take the first order partial derivative with respect to α_A to give

$$\frac{\partial \hat{V}_A^F(x)}{\partial \alpha_A} = \left[(1 - \beta_0) \frac{D_A^d}{\delta_0} + \beta_0 \frac{I_A}{\bar{x}_A^F} \right] \left(\frac{x}{\bar{x}_A^F} \right)^{\beta_0} \frac{d\bar{x}_A^F}{d\alpha_A}$$
(A3.2)

According to Proposition 2.1, A's follower threshold decreases with the level of α_A . Thus, the third term on the right hand side of Equation (A3.2) is negative (i.e., $\frac{d\bar{x}_A^F}{d\alpha_A} < 0$). In other words, an optimist perceived follower threshold is always lower than an otherwise realist perceived follower threshold (i.e. $\bar{x}_A^F \leq \hat{x}_A^F$). Combining with the fact that $\hat{x}_A^F = \frac{\beta_0}{\beta_0 - 1} \frac{\delta_0 I_A}{D_A^d}$, the first term on the right hand side of Equation (A3.2) satisfies

$$(1 - \beta_0)\frac{D_A^d}{\delta_0} + \beta_0 \frac{I_A}{\bar{x}_A^F} \ge (1 - \beta_0)\frac{D_A^d}{\delta_0} + \beta_0 \frac{I_A}{\hat{x}_A^F} = 0$$
(A3.3)

Given that $\left(\frac{x}{\bar{x}_A^F}\right)^{\beta_0} > 0$, we therefore have $\frac{\partial \hat{V}_A^F(x)}{\partial \alpha_A} \ge 0$ for all feasible values of α_A . That is, \hat{V}_A^F is maximised at $\alpha_A = 0$.

Proof of Proposition 3.2

 \hat{V}^{LB}_A is given by

$$V_A^{LB}(x) = \frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \bar{x}_B^F \left(\frac{x}{\bar{x}_B^F}\right)^{\beta_A} + \left(\frac{D_A^m}{\delta_0 - \alpha_A} \bar{x}_A^E - I_A\right) \left(\frac{x}{\bar{x}_A^E}\right)^{\beta_A}$$
(A3.4)

where $\bar{x}_A^E = \min\{\bar{x}_A^L, \bar{x}_B^P\}$. Consider the first order derivative of \hat{V}_A^{LB} with respect to α_A ,

$$\frac{\partial \hat{V}_{A}^{LB}(x)}{\partial \alpha_{A}} = \left[(1 - \beta_{0}) \frac{D_{A}^{m}}{\delta_{0}} + \frac{I\beta_{0}}{\bar{x}_{A}^{E}} \right] \left(\frac{x}{\bar{x}_{A}^{E}} \right)^{\beta_{0}} \frac{d\bar{x}_{A}^{E}}{d\alpha_{A}}$$
(A3.5)

If and only if $\bar{x}_A^E < \frac{\beta_0}{\beta_0 - 1} \frac{\delta_0 I_A}{D_A^m} = \hat{x}_A^L$, then the term $\left[(1 - \beta_0) \frac{D_A^m}{\delta_0} + \frac{I_A \beta_0}{\bar{x}_A^E} \right] > 0$. Note that the optimal leader threshold to the rational shareholders \hat{x}_A^L is always greater than the one which an optimistic manager perceives (similar reason as $\bar{x}_A^F < \hat{x}_A^F$), i.e. $\bar{x}_A^L < \hat{x}_A^L$.

When manager A's optimism level is low, firm A assumed to be the leader can only pre-empts firm B which implies $\bar{x}_A^E = \bar{x}_B^P < \bar{x}_A^L < \hat{x}_A^L$. According to Proposition 2.2, $\frac{d\bar{x}_A^E}{d\alpha_A} = \frac{d\bar{x}_B^P}{d\alpha_A} > 0$, which implies \hat{V}_A^{LB} increases with α_A .

When manager A's optimism level is high enough to enter at his perceived optimal leader threshold \bar{x}_A^L , then

$$\frac{\partial \hat{V}_{A}^{LB}(x)}{\partial \alpha_{A}} = \left[(1 - \beta_{0}) \frac{D_{A}^{m}}{\delta_{0}} + \frac{I\beta_{0}}{\bar{x}_{A}^{L}} \right] \left(\frac{x}{\bar{x}_{A}^{L}} \right)^{\beta_{0}} \frac{d\bar{x}_{A}^{L}}{d\alpha_{A}}$$
(A3.6)

Since $\left[(1 - \beta_0) \frac{D_A^m}{\delta_0} + \frac{I_A \beta_0}{\bar{x}_A^L} \right] > 0$ for $\bar{x}_A^L < \hat{x}_A^L$ and $\left(\frac{x}{\bar{x}_A^L} \right)^{\beta_0} > 0$, the only difference from the former case is that

$$\frac{d\bar{x}_{A}^{L}}{d\alpha_{A}} = \frac{I_{A}}{2D_{A}^{m}} \left[\frac{\frac{r + \alpha_{A} - \delta_{0}}{\eta^{2}} - \frac{1}{2}}{\sqrt{\left(\frac{r + \alpha_{A} - \delta_{0}}{\eta^{2}} - \frac{1}{2}\right)^{2} + \frac{2r}{\eta^{2}}}} - 1 \right] < 0$$
(A3.7)

Here $\frac{\partial \hat{V}_A^{LB}(x)}{\partial \alpha_A} < 0$, i.e. \hat{V}_A^{LB} decreases with α_A .

Therefore, \hat{V}_A^{LB} can be maximised when α_A just letting $\bar{x}_B^P = \bar{x}_A^L$.

Proof of Proposition 3.3

Given $\frac{d\bar{x}_A^P}{d\alpha_B} > 0$ (see Proposition 2.2), we want to prove that $\frac{d\bar{x}_A^P}{d\alpha_B}$ increases with FMA_A.

If we define $f(x, \alpha_B) = V_A^L(x, \alpha_B) - V_A^F(x)$, then \bar{x}_A^P solves $f(\bar{x}_A^P, \alpha_B) = 0$.

Consider

$$\frac{d\bar{x}_{A}^{P}}{d\alpha_{B}} = -\frac{\partial f(\bar{x}_{A}^{P}, \alpha_{B})}{\partial \alpha_{B}} \middle/ \frac{\partial f(\bar{x}_{A}^{P}, \alpha_{B})}{\partial \bar{x}_{A}^{P}}$$
(A3.8)

where

$$\frac{\partial f(\bar{x}_A^P, \alpha_B)}{\partial \alpha_B} = \frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} (1 - \beta_A) \left(\frac{\bar{x}_A^P}{\bar{x}_B^F}\right)^{\beta_A} \frac{d\bar{x}_B^F}{d\alpha_B}$$
(A3.9)

$$\frac{\partial f(\bar{x}_A^P, \alpha_B)}{\partial \bar{x}_A^P} = \frac{\beta_A}{\bar{x}_A^P} \left[\frac{D_A^d - D_A^m}{\delta_0 - \alpha_A} \left(\frac{\bar{x}_A^P}{\bar{x}_B^F} \right)^{\beta_A} - \left(\frac{D_A^d \bar{x}_A^F}{\delta_0 - \alpha_A} - I_B \right) \left(\frac{\bar{x}_A^P}{\bar{x}_A^F} \right)^{\beta_A} \right] + \frac{D_A^m}{\delta_0 - \alpha_A}$$
$$= \frac{\beta_A}{\bar{x}_A^P} \left(I_A - \frac{D_A^m}{\delta_0 - \alpha_A} \bar{x}_A^P \right) + \frac{D_A^m}{\delta_0 - \alpha_A}$$
(A3.10)

Without loss of generality, let $D_A^m = k D_A^d = k D$ and $I_A = \phi D$ where $k = D_A^m / D_A^d = FMA_A > 1$. Then, we need to verify if

$$\frac{d\bar{x}_A^P}{d\alpha_B} = \frac{\frac{(k-1)D}{\delta_0 - \alpha_A} (1 - \beta_A) \left(\frac{1}{\bar{x}_B^F}\right)^{\beta_A} \frac{d\bar{x}_B^F}{d\alpha_B}}{\left[\frac{D}{\delta_0 - \alpha_A} (1 - \beta_A)k + \frac{\beta_A \phi D}{\bar{x}_A^P(k)}\right] \left(\frac{1}{\bar{x}_A^P(k)}\right)^{\beta_A}}$$
(A3.11)

increases with k. We notice that the numerator on the right hand side of (A3.14) is increasing in k as $D/(\delta_0 - \alpha_A) > 0$, $1 - \beta_A < 0$, $\left(\frac{1}{\bar{x}_B^F}\right)^{\beta_A} > 0$ and $\frac{d\bar{x}_B^F}{d\alpha_B} < 0$ (see Proposition 2.1). Let

$$g(k) = \left[\frac{D}{\delta_0 - \alpha_A}(1 - \beta_A)k + \frac{\beta_A \phi D}{\bar{x}_A^P(k)}\right] \left(\frac{1}{\bar{x}_A^P(k)}\right)^{\beta_A}$$
(A3.12)

where $\bar{x}_A^P(k)$ is a function of k. We define $h(x,k) = V_A^L(x,k) - V_A^F(x,k)$, then $\bar{x}_A^P(x,k) = V_A^L(x,k) - V_A^F(x,k)$.

and k satisfy $h(\bar{x}_A^P, k) = 0$, i.e.

$$\frac{(1-k)D}{\delta_0 - \alpha_A} \bar{x}_B^F \left(\frac{\bar{x}_A^P}{\bar{x}_B^F}\right)^{\beta_A} + \frac{kD}{\delta_0 - \alpha_A} \bar{x}_A^P - \phi D - \left(\frac{\bar{x}_A^F D}{\delta_0 - \alpha_A} - \phi D\right) \left(\frac{\bar{x}_A^P}{\bar{x}_A^F}\right)^{\beta_A} = 0 \quad (A3.13)$$

Consider

$$\frac{d\bar{x}_A^P}{dk} = -\frac{\partial h(\bar{x}_A^P, k)}{\partial k} \bigg/ \frac{\partial h(\bar{x}_A^P, k)}{\partial \bar{x}_A^P}$$
(A3.14)

where

$$\frac{\partial h(\bar{x}_A^P, k)}{\partial k} = D \left[-\frac{\bar{x}_B^F}{\delta_0 - \alpha_A} \left(\frac{\bar{x}_A^P}{\bar{x}_B^F} \right)^{\beta_A} + \frac{\bar{x}_A^P}{\delta_0 - \alpha_A} \right]$$
(A3.15)

$$\frac{\partial h(\bar{x}_A^P, k)}{\partial \bar{x}_A^P} = D\left\{ \left[\frac{1-k}{\delta_0 - \alpha_A} \bar{x}_B^F \left(\frac{\bar{x}_A^P}{\bar{x}_B^F} \right)^{\beta_A} - \left(\frac{\bar{x}_A^F}{\delta_0 - \alpha_A} - \phi \right) \left(\frac{\bar{x}_A^P}{\bar{x}_A^F} \right)^{\beta_A} \right] \frac{\beta_A}{\bar{x}_A^P} + \frac{k}{\delta_0 - \alpha_A} \right\} = D\left[\frac{\beta_A \phi}{\bar{x}_A^P} - (\beta_A - 1) \frac{k}{\delta_0 - \alpha_A} \right]$$
(A3.16)

Thus,

$$\frac{d\bar{x}_A^P}{dk} = \frac{\frac{\bar{x}_B^F}{\delta_0 - \alpha_A} \left(\frac{\bar{x}_A^P}{\bar{x}_B^F}\right)^{\beta_A} - \frac{\bar{x}_A^P}{\delta_0 - \alpha_A}}{\frac{\beta_A \phi}{\bar{x}_A^P} - (\beta_A - 1)\frac{k}{\delta_0 - \alpha_A}}$$
(A3.17)

The numerator of (A3.20) is positive if and only if $\frac{\bar{x}_B^F}{\bar{x}_A^P} > \left(\frac{\bar{x}_B^F}{\bar{x}_A^P}\right)^{\beta_A}$, which is true as $\frac{\bar{x}_B^F}{\bar{x}_A^P} > 1$ and $\beta_A > 1$. The denominator of (A3.20) is positive if and only if

$$\frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)\phi D}{kD} > \bar{x}_A^P \tag{A3.18}$$

Since $\bar{x}_A^L = \frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)\phi D}{kD}$ and the optimal leader threshold \bar{x}_A^L is always greater than \bar{x}_A^P , it suggests that $\frac{d\bar{x}_A^P}{dk} > 0$ given the numerator of (A3.20) is also positive.

Then we consider

$$\frac{dg(k)}{dk} = \underbrace{-\left[\frac{D(\beta_A - 1)}{\delta_0 - \alpha_A} + \frac{\beta_A \phi D}{\left(\bar{x}_A^P\right)^2} \frac{d\bar{x}_A^P}{dk}\right] \left(\frac{1}{\bar{x}_A^P}\right)^{\beta_A}}_{(1)} + \underbrace{\underbrace{\frac{\beta_A}{\bar{x}_A^P} \left[\frac{D(\beta_A - 1)}{\delta_0 - \alpha_A}k - \frac{\beta_A \phi D}{\bar{x}_A^P}\right] \left(\frac{1}{\bar{x}_A^P}\right)^{\beta_A} \frac{d\bar{x}_A^P}{dk}}_{(2)}}_{(2)}$$

The first term (1) on the right hand side of (A3.22) is negative as $\frac{D(\beta_A - 1)}{\delta_0 - \alpha_A} > 0$, $\frac{\beta_A \phi D}{(\bar{x}_A^P)^2} \frac{d\bar{x}_A^P}{dk} > 0$ and $\left(\frac{1}{\bar{x}_A^P}\right)^{\beta_A} > 0$. The second term (2) is negative if and only if

$$\frac{D(\beta_A - 1)}{\delta_0 - \alpha_A} k - \frac{\beta_A \phi D}{\bar{x}_A^P} < 0 \tag{A3.20}$$

This is equivalent to

$$\bar{x}_A^P < \frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)\phi D}{kD}$$
(A3.21)

which holds as $\bar{x}_A^P < \bar{x}_A^L = \frac{\beta_A}{\beta_A - 1} \frac{(\delta_0 - \alpha_A)\phi D}{kD}$. Thus, we can conclude that $\frac{dg(k)}{dk} < 0$ which implies that the denominator of (A3.14) is decreasing in k. Combining the fact that the numerator of (A3.14) is increasing in k, we have shown that $\frac{d\bar{x}_A^P}{d\alpha_B}$ increases with k (i.e. FMA_A).

Chapter 4

Competition, Investment Reversibility and Stock Returns

4.1 Introduction

How does product market competition affect stock returns? This question has implications for how a firm's external rather than internal environment influences its own risk. However, the relation cannot be simply signed given that mixed empirical evidence has been found in the literature (e.g., Hou and Robinson, 2006; Bustamante and Donangelo, 2017). In this chapter, we revisit this important question and highlight the crucial role of investment reversibility in determining the competition-return relation both theoretically and empirically.

Aguerrevere [2009] first theoretically links firms' investment decisions under competition to their systematic risk. He assumes investment is irreversible and considers only expansion options. In fact, most investment is not completely irreversible but partially reversible. Thus, we relax this assumption and consider a wider range of firms' decisions (i.e. both investment and disinvestment decisions). An increasing number of researchers have recognised that accounting for investment reversibility and disinvestment options is necessary when predicting firms' systematic risk and stock returns (e.g., Hackbarth and Johnson, 2015; Gu et al., 2017; Aretz and Pope, 2018). However, how competition interacts with investment reversibility and what the implications on risk are have not yet been studied. We bridge this gap in the literature and find an alternative perspective to understand the mixed evidence mentioned at the beginning of this chapter.

To show the effect of investment reversibility on the competition-return relation, we develop a more comprehensive Cournot competition model in which firms can scale up or down their capacity as the market demand stochastically evolves. In contrast to prior such models [e.g. Grenadier, 2002; Aguerrevere, 2009; Morellec and Zhdanov, 2019], we further incorporate contraction options in addition to assets in place and expansion options. Each firm makes investment and disinvestment decisions simultaneously under competition, which determines the dynamics of expansion and contraction option values. Thus, the presence of competitors can influence the riskiness of the firm's options. On the other hand, by introducing fixed operating costs, the assets-in-place component can also affect the firm's risk through the channel of operating leverage as first noted by Carlson et al. [2004].

We find two opposing effects of competition on firms' risk and the relative importance of these two opposing effects is determined by investment reversibility. If investment is highly reversible, the negative effect dominates the positive effect. Therefore, the competition-return relation is more negative for higher investment reversibility.

For either expansion options or contraction options, the option-implied component of risk is lower for firms in more competitive industries. This is called the *real option effect*. More competition implies that firms exercise expansion options earlier because of pre-emption by other competitions. Expanding at a lower threshold destroys the firm's option value of waiting. On the other hand, given that the output price is inversely correlated with total output, an increase in the output price follows any firm's disinvestment *ceteris paribus*. That is, a firm benefits from other firms' disinvestment as its existing assets then generate a higher profit. Hence, competition increases the value of contraction options. Exercising an expansion option can be viewed as exchanging riskless cash for risky assets whereas exercising a contraction option implies an opposite action (i.e. exchanging risky assets for riskless cash). Therefore, a firm with a higher value of expansion (contraction) options is more (less) risky. The *real option effect* predicts that competition reduces risk since the value of expansion (contraction) option decreases (increases) with the level of competition.

Regardless of options to adjust capacity, competition increases the firm's operating leverage and thus its risk. Intuitively, firms in more competitive industries earn less profit. Since firms are committed to production costs, lower profitability implies higher operating leverage. Meanwhile, a firm's profit margin works as a cushion to buffer negative demand shocks. Competition reduces the firm's profit margin, thereby increasing the firm's sensitivity to the demand shock. This *operating leverage effect* is also documented by Aguerrevere [2009] and Bustamante and Donangelo [2017]. However, they conclude that the operating leverage effect dominates when demand is low. By endogenizing the option to disinvest, the firm can smooth out profit flows by reselling its assets and saving associated production costs if demand goes down. Disinvestment options attenuate the operating leverage effect.

We further show that which of these two opposing effects dominates depends on investment reversibility instead of the level of demand as in Aguerrevere [2009]. Intuitively, if investment is more reversible, firms are more likely to adapt their scale of capital in response to the market demand and are less committed to the production costs. That is, firms are less sensitive to the risk arising from assets in place. Therefore, the operating leverage effect which predicts the positive effect of competition is reduced as investment reversibility increases. In other words, the real option effect dominates for higher investment reversibility. Overall, our model predicts a negative interaction effect of competition and investment reversibility on the firms' risk.

The paper proceeds by taking our theoretical prediction to data. We measure product market competition by the widely used sales-based Herfindahl-Hirschman Index (*HHI*). Notably *HHI* is an inverse measure of competition. To measure investment reversibility, we use the asset redeployability index constructed by Kim and Kung [2016]. By using the Bureau of Economic Analysis (BEA) capital flow table, they first compute the asset-level redeployability as the proportion of firms that use a given asset. Then they compute the industry-level redeployability by taking the value-weighted average of asset-level redeployability. Lastly they compute the firm-level redeployability index as the sales-weighted average of industry-level redeployability across business segments in which the firm operates. The redeployability index will be higher for firms that use assets with more alternative uses. If a given asset can be used by more industries or firms, there should be more potential buyers in the secondary market. The high demand of assets tends to increase the resale prices which coincides with the definition of investment reversibility in our model. Kim and Kung [2016] also relate the asset redeployability measure to the inverse of investment irreversibility and real options theory.

In the empirical analysis, we first examine the monthly excess returns of portfolios constructed via independent sorts on HHI and asset redeployability. For the low redeployability quintile, returns increase with the level of competition. However, competition decreases returns for the high redeployability quintile. This pattern shows that the competition-return relation is more negative for firms with more redeployable assets. Specifically, buying the high-minus-low competition portfolio for firms with a low redeployability index and selling the high-minus-low competition portfolio for firms with a high redeployability index yields a monthly excess return of 0.58%. After controlling for other standard risk factors in asset pricing, the abnormal returns show similar patterns across constructed portfolios. Next we run panel and Fama-MacBeth regressions at the firm or industry level including controls. The interaction effect of competition and investment reversibility on stock returns is significantly negative. Additional tests using alternative measures of competition (i.e. assets-based *HHI* and concentration ratio) show significant results that further confirm our main prediction. Lastly, we show that our results are also robust to a different measure of investment reversibility—inflexibility—which is motivated by real options theory and reflects the width of the inaction region [see Gu et al., 2017].

The rest of this Chapter is organized as follows. Section 4.2 reviews the related literature. Section 4.3 describes the model and derives the main prediction. Section 4.4 presents the empirical measures and results. Section 4.5 concludes.

4.2 Related Literature

This chapter is part of a growing literature on investment-based asset pricing. More specifically, our paper explores the implications of product market competition. Aguerrevere [2009] is among the first to theoretically study the relationship between competition and firms' risk. Based on the Cournot oligopoly framework developed by Grenadier [2002], he shows that the cross-sectional effect of competition on expected return depends on the level of demand. To investigate the time-series dynamics of betas, Carlson et al. [2014] consider an asymmetric duopoly game and study the impacts of own and rival expansion or contraction actions on risk. In a leaderfollower equilibrium, the rival's action always reduces own-firm risk, namely hedging effect. By focusing on different investment equilibria in duopoly, Bustamante [2014] predicts that close competitors are more likely to invest simultaneously which helps to explain return co-movement. Bustamante and Donangelo [2017] study how competition interacts with stock returns by allowing potential entry by new firms. They find that firms in more competitive industries are faced with greater entry threat by new firms. Bustamante and Donangelo [2017] also document the operating leverage effect and further allow entry threat by new firms. Consistent with Carlson et al. [2014], they show that potential entry lowers the systematic risk of incumbents (i.e. hedging effect). Empirically, they find an overall negative relation between competition and stock returns. With a model similar to Grenadier [2002] and Aguerrevere [2009], Morellec and Zhdanov [2019] show that competition yields a negative relation between volatility and equity returns and the relation is more negative when the degree of competition increases. Our paper augments this line of literature by further incorporating the possibility of disinvestment and highlighting the role of investment reversibility.

Our study is also related to the literature that links firms' contraction options to stock returns. Although original real options models [e.g., Dixit and Pindyck, 1994; McDonald and Siegel, 1986] typically assume irreversible investment, in reality, investment is mostly partially reversible. Partially reversible investment implies that firms hold not only expansion options (or investment options) but also contraction options (or disinvestment options). By introducing disinvestment options, Aretz and Pope [2018] find a near-monotonically negative relation between capacity overhang and stock returns. This is because disinvestment options reduce systematic risk especially when disinvestment options are most valuable and disinvestment option values increase with the degree of capacity overhang. Hackbarth and Johnson [2015] develop a unified model that combines firms' expansion options, assets in place and contraction options and predict that risk and expected return are sinusoidal functions of productivity. Their findings reconcile several seemingly contradictory anomalies. Specifically, value and investment effects coincide with the region where operating leverage effects dominate (i.e. downward sloping riskprofitability relation), while momentum and profitability effects are consistent with an upward sloping relation caused by real options effects. Using the same modelling method, Gu et al. [2017] further show how firms' flexibility to scale up and down their asset base determines the relation between operating leverage and systematic risk. They predict that flexibility makes risk negatively related to operating leverage. Our paper contributes to this strand of literature by extending the analysis to a competitive setting (i.e. including strategic interactions between firms). Our model predicts a negative relation between competition and stock returns for expansion and contraction option regions and a positive relation for assets-in-place region. More importantly, we find that the relative importance of these two opposing effects depends on investment reversibility.

Empirically, our paper is related to the literature on the relationship between product market competition and stock returns. Hou and Robinson [2006] find a negative relation between industry concentration and stock returns. Gu [2016] documents that firms in competitive industries have higher expected returns than firms in concentrated industries, especially among R&D-intensive firms. In contrast to Hou and Robinson [2006], Bustamante and Donangelo [2017] find a positive relation between industry concentration and stock returns using alternative measures of industry concentration. The mixed empirical evidence calls for more understanding of the complex competition-return relation. Building on our theory, we reconcile the seemingly conflicting empirical evidences by showing that the effect of competition on stock returns is more negative when investment is more reversible.

Our empirical analysis is also related to the literature on investment reversibility. Balasubramanian and Sivadasan [2009] construct an industry-level measure of capital resalability. They find that industry mean productivity increases with capital resalability and productivity dispersion decreases with capital resalability. Kim and Kung [2016] propose an asset redeployability index measuring the extent to which assets have alternative uses. Their empirical results show that corporate investment is more negatively correlated with uncertainty when firms' assets are less redeployable. Thus, it is evident that irreversibility indeed significantly influences firms' investment decisions, capital accumulation and ultimately economic growth. Motivated by real options theory, Gu et al. [2017] construct a measure for the firm's inflexibility to adjust their installed capital. Investment is less reversible for more inflexible firms. Empirically, they find a positive interaction effect between operating leverage and inflexibility in predicting returns. Our paper uses both the asset redeployability index constructed by Kim and Kung [2016] and the inflexibility measure as in Gu et al. [2017] to examine how these measures interact with the level of competition in determining stock returns.

4.3 Theoretical Analysis

4.3.1 Model

Our model is based on Grenadier [2002], Aguerrevere [2009] and Morellec and Zhdanov [2019], who use a real-option framework to derive equilibrium investment strategies in symmetric Cournot competition. Notably, they assume that investment is irreversible. We further relax this assumption suggesting that firms are able to scale down their capacity by reselling installed capital. Thus, our model incorporates disinvestment decisions in addition to investment decisions.

Consider an oligopolistic industry with n identical firms producing a single, homogeneous product. The degree of product market competition is measured by the number of firms (i.e. more firms implies a higher degree of competition). Each unit of capacity can produce one unit of output per unit of time at a variable cost of c. All the firms produce at full capacity. Let $q_{i,t}$ denote the firm i's capacity (or output produced by firm i) at time t. Then the total industry output Q_t is given by $Q_t = \sum_{i=1}^n q_{i,t}$. Assume that the output price P_t is a function of Q_t and a stochastic demand shock Y_t , i.e.

$$P_t = Y_t Q_t^{-\frac{1}{\gamma}} \tag{4.1}$$

where the elasticity of demand γ is a constant greater than 1. Equation (4.1) is also known as the inverse demand function. The output price P_t is strictly decreasing in Q_t . The demand shock Y_t under the risk neutral measure follows the stochastic process

$$dY_t = \mu Y_t dt + \sigma Y_t dW_t \tag{4.2}$$

where μ and σ are positive constants corresponding to drift and volatility, and dW_t is the increment of a standard Wiener process. For convergence, the drift satisfies $\mu < r$ where r is the risk-free interest rate.

For model tractability, we follow Grenadier [2002], Aguerrevere [2009] and Morellec and Zhdanov [2019] and thus focus on open-loop equilibria ¹. For a given level of total output Q_t , firms play a static Cournot game where each firm can choose its own capacity level to maximize profits given other firms' choices.

As the market demand Y_t evolves stochastically, each firm has the flexibility to scale its capacity level upward or downward. The investment cost of one extra unit of capacity is a constant I > 0. We assume investment is partially reversible and the resale price for disinvesting one unit of capacity is k * I where 0 < k < 1². A higher k indicates the investment is more reversible. There is a sunk cost of (1 - k)I when expanding the firm with an additional unit of capacity. Investment timing decisions are also important under uncertainty given part of the investment cost can never be recovered.

We assume that the capacity Q_t is infinitely divisible. Since firms are identical in the same industry, we have $q_{i,t} = \frac{Q_t}{n}$ for any firm *i*. For a finite number of firms, $q_{i,t}$ is also infinitely divisible. It implies that each firm can increase or decrease its capacity by an infinitesimal amount $dq_{i,t}$. The problem for the firm is to choose the optimal path of capacity that maximizes the present value of its future cash flows. The firm's value is contingent on the total industry capacity Q_t and the

¹In open-loop equilibria (also known as precommitment equilibria), firms simultaneously commit themselves to entire time paths of investment [Fudenberg and Tirole, 1991, Chap.13]. See Back and Paulsen [2009] for more discussions on this assumption.

 $^{^{2}}k$ is less than 1 to preclude any arbitrage opportunity.

level of the demand shock Y_t , i.e.

$$V_n(Y,Q) = \max_{\{q_{i,t}:t>0\}} \mathbb{E}\left[\int_0^{+\infty} e^{-rt} \left((Y_t Q_t^{-\frac{1}{\gamma}} - c)q_{i,t} dt - I dq_{i,t}^+ + kI dq_{i,t}^- \right) \right]$$
(4.3)

where $dq_{i,t}^+$ and $dq_{i,t}^-$ represent increased or decreased amount of capacity at time t. The subscript n denotes that the firm is in an industry with n identical firms hereafter. The instantaneous cash flow of the firm comes from the revenue of ongoing operations, the cost of investment in new capacity (if investment occurs), and the revenue of reselling existing capacity (if disinvestment occurs).

The optimization problem for firm i can be viewed as a sequence of investment and disinvestment options. For a given level of Q_t , firm i needs to make decisions on when to invest and disinvest in a marginal unit of capital. As in Grenadier [2002], a simplified approach is to consider a myopic strategy assuming that the supply by firm i's competitors, Q_{-i} , remains fixed ³. In Proposition 4.1, we derive the optimal investment and disinvestment thresholds.

Proposition 4.1. In the n-firm industry, when investment is partially reversible, a firm's investment in a marginal unit of capital occurs as soon as Y rises to reach the threshold $\overline{Y_n}(Q)$ which satisfies

$$\overline{Y_n}(Q) = \frac{\beta_1}{\beta_1 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(I + \frac{c}{r}\right) \frac{\phi - x^{\beta_2}}{x - x^{\beta_2}} Q^{\frac{1}{\gamma}}$$
(4.4)

or the output price P_t hits the threshold $\overline{P_n}$ from below

$$\overline{P_n} = \frac{\beta_1}{\beta_1 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(I + \frac{c}{r}\right) \frac{\phi - x^{\beta_2}}{x - x^{\beta_2}}$$
(4.5)

The firm's disinvestment in a marginal unit of capital occurs as soon as Y falls

³Leahy [1993] shows that a competitive firm's optimal investment strategy coincides with a myopic monopolist's. The optimal investment timing is determined by comparing the value of investing later with the value of investing immediately. Competition erodes both values simultaneously and therefore the trade-off is unaffected. Grenadier [2002] extends this to an oligopoly setting.

below the threshold $\underline{Y}_n(Q)$ which satisfies

$$\underline{Y_n}(Q) = \frac{\beta_2}{\beta_2 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(kI + \frac{c}{r}\right) \frac{x - \phi^{-1} x^{\beta_1 + 1}}{x - x^{\beta_1}} Q^{\frac{1}{\gamma}}$$
(4.6)

or the output price P_t hits the threshold P_n from above

$$\underline{P_n} = \frac{\beta_2}{\beta_2 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(kI + \frac{c}{r}\right) \frac{x - \phi^{-1} x^{\beta_1 + 1}}{x - x^{\beta_1}}$$
(4.7)

 $\begin{array}{l} \beta_1 \ and \ \beta_2 \ are \ the \ positive \ and \ negative \ roots \ of \ the \ quadratic \ equation \ \frac{\sigma^2}{2}\xi(\xi-1) + \\ \mu\xi - r = 0. \ \phi \ is \ defined \ as \ \phi = (kI + \frac{c}{r})/(I + \frac{c}{r}) \ and \ x \ solves \ \frac{\beta_2}{\beta_2 - 1} \frac{\phi - x^{\beta_1}}{x - x^{\beta_1}} = \\ \frac{\beta_1}{\beta_1 - 1} \frac{\phi - x^{\beta_2}}{x - x^{\beta_2}}. \end{array}$

Proof. See Appendix 4.A.

For a given level of Q, both the investment threshold $\overline{Y_n}(Q)$ and the disinvestment threshold $\underline{Y_n}(Q)$ decrease with the number of firms n. However, the implications of competition on investment and disinvestment timing appear to be different. A lower investment threshold implies accelerated exercise of investment options whereas a lower disinvestment threshold implies delayed exercise of disinvestment options.

Intuitively, competition accelerates investment as the possibility of preemption by competitors diminishes the value of waiting. Since the output price is a decreasing function of the total output, investing before other competitors enables the firm to sell its products at a higher price until other firms invest⁴.

Meanwhile, competition delays disinvestment. The output price would increase after disinvestment and this is benefitial to the existing capacity of the firm. Disinvesting after other competitors allows the firm to enjoy a price boost induced by other firms' disinvestment. Hence, each firm has an incentive to be the last-mover

 $^{^4{\}rm This}$ result is consistent with Grenadier [2002], Aguerrevere [2009] and Morellec and Zhdanov [2019].

when facing disinvestment decisions. This is also known as war of $attrition^5$.

Since firms are identical within one industry, in equilibrium each firm should have the same level of capacity at every instant. This implies that symmetric firms move simultaneously. In our continuous-time model, the firms can adjust their capacity within an infinitesimal time based on the realization of Y_t . That is, the desired capacity conditional on the current demand level, $Q_n^*(Y_t)$, can be reached at every instant. The investment and disinvestment rules are given by Proposition 4.1, which provide mappings between the demand level and the capacity level for an *n*firm industry. Comparing $Q_n^*(Y_t)$ with the optimal capacity for a monopoly industry $Q_1^*(Y_t)$ using either Equation (4.4) or (4.6) yield the same following relationship

$$Q_n^*(Y_t) = \left[\frac{n\gamma - 1}{n(\gamma - 1)}\right]^{\gamma} Q_1^*(Y_t)$$
(4.8)

Note that $Q_n^*(Y_t)$ increases with n since $\left[\frac{n\gamma-1}{n(\gamma-1)}\right]^{\gamma}$ is an increasing function of n. This relationship has a natural interpretation. Competition accelerates investment and delays disinvestment suggesting that capital accumulation is faster for more competitive industries.

Next we consider the value of the firm in the inaction region. Following standard arguments, $V_n(Y, Q)$ satisfies the following differential equation

$$rV_n(Y,Q) = \mu Y \frac{\partial V_n(Y,Q)}{\partial Y} + \frac{1}{2}\sigma^2 Y^2 \frac{\partial^2 V_n(Y,Q)}{\partial Y^2} + \frac{Q}{n} (YQ^{-\frac{1}{\gamma}} - c)$$
(4.9)

With the optimal investment and disinvest thresholds derived in Proposition 4.1, the value-matching conditions are given by

$$V_n(\overline{Y_n}, Q) = V_n(\overline{Y_n}, Q + dQ) - \frac{I}{n}dQ$$
(4.10)

⁵Disinvestment decisions resemble exit decisions. Murto [2004] studies the problem of exit and shows that, in contrast to pre-emption in entry, strategic interaction leads to a war of attrition in exit.

$$V_n(\underline{Y_n}, Q) = V_n(\underline{Y_n}, Q - dQ) + \frac{kI}{n}dQ$$
(4.11)

where $\overline{Y_n}$ is the optimal investment threshold for firm *i* to increase its capacity from q_i to $q_i + dq$ and $\underline{Y_n}$ is the optimal disinvestment threshold for firm *i* to decrease its capacity from q_i to $q_i - dq$. In the symmetric equilibrium, the total industry capacity increases (decreases) by dQ if each firm invests (disinvests) dq at the cost (benefit) of Idq (kIdq). The following proposition solves for $V_n(Y, Q)$.

Proposition 4.2. In the n-firm industry where symmetric Cournot competition is considered and investment is partially reversible, the firm has the value function given by

$$V_n(Y,Q) = \underbrace{A(Q)Y^{\beta_1}}_{expansion \ option} + \underbrace{B(Q)Y^{\beta_2}}_{contraction \ option} + \underbrace{\frac{Q}{n}\left(\frac{YQ^{-\frac{1}{\gamma}}}{r-\mu} - \frac{c}{r}\right)}_{assets \ in \ place}$$
(4.12)

where

$$A(Q) = \frac{Q}{n} \frac{\gamma}{\gamma - \beta_1} a(\underline{P_n}, \overline{P_n}) Q^{-\frac{\beta_1}{\gamma}}$$
(4.13)

$$B(Q) = \frac{Q}{n} \frac{\gamma}{\gamma - \beta_2} b(\underline{P_n}, \overline{P_n}) Q^{-\frac{\beta_2}{\gamma}}$$
(4.14)

$$a(\underline{P_n}, \overline{P_n}) = \frac{1}{\overline{P_n}^{\beta_1} \underline{P_n}^{\beta_2} - \underline{P_n}^{\beta_1} \overline{P_n}^{\beta_2}} \left[\left(I + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\overline{P_n}}{r - \mu} \right) \underline{P_n}^{\beta_2} - \left(kI + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\underline{P_n}}{r - \mu} \right) \overline{P_n}^{\beta_2} \right]$$

$$b(\underline{P_n}, \overline{P_n}) = \frac{1}{\underline{P_n}^{\beta_1} \overline{P_n}^{\beta_2} - \overline{P_n}^{\beta_1} \underline{P_n}^{\beta_2}} \left[\left(I + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\overline{P_n}}{r - \mu} \right) \underline{P_n}^{\beta_1} - \left(kI + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\underline{P_n}}{r - \mu} \right) \overline{P_n}^{\beta_1} \right]$$

$$(4.16)$$

Proof. See Appendix 4.A.

Equation (4.12) shows that the firm's value can be decomposed into three components, i.e. the expansion option, the contraction option, and assets in place. As Y goes to zero, the first term representing the expansion options disappears. This is because the firm would be unlikely to exercise options to expand if the market

demand declines to an extremely low level. Likewise, the component of contraction option becomes absent as Y tends to infinity. The contraction option is valuable when the firm is likely to disinvest. The last term represents the value of assets in place (i.e. the present value of profit flows keeping the level of market capacity fixed).

4.3.2 Hypothesis Development

To explore the asset pricing implications, we can use the firm's valuation to derive the function for beta. Following Carlson et al. [2004], the systematic risk β is defined as the elasticity of the firm's value with respect to the underlying stochastic demand, i.e. $\beta = \frac{\partial V_n(Y,Q)}{\partial Y} \frac{Y}{V_n}$.

Proposition 4.3. The firm's systematic risk is given by

$$\beta = 1 + \underbrace{(\beta_1 - 1) \frac{A(Q)Y^{\beta_1}}{V_n}}_{expansion \ option} + \underbrace{(\beta_2 - 1) \frac{B(Q)Y^{\beta_2}}{V_n}}_{contraction \ option} + \underbrace{\frac{Q}{n} \frac{c/r}{V_n}}_{operating \ leverage}$$
(4.17)

Proof. See Appendix 4.A.

As seen in Equation (4.17), β is associated with the relative values of the firm's expansion option, contraction option, and operating leverage. As $\beta_1 > 1$, expansion option increases the firm's risk. Similarly, as $\beta_2 < 1$, the contraction option decreases the firm's risk. β also increases with operating leverage.

In contrast to Aguerrevere [2009], we extend the firm's range of options by introducing a contraction option. Thus, the effect of competition on the value of the contraction option also plays an important role in determining β . Different from the effect on expansion options, competition has a positive impact on the value of contraction options. One firm can benefit from its competitors' disinvestment as the output price increases more if more firms contract at the same time. Hence, more competition implies higher values of contraction options. As for the firm's risk, the contraction option lowers risk as it features an opportunity to exchange risky assets for riskless cash. The effect is even stronger when the contraction option is more valuable [see e.g., Aretz and Pope, 2018]. Consequently, as the market demand decreases (i.e. contraction option becomes more valuable), firms in more concentrated industries are riskier.

On the other hand, when the demand is high, the component of the expansion option becomes dominant. Consistent with prior research, we find a negative competition-return relation as competition erodes the value of the expansion option. For illustration purposes, we use the term *real option effect* to describe the negative effect of competition on β through either expansion or contraction option channel. For a moderate level of demand, neither expansion nor contraction is likely to occur. Then the firm's risk is mainly affected by operating leverage. Competition reduces the firm's profit margin and thus increases operating leverage. Since risk increases with operating leverage, the effect of competition on β is positive. This *operating leverage effect* is first noted by Aguerrevere [2009]. However, we further show that when the *operating leverage effect* dominates depends on the level of investment reversibility instead of the market demand.

To delineate these effects, for a given value of k, we plot betas for different levels of competition (i.e. the number of firms n). Then we gradually increase kto see how the effect of competition on β changes as the reversibility of investment increases.

[Place Figure 4.1 about here]

Figure 4.1 plots firms' systematic risk β against market demand Y in the inaction region. The lower boundary $\underline{Y_n}$ is the disinvestment threshold. Once Y decreases to $\underline{Y_n}$, it becomes optimal for the firm to exercise the contraction option. Similarly, the expansion option is close to exercise when Y is about to hit the upper boundary $\overline{Y_n}$ from below. In Figure 4.1a, 4.1b and 4.1c, as Y increases, there are three distinct regions corresponding to where the contraction option, operating leverage, or the expansion option dominate respectively.

As investment reversibility k increases, the middle region where operating leverage effect is dominant shrinks. In Figure 4.1d, this region even disappears when the investment reversibility k is high. That is, the real option effect is dominant for higher values of investment reversibility k. A higher level of investment reversibility implies a greater liquidation value and thus more incentive for firms to disinvest when the demand level goes down. Upon disinvestment, the firm is no longer committed to the production costs induced by the assets that have been sold off. The operating leverage effect emerges because of the commitment to production costs. The possibility of disinvestment helps the firm suffer less from the risk of reduced demand. Hence, increases in investment reversibility weaken the operating leverage effect which predicts a positive effect of competition on the firm's risk. Therefore, betas are more negatively correlated with the level of competition for a higher level of investment reversibility.

To sum up, our model predicts a negative interaction effect of product market competition and investment reversibility on the firm's systematic risk. The standard asset pricing theory suggests that expected excess return is proportional to the systematic risk loading. Our conclusion can also be applied to the prediction of firms' excess returns.

4.4 Empirical Analysis

This section first introduces details on the construction of empirical measures and then presents empirical findings verifying our model's prediction. Lastly, we also show robustness checks for alternative measures.

4.4.1 Data

Our sample is constructed with data from multiple sources. We obtain monthly stock returns from the Center for Research in Security Prices (CRSP) database. Our sample only includes NYSE-, Amex- and Nasdaq-listed securities with share codes 10 or 11. Firms in financial (SIC codes between 6000 and 6999) and regulated (SIC codes between 4900 and 4999) industries are removed from our sample.

The accounting data is taken from COMPUSTAT annual files. The asset redeployability index is obtained from Kim and Kung [2016]. In order to ensure that information on firm characteristics (including COMPUSTAT-based variables and asset redeployability index) are incorporated into stock returns, we match monthly returns from January to June of year t with firm-level characteristics variables of year t - 2 and returns from July to December of year t with these variables of year t - 1. Our final sample covers the period from 1990 to 2016⁶.

Following Hou and Robinson [2006] and Gu [2016], we use three-digit Standard Industrial Classification (SIC) code to classify industries. This is a reasonable choice as an extremely fine industry classification (e.g. four-digit SIC) has the risk of separating firms operating similar businesses and produces statistically unreliable results. On the other hand, an insufficiently fine-grained classification (e.g. two-digit SIC) may mistakenly group firms operating in unrelated business lines together ⁷.

4.4.2 Empirical Measures

Industry concentration

Herfindahl-Hirschman Index

Industry competition is inversely related to industry concentration. We adopt the most widely used measure of industry concentration in the economics

⁶The choice of sample period is constrained by the availability of asset redeployability.

⁷For example, the industry with SIC code 3740 and the industry with SIC code 3743 have exactly the same description "Railroad Equipment". However, other industries that have SIC codes also starting with 37 are described as aircraft, ship, or motorcycle equipment, which are less relevant.

and finance literature: Herfindahl–Hirschman Index $(HHI)^{8}$, defined as below

$$HHI = \sum_{i=1}^{N} {s_i}^2$$
 (4.18)

where N is the number of firms within the same three-digit SIC industry and s_i is the market share of firm *i*. From its definition, values of the Herfindahl–Hirschman Index range from 0 to 1 since market share s_i is non-negative. A higher Herfindahl–Hirschman Index corresponds to higher industry concentration and thus lower level of competition level. The most common proxy for s_i is firm *i*'s net sales relative to the total net sales of the industry. Thus, we use sales-based *HHI* as the main measure for industry concentration throughout this chapter. As a robustness check, we also use total assets to compute market share and construct assets-based *HHI*. Following Hou and Robinson (2006), we take average values of annual *HHI* over past three years in case there may be potential data errors or outliers. This is also consistent with our model's assumption that industry concentration is not time-varying.

Investment reversibility

In order to empirically test our prediction, we need a measure to serve as a proxy for the reversibility of investment. According to Kim and Kung [2016], asset redeployability describes how widely the asset can be used in other firms or industries. Higher asset redeployability suggests more potential buyers in the second-hand market and thus higher resale price of the asset. This is consistent with the definition of k.

Asset Redeployability Index

The key variable to measure the firm's investment reversibility is asset redeployability index constructed by Kim and Kung [2016]. Here we briefly outline the

⁸Numerous empirical research, including Hou and Robinson [2006], Giroud and Mueller [2011], and Gu [2016], uses the *HHI* to measure industry competition. It is also supported by economic theory, such as Tirole [1988].

construction procedure.

The procedure starts with construction of asset-level redeployability scores. As in Kim and Kung [2016], the score is computed using 1997 Bureau of Economic Analysis (BEA) capital flow table. The BEA capital flow table contains the usage of 180 asset categories by 123 industries. The asset-level score is computed as the sum of weights of industries that use the asset among the 123 industries. There are two choices of weights: (i) equal weighted (one over the total number of BEA industries); (ii) value weighted (the sum of market capitalization of all public firms in an industry over the sum of market capitalization across all public firms). We adopt the second method in our main specification. The formula for computing the asset-level score is:

$$Redeployability_{a,t} = \sum_{j=1}^{123} I_{a,j} * \frac{MV_{j,t}}{\sum_{j=1}^{123} MV_{j,t}}$$
(4.19)

where $Redeployability_{a,t}$ is the redeployability score of asset a. $I_{a,t}$ is an indicator equal to 1 if asset a is used by BEA industry j and 0 otherwise. $MV_{j,t}$ is the market value of Compustat firms in BEA industry j in year t.

In the second step, an industry-level asset redeployability score is constructed by taking the weighted average of the asset-level redeployability scores across all 180 assets. The weight is the fraction of industry expenditure on a specific asset. Therefore, if an asset is not used by an industry in their production process, then the weight assigned to that asset is zero. The formula for computing industry-level redeployability is:

$$Redeployability_{j,t} = \sum_{a=1}^{180} w_{j,a} * Redeployability_{a,t}$$
(4.20)

$$w_{j,a} = \frac{E_{j,a}}{\sum_{a=1}^{180} E_{j,a}}$$
(4.21)

where $Redeployability_{j,t}$ is the asset redeployability index of industry j in year t

and $Redeployability_{a,t}$ is the redeployability score of asset a in year t. $w_{j,a}$ is the weight assigned to asset a in computing the index of industry j. $E_{j,a}$ is industry j's expenditure on asset a.

The last step is to compute firm-level asset redeployability index as the weighted average of industry-level redeployability indices across business segments in which the firm operates. The weight is computed as:

$$Redeployability_{i,t} = \sum_{j=1}^{n_{i,t}} w_{i,j,t} * Redeployability_{j,t}$$
(4.22)

$$w_{i,j,t} = \frac{s_{i,j,t}}{\sum_{j=1}^{n_{i,t}} s_{i,j,t}}$$
(4.23)

where $Redeployability_{i,t}$ is the asset redeployability index of firm i in year t and $Redeployability_{j,t}$ is the asset redeployability index of industry j in year t. $n_{i,t}$ is the number of industry segments that firm i is affiliated with in year t⁹. $w_{i,j,t}$ is the weight assigned to industry segment j in computing the index of firm i. $s_{i,j,t}$ is firm i sales revenue from industry segment j in year t¹⁰.

Generally, asset redeployability index measures how widely assets owned by the firm on average can be used in other industries. If assets can be reused in many other industries, then search costs for potential buyers would be lower and the resale prices would be correspondingly higher. Recall that investment reversibility can be described by the liquidation values of assets relative to their initial purchase prices. Higher asset redeployability indicates higher investment reversibility. Kim and Kung [2016] also link asset redeployability to investment reversibility and further test the implications of real options theory. Given a real-option framework has been applied in this chapter, we regard asset redeployability index as a suitable measure for investment reversibility.

⁹This information can be extracted from Compustat Segment Files.

¹⁰In Kim and Kung [2016], if Compustat Segment Files do not contain the date for a firm in a year, they impute the firm-level asset redeployability index from industry-level index based on the firm's industry classification in Compustat.

4.4.3 Empirical Results

The central prediction of our model is that the competition-return relation depends crucially on the firm's asset redeployability. If the firm's asset redeployability is high, then the real option effect would dominate the operating leverage effect and competition is more likely to decrease the firm's systematic risk. On the other hand, if the firm's asset redeployability is low, then the operating leverage effect prevails over the real option effect and competition is more likely to increase the firms' systematic risk. Therefore, we first investigate the negative interaction effect between competition and asset redeployability.

Summary Statistics

Table 4.1 lists the top five and bottom five industries sorted by sales-based *HHI* for least and most redeployable quintiles respectively. Within the lowest redeployability quintile, the most competitive industries include crude petroleum and natural gas, coal mining, and air transportation. Meanwhile, the least competitive industries within the lowest redeployability quintile include rubber product, fiber and silk. On the opposite side, the most competitive industries within the highest redeployability quintile include equipment rental and leasing, machinery. The least competitive industries within the highest redeployability quintile include rubber footwear, paper product, and nonresidential building contractors.

[Place Table 4.1 about here]

Table 4.2 reports summary statistics of industry concentration measures and investment reversibility measures used in our paper ¹¹. The mean of HHI(sales) in our sample is 0.189 and the standard deviation of HHI(sales) is 0.155. HHI(assets) has a similar magnitude to HHI(sales). The mean of the concentration ratio (CR5)

¹¹Table 4.2 also shows summary statistics of alternative measures of industry concentration (i.e. CR5) and investment reversibility (i.e. Inflexibility) which have detailed definitions in Section C.3.

is 0.689. The firm-level *Redeployability* measure constructed by Kim and Kung [2016] is the main measure of investment reversibility in our empirical analysis. Theoretically, its value should range from 0 to 1. Here in our sample *Redeployability* has a mean around 0.4. As an alternative measure of investment reversibility, *Inflexibility* constructed as in Gu et al. [2017] has a mean of 1.794.

[Place Table 4.2 about here]

In Table 4.3, we summarise average characteristics of sorted portfolios. The first two rows present the sorting variables HHI(sales) and Redeployability. As expected, HHI(sales) increases as the intensity of competition goes down and this pattern is similar for both low and high redeployability quintiles. Redeployability is around 0.25 (0.54) for the low (high) redeployability quintile. $\log(Size)$ exhibits a decreasing(an increasing) trend when asset redeployability is low (high), which is consistent with our model's prediction about stock returns. This is because market value can be better preserved if returns are higher. Average book-to-market ratios are generally higher in less competitive industries. Similar to the findings of MacKay and Phillips [2005] and predictions by Brander and Lewis [1986] and Maksimovic [1988], financial leverage is higher in more concentrated industries . $\log(Assets)$ and $\log(Sales)$ are increasing as competition decreases since firms in less competitive industries might have larger scale. Average return on assets is roughly flat across different levels of competition and redeployability.

[Place Table 4.3 about here]

Interaction effect between competition and redeployability

Portfolio sorts

Table 4.4 reports equal-weighted and value-weighted average monthly excess returns and abnormal returns for portfolios sorted based on HHI and asset rede-

ployability independently. In Panel A, we show the equal-weighted portfolio returns. In Panel B, we calculate value-weighted portfolio returns instead.

[Place Table 4.4 about here]

Specifically, in month t, stocks are sorted into terciles based on their HHI. Then, independently, we assign these stocks into quintile portfolios based on asset redeployability. This procedure results in fifteen portfolios with different levels of competition and asset redeployability. Cross-sectional average monthly returns in month t+1 are calculated within each portfolio. The portfolios are rebalanced every month.

In Table 4.4, we display the results for firms with low redeployability (i.e. lowest quintile of asset redeployability) and high redeployability (i.e. highest quintile of asset redeployability), respectively. As shown in both Panel A and B, portfolio returns increase monotonically with industry competition for the low redeployability quintile, while returns decrease with industry competition for the high redeployability quintile. The results hold for both equal-weighted and value-weighted returns. To construct the interaction portfolio, we first form high-minus-low competition portfolios based on industry competition (HHI) for high and low redeployability respectively (see Column (4) and (9)). Then we long the competition high-minuslow portfolio with low redeployability and short the competition high-minus-low portfolio with high redeployability (see Column (11)). The equal-weighted (valueweighted) interaction portfolio yields a monthly return of 0.58% (0.59%). It is also statistically significant, confirming our double sorting pattern.

To account for other risk factors, we also use several well-known factor models to adjust returns. The classic Fama and French [1993] three-factor model, the Carhart [1997] four-factor model, the Fama and French [2015] five-factor model and the Stambaugh and Yuan [2016] four-factor model are considered ¹². We regress the

¹²Fama and French [1993] three-factor model includes market, size, and value factors. Carhart

monthly excess returns of portfolios on the factors and the abnormal returns are the estimated constant in the regressions. In addition, we also compute characteristics-adjusted returns according to the methodology developed by Daniel et al. [1997], who propose a procedure to adjust individual stock returns for size, book-to-market, and momentum. They employ a sequential sorting methodology. In each month, all stocks are first sorted into size quintiles. Within each size quintile, the stocks are further sorted into quintiles based on their book-to-market ratio ¹³. Within each of the 25 portfolio constructed from previous sorting step, stocks are sorted into quintiles again based on their past 12-month return, excluding the most recent month. The characteristics-adjusted returns are computed by subtracting corresponding benchmark returns from individual stock returns.

For adjusted returns, we still see a significant interaction effect between competition and asset redeployability on returns. Interestingly, adjusted returns are typically lower than excess returns. For instance, the excess return for the quintile of the most (least) competitive industries within low redeployability tercile is 1.02%(0.62%) whereas Fama and French [2015] five factor model adjusted return is 0.30%(-0.35%). This is consistent with Hou and Robinson [2006]'s results. However, the spreads of the interaction portfolios are of a similar magnitude even if we adjust for risk factors, ranging from 0.51% (0.52%) to 0.68% (0.71%) for equal-weighted (valueweighted) portfolios. These patterns verify our theoretical conclusion: the effect of competition on stock returns becomes more negative as investment reversibility increases. The effect cannot be explained by traditional risk factors or mispricing. Therefore, the interaction between competition and redeployability is important in understanding the cross-section of stock returns.

Panel regressions

^[1997] adds momentum to Fama and French [1993]'s model. Fama and French [2015] add profitability and investment patterns to Fama and French [1993] model. Stambaugh and Yuan [2016] include two mispricing factors apart from market and size factors in their model.

¹³Following Daniel et al. [1997], we use industry-adjusted book-to-market ratio by subtracting the long-term industry average book-to-market ratio from each individual firm's ratio.

To control for more factors that could also affect expected returns, we run panel regressions of excess returns on the interaction between the competition measure and the asset redeployability index. Specifically, we estimate the following model.

$$Y_{i,t} = \alpha + \beta_1 H H I_{i,t-1} + \beta_2 A R_{i,t-1} + \beta_3 H H I_{i,t-1} * A R_{i,t-1} + \beta_4 X_{i,t-1} + v_t + \epsilon_{i,t} \quad (4.24)$$

where $Y_{i,t}$ is monthly excess return for firm *i* at time *t*, $HHI_{i,t-1}$ is firm *i*'s lagged Herfindahl–Hirschman Index, $AR_{i,t-1}$ is firm *i*'s lagged asset redeployability index, and $X_{i,t-1}$ represents a set of control variables. v_t represents the time fixed effect.

Here we include control variables standard in the asset pricing literature, namely, size, book-to-market ratio, reversal, momentum and leverage. log(size) is the natural logarithm of the market value of equity. *Book-to-Market* is the ratio of the book value of equity to the market value of equity. $lag(1-month\ return)$ is the stock return over previous month. It is included to control for the reversal effect. $lag(12-month\ return)$ is the stock return over the 11 months preceding the previous month. It is included to control for the momentum effect. *Leverage* is the total liabilities over the sum of market value of equity and total liabilities. We include the time fixed effect to examine the cross-sectional effect. Standard errors are double clustered by firm and time to suppress both cross-sectional correlation and time-series correlation in error term [see, e.g. Petersen, 2009; Cochrane, 2009].

The hypothesis derived from our model asserts a significant and positive coefficient on the interaction term (i.e. positive β_3) since *HHI*, as an industry concentration measure, is inversely related to competition.

[Place Table 4.5 about here]

Table 4.5 reports the results for panel regressions. In Column (1), we perform a univariate analysis by regressing excess return on the HHI and find an insignificant coefficient. This implies that the competition-return relation is mixed ¹⁴, which calls for our further understanding. Asset redeployability (*Redpb*) alone also exhibits an insignificant effect as shown in Column (2). Column (3) reports the results for the baseline regression with an interaction term between *HHI* and *Redpb*. The coefficient on the interaction term is significantly positive supporting our results from the double sorts. After controlling for other asset pricing factors as in Column (4), the coefficient on the interaction term remains significantly positive and similar in magnitude.

In Column (4), we include control variables. The coefficient on the interaction term remains statistically positive. The magnitude is even larger after adding control variables. The return spread between a monopolist ¹⁵ and a firm in most competitive industry is 4.718% higher for firms with highest redeployability than it is for those with lowest redeployability. All control variables, such as size, book-to-market, have the same sign as in the literature.

Columns (5) and (6) use alternative asset redeployability measures constructed in different ways but in the same vein. The difference between asset redeployability index used in specification (5), (6) and baseline specification (3) lies in the construction of asset-level redeployability score. As explained in section 4.4.2, asset-level redeployability score employed by specification (3) uses industry value as weights in computing how the asset is used among the 123 BEA industries. The asset-level redeployability score employed by specification (6) uses equal weights for each industry in determining how the asset is used among the 123 BEA industries. The asset-level redeployability score employed by specification (5) incorporates the correlation of outputs among firms within a given industry. The intuition is that, when the output comovement within an industry is high, a firm that intends to resell

 $^{^{14}}$ Even from the existing literature, we cannot draw a clear conclusion about the effect of competition on stock returns. Hou and Robinson [2006] find a positive relation whereas Bustamante and Donangelo [2017] find it to be negative.

¹⁵The highest value of HHI in my sample period is 1 suggesting that there exists monopoly industries when using three-digit SIC to classify industries.

its assets is more likely to find that other firms in the industry also perform poorly. This would decrease the demand of the asset ¹⁶ and increase the supply of the asset. As a result, it is more difficult for firms in such industries to resell their assets, especially during economic downturns. This leads to lower asset redeployability in such industries ¹⁷.

Using panel regressions, we find that the coefficient of interest, β_3 , is positive and statistically significant in all specifications. These findings are highly consistent with our model prediction that the effect of competition (concentration, in our estimation) on stock return is more negative (positive) when the firm's asset redeployability is higher.

Fama-Macbeth regressions

As a standard method in asset pricing, Fama-Macbeth regressions are conducted to further confirm the interaction effect of our interest. For all the Fama-Macbeth regressions throughout the paper, the estimates of the coefficients are the time-series average of cross-sectional regression loadings. The t-statistics based on Newey-West standard errors are reported in square brackets below.

Table 4.6 reports the firm-level Fama-Macbeth regressions and we use the same set of control variables as in the panel regressions (Table 4.5). Column (1) shows that competition alone has no significant effect on stock returns although the sign of the coefficient is negative suggesting a positive competition-return relation. Column (2) investigates the effect of asset redeployability on stock returns. The effect is also ambiguous as the coefficient is insignificant.

[Place Table 4.6 about here]

The last four columns incorporate the interaction term. Different asset redeployability measures are used in Columns (5) and (6). Overall they show very

¹⁶Peer firms in the same industry are considered as high valuation buyers.

¹⁷Kim and Kung [2016] multiply each industry's weight by an adjustment term to construct assetlevel scores. The adjustment term is inversely related to the within-industry output correlation.

strong and positive interaction effect between HHI and asset redeployability. This is consistent with our previous results.

Industry-level regressions

Table 4.7 repeats the empirical analysis in Table 4.6 but uses all the variables at industry level. As an industrial concentration measure, HHI is an industrylevel variable that remains the same as in Table 4.6. We take average values of stock returns, asset redeployability and other control variables by SIC three-digit industries. Our main results are also robust after controlling for size, book-to-market, past stock returns and financial leverage. The interaction term between HHI and Redpb is still positive and significant at 5% level. Comparing with firm-level regression results, size and past 1-month return have an inverse effect on stock returns. The positive sign of size implies that industries with greater average market value earn higher returns. The insignificantly positive coefficient on past 1-month return suggests that reversal effect is not evident at industry level. Together with the significantly positive effect of past 1-year return, the trend of average industry returns are more likely to persist.

[Place Table 4.7 about here]

Unlevered returns

One potential concern about using the asset redeployability measure is that it might be positively correlated with corporate financial leverage and the results are thus driven not by redeployability but by leverage. Intuitively, firms with more redeployable assets are more likely to have a higher liquidation value in the event of bankruptcy. Implicitly, debt holders have better protection so that they are willing to accept an even lower interest rate. This makes debt more accessible and cheap to these firms. Therefore, more redeployable firms should have a higher leverage.

Although leverage has been controlled for in the previous regressions, we

further address this concern by using unlevered returns as a robustness check ¹⁸. Unlevered returns are stock returns without the impact of firms' financial leverage. Following the standard procedure, we delever stock returns by dividing excess returns by the sum of one plus the leverage ratio, i.e.

Unlevered return =
$$\frac{\text{excess return}}{1 + \text{liability}/(\text{liability} + \text{market value})}$$
 (4.25)

Table 4.8 reports the results of regressing unlevered returns on the same set of variables except for leverage ¹⁹. In the univariate regressions (i.e. Columns (1) and (2)), HHI or asset redeployability have an insignificantly negative effect on unlevered returns. This is similar to the effects on excess returns. Columns (3) to (6) show that the coefficient on the interaction term is still positive and significant at 1% level, although the magnitude slightly decreases compared to that for excess returns. Interestingly, after controlling for the interaction effect between HHI and redeployability, we see a significantly negative effect of redeployability on unlevered returns. Overall, we find supportive evidences on the positive interaction effect even when accounting for the impact of asset redeployability on financial leverage.

[Place Table 4.8 about here]

Robustness checks

Alternative measures of industry concentration

Next we explore the robustness of our main results to an alternative measure of industry concentration. We perform the Fama-Macbeth regression analysis again for asset-based HHI and 5-firm concentration ratio (CR5).

 $^{^{18}\}mathrm{Doshi}$ et al. [2019] shows that leverage induces heterosked asticity in returns and unlevering returns removes this pattern.

 $^{^{19}\}mathrm{Here}$ the control variable *leverage* is excluded since we already removed the leverage effect by unlevering returns.
Asset-based HHI uses total assets to calculate market share instead of using net sales. The concentration ratio is defined as the ratio of the sales of the top nfirms in an industry to total industry sales. This ratio, by definition, ranges from 0 to 1. A low concentration ratio for an industry indicates that there are a number of firms with similar size, while a high concentration ratio suggests that the industry is dominated by a few large firms. Thus, similar to HHI, a higher value of the concentration ratio implies lower industry competition. Here we use the 5-firm ratio, i.e. the ratio of the sales of the top five firms in an industry to total industry sales. Similar to the construction of sales-based HHI, we average the values of both measures over the past 3 years.

We regress the excess stock returns on asset-based HHI or CR5, asset redeployability, the interaction term and controls. In Table 4.9, Panel A (i.e. columns (1) to (5)) presents the results for asset-based HHI. Panel B reports the results for CR5. As shown in the table, the results mirror our findings in the previous analysis. The impact of industry concentration on stock returns is negative but insignificant (see Columns (1) and (6)). The effect of industry concentration becomes significant after adding in the interaction term. In both panels, we find the coefficients on the interaction term are both statistically and economically significant and positive. Hence, we show the positive interaction effect between industry concentration and asset redeployability is robust to alternative concentration measures.

[Place Table 4.9 about here]

Alternative measure of investment reversibility

In this section, we use a firm-level inflexibility measure as an alternative measure of investment reversibility. The inflexibility measure is an inverse proxy for investment reversibility. It is first used by Gu et al. [2017], who develop this measure based on their theory. They utilize the fact that the firm's flexibility to adjust its capacity is correlated with the width of the firm's inaction region. A firm with less flexible operations would wait longer before adjusting its scale to adapt to changes in profitability.

The firm-level inflexibility is defined as the firm's historical range of operating costs scaled by sales over the standard deviation of log growth rate of sales scaled by total assets, i.e.

$$INFLEX_{i,t} = \frac{\max_{i,0,t} \left(\frac{OPC}{Sales}\right) - \min_{i,0,t} \left(\frac{OPC}{Sales}\right)}{\operatorname{std}_{i,0,t} \left(\Delta \log \left(\frac{Sales}{Assets}\right)\right)}$$
(4.26)

where $\max_{i,0,t} \left(\frac{OPC}{Sales}\right)$ is the maximum value of firm's operating cost (Compustat item XSGA + COGS) over sales (Compustat item SALE) from year 0 (i.e. the initial year that the firm appears in Compustat) until year t. Similarly, $\min_{i,0,t} \left(\frac{OPC}{Sales}\right)$ is the minimum value of the firm's scaled operating cost over the period from year 0 to year t. Thus, $\max_{i,0,t} \left(\frac{OPC}{Sales}\right) - \min_{i,0,t} \left(\frac{OPC}{Sales}\right)$ is the historical range of operating cost over sales, which is equivalent to the range of profit over sales. It is a proxy for the width of the inaction region of the state variable in the theoretical model of Gu et al. [2017]. Intuitively, the firm's optimal strategy is to scale up capacity when productivity or profitability increases, while it is optimal to scale down capacity when profitability decreases. Holding uncertainty constant, if the firm has enough flexibility, i.e. the adjustment cost is low, we should observe a narrow inaction region as the firm would quickly respond to changes in profitability.

The denominator on the right hand side of equation (36), $\operatorname{std}_{i,0,t} \left(\Delta \log \left(\frac{Sales}{Assets} \right) \right)$, is the standard deviation of the growth rate of sales scaled by total assets (Compustat item AT) over the period from year 0 to year t. Based on real options theory, when uncertainty is higher, the value of waiting is higher. Thus, it is optimal for the firm not to make adjustments quickly. In this case, the inaction region could be wide even if the firm is fully flexible. We thus use the standard deviation of the sales growth rate to adjust for the effect of uncertainty on the width of the inaction region. The inflexibility measure reflects firms' investment irreversibility when controlling for uncertainty. Our model predicts that the impact of industry competition on stock returns becomes more negative when investment is more reversible. In other words, the competition-return relation should be more positive for firms with high inflexibility (i.e. more irreversible investment).

We use the sales-based HHI to measure industry concentration. Since HHI is negatively correlated with industry competition, we should expect a negative interaction effect between HHI and inflexibility. Table 4.10 reports the results for Fama-Macbeth regressions using inflexibility measure instead of asset redeployability. In Column (1), we re-examine the unconditional effect of HHI on stock returns and find the coefficient is insignificantly negative. Column (2) shows that inflexibility becomes insignificant once the interaction term is included. Columns (3)-(5) report the results with the interaction term. With or without control variables, the coefficient on the interaction term is consistently significant and negative. These findings again support our hypothesis. As an alternative measure of investment reversibility, inflexibility indeed has an explanatory power for the competition-return relation, which is consistent with our theoretical prediction.

[Place Table 4.10 about here]

4.5 Conclusion

The relationship between competition and stock returns is a subject of continued attention in the literature. Given the mixed evidence on this relationship in the existing literature, we seek an alternative perspective to analyse this important question.

Recently, investment-based asset pricing has featured the reversibility of investment by showing that a firm's options to expand and contract jointly determine the dynamics of its systematic risk. Motivated by this growing strand of literature, we relax the assumption that investment is irreversible. We develop a more comprehensive Cournot-competition framework that incorporates contraction options in addition to assets in place and expansion options. In contrast to Aguerrevere [2009], we find that the effect of competition on stock returns does not necessarily depend on the level of market demand. Instead, the competition-return relation is more negative as investment becomes more reversible.

Specifically, we have shown that product market competition has distinct impacts on the risk associated with assets in place and options held by the firm. Regardless of the firm's options to adjust capacity, competition increases risk as operating leverage is higher for firms in more competitive industries. This is called the *operating leverage effect*. On the other hand, competition can also reduce risk through the option channel. A firm in more competitive industries is less sensitive to the changes in the market demand as the reactions of other competitors would attenuate its potential gains or losses. This negative effect of competition is called the *real option effect*, which dominates the positive *operating leverage effect* when investment is highly reversible. This is because investment reversibility enables the firm to escape from the risk arising from assets in place.

We also find empirical evidence consistent with our theoretical prediction that there is a negative interaction effect between competition and investment reversibility on stock returns. Our results are robust to different measures of competition and investment reversibility. Overall, this chapter contributes to the investment-based asset pricing literature by revealing the important role of investment reversibility in affecting the competition-return relation.

Appendix 4.A Technical Proofs

Proof of Proposition 4.1

Let $M(Y, q_i, Q_{-i})$ denote the value of the myopic firm. Using standard dynamic programming method, $M(Y, q_i, Q_{-i})$ satisfies

$$rM = \mu Y \frac{\partial M}{\partial Y} + \frac{1}{2}\sigma^2 Y^2 \frac{\partial^2 M}{\partial Y^2} + \left[Y(q_i + Q_{-i})^{-\frac{1}{\gamma}} - c \right] q_i$$
(A4.1)

subject to the following value-matching conditions

$$M(\overline{Y}(q_i, Q_{-i}), q_{-i}, Q_{-i}) = M(\overline{Y}(q_i, Q_{-i}), q_i + dq_i, Q_{-i}) - Idq_i$$
$$M(\underline{Y}(q_i, Q_{-i}), q_{-i}, Q_{-i}) = M(\underline{Y}(q_i, Q_{-i}), q_i - dq_i, Q_{-i}) + kIdq_i$$

where $\overline{Y}(q_i, Q_{-i})$ and $\underline{Y}(q_i, Q_{-i})$ are the optimal investment and disinvestment triggers respectively. Rearranging and taking the limit to give

$$\begin{split} \frac{\partial M}{\partial q_i}\Big|_{Y=\overline{Y}(q_i,Q_{-i})} &= \lim_{dq_i \to 0} \frac{M(\overline{Y}(q_i,Q_{-i}),q_i+dq_i,Q_{-i}) - M(\overline{Y}(q_i,Q_{-i}),q_{-i},Q_{-i})}{dq_i} = I \\ \frac{\partial M}{\partial q_i}\Big|_{Y=\underline{Y}(q_i,Q_{-i})} &= \lim_{dq_i \to 0} \frac{M(\underline{Y}(q_i,Q_{-i}),q_i,Q_{-i}) - M(\underline{Y}(q_i,Q_{-i}),q_{-i}-dq_i,Q_{-i})}{dq_i} = kI \\ (A4.3) \end{split}$$

The smooth-pasting conditions are

$$\frac{\partial^2 M}{\partial q_i \partial Y}\Big|_{Y=\overline{Y}(q_i,Q_{-i})} = 0 \tag{A4.4}$$

$$\frac{\partial^2 M}{\partial q_i \partial Y}\Big|_{Y=\underline{Y}(q_i, Q_{-i})} = 0 \tag{A4.5}$$

Let $m(Y, q_i, Q_{-i})$ denote the marginal value of the myopic firm, i.e. $m(Y, q_i, Q_{-i}) = \frac{\partial M(Y, q_i, Q_{-i})}{\partial q_i}$. In a symmetric Cournot equilibrium, $q_i = \frac{Q}{n}$ and $Q_{-i} = \frac{(n-1)Q}{n}$. Substituting the equilibrium results into above equations, we have $m(Y, \frac{Q}{n}, \frac{(n-1)Q}{n}) = \frac{(n-1)Q}{n}$.

m(Y,Q) given by

$$rm(Y,Q) = \mu Y \frac{\partial m}{\partial Y} + \frac{1}{2}\sigma^2 Y^2 \frac{\partial^2 m}{\partial Y^2} + \frac{n\gamma - 1}{n\gamma} Y Q^{-\frac{1}{\gamma}} - c$$
(A4.6)

s.t.

$$m(\overline{Y}(Q), Q) = I \tag{A4.7}$$

$$m(\underline{Y}(Q), Q) = kI \tag{A4.8}$$

$$\frac{\partial m}{\partial Y}\Big|_{Y=\overline{Y}(Q)} = 0 \tag{A4.9}$$

$$\left. \frac{\partial m}{\partial Y} \right|_{Y = \underline{Y}(Q)} = 0 \tag{A4.10}$$

The solution of m(Y,Q) has the form

$$m(Y,Q) = a(Q)Y^{\beta_1} + b(Q)Y^{\beta_2} + \frac{n\gamma - 1}{n\gamma}\frac{YQ^{-\frac{1}{\gamma}}}{r - \mu} - \frac{c}{r}$$
(A4.11)

where β_1 and β_2 are the positive and negative roots of the quadratic equation $\frac{\sigma^2}{2}\xi(\xi-1) + \mu\xi - r = 0$. To simplify calculation, we set $\underline{Y}(Q) = x\overline{Y}(Q)$ with 0 < x < 1. Substituting this equation into (A4.7) - (A4.10) and solving those equations simultaneously yields the triggers

$$\overline{Y_n}(Q) = \frac{\beta_1}{\beta_1 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(I + \frac{c}{r}\right) \frac{\phi - x^{\beta_2}}{x - x^{\beta_2}} Q^{\frac{1}{\gamma}}$$
(A4.12)

$$\underline{Y_n}(Q) = \frac{\beta_2}{\beta_2 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(kI + \frac{c}{r}\right) \frac{x - \phi^{-1} x^{\beta_1 + 1}}{x - x^{\beta_1}} Q^{\frac{1}{\gamma}}$$
(A4.13)

where $\phi = (kI + \frac{c}{r})/(I + \frac{c}{r})$ and x solves $\frac{\beta_2}{\beta_2 - 1} \frac{\phi - x^{\beta_1}}{x - x^{\beta_1}} = \frac{\beta_1}{\beta_1 - 1} \frac{\phi - x^{\beta_2}}{x - x^{\beta_2}}$. The subscript n indicates the triggers are for the firm in an n-firm industry. Notably x is independent of Q and n. Since $P = YQ^{-\frac{1}{\gamma}}$, the price thresholds are

$$\overline{P_n}(Q) = \frac{\beta_1}{\beta_1 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(I + \frac{c}{r}\right) \frac{\phi - x^{\beta_2}}{x - x^{\beta_2}}$$
(A4.14)

$$\underline{P_n}(Q) = \frac{\beta_2}{\beta_2 - 1} \frac{n\gamma}{n\gamma - 1} (r - \mu) \left(kI + \frac{c}{r}\right) \frac{x - \phi^{-1} x^{\beta_1 + 1}}{x - x^{\beta_1}}$$
(A4.15)

Proof of Proposition 4.2

In the inaction region, the firm's value $V_n(Y, Q)$ satisfies the differential equation given in Equation (4.9), which has the general solution

$$V_n(Y,Q) = A(Q)Y^{\beta_1} + B(Q)Y^{\beta_2} + \frac{Q}{n}\left(\frac{YQ^{-\frac{1}{\gamma}}}{r-\mu} - \frac{c}{r}\right)$$
(A4.16)

where $\beta_1 > 1$ and $\beta_2 < 0$ are the two roots of the quadratic equation $\frac{\sigma^2}{2}\xi(\xi - 1) + \mu\xi - r = 0$. The first and second terms coexist for that the firm holds both investment and disinvestment options.

Considering the value-matching conditions given by Equation (4.10) and (4.11), we can rearrange and take the limit to give

$$\frac{\partial V_n(\overline{Y_n}(Q), Q)}{\partial Q} = \lim_{dQ \to 0} \frac{V_n(\overline{Y_n}(Q), Q + dQ) - V_n(\overline{Y_n}(Q), Q)}{dQ} = \frac{I}{n}$$
(A4.17)

$$\frac{\partial V_n(\underline{Y}_n(Q), Q)}{\partial Q} = \lim_{dQ \to 0} \frac{V_n(\underline{Y}_n(Q), Q) - V_n(\underline{Y}_n(Q), Q - dQ)}{dQ} = \frac{kI}{n}$$
(A4.18)

Plugging Equation (A4.21) into Equations (A4.22) and (A4.23) respectively yields

$$A'(Q)\overline{Y_n}(Q)^{\beta_1} + B'(Q)\overline{Y_n}(Q)^{\beta_2} + \frac{1}{n}\left(\frac{\gamma - 1}{\gamma}\overline{\frac{Y_n}(Q)Q^{-\frac{1}{\gamma}}}{r - \mu} - \frac{c}{r}\right) = \frac{I}{n}$$
(A4.19)

$$A'(Q)\underline{Y_n}(Q)^{\beta_1} + B'(Q)\underline{Y_n}(Q)^{\beta_2} + \frac{1}{n}\left(\frac{\gamma - 1}{\gamma}\underline{Y_n}(Q)Q^{-\frac{1}{\gamma}}}{r - \mu} - \frac{c}{r}\right) = \frac{kI}{n}$$
(A4.20)

Thus, we can solve for A'(Q) and B'(Q). Integrating A'(Q) and B'(Q) between 0 and Q, A(Q) and B(Q) can be expressed as

$$A(Q) = \frac{Q}{n} \frac{\gamma}{\gamma - \beta_1} a(\underline{P_n}, \overline{P_n}) Q^{-\frac{\beta_1}{\gamma}}$$
(A4.21)

$$B(Q) = \frac{Q}{n} \frac{\gamma}{\gamma - \beta_2} b(\underline{P_n}, \overline{P_n}) Q^{-\frac{\beta_2}{\gamma}}$$
(A4.22)

where

$$a(\underline{P_n}, \overline{P_n}) = \frac{1}{\overline{P_n}^{\beta_1} \underline{P_n}^{\beta_2} - \underline{P_n}^{\beta_1} \overline{P_n}^{\beta_2}} \left[\left(I + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\overline{P_n}}{r - \mu} \right) \underline{P_n}^{\beta_2} - \left(kI + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\underline{P_n}}{r - \mu} \right) \overline{P_n}^{\beta_2} \right]$$

$$(A4.23)$$

$$b(\underline{P_n}, \overline{P_n}) = \frac{1}{\underline{P_n}^{\beta_1} \overline{P_n}^{\beta_2} - \overline{P_n}^{\beta_1} \underline{P_n}^{\beta_2}} \left[\left(I + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\overline{P_n}}{r - \mu} \right) \underline{P_n}^{\beta_1} - \left(kI + \frac{c}{r} - \frac{\gamma - 1}{\gamma} \frac{\underline{P_n}}{r - \mu} \right) \overline{P_n}^{\beta_1} \right]$$

$$(A4.24)$$

Notably, we assume that $\beta_1 > \gamma$ to ensure the existence of an equilibrium as in Grenadier [2002], Aguerrevere [2009], and Morellec and Zhdanov [2019].

Proof of Proposition 4.3

The firm's systematic risk β can be derived as

$$\beta = \frac{\partial V_n(Y,Q)}{\partial Y} \frac{Y}{V_n(Y,Q)}$$
(A4.25)

where $V_n(Y,Q)$ is given by Equation (4.12). Taking the partial derivative with respect to Y yields

$$\frac{\partial V_n(Y,Q)}{\partial Y} = \beta_1 A(Q) Y^{\beta_1 - 1} + \beta_2 B(Q) Y^{\beta_2 - 1} + \frac{Q}{n} \frac{Q^{-\frac{1}{\gamma}}}{r - \mu}$$
(A4.26)

Thus,

$$\beta = 1 + (\beta_1 - 1)\frac{A(Q)Y^{\beta_1}}{V_n} + (\beta_2 - 1)\frac{B(Q)Y^{\beta_2}}{V_n} + \frac{Q}{n}\frac{c/r}{V_n}$$
(A4.27)

Appendix 4.B Figures and Tables



Figure 4.1: Betas of Firms in Different Competitive Industries for Different Levels of Asset Redeployability. Each subfigure shows the beta of the firm as a function of Y for a given level of k when the industry's total output at time t depends on the number of firms in the industry. Parameter values are r = 0.06, $\mu = 0.01$, $\sigma = 0.2$, I = 1, c = 0.06 and $\gamma = 1.1$.

This table p redeployabili market capit	ity me alizati	s the top 5 and bottom 5 three-digit SIC industries sort asure in 2014. We use the firm-level asset redeployabilition of Compustat firms in each BEA industry-year as the	ted by ty mea weight.	HHI for the first (low) and fifth (high) of the average sure based on asset-level redeployability score that uses
		Most competitive industries		Least competitive industries
	SIC	Industry Title	SIC	Industry Title
	131	Crude Petroleum and Natural Gas	109	Miscellaneous Metal Ores
	820	Educational Services	306	Fabricated Rubber Products
Low redpb	451	Air Transportation, Scheduled, And Air Courier	222	Broadwoven Fabric Mills, Manmade Fiber And Silk
	799	Miscellaneous Amusement And Recreation	387	Watches, Clocks, Clockwork Operated Devices, and Parts
	122	Bituminous Coal And Lignite Mining	301	Tires And Inner Tubes
	738	Miscellaneous Business Services	835	Child Day Care Services
	508	Machinery, Equipment, And Supplies	784	Video Tape Rental
High redpb	735	Miscellaneous Equipment Rental And Leasing	154	General Building Contractors-Nonresidential
	504	Professional And Commercial Equipment And Supplies	302	Rubber And Plastics Footwear
	517	Petroleum And Petroleum Products	511	Paper And Paper Products

Table 4.1: Most and Least Competitive Industries by Redeployability

Table 4.2: Summary of Measures

This table presents summary statistics of industry concentration measures and investment reversibility measures. The sample Industry is defined at the level of three-digit SIC codes. HHI(sales) is the 3-year average Herfindahl-Hirschman Index based on net sales. HHI(assets) is the 3-year average Herfindahl-Hirschman Index based on total assets. CR5 is the concentration ratio of the combined net sales of top 5 firms to the industry's total net sales. Redeployability is a firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight. Redeployability (R2) is a firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight, and incorporates correlation of outputs among firms within industries in the measure. Redeployability(EW) is a firm-level asset redeployability measure based on asset-level redeployability score that uses the equal weight for each BEA industry-year. Inflexibility is the firm's historical range of operating costs scaled by sales over the volatility of the logarithm growth rate of sales over assets. The sample period is from January 1990 to December 2016.

Mean Std D		Median	75%		
HHI(sales)	0.189	0.155	0.085	0.144	0.238
HHI(assets)	0.194	0.159	0.081	0.143	0.252
CR5	0.689	0.184	0.530	0.679	0.839
Redeployability	0.405	0.104	0.358	0.416	0.467
Redeployability(R2)	0.208	0.055	0.183	0.214	0.240
Redeployability(EW)	0.340	0.083	0.307	0.353	0.384
Inflexibility	1.794	3.701	0.474	0.956	1.672

This table presents summary statistics of portfolio characteristics sorted on sales-based
Herfindahl-Hirschman Index (HHI) and firm-level asset redeployability. In each month t ,
NYSE-, AMEX- and NASDAQ-listed stocks are sorted into quintiles based on firm-level
asset redeployability. Independently, firms are sorted into terciles based on industry-level
HHI , where $Comp_H(Comp_L)$ contains the stocks with lowest(highest) HHI . $HHI(sales)$
is the 3-year average Herfindahl-Hirschman Index based on net sales. Redeployability is
a firm-level asset redeployability measure based on asset-level redeployability score that
uses market capitalization of Compustat firms in each BEA industry-year as the weight.
log(Size) is the logarithm of market equity. B/M is the book value of equity divided by
market equity. Leverage is the ratio of total liabilities to the sum of market value of equity
and total liabilities. log(Assets) is the logarithm of total assets. log(Sales) is the logarithm
of net sales. Return on assets the operating income before depreciation (OIBDP) divided by
lagged total assets. Capital expenditure is defined as capital expenditure (CAPX) divided
by lagged total assets. The sample period is from January 1990 to December 2016.
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 Table 4.3: Characteristics of Sorted Portfolios

	Low	redeployal	oility	High	redeploya	bility
	$\operatorname{Comp}_{\mathrm{H}}$	$\operatorname{Comp}_{\mathrm{M}}$	$\operatorname{Comp}_{\operatorname{L}}$	$\operatorname{Comp}_{\mathrm{H}}$	$\operatorname{Comp}_{\mathrm{M}}$	$\operatorname{Comp}_{\operatorname{L}}$
HHI(sales)	0.07	0.15	0.37	0.08	0.15	0.38
Redeployability	0.24	0.26	0.26	0.55	0.53	0.53
$\log(\text{Size})$	20.05	19.99	19.86	19.87	19.92	20.05
B/M	0.50	0.52	0.66	0.51	0.57	0.54
Leverage	0.25	0.31	0.37	0.32	0.37	0.36
$\log(Assets)$	19.61	19.75	19.90	19.60	19.87	19.95
$\log(Sales)$	19.25	19.51	19.70	19.48	20.10	20.15
Return on assets	0.14	0.14	0.14	0.13	0.15	0.16

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firm-level asset redeployability. In each month t, NYSE-, AMEX- and NASDAQ-listed stocks are sorted into quintiles based on firm-level asset redeployability. Independently, firms are sorted into terciles based on industry-level HHI, where $Comp_H(Comp_L)$ contains the stocks for B/M, size, past returns as in Daniel et al. [1997]. Stocks with share price less than \$5 at the end of month t are excluded. Panal A reports the equal-weighted portfolio returns and Panal B reports the value-weighted portfolio returns. The sample period is from January 1990 to December 2016. t-statistics using Newey-West standard errors are reported in parentheses. *, **, *** indicate statistical significance at the This table presents the monthly excess returns (in percentage) of portfolios sorted on sales-based Herfindahl-Hirschman Index (HHI) and with lowest (highest) HHI. Monthly portfolio average returns are calculated over month t + 1. Portfolio abnormal returns are computed by regressing monthly portfolio excess returns on risk factors in the Fama and French [1993] three-factor model, the Carhart [1997] four-factor model, the Fama and French [2015] five-factor model, and the Stambaugh and Yuan [2016] four-facotr model. DGTW returns are adjusted 10%, 5%, and 1% levels respectively.

		Low r	edeployab	ility			High re	edeployabi	lity		Redeploy _H	- Redeploy _L
	(1)	(2)	(3)	(4)	(5)	(9)	(2)	(8)	(6)	(10)	(11)	(12)
	$\operatorname{Comp}_{\mathrm{H}}$	$\operatorname{Comp_M}$	$\operatorname{Comp}_{\mathrm{L}}$	H-L	t-stat	$\mathrm{Comp}_{\mathrm{H}}$	$\operatorname{Comp_M}$	$\operatorname{Comp}_{\mathrm{L}}$	H-L	t-stat	(4) - (9)	t-stat
$A.\ Equal-weighted\ returns$												
Excess return	1.02	0.75	0.62	0.40^{*}	[1.72]	0.56	0.73	0.74	-0.18	[-1.18]	0.58^{***}	[2.70]
Fama and French 3-factor α	0.05	-0.14	-0.28	0.32^{*}	[1.68]	-0.26	-0.14	-0.08	-0.18	[-1.44]	0.51^{**}	[2.40]
Carhart 4-factor α	0.18	-0.08	-0.19	0.37^{*}	[1.90]	-0.21	-0.07	0.00	-0.22*	[-1.67]	0.59^{***}	[2.75]
Fama and French 5-factor α	0.30	-0.20	-0.35	0.64^{***}	[3.37]	-0.17	-0.20	-0.21	0.04	[0.34]	0.60^{***}	[2.73]
Stambaugh and Yuan 4-factor α	0.44	-0.01	-0.17	0.61^{***}	[2.99]	-0.18	-0.14	-0.12	-0.06	[-0.43]	0.68^{***}	[3.03]
DGTW (1997) adjusted return	0.35	0.10	-0.14	0.49^{**}	[2.53]	-0.13	-0.04	-0.02	-0.11	[-0.89]	0.60^{***}	[3.25]
$B. \ Value-weighted \ returns$												
Excess return	1.00	0.75	0.61	0.39^{*}	[1.67]	0.55	0.68	0.74	-0.19	[-1.32]	0.59^{***}	[2.68]
Fama and French 3-factor α	0.03	-0.14	-0.29	0.32^{*}	[1.65]	-0.27	-0.18	-0.07	-0.20	[-1.62]	0.52^{**}	[2.45]
Carhart 4-factor α	0.18	-0.07	-0.20	0.37^{*}	[1.89]	-0.22	-0.09	0.01	-0.23*	[-1.83]	0.60^{***}	[2.79]
Fama and French 5-factor α	0.27	-0.22	-0.38	0.65^{***}	[3.37]	-0.21	-0.25	-0.21	-0.00	[-0.00]	0.65^{***}	[2.94]
Stambaugh and Yuan 4-factor α	0.42	-0.02	-0.20	0.62^{***}	[2.95]	-0.21	-0.15	-0.12	-0.09	[-0.64]	0.71^{***}	[3.14]
DGTW (1997) adjusted return	0.31	0.10	-0.13	0.44^{**}	[2.43]	-0.11	-0.05	-0.02	-0.09	[-0.80]	0.53^{***}	[3.04]

Table 4.5: Panel Regressions

This table presents results from panel regressions of firms' excess returns on Herfindahl-Hirschman Index (HHI), asset redeployability (Redpb), the interaction term (HHI*Redpb), and other control variables. $\log(Size)$ is the natural logarithm of the market value of equity. Book-to-Market is the ratio of book value of equity to market value of equity. lag(1-month return) is the stock return over previous month. lag(12-month return) is the past 12month stock return excluding previous month (i.e. from month -12 to month -2). Leverage is defined as the ratio of total liabilities to the sum of market value of equity and total liabilities. Column (2)-(4) use the firm-level asset redeployability measure based on assetlevel redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight. Column (5) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight, and incorporates correlation of outputs among firms within industries in the measure. Column (6) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses the equal weight for each BEA industry-year. The sample period is from January 1990 to December 2016. All regressions include year-month fixed effects. Standard errors are clustered by firm and year-month. t-statistics are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

(1) (2) (3) (1) -0.095 [0]		(5)	(6)			
HHI _{t-1}	-0.095		-1.956**	-2.318***	-2.828***	-2.603***
	[-0.23]		[-2.26]	[-2.87]	[-3.69]	[-2.84]
$\operatorname{Redpb}_{t-1}$		-0.408	-1.198	-1.090	-2.477*	-1.124
		[-0.77]	[-1.52]	[-1.53]	[-1.82]	[-1.30]
$\mathrm{HHI}_{t\text{-}1} * \mathrm{Redpb}_{t\text{-}1}$			4.542**	4.718^{***}	11.648^{***}	6.337***
			[2.38]	[2.62]	[3.36]	[2.69]
$\log(\mathrm{Size})_{t\text{-}1}$				-0.010	-0.011	-0.010
				[-0.25]	[-0.27]	[-0.25]
$\mathrm{Book\text{-}to\text{-}Market}_{t\text{-}1}$				0.250^{***}	0.253^{***}	0.252^{***}
				[2.89]	[2.93]	[2.91]
lag(1-month return)				-1.730	-1.735	-1.730
				[-1.56]	[-1.57]	[-1.56]
lag(12-month return)				0.283	0.282	0.283
				[1.26]	[1.25]	[1.26]
$Leverage_{t-1}$				0.793^{*}	0.797^{*}	0.794^{*}
				[1.73]	[1.74]	[1.73]
#Obs	$767,\!109$	$767,\!109$	$767,\!109$	$700,\!457$	$698,\!296$	$700,\!457$
Year-month FE	Yes	Yes	Yes	Yes	Yes	Yes
\mathbb{R}^2	14.3%	14.3%	14.3%	14.6%	14.6%	14.6%

Table 4.6: Fama-MacBeth Regressions for Excess Returns

This table presents results from Fama-MacBeth regressions of firms' excess returns on Herfindahl-Hirschman Index (HHI), asset redeployability (Redpb), the interaction term (HHI * Redpb), and other control variables. $\log(Size)$ is the natural logarithm of the market value of equity. Book-to-Market is the ratio of book value of equity to market value of equity. lag(1-month return) is the stock return over previous month. lag(12-month return) is the past 12-month stock return excluding previous month (i.e. from month -12 to month -2). Leverage is defined as the ratio of total liabilities to the sum of market value of equity and total liabilities. Column (2)-(4) use the firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight. Column (5) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight, and incorporates correlation of outputs among firms within industries in the measure. Column (6) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses the equal weight for each BEA industry-year. The sample period is from January 1990 to December 2016. t-statistics using Newey-West standard errors are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
HHI _{t-1}	-0.114		-2.467***	-2.886***	-2.905***	-3.125***
	[-0.24]		[-2.62]	[-3.54]	[-3.55]	[-3.37]
$\operatorname{Redpb}_{t-1}$		-0.249	-1.188	-1.120	-2.120	-1.328
		[-0.44]	[-1.54]	[-1.63]	[-1.58]	[-1.58]
$\mathrm{HHI}_{t\text{-}1} * \mathrm{Redpb}_{t\text{-}1}$			5.595^{***}	5.806^{***}	11.051***	7.541^{***}
			[2.96]	[3.23]	[3.05]	[3.16]
$\log(\mathrm{Size})_{t\text{-}1}$				-0.005	-0.006	-0.006
				[-0.13]	[-0.15]	[-0.15]
$\mathrm{Book}\text{-}\mathrm{to}\text{-}\mathrm{Market}_{t\text{-}1}$				0.145^{**}	0.147^{**}	0.146^{**}
				[2.07]	[2.10]	[2.08]
lag(1-month return)				-1.620***	-1.628***	-1.610***
				[-3.86]	[-3.89]	[-3.84]
lag(12-month return)				0.309^{*}	0.310^{*}	0.312^{*}
				[1.82]	[1.82]	[1.83]
$\mathrm{Leverage}_{t-1}$				0.469	0.476	0.470
				[1.35]	[1.37]	[1.35]
# Months	323	323	323	323	323	323
\mathbf{R}^2	0.4%	0.4%	0.9%	4.3%	4.3%	4.3%

Table 4.7: Industry Level Fama-MacBeth Regressions

This table presents results from industry-level Fama-MacBeth regressions of excess returns on Herfindahl-Hirschman Index (HHI), asset redeployability (Redpb), the interaction term (*HHI* * *Redpb*), and other control variables. All variables are first averaged within each (three-digit SIC) industry. $\log(Size)$ is the natural logarithm of the market value of equity. Book-to-Market is the ratio of book value of equity to market value of equity. lag(1-month return) is the stock return over previous month. lag(12-month return) is the past 12-month stock return excluding previous month (i.e. from month -12 to month -2). Leverage is defined as the ratio of total liabilities to the sum of market value of equity and total liabilities. Column (2),(3),and (5) use the firm-level asset redeployability measure based on assetlevel redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight. Column (6) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight, and incorporates correlation of outputs among firms within industries in the measure. Column (7) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses the equal weight for each BEA industry-year. The sample period is from January 1990 to December 2016. t-statistics using Newey-West standard errors are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HHI _{t-1}	-0.04		-2.15**		-2.20**	-2.25***	-2.58***
	[-0.24]		[-2.56]		[-2.58]	[-2.85]	[-2.62]
$\operatorname{Redpb}_{t-1}$		0.33	-1.13		-0.99	-2.08	-1.13
		[0.66]	[-1.56]		[-1.38]	[-1.55]	[-1.29]
$\mathrm{HHI}_{t\text{-}1} * \mathrm{Redpb}_{t\text{-}1}$			5.10^{**}		4.91**	9.41**	6.87^{**}
			[2.51]		[2.41]	[2.55]	[2.48]
$\log(\mathrm{Size})_{t\text{-}1}$				0.09**	0.10^{**}	0.10^{**}	0.09^{*}
				[1.98]	[2.05]	[2.10]	[1.94]
$\mathrm{Book\text{-}to\text{-}Market}_{t\text{-}1}$				0.26^{*}	0.27^{*}	0.28^{*}	0.28^{*}
				[1.73]	[1.82]	[1.87]	[1.84]
lag(1-month return)				1.20	0.97	0.95	1.02
				[1.60]	[1.29]	[1.26]	[1.37]
lag(12-month return)				0.81***	0.76^{***}	0.76***	0.77^{***}
				[2.97]	[2.82]	[2.80]	[2.84]
$\mathrm{Leverage}_{t-1}$				0.30	0.32	0.30	0.32
				[0.79]	[0.83]	[0.78]	[0.84]
# Months	323	323	323	323	323	323	323
\mathbb{R}^2	0.8%	0.9%	2.5%	9.4%	11.7%	11.7%	11.6%

Table 4.8: Fama-MacBeth Regressions for Unlevered Return

This table presents results from Fama-MacBeth regressions of firms' unlevered returns on Herfindahl-Hirschman Index (HHI), asset redeployability (Redpb), the interaction term (HHI * Redpb), and other control variables. Unlevered stock returns are excess returns divided by the sum of one plus leverage. $\log(Size)$ is the natural logarithm of the market value of equity. Book-to-Market is the ratio of book value of equity to market value of equity. lag(1-month return) is the stock return over previous month. lag(12-month return) is the past 12-month stock return excluding previous month (i.e. from month -12 to month -2). Leverage is defined as the ratio of total liabilities to the sum of market value of equity and total liabilities. Column (2)-(4) use the firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight. Column (5) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses market capitalization of Compustat firms in each BEA industry-year as the weight, and incorporates correlation of outputs among firms within industries in the measure. Column (6) uses the firm-level asset redeployability measure based on asset-level redeployability score that uses the equal weight for each BEA industry-year. The sample period is from January 1990 to December 2016. t-statistics using Newey-West standard errors are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

(1) (2) (3) (1) -0.223		(5)	(6)			
HHI _{t-1}	-0.223		-2.130***	-2.250***	-2.277***	-2.412***
	[-0.58]		[-2.89]	[-3.40]	[-3.44]	[-3.17]
$\operatorname{Redpb}_{t-1}$		-0.252	-0.999*	-0.999*	-1.911*	-1.140*
		[-0.63]	[-1.79]	[-1.86]	[-1.84]	[-1.73]
$\mathrm{HHI}_{t\text{-}1} * \mathrm{Redpb}_{t\text{-}1}$			4.585***	4.607***	8.872***	5.906^{***}
			[3.40]	[3.36]	[3.25]	[3.18]
$\log(\mathrm{Size})_{t\text{-}1}$				-0.001	-0.001	-0.001
				[-0.02]	[-0.04]	[-0.04]
$\mathrm{Book}\text{-}\mathrm{to}\text{-}\mathrm{Market}_{t\text{-}1}$				0.136	0.138	0.138
				[1.53]	[1.56]	[1.54]
lag(1-month return)				-1.214***	-1.223***	-1.206***
				[-3.50]	[-3.54]	[-3.48]
lag(12-month return)				0.261^{*}	0.262^{*}	0.263^{*}
				[1.91]	[1.92]	[1.92]
# Months	323	323	323	323	323	323
\mathbb{R}^2	0.4%	0.4%	0.9%	3.7%	3.7%	3.7%

	Concentration
	Industry
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market capitalization of Compustat firms in each BEA industry-year as the weight. $\log(Size)$ is the natural logarithm of the market value of Hirschman Index using total assets to compute market share. In Panel B, IndCon is the concentration ratio of the combined net sales of top 5 firms to the industry's total net sales. Redpb is the firm-level asset redeployability measure based on asset-level redeployability score that uses equity. Book-to-Market is the ratio of book value of equity to market value of equity. lag(1-month return) is the stock return over previous month. $lag(12-month \ return)$ is the past 12-month stock return excluding previous month (i.e. from month -12 to month -2). Leverage is defined as the ratio of total liabilities to the sum of market value of equity and total liabilities. The sample period is from January 1990 to December 2016. t-statistics using Newey-West standard errors are reported in parentheses. *, **, *** indicate statistical significance at the asset redeployability (Redpb), the interaction term (IndCon * Redpb), and other control variables. In Panel A, IndCon is the Herfindahl-This table presents results from Fama-MacBeth regressions of firms' excess returns on alternative industry concentration measures (IndCon), 10%, 5%, and 1% levels respectively.

		Panel	A: HHI(t	otal assets)		Pane	l B: Con	centration	Ratio 5
•	(1)	(2)	(3)	(4)	(5)	(9)	(2)	(8)	(6)
$\operatorname{IndCon}_{t-1}$	-0.007	~	-1.187	-1.511^{**}	-1.619^{**}	-0.019	-0.797	-0.934^{**}	-1.081**
	[-0.02]		[-1.60]	[-2.16]	[-2.34]	[-0.07]	[-1.59]	[-2.05]	[-2.58]
$\operatorname{Redpb}_{\operatorname{t-1}}$		-0.186	-0.410	-0.386	-0.348		-0.759	-0.725	-0.720
		[-0.50]	[-0.85]	[-0.89]	[-0.82]		[-1.26]	[-1.32]	[-1.35]
$IndCon_{t-1} * Redpb_{t-1}$			2.206^{*}	2.378^{**}	2.311^{**}		1.343^{*}	1.391^{**}	1.456^{**}
			[1.80]	[2.03]	[1.99]		[1.96]	[2.16]	[2.27]
$\log({\rm Size})_{t-1}$				-0.023	-0.003			-0.022	-0.001
				[-0.54]	[-0.07]			[-0.51]	[-0.03]
$Book-to-Market_{t-1}$				0.123	0.144^{**}			0.128	0.146^{**}
				[1.08]	[2.06]			[1.17]	[2.12]
lag(1-month return)					-1.623^{***}				-1.648^{***}
					[-3.88]				[-3.97]
lag(12-month return)					0.313^{*}				0.311^{*}
					[1.83]				[1.83]
Leverage _{t-1}					0.472				0.501
					[1.36]				[1.50]
# Months	323	323	323	323	323	323	323	323	323
${ m R}^2$	0.4%	0.4%	1.0%	2.2%	4.3%	0.7%	1.3%	2.4%	4.5%

Table 4.10): Alternative	Measure of	f Investment	Irreversi	oilit	JV
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This table presents results from Fama-MacBeth regressions of firms' excess returns on Herfindahl-Hirschman Index (HHI), firm-level inflexibility (Inflex), the interaction term (HHI*Inflex), and other control variables. Inflex is defined as the firm's historical range of operating costs scaled by sales over the volatility of the logarithm growth rate of sales over assets. $\log(Size)$ is the natural logarithm of the market value of equity. Book-to-Market is the ratio of book value of equity to market value of equity. $lag(1-month\ return)$ is the stock return over previous month. $lag(12-month\ return)$ is the past 12-month stock return excluding previous month (i.e. from month -12 to month -2). Leverage is defined as the ratio of total liabilities to the sum of market value of equity and total liabilities. The sample period is from January 1990 to December 2016. t-statistics using Newey-West standard errors are reported in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

	(1)	(2)	(3)	(4)	(5)
HHI _{t-1}	-0.114		-0.050	-0.179	-0.260
	[-0.26]		[-0.14]	[-0.57]	[-1.12]
$Inflex_{t-1}$		-0.024**	0.002	0.003	0.008
		[-2.13]	[0.12]	[0.21]	[0.63]
$\mathrm{HHI}_{t\text{-}1} * \mathrm{Inflex}_{t\text{-}1}$			-0.181***	-0.185***	-0.192***
			[-2.86]	[-2.94]	[-3.00]
$\log(\mathrm{Size})_{t\text{-}1}$				-0.039	-0.022
				[-1.02]	[-0.64]
$\operatorname{Book-to-Market}_{t\text{-}1}$				0.048	0.098
				[0.46]	[1.40]
lag(1-month return)					-1.661***
					[-3.80]
lag(12-month return)					0.278^{*}
					[1.69]
$Leverage_{t-1}$					0.289
					[1.00]
# Months	323	323	323	323	323
\mathbb{R}^2	0.4%	0.3%	0.7%	1.9%	4.1%

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