Managerial Short-Termism and Market Competition

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Abstract

I develop a model to study managerial short-termism in an imperfectly competitive product market. In the model, two publicly-traded firms, each run by a manager, are considering a new investment opportunity. Each manager privately observes her firm's fixed cost and makes an investment decision to maximize her expected compensation. I show that, in equilibrium, both firms induce their respective managers to behave myopically by tying their pay to short-term stock prices. Due to information asymmetry between managers and investors, managers under such compensation contracts tend to overinvest to raise investors' expectations and short-term stock prices, which gives their respective firms the competitive advantage. However, the equilibrium constitutes a form of the prisoner's dilemma, since aggressive investment actions by both firms squeeze their profits. Finally, I discuss policy implications and find consistent empirical evidence for the effects of product market competition on the duration of compensation contracts.

Keywords: Short-termism; myopia; executive compensation; market competition

JEL Classification: G34, L13, M12, M52

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1 Introduction

Managerial short-termism (myopia) is commonly viewed as a considerable problem that faces modern firms, which can undercut the economy's growth in the long run.[1] According to Edmans, Gabaix, and Jenter (2017), short-termism is broadly defined to encompass any action that increases current returns at the expense of future returns: Scrapping positive-net present value (NPV) investments that reduce short-term performance, taking negative-NPV projects that boost short-term performance, earnings management, and accounting manipulation.

Short-termism has been heavily criticized since the late 1970s (Kaplan, 2018). Classic theories focus on the distortions that are caused by managers with exogenous short-term concerns (Narayanan, 1985; Stein, 1989; Bebchuk and Stole, 1993), and accumulated empirical evidence tends to confirm that short-termism has significant consequences (Graham, Harvey, and Rajgopal, 2005; Budish, Roin, and Williams, 2015; Edmans, Fang, and Lewellen, 2017; Edmans, Fang, and Huang, 2017). Poor corporate governance and improperly structured incentive compensation are often cited as accomplices to short-termism. Yet, even with these persistent concerns about short-termism, as well as improved corporate governance and regulation to curb it in the past decades, modern firms seem to remain plagued by such behavior. Thus, recent theories have explored how short-term incentives can be part of optimal compensation contracts due to such factors as shareholder preference (Bolton, Scheinkman, and Xiong, 2006), early feedback about managerial talent (Laux, 2012), managerial risk aversion (Peng and Röell, 2014), and the possibility of manipulation (Marinovic and Varas, 2017). While these papers are insightful, there is one prominent component that remains understudied by all existing theories on short-termism: The competition between firms in terms of innovation, production, and sales.

This paper attempts to fill this gap by providing a micro-foundation for managerial short-

[1] As surveyed by Graham, Harvey, and Rajgopal (2005), 78% of executives would sacrifice long-term firm values to meet targets for short-term earnings; plus, a recent survey shows that, over the past several years, the pressure on senior executives to deliver short-term results has only increased (Barton, Bailey, and Zoffer, 2016). The general public has also expressed great concerns about short-termism ("How short-termism saps the economy", *Wall Street Journal*, September 27, 2016; "Short-termism is harming the economy," *Wall Street Journal*, June 6, 2018). Of course, there are some different views: For example, Kaplan (2018) argues that the concerns of short-termism may be overstated, given that there is little long-term evidence consistent with these worries.

termism in an imperfectly competitive product market and exploring its aggregate implications on the economy. In addition to the fact that product market competition is ubiquitous and should be factored into the picture, my paper follows a simple rationale: Conventional wisdom on short-termism must be applied with caution. While short-termism distorts a single firm's investment, it is not *a priori* clear whether the distortions are overwhelmingly detrimental when the firm is faced with inter-firm competition.

My model builds on the classic entry game (e.g., Spence, 1977; Sutton, 2007), where entry is broadly interpreted as exploring a new investment opportunity, and extends it by introducing stock-based executive compensation. In the model, two publicly-traded firms are contemplating a new investment opportunity (e.g., to develop new products, or to enter a new geographical market) and each firm is run by a manager. There are three stages. In the first stage, each firm's shareholders simultaneously choose a compensation contract for their manager to maximize the expected long-term firm value. Following Bolton, Scheinkman, and Xiong (2006), I assume that the compensation contract can offer both a short-term and a long-term equity stake to the manager. In the second stage, each firm will incur a fixed cost when investing, and the cost is not observed by the rival firm or its investors. The firm's manager, who privately learns her firm's fixed cost, makes an investment decision to maximize her expected compensation. After observing the firms' investment decisions, investors trade the firms' stocks in a competitive financial market. Production and product sales then take place in the last stage, and firm profits are realized.

Before analyzing this economy, I begin my study by examining a single-firm benchmark. I first show that, if the firm's manager's pay loads positively on short-term stock performance ("short-term compensation contract"), she is likely to make aggressive investment decisions (overinvest), i.e., investment may still take place even when it hurts her firm's long-term profit. The behavior can be explained by information asymmetry. Investors do not directly observe the firm's fixed cost and must draw inferences about it (hence, the firm's long-term value) from its investment decision. By launching the project, the manager signals a low cost to investors, thereby raising their expectations and boosting the firm's short-term stock price. The manager's short-termist action, however, impairs the long-term firm value, because she invests even when it is unprofitable to do so. In anticipation of this behavior, the firm's shareholders always find it optimal to tie their manager's pay exclusively to the long-term firm value, i.e., choose a long-term compensation contract, so the manager does not receive her compensation until the shareholders' concerns about her action are resolved.

The above finding, however, is not necessarily consistent under market competition. After studying the single-firm benchmark, I show that when there are two firms considering the new investment opportunity, long-term compensation contracts never arise as an equilibrium outcome, and shareholders of both firms tie their managers' pay to short-term stock performance, thereby encouraging short-termist behavior. In other words, under market competition, managerial short-termism arises as a *choice*, not an *inability* to induce long-term managerial behavior. The intuition is as follows. As mentioned before, short-term compensation contracts induce managers to overinvest to boost short-term stock prices. If used strategically then, a short-term compensation contract can help one firm commit to an aggressive investment strategy and establish a competitive advantage over the other. Therefore, even though short-term compensation contracts bring about investment distortions to the whole of the system, shareholders are still willing to offer them to induce managers to behave aggressively.

Nonetheless, in equilibrium, short-term compensation contracts are not ideal for firms when competing firms *both* choose them. In fact, the two firms are always worse off relative to the case in which they were restricted to choosing long-term compensation contracts, since the two short-termist managers invest aggressively, leading to fiercer competition, which then backfires on both firms' profits. Therefore, this equilibrium constitutes a form of the prisoner's dilemma.

A further efficiency analysis reveals that, though short-term compensation contracts (and the induced short-termist behavior) erode firm profits, they can actually benefit social welfare. This is because, in equilibrium, the fierce competition hurts the firms, but benefits consumers, because product prices become lower and demand is higher. Overall, what this model suggests is that the positives of short-termism can be said to dominate its adverse effects under certain circumstances, namely in its contribution to social welfare, which highlights the difference between firm effeciency and society efficiency in the context of short-termism. Echoing Donaldson, Malenko, and Piacentino (2018), this paper also "provides a counterpoint to the broadly negative view of corporate short-termism."

Given the above results, one natural solution for firms to curb short-termism and escape the prisoner's dilemma is to communicate with the financial market in a more direct way, e.g., disclosure. I thus consider an extended economy in which firms are allowed to choose ex ante disclosure policies about the cost information. I find that, even if firms have the option to disclose their cost information, they will never choose to do so, suggesting that firms cannot collusively escape the prisoner's dilemma via voluntary disclosure. This is because upon disclosure a firm will have no means to commit its manager to an aggressive investment strategy and hence cannot establish a competitive edge in the market. One consequent policy implication is that while a mandatory disclosure policy may enable firms to curb or eliminate managerial short-termist behavior, such a policy can reduce market competitiveness and hurt consumers; therefore, any policy that limits managerial short-termism must not focus narrowly on the short-termist behavior alone but also recognize the systemic nature of the issue.

In addition, I consider other forms of product competition (e.g., price/quantity competition with differentiated products) and find that the key insight remains robust: Long-term compensation contracts cannot be sustained as an equilibrium outcome when firms are faced with inter-firm competition. Moreover, the extended model suggests that under certain parameter space, firms facing fiercer competition are more likely to write compensation contracts with shorter duration. I investigate the prediction empirically. I follow Gopalan et al. (2014) and construct pay duration using detailed grant level compensation data. Then I use product similarity from Hoberg-Phillips TNIC data or industry sales as a proxy for product market competition. I find that, consistent with my theory, firms' pay duration is negatively related to competitive pressures.

This paper contributes to the classic, but rapidly growing literature on short-termism/myopia.

Narayanan (1985) shows that managers who are concerned with their labor-market reputations have the incentive to take actions that boost measures of short-term performance, even at the expense of long-run shareholder value. Stein (1989) makes a similar point by showing that managers, if they care about stock prices over a near-term horizon, may behave myopically even in a fully efficient market; in fact, under certain circumstances, they forsake good investments to boost short-term earnings. Other theories on short-termism include Miller and Rock (1985), Stein (1988), Bebchuk and Stole (1993), Bizjak, Brickley, and Coles (1993), and Goldman and Slezak (2006), who show that managers' short-term concerns typically hurt the interest of shareholders.

More recent works investigate short-termism in the optimal contracting framework.[2] There are several justifications for why managerial compensation should depend on both short-term and long-term stock prices. For example, Bolton, Scheinkman, and Xiong (2006) show that, due to the conflict of interest between future shareholders and current short-termist shareholders, the latter may design a contract that encourages ramping up short-term stock prices. Then, Laux (2012) postulates that long vesting terms fail to provide early feedback about CEO talent and may encourage myopia when CEO turnover is possible. Furthermore, Peng and Röell (2014) demonstrate that, though long-term incentives mitigate the economic waste associated with manipulation, risk-averse managers are exposed to extra risks; therefore, the optimal mix of short-term and long-term incentives is dependent on the trade-off between manipulation and risk-sharing. More recently, Marinovic and Varas (2017) find that the manager's compensation becomes increasingly sensitive to short-term performance over her contract horizon.

My paper adds to the literature on short-termism by offering a novel and empirically relevant explanation for managerial short-termism: In an imperfectly competitive market, one firm may induce managerial short-termist behavior to gain a competitive advantage over its rival. In a broad sense, my paper reinforces a basic point that a firm' product market decisions and its

[2] Murphy (1999), Bebchuk and Fried (2003), Edmans and Gabaix (2009), Frydman and Jenter (2010), Murphy (2013), Edmans and Gabaix (2016), and Edmans, Gabaix, and Jenter (2017) provide thorough surveys of the theoretical and empirical literature on executive compensation. As implied by Edmans, Gabaix, and Jenter (2017), there are two broad perspectives regarding the cause of short-termism: "rent extraction" view, and "shareholder value" view. My paper belongs to the second group.

manager's incentive schemes are fundamentally related.

Another stream of related literature discusses how managerial incentive contracts can be used in the competitive market and, reversely, how product market competition influences managerial incentives contracts. For example, a firm can deter a competitor's entry if its manager is principally concerned about maintaining her firm's dominance over the market, making considerations of profit secondary in priority (Vickers, 1985). A firm can also commit to an aggressive production strategy and improve its profit by paying its manager according to both profits and sales (Fershtman and Judd, 1987; Sklivas, 1987) or by offering non-executive employees equity-based compensation (Bova and Yang, 2017). While the pre-commitment to managerial incentives intensifies competition in all the above models, Aggarwal and Samwick (1999) show that firms could soften their competition if their managers are compensated based on both their own and their rivals' performances. More recently, Antón, Ederer, Giné, and Schmalz (2018) study how common ownership and competition concerns shape incentive contracts. This paper is more broadly related to the literature on commitment in oligopoly theory, in which physical capital, location, product choice, or R&D choices can influence the subsequent output market. Titman (1984), Brander and Lewis (1986), and Maksimovic (1990) are among the pioneers who study the strategic relationship between oligopoly and financial markets.

My paper adds to this literature in the following ways. First, I demonstrate the strategic effect of short-term compensation contracts under market competition. Second, my model features more general forms of competition: While much of the existing literature implicitly or explicitly assumes market structure to be exogenous, I consider market structure as an outcome of strategic incentive schemes.

2 The Model

I study an economy in which two publicly-traded firms are considering a new investment opportunity. Each firm hires a manager to make the investment decision. There are three periods,

$t \in \{0, 1, 2\}$. At $t = 0$, the two firms' shareholders simultaneously write compensation contracts for their respective managers. At $t = 1$, each manager privately observes her firm's fixed cost and simultaneously decides whether or not to invest. Subsequent to their investment decisions, their firms' stock prices are determined in a financial market. At $t = 2$, firm profits are realized, managers receive their compensation, and both firms are liquidated. Figure 1 shows the sequence of events, while main model variables are tabulated and explained in Appendix A.

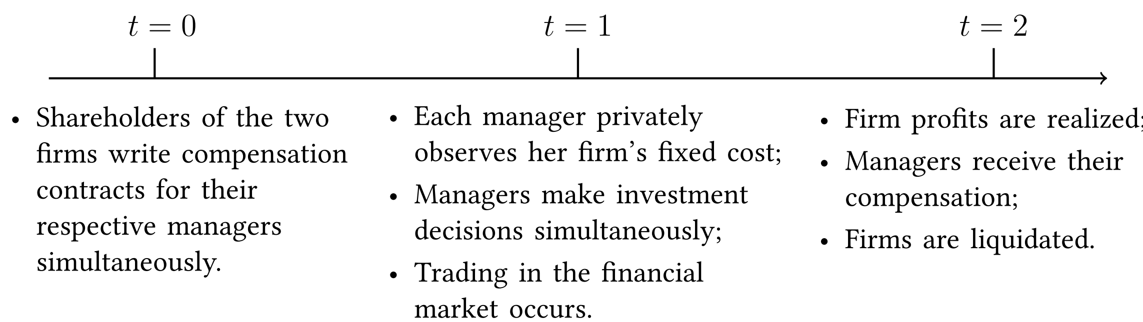


Figure 1: Timeline of events

The Firms The two publicly-traded firms are indexed by $i, j \in \{1, 2\}$, $i \neq j$. Denote by $A_i \in \{0, 1\}$ firm i's investment decision. Note that the action A_i can be thought of in very general terms, representing any investment decision that affects the firm's value; for example, to build a new product line, to enter a new geographical market, or to engage in a race to obtain an innovation. I simply refer to it as a project choice. $A_i = 1$ indicates that firm i launches the new project, whereas $A_i = 0$ denotes that firm i chooses not to do so.[3]

Firm i must incur a nonrecoverable fixed cost, C_i, to launch the new project, e.g., building production facilities, hiring workforce, setting up distribution channels, or R&D. The fixed cost is incurred over the long run and is stochastic in nature. At $t = 1$, each manager observes her firm's fixed cost, which is not known to investors until $t = 2$ if the firm invests in the project; if a firm does not take on the project, it does not incur any cost. Assuming cost uncertainty and proprietary cost information is standard in the literature (e.g., Gal-Or, 1986; Shapiro, 1986; Bloch,

[3]Without loss of generality, I focus on firm i, which can be either firm 1 or firm 2 ($i \in \{1, 2\}$), and firm j is the other firm.

Fabrizi, and Lippert, 2015) and also motivated in real life. For example, when firms contemplate entering a new geographical market, they need to investigate various production and distribution alternatives. In an R&D race, firms often build prototypes and run small-scale experiments before investing in a large-scale project. During these processes, each manager, as the insider, can learn about her firm's cost better and earlier than the financial market. For the sake of tractability, I assume that C_i is, independent of anything else, uniformly distributed over the unit interval, i.e., $C_i \sim U[0,1]$.[4]

Firms that do not invest in the project make (normalized) revenues of 0. If only one firm launches the project (i.e., $A_i \neq A_j$), it becomes a monopolist in the new business and makes a monopoly revenue of $H \in [0,1]$, where H represents the potential size of the project.[5] For example, if firms are considering whether or not to enter a new market, H measures the market size. If both firms invest in the project (i.e., $A_i = A_j = 1$), they compete with each other and each makes a duopoly revenue of 0. One interpretation of the model is that the firms compete à la Bertrand and their products are perfect substitutes. It is then well-established that the firms will compete away all their profits: The duopoly revenue is equal to the variable production cost, which I normalize to zero. In Section 5.3, I relax this assumption and consider other forms of product competition.

Finally, the initial value of firm i is assumed to be zero, so that firm value is equal to its profit at $t = 2$.

Financial Market and Managerial Compensation Contracts At the end of $t = 1$, upon observing the two firms' investment decisions, A_i and A_j, investors trade the firms' stocks in a competitive financial market. The stock price of firm i is determined by risk-neutral competitive market makers (Kyle, 1985) and incorporates all available public information. To be specific, given both firms' investment decisions, firm i's short-term stock price, $\hat{S}_i$, is a reflection of investors'

[4]The independence assumption is for model tractability, and the results are robust when the two firms' fixed costs are partially correlated.

[5]I assume $H \in [0,1]$; otherwise if $H > 1$, in a single-firm setting (which will be specified in Section 3) the firm must always invest in the project. Furthermore, since I normalize the fixed cost to the uniform distribution, the project potential H is measured relative to the fixed cost.

expectation of the firm's long-term value, $\hat{V}_i$, conditional on all public information at $t = 1$:

$$\hat{S}_i = \mathbb{E}\left(\hat{V}_i | A_i, A_j\right), \text{ where } \hat{V}_i = \begin{cases} \Pi_i - C_i - \hat{W}_i & \text{if } A_i = 1, \\ -\hat{W}_i & \text{if } A_i = 0. \end{cases} \tag{1}$$

Note $\hat{V}_i$ is the value of firm i at $t = 2$, $\Pi_i \in \{H, 0\}$ is its revenue, C_i is its fixed cost, and $\hat{W}_i$ is manager i's compensation (which will be specified shortly). Each firm has one share outstanding; thus, $\hat{S}_i$ is equal to firm i's market capitalization at $t = 1$.

Both managers are assumed to be risk neutral and their reservation utility is $\hat{W}_0$. Note the assumption of risk-neutrality shuts down the "risk-sharing" component in executive compensation and allows me to focus on the incentive effect of compensation contracts. Following the literature on executive compensation (e.g., Bolton, Scheinkman, and Xiong, 2006), I only consider linear compensation contracts. Firm i offers both a short-term and a long-term equity stake in the compensation contract to its manager, where the latter is the realized profit or true value of the firm at $t = 2$:

$$\hat{W}_i = \hat{a}_i \hat{S}_i + \hat{b}_i \hat{V}_i + \hat{d}_i. \tag{2}$$

Note the short-term stock price, $\hat{S}_i$, and the long-term firm value, $\hat{V}_i$, are given by (1). $\{\hat{a}_i, \hat{b}_i, \hat{d}_i\}$ represents the compensation contract. Specifically,

- $\hat{a}_i$ denotes the weight that the compensation contract places on the short-term stock price, e.g., the fraction of vested manager shares;
- $\hat{b}_i$ measures the weight that the compensation contract places on long-term firm value, e.g., the fraction of manager shares that must be held until $t = 2$;
- $\hat{d}_i$ represents the non-performance-based compensation component, e.g., the manager's fixed base salary.

Firm i is owned by risk-neutral long-term shareholders.[6] At $t = 0$, through the board of directors, or the compensation committee, they choose a compensation contract $\{\hat{a}_i, \hat{b}_i, \hat{d}_i\}$ to maximize the expected long-term firm profit, denoted by $\hat{\pi}_i$, subject to their manager's participation and incentive constraints. Note $\hat{\pi}_i$ is equal to firm i's expected long-term valuation $\left(\mathbb{E}\left[\hat{V}_i\right]\right)$, given that the firm's initial value is normalized to zero. Formally, the problem facing firm i's shareholders is given by:

$$\max_{\hat{a}_i, \hat{b}_i, \hat{d}_i} \hat{\pi}_i = \mathbb{E}\left[\hat{V}_i\right] \tag{3}$$

$$\text{s.t.} \quad \mathbb{E}[\hat{W}_i^*] \geq \hat{W}_0,$$

$$A_i^* \in \arg\max_{A_i} \mathbb{E}\left[\hat{W}_i\right],$$

where, once again, $\hat{W}_0$ is the manager's reservation utility.

Denote $a_i = \frac{\hat{a}_i}{1+\hat{a}_i+\hat{b}_i}$, $b_i = \frac{\hat{b}_i}{1+\hat{a}_i+\hat{b}_i}$, and $d_i = \frac{\hat{d}_i}{1+\hat{a}_i+\hat{b}_i}$. To simplify analysis, in Appendix B, I show that (2) is equivalent to the following contract form in providing incentives to the manager:

$$W_i = \omega_i S_i + (1 - \omega_i) V_i, \tag{4}$$

where $W_i = \frac{\hat{W}_i - d_i}{a_i + b_i}$, $\omega_i = \frac{a_i}{a_i + b_i} \in [0, 1]$,

$$S_i = \mathbb{E}\left(V_i | A_i, A_j\right), \text{ and } V_i = \begin{cases} \Pi_i - C_i & \text{if } A_i = 1, \\ 0 & \text{if } A_i = 0. \end{cases} \tag{5}$$

In practice, executive compensation constitutes only a small percentage of public firms' value. Thus, S_i and V_i are very close to $\hat{S}_i$ and $\hat{V}_i$, respectively. In the rest of the paper, I simply refer to S_i as firm i's stock price and V_i as firm value (Fershtman and Judd, 1987; Sklivas, 1987; Reitman, 1993; Spagnolo, 2000).[7] The expected profit of firm i at $t = 0$ is $\pi_i = \mathbb{E}[V_i]$, accordingly. From this

[6] One standard justification for shareholders' risk neutrality is that they can easily diversify firm-specific risk.

[7] As will be clear later in Section 4.2, this approach will not change the equilibrium characterization. In fact, in equilibrium the difference between S_i and $\hat{S}_i$, or between V_i and $\hat{V}_i$, is a constant, i.e., $S_i = \hat{S}_i + \hat{W}_0$, $V_i = \hat{V}_i + \hat{W}_0$.

point on, I work with the contract as noted in specification (4).

3 Benchmark: A Single Firm

Before considering the model with two firms, I first study a benchmark where there is only one firm. This single firm is run by a manager, who makes the investment decision. The firm's shareholders ex ante choose a compensation contract that will maximize the long-term firm value. In this section, I will present how the compensation contract affects the manager's investment decision, and then, derive the optimal contract.

Suppose that the single firm's compensation contract assigns a weight $\omega^0 \in [0,1]$ to the short-term stock price and a weight $1-\omega^0$ to the long-term firm value, where the superscript 0 represents the single-firm benchmark. The manager's investment decision follows a threshold policy: Investment takes place if and only if $C \leq \bar{C}^0$, where $\bar{C}^0$ is the cut-off point at which the manager is indifferent about investing or not.[8] To break ties, I assume that, when a manager is indifferent about whether or not to invest, she always invests.

Conditional on the manager launching the project, the short-term stock price at $t=1$ is

$$S^0(\omega^0) = \mathbb{E}\left(H - C | C \leq \bar{C}^0(\omega^0)\right) = H - \frac{\bar{C}^0(\omega^0)}{2}, \tag{6}$$

which is a function of ω^0. Long-term firm value is $V^0 = H - C$. Therefore, if the manager enters, her compensation is the weighted average of the short-term stock price and long-term firm value:

$$W^0(C) = \omega^0 \left(H - \frac{\bar{C}^0}{2}\right) + (1-\omega^0)(H - C). \tag{7}$$

If the manager does not invest, her compensation is 0. Since the manager must be indifferent

[8]The manager follows a cut-off policy because, if she invests when $C = C'$, she must be willing to do so when $C < C'$.

about whether or not to invest at $C = \bar{C}^0$, it follows that

$$W^0\left(\bar{C}^0\right) = \omega^0\left(H - \frac{\bar{C}^0}{2}\right) + \left(1-\omega^0\right)\left(H - \bar{C}^0\right) = 0,$$

which yields $\bar{C}^0 = \frac{2H}{2-\omega^0}$. Note that, if $\frac{2H}{2-\omega^0} > 1$, the manager always launches the project. In this case, let $\bar{C}^0 = 1$. Hence the manager's investment decision can be summarized in the following cut-off point:

$$\bar{C}^0\left(\omega^0\right) = \min\left\{\frac{2H}{2-\omega^0}, 1\right\}. \tag{8}$$

If the manager is compensated based solely on firm value at $t = 2$ (i.e., $\omega^0 = 0$), equation (8) shows that the investment will occur up to the point at which the firm's revenue is just exhausted by its investment outlay, i.e., $C \le \bar{C}^0(0) = H$. However, if the manager also cares about the short-term stock price (i.e., $\omega^0 > 0$), the investment strategy will become more aggressive: It will entail a higher threshold, $\bar{C}^0\left(\omega^0\right) > \bar{C}^0\left(0\right) = H$. Therefore, with the short-term compensation contract, investment becomes suboptimal when $C \in (H, \bar{C}^0(\omega^0)]$: The manager launches the project even though this decision yields a long-term loss to the firm. In other words, the manager with short-term valuation concerns behaves myopically.

The key friction underlying this result is the information asymmetry between the manager and investors. Investors do not observe the firm's fixed cost and can only draw inferences about it based on the manager's investment decision. By launching the project, the manager signals low cost to investors, thereby raising investors' expectations and boosting the short-term stock price. Therefore, under short-term compensation contract (i.e., $\omega_0 > 0$), the manager tends to make aggressive investment decisions: Short-term valuation concerns strengthen the investment decision. This is consistent with the empirical evidence documented in Cohn, Gurun, and Moussawi (2016), Edmans, Fang, and Huang (2017), and Kolasinski and Yang (2018). The following lemma summarizes this finding.

Lemma 1 (Short-termism)**.** *In the single-firm benchmark, a short-term compensation contract (i.e.,*

$\omega^0 > 0$*) induces the manager to make suboptimal investment decision if* $C \in (H, \bar{C}^0(\omega^0)]$*, where* $\bar{C}^0(\omega^0)$ *is given by (8).*

Now, I examine firm profits under the short-term compensation contract. With the investment threshold given by (8), expected long-term firm value is $\int_0^{\bar{C}^0(\omega^0)}(H-C)dC$, which can be simplified as follows:

$$\pi^0(\omega^0) = \begin{cases} \frac{2H^2(1-\omega^0)}{(2-\omega^0)^2} & \text{if } \frac{2H}{2-\omega^0} \le 1, \\ H - \frac{1}{2} & \text{otherwise.} \end{cases} \tag{9}$$

This is lower than what the firm's value would be when the manager's pay is tied exclusively to the firm's long-term value: $\pi^0(\omega^0) \le \pi^0(0) = \frac{H^2}{2}$, where the inequality is strict when $\omega^0 > 0$. Therefore, for shareholders who want to maximize long-term firm value (long-term shareholders), they will compensate the manager based solely on the long-term firm value. That is, the optimal compensation contract is characterized by $\omega^{0*} = 0$. The following proposition summarizes the equilibrium compensation contract in the single-firm benchmark.

Proposition 1 (Single-firm benchmark)**.** *In the single-firm benchmark, the firm's optimal compensation contract is uniquely characterized by* $\omega^{0*} = 0$*, and the equilibrium expected firm value is* $\pi^{0*} = \frac{H^2}{2}$*.*

4 Short-Termism in Competitive Product Markets

In this section, I show how market competition influences the optimal contracting. Recall that the shareholders of the two competing firms simultaneously choose compensation contracts at $t = 0$, the two managers simultaneously make investment decisions at $t = 1$, and firm profits and managers' compensation are realized at $t = 2$. I focus on the symmetric Bayesian Nash equilibrium in pure strategies: In a symmetric equilibrium, firms' compensation contracts are identical, and managers follow the same investment strategy.

The investment strategy is a mapping from a firm's fixed cost ($C_i \in [0,1]$) to its manager's binary investment decision ($A_i = \{0,1\}$). The manager follows a threshold policy: She invests if and only if $C_i \leq \bar{C}_i$, where $\bar{C}_i$ is the cut-off point, at which manager i is indifferent about whether or not to invest.[9] Formally, the equilibrium is defined as follows.

Definition 1. *An equilibrium is characterized by compensation contracts, ω_i and ω_j; each manager's investment strategy: $[0,1] \to \{0,1\}$; and stock prices, S_i and S_j, such that:*

(1) *At $t = 0$, shareholders of firm i and j optimally choose compensation contracts for their respective managers to maximize their firms' expected value;*

(2) *At $t = 1$, each manager makes the optimal investment decision to maximize her expected compensation, and stock prices are determined by equation (5).*

I then use backward induction to find the subgame perfect equilibrium.

4.1 Equilibrium Investment Strategies at $t = 1$

Given compensation contracts, ω_i and ω_j, consider the subgame at $t = 1$ in which each manager makes an investment decision to maximize her expected compensation.

Take manager i's compensation as an example: According to (4) and (5), if firm i does not invest in the project, manager i receives zero compensation. If firm i invests, manager i's compensation depends on whether or not firm j also explores the investment opportunity. Specifically, if firm j does not invest, firm i becomes a monopolist in the new business, making a profit of $H - C_i$, and manager i's compensation is

$$\omega_i \mathbb{E}\left[H - C_i | C_i \leq \bar{C}_i\right] + (1 - \omega_i)(H - C_i). \tag{10}$$

The first term, $\omega_i \mathbb{E}\left[H - C_i | C_i \leq \bar{C}_i\right]$, represents that ω_i of manager i's pay is tied to the short-term stock price at $t = 1$, $S_i = \mathbb{E}\left[H - C_i | C_i \leq \bar{C}_i\right]$, which is the expectation of long-term

[9]Note that if the manager launches the project when $C_i = C_i'$, she always does so when $C_i \leq C_i'$. Hence, the investment strategy must follow a threshold policy.

firm value, $H - C_i$, given that only firm i launches the project (recall that firm i invests when $C_i \leq \bar{C}_i$, where $\bar{C}_i$ is the investment cut-off point of firm i). The second term of the above expression, $(1-\omega_i)(H-C_i)$, reflects that $1-\omega_i$ of manager i's pay is tied to the long-term firm value, $H - C_i$. Manager i receives this compensation when firm j does not invest in the project, which occurs with probability $1 - \bar{C}_j$, where $\bar{C}_j$ is firm j's investment cut-off point.

Manager i's compensation when firm j also invests in the project is as follows: With a probability of $\bar{C}_j$, firm j also launches the project, and the Bertrand competition yields a revenue of 0 for both firms; thus, firm i incurs a loss of C_i, and manager i's compensation becomes

$$-\omega_i \mathbb{E}\left[C_i | C_i \leq \bar{C}_i\right] - (1-\omega_i)C_i, \tag{11}$$

where $S_i = -\mathbb{E}\left[C_i | C_i \leq \bar{C}_i\right]$ is firm i's stock price at $t = 1$.[10] Taken together, given the contracts ω_i and ω_j, manager i's compensation is the weighted average of the two terms (10) and (11):

$$\begin{aligned} W_i(C_i) = \left(1-\bar{C}_j\right) & \underbrace{\left(\omega_i \mathbb{E}\left[H - C_i | C_i \leq \bar{C}_i\right] + (1-\omega_i)(H - C_i)\right)}_{\text{firm } j \text{ does not invest}} \\ + \bar{C}_j & \underbrace{\left(-\omega_i \mathbb{E}\left[C_i | C_i \leq \bar{C}_i\right] - (1-\omega_i)C_i\right)}_{\text{firm } j \text{ invests}}. \end{aligned} \tag{12}$$

Before characterizing the equilibrium investment strategies, note that both managers cannot always invest in the project ($\bar{C}_i^* = \bar{C}_j^* = 1$). If they do, their firms' revenues at $t = 2$ would always be zero and both firms would incur a loss in the long term. As such, if one manager adopts an always-investment strategy, her rival will never follow such a strategy. Therefore, the assumed equilibrium does not exist. In a similar vein, the equilibrium cannot be that both managers always stay away from the project ($\bar{C}_i^* = \bar{C}_j^* = 0$), since the manager of a low-fixed-cost firm is better off launching the project and receiving positive compensation rather than none. The result is

[10] The stock price is negative, because the initial firm value is normalized to 0; so, negative long-term firm profit can lead to a negative stock price, which should be interpreted as a negative stock return. Meanwhile, the compensation can be negative, because I focus on the contract form (4), where $W_i = \frac{W_i' - d_i}{a_i + b_i}$. Hence, even though the participation constraint ($\mathbb{E}\left[W_i'\right] \geq W_0'$) always holds, after the transformation W_i can be negative.

formally summarized in the following lemma.

Lemma 2. *For any compensation contracts ω_i and ω_j, there does not exist an equilibrium in which both managers always invest in the project or always stay away from it.*

I next solve for the equilibrium investment strategies at $t = 1$. First, consider the case in which the firms choose the same compensation contracts: $\omega_i = \omega_j = \omega$. With the same contracts, the managers follow the same investment strategy: $\bar{C}_i^* = \bar{C}_j^*$, which must be interior solutions based on Lemma 2. That is, in equilibrium, $\bar{C}_i^*, \bar{C}_j^* \in (0, 1)$, and both managers are indifferent about whether or not to invest at the cut-off points. Plugging $C_i = \bar{C}_i$ into (12) and equating it to zero yields manager i' equilibrium investment strategy:

$$\bar{C}_i(\bar{C}_j) = \frac{2H(1 - \bar{C}_j)}{2 - \omega}.$$

In the symmetric equilibrium, $\bar{C}_i = \bar{C}_j$. Therefore, the two firms' equilibrium cut-off points are:

$$\bar{C}_i^* = \bar{C}_j^* = \frac{2H}{2 + 2H - \omega}. \tag{13}$$

As does manager i's compensation, firm i's profit also depends on whether firm j invests in the project or not: It makes a profit of $H - C_i$ when firm j does not invest in the project, which occurs with probability $1 - \bar{C}_j$; whereas, its profit is $-C_i$ (a loss of C_i) when firm j does invest, which occurs with probability $\bar{C}_j$. Therefore, at $t = 0$, firm i's expected profit is

$$\pi_i = \int_0^{\bar{C}_i} \left((H - C_i) \left(1 - \bar{C}_j\right) - C_i \bar{C}_j \right) dC_i. \tag{14}$$

Substituting $\bar{C}_i$ and $\bar{C}_j$ in (14) with (13) yields firm i' expected profit, and firm j's expected profit can be obtained symmetrically,

$$\pi_i^* = \pi_j^* = \frac{2H^2(1 - \omega)}{(2 + 2H - \omega)^2}. \tag{15}$$

Next, consider the subgame in which the two firms adopt different contracts ($\omega_i \neq \omega_j$). Assume without loss of generality that $\omega_i > \omega_j$, i.e., manager i's pay loads more on the short-term stock price. When $\omega_i > \omega_j$, for certain parameter range there are multiple equilibria, and I focus on the more natural subgame equilibrium in which manager i behaves more aggressively than manager j when making her investment decision, i.e., $\bar{C}_i^* \geq \bar{C}_j^*$.[11] The equilibrium investment strategies are then discussed in the following two scenarios.

- **Scenario 1**. First, if the short-term stock price is lightly weighted in manager i's compensation contract (i.e., $\omega_i > \omega_j$ and $\omega_i \leq 2(1-H)$), the two firms' investment cut-off points are interior solutions: $\bar{C}_i^*, \bar{C}_j^* \in (0,1)$. Setting $W_i(\bar{C}_i) = 0$ and $W_j(\bar{C}_j) = 0$, where $W_i(\cdot)$ is given by (12) and $W_j(\cdot)$ is defined symmetrically, and solving the two equations yields the equilibrium investment cut-off points:

$$(\bar{C}_i^*, \bar{C}_j^*) = \left(\frac{2H\,(2H-2+\omega_j)}{4H^2-(2-\omega_i)(2-\omega_j)}, \frac{2H\,(2H-2+\omega_i)}{4H^2-(2-\omega_i)(2-\omega_j)} \right). \tag{16}$$

  Simple analysis reveals that, if firm i increases the weight on short-term stock performance in its compensation contract, manager i becomes more aggressive and her investment strategy entails a higher cut-off point (i.e., $\frac{\partial \bar{C}_i^*}{\partial \omega_i} > 0$); meanwhile, manager j is forced to adopt a more prudent investment strategy: Her investment cut-off point decreases (i.e., $\frac{\partial \bar{C}_j^*}{\partial \omega_i} < 0$).

  This demonstrates the "foreclosure effect" of the short-term compensation contract; that is, by choosing a short-term compensation contract, firm i reduces the odds of its rival firm's investment. The rationale is straightforward: Given that manager i is more likely to launch the project under the short-term contract, it becomes harder for firm j to survive and manager j becomes less willing to invest. Finally, substituting (16) into (14), I obtain firms' expected profits as follows:

$$(\pi_i^*, \pi_j^*) = \left(\frac{2H^2(1-\omega_i)\,(2H-2+\omega_j)^2}{\left(4H^2-(2-\omega_i)(2-\omega_j)\right)^2}, \frac{2H^2(1-\omega_j)\,(2H-2+\omega_i)^2}{\left(4H^2-(2-\omega_i)(2-\omega_j)\right)^2} \right). \tag{17}$$

[11] The detailed discussion about equilibrium selection is provided in the proof of Lemma 3 in Appendix B.

- **Scenario 2**. If firm i places a heavy weight on its short-term stock price (i.e., $\omega_i > \omega_j$ and $\omega_i > 2(1-H)$), manager i will become so aggressive that she will always launch the project. Meanwhile, if firm j also invests in the project, it earns zero revenue and incurs a loss. In this case, manager j will never invest in the project. Thus, the equilibrium cut-off points are $(\bar{C}_i^*, \bar{C}_j^*) = (1, 0)$ and firms' expected profits are $(\pi_i^*, \pi_j^*) = \left(H - \frac{1}{2}, 0\right)$.

The following lemma formally summarizes the subgame equilibrium.

Lemma 3 (Equilibrium investment strategies)**.** *Given compensation contracts, ω_i and ω_j, the equilibrium entails a cut-off strategy, firm i (j) invests if and only if $C_i \leq \bar{C}_i^*$ ($C_j \leq \bar{C}_j^*$), where the investment cut-off points are as follows:*

(1) *if $\frac{1}{2} \leq H \leq 1$, $\omega_i > \omega_j$ and $\omega_i > 2(1-H)$, $\left(\bar{C}_i^*, \bar{C}_j^*\right) = (1, 0)$,*

(2) *if $\frac{1}{2} \leq H \leq 1$, $\omega_j > \omega_i$ and $\omega_j > 2(1-H)$, $\left(\bar{C}_i^*, \bar{C}_j^*\right) = (0, 1)$, and*

(3) *otherwise, $\bar{C}_i^*$ and $\bar{C}_j^*$ are given by (16).*

Lemma 3 states that the firms' equilibrium investment strategies depend on the project potential, H, and compensation contracts, ω_i and ω_j. If the project potential is small (i.e., $0 \leq H < \frac{1}{2}$) or their compensation contracts do not place heavy weight on short-term stock prices (i.e., $\frac{1}{2} \leq H \leq 1$ and $\omega_i, \omega_j < 2(1-H)$), both managers may or may not invest in the project, i.e., $\bar{C}_i^*, \bar{C}_j^* \in (0, 1)$. But if the project potential is large enough and her pay is tied excessively to the short-term stock price, a manager will always launch the project, while her rival will never invest.

4.2 Equilibrium Contract Choice at $t = 0$

Knowing how their contract choices will affect their managers' $t = 1$ investment, at $t = 0$ each firm's shareholders choose compensation contracts that will maximize the firm's expected long-term value. For convenience, I repeat the profit maximization problem that faced firm i's shareholders in (3):

$$\max_{\hat{a}_i,\hat{b}_i,\hat{d}_i} \hat{\pi}_i = \mathbb{E}\left[\hat{V}_i\right] \tag{3}$$
$$\text{s.t.} \quad \mathbb{E}[\hat{W}_i^*] \geq \hat{W}_0,$$
$$A_i^* \in \arg\max_{A_i} \mathbb{E}\left[\hat{W}_i\right],$$

There are two constraints to consider. The first is manager i's participation constraint, which is always binding under an optimal contract, so that, in equilibrium, managerial compensation is equal to the constant outside option: $\mathbb{E}[\hat{W}_i^*] = \hat{W}_0$.[12] Together with the equivalent contract form (4), shareholders' objective function in (3) can be reduced to choosing ω_i that will maximize firm value, V_i:

$$\omega_i = \arg\max_{\omega_i} \mathbb{E}[\hat{V}_i] = \arg\max_{\omega_i} \mathbb{E}[V_i] + \mathbb{E}[\hat{W}_i^*] = \arg\max_{\omega_i} \mathbb{E}[V_i].$$

The second is the manager's incentive constraint, which ensures that manager i's $t = 1$ investment strategy is optimal under the contracted ω_i. However, this constraint is eased in the subgame equilibrium (discussed in Section 4.1), since manager i's investment decision maximizes her expected compensation. Taken together, given firm j's contracted ω_j, firm i's shareholders will choose the optimal ω_i that maximizes the expected long-term firm value $\pi_i = \mathbb{E}[V_i]$.

Analysis states that the equilibrium compensation contracts depend on the project potential, H. Recall from Lemma 3 that, when the project potential is small (i.e., $0 \leq H \leq \frac{1}{2}$), the investment cut-off points are interior solutions for any ω_i and ω_j (i.e., $\bar{C}_i^*, \bar{C}_j^* \in (0, 1)$); that is, both firms may or may not launch the project. Equation (17) presents the firms' expected profits, π_i^* and π_j^*. Given firm j's contracted ω_j, firm i's best response is determined by the first-order condition of π_i^* with respect to ω_i:

$$\omega_i(\omega_j) = \frac{4H^2}{2 - \omega_j}.$$

It is obvious that, when the project potential, H, increases or, w_j, increases (i.e., firm j places

[12] Otherwise, if $\mathbb{E}[\hat{W}_i^*] > \hat{W}_0$, shareholders can always choose the non-performance-based component $\hat{d}_i$, so that the first constraint in (3) is binding and firm value increases.

heavier weight on its short-term stock price), firm i would optimally respond by "shortening" its contract, i.e., it also assigns a heavier weight to its short-term stock price. Further, firm j's best response function is derived symmetrically. In the symmetric equilibrium, we have $\omega_i^* = \omega_j^* = \omega^* = 1 - \sqrt{1 - 4H^2}$.

However, when the project potential is large enough (i.e., $\frac{1}{2} \leq H \leq 1$), the monopoly revenue, H, is so attractive that both firms prefer to launch the project and, at the same time, to deter the rival firm. The firms, thus, engage in fierce competition: To commit to an aggressive investment strategy, each firm increases the weight accorded to the short-term stock price in its compensation contract. Then, both firms end up in an extreme situation, where both managers' pay is tied exclusively to short-term stock prices, i.e., $\omega_i^* = \omega_j^* = \omega^* = 1$. In other words, unlike the optimal contract in the single-firm benchmark, the managers receive their compensation even before the uncertainty about the desirability of their actions is resolved. The following proposition summarizes the optimal compensation contracts.[13]

Proposition 2 (Optimal compensation contracts)**.** *In equilibrium, long-term compensation contracts cannot be sustained: The firms' shareholders will choose short-term compensation contracts for their managers, which are uniquely characterized by*

$$\omega_i^* = \omega_j^* = \omega^* = \begin{cases} 1 - \sqrt{1 - 4H^2} & \text{if} \quad 0 \leq H < \frac{1}{2}, \\ 1 & \text{if} \quad \frac{1}{2} \leq H \leq 1. \end{cases} \tag{18}$$

The resulting optimal compensation contracts induce managerial short-termist behavior.

Clearly, under market competition, the long-term compensation contracts (i.e., $\omega_i = \omega_j = 0$) cannot be sustained as an equilibrium outcome. Unlike the single-firm benchmark, when facing inter-firm competition, the firms prefer the short-term compensation contract to the long-term one, since the former helps them commit to aggressive investment strategies, which will make

[13] Recall that compensation contract form (4) is equivalent to form (2). Following Proposition 2, it is straightforward that the optimal contracts in form (2) are $\hat{a}_i^* = \hat{a}_j^* = \frac{1-\omega^*}{\omega^*} y$, $\hat{b}_i^* = \hat{b}_j^* = y$, $y \in \mathbb{R}^+$, and $\hat{d}_i^* = \hat{d}_j^* = \hat{d}^*$ is chosen so that the managers' participant constraint in (3) is binding. Note that there is a continuum of optimal contracts in the form (2) that is equivalent to optimal contracts that are characterized in Proposition 2.

them more competitive in the market. Further, substituting (18) into (14) yields the firms' expected profits:

$$\pi_i^* = \pi_j^* = \pi^* = \begin{cases} \frac{2H^2\sqrt{1-4H^2}}{\left(1+2H+\sqrt{1-4H^2}\right)^2} & \text{if } \ 0 \leq H < \frac{1}{2}, \\ 0 & \text{if } \ \frac{1}{2} \leq H \leq 1. \end{cases} \tag{19}$$

Equation (19) suggests that, when the project has a high potential (i.e., $\frac{1}{2} \leq H \leq 1$), both managers are induced to invest in the project aggressively, given that they are compensated based solely on the short-term stock prices (i.e., $\omega_i^* = \omega_j^* = 1$). In turn, both firms make zero expected profits (i.e., $\pi_i^* = \pi_j^* = 0$).

Does the Short-term Compensation Contract Result in Short-termism? The above analysis shows that, under market competition, a firm will prefer to make use of a short-term compensation contract to induce its manager's aggressive investment behavior. But is such strategic aggressiveness really short-termist? Said differently, does such aggressive short-termism result in the distortion in long-term firm value? To answer this question, I examine the *ex post* optimal investment strategy from the shareholders' perspective. As before, I will use firm i as my example.

Given the optimal contracts at $t = 0$, firm i's expected long-term value from investment equals the expected revenue minus the fixed cost, i.e., $H\left(1 - \bar{C}_j^*\right) - C_i$. If the shareholders, *not* their manager, were to make the investment decision at $t = 1$, they would choose to launch the project if and only if the long-term expected revenue exceeded the fixed cost: $C_i \leq H\left(1 - \bar{C}_j^*\right) \equiv \bar{C}_i^S$, where the superscript S indicates the cut-off point when it is the shareholders who make the investment decision at $t = 1$. Substituting $\bar{C}_j^*$ with (13), I obtain

$$\bar{C}_i^S = \frac{2H - H\omega^*}{2 + 2H - \omega^*}.$$

Simple comparison yields that $\bar{C}_i^* > \bar{C}_i^S$; that is, for certain fixed costs (i.e., $C_i \in \left(\bar{C}_i^S, \bar{C}_i^*\right)$), while firm i's manager may choose to explore the investment opportunity, its shareholders would rather not do so, since to launch the project only yields a loss to the long-term firm value. Therefore, short-term compensation contracts indeed induce managerial short-termism. In fact, this misalignment of interests is necessary for the shareholders as it serves as a credible commitment device for aggressive investment. This is in line with the idea that "the essence of commitment is to bind oneself to carrying out actions that would not be in one's self-interest to take at the time of the decision" (Katz, 1991).

Prisoner's Dilemma Now, to further understand the equilibrium outcome in the competitive market, I examine the case in which both firms are restricted to choosing long-term compensation contracts for their managers ($\omega_i = \omega_j = 0$). Substituting $\omega_i = \omega_j = 0$ into (15) yields the firms' expected profits:

$$\pi_i^{LT} = \pi_j^{LT} = \pi^{LT} = \frac{H^2}{2(1+H)^2},$$

where the superscript LT represents both firms' adoption of long-term compensation contracts. Analysis shows that the preferred cooperative equilibrium for firms would involve only long-term compensation contracts: $\pi^{LT} > \pi^*$, where π^* is given by (19). This is because, when both firms choose short-term compensation contracts, their managers' aggressive investment actions will breed fierce product market competition that will only hurt profits for both firms.

With that being said, although both firms would be better off when they both choose long-term compensation contracts, such an equilibrium cannot be sustained. If one firm chooses a long-term compensation contract, the other now has an incentive to deviate and to deter its rival firm. Once again, in equilibrium, both firms end up tying their respective managers' pay to short-term stocks, which constitutes a form of the prisoner's dilemma. Under market competition, it is difficult for either firm to escape this unfortunate outcome.

Proposition 3 (Prisoner's dilemma)**.** *Both firms are worse off when choosing short-term compensation contracts in equilibrium as compared to the case in which they both choose long-term compensation contracts (i.e.,* $\omega_i = \omega_j = 0$*):* $\pi^* < \pi^{LT}$.

A Numerical Example I now use a simple example to illustrate the key insights thus far. Assume that firms choose between two compensation contracts: A long-term one with $\omega_i = 0$ and a short-term one with $\omega_i = 0.35$. Under the long-term compensation contract, the manager's pay is tied exclusively to the long-term firm value, whereas, under the short-term compensation contract, 35% of the manager's pay is tied to her firm's short-term stock price and the remaining 65% to the long-term firm value. The project potential is $H = 0.8$.

Table 1: Expected firm profits matrix

		Firm j	
		Long	Short
Firm i	Long	$(0.099, 0.099)$	$(0.006, \underline{0.243})$
	Short	$(\underline{0.243}, 0.006)$	$(\underline{0.079}, \underline{0.079})$

The two firms' expected profits, (π_i, π_j), are presented in Table 1, where the underlined numbers indicate each firm's best response. If both firms choose long-term compensation contracts, their investment cut-off points are $\bar{C}_i^* = \bar{C}_j^* = 0.444$, and both make expected profits of 0.099. However, if firm j chooses a long-term compensation contract, firm i is better off deviating to a short-term one, thereby making an expected profit of $0.243 > 0.099$.

Let us review this result: As discussed throughout this paper, a manager with short-term valuation concerns tends to make aggressive investment decisions. Due to information asymmetry between the manager and the financial market, investors interpret the investment as a signal of firm i's low fixed cost (and, thus, high profit), thereby boosting its short-term stock price. As a result, by offering its manager a short-term compensation contract, firm i commits to an aggressive investment strategy: Its investment cut-off point increases from 0.444 to 0.865, gaining an extra profit of 0.144. Firm i's profit improvement, however, comes at the expense of its rival firm: Firm j invests less often, with its cut-off point decreasing from 0.444 to 0.108, and its profit drops by 0.093.

Once again, we see that, under market competition there will never be an equilibrium in which both firms choose long-term compensation contracts; the unique equilibrium in the example is that both firms choose short-term compensation contracts. In fact, each firm's equilibrium profit is lower when they both choose short-term contracts than when they both choose long-term contracts: $0.079 < 0.099$. In other words, both managers make aggressive investment decisions, which intensifies market competition and drives down both firms' profits; thus, the equilibrium outcome constitutes a form of the prisoner's dilemma.

5 Discussions and Extensions

In this section, I first analyze social welfare to explore the aggregate implications of managerial short-termism. I then extend the basic model by considering firms' disclosure policies and other forms of product competition; I show that the main finding – under market competition, firms will induce managerial short-termism by offering short-term compensation contracts to their managers – remains robust in the extensions. Finally, I discuss policy implications of the model.

5.1 Welfare Analysis

As discussed above, in the single-firm benchmark, a firm's shareholders will always choose a long-term compensation contract for their manager, which leads to the first-best outcome. Under market competition, however, both firms choose short-term compensation contracts for their managers.

Established knowledge suggests that social welfare improves with increased competition. However, given that the market competition is associated with short-termist managerial behavior (and hence investment distortions), it remains unclear how social welfare changes between the single-firm benchmark and the one under market competition. Moreover, how would social welfare be affected if firms are restricted to choosing long-term compensation contracts, thereby preventing short-termist behavior?

I now explore the normative implications of market competition and short-term compensation contracts. The variables of interest are industry profits ($\pi_i + \pi_j$), consumer surplus (CS), and social welfare (SW), which is the total value of industry profits and consumer surplus.

To facilitate efficiency analysis, I assume that the consumer market takes the following specification: If only firm i launches the project, the demand of its products will be $Q_i = 2\sqrt{H} - P_i$, where P_i is the price that it offers to consumers. It follows immediately that the firm optimally charges a price $P_i = \sqrt{H}$ and makes a revenue of H. In this case, firm i's profit is $\pi_i = H - C_i$, and consumer surplus is $CS = \int_{\sqrt{H}}^{2\sqrt{H}} (v - P)\, dv = \frac{1}{2}H$. Social welfare is then the total value of firm profit and consumer surplus, i.e., $SW = \frac{3}{2}H - C_i$.

If both firms i and j invest in the project, since the products are undifferentiated, the firm that offers a lower price will gain the entire market, i.e., the two firms compete à la Bertrand. In equilibrium, the firms end up charging $P_i = P_j = 0$ and making zero revenue. The industry profits are $\pi_i + \pi_j = -C_i - C_j$. Given $P_i = P_j = 0$, consumer surplus is $CS = \int_0^{2\sqrt{H}} v dv = 2H$, and social welfare is $SW = 2H - C_i - C_j$.

Finally, if neither firm invests in the project, industry profits, consumer surplus, and social welfare are all zero. The expected social welfare is then

$$\begin{aligned} SW = & \underbrace{\int_0^{\bar{C}_i} \int_{\bar{C}_j}^1 \left(\frac{3}{2}H - C_i\right) dC_j dC_i}_{\text{firm } i \text{ invests while firm } j \text{ does not}} + \underbrace{\int_{\bar{C}_i}^1 \int_0^{\bar{C}_j} \left(\frac{3}{2}H - C_j\right) dC_j dC_i}_{\text{firm } j \text{ invests while firm } i \text{ does not}} \\ & + \underbrace{\int_0^{\bar{C}_i} \int_0^{\bar{C}_j} (2H - C_i - C_j)\, dC_j dC_i}_{\text{both firm } i \text{ and firm } j \text{ invest}} + \underbrace{0}_{\text{neither firm } i \text{ nor firm } j \text{ invests}}. \end{aligned} \tag{20}$$

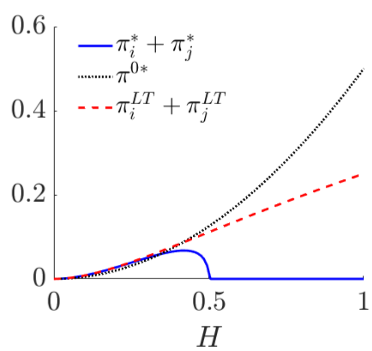
Substituting the equilibrium cut-off points (18) into (20) yields the equilibrium expected social welfare. Expected industry profits and consumer surplus can be derived similarly.

To understand the welfare implications in equilibrium, there are two important benchmarks. The first is the single-firm benchmark, and the second is the economy in which both firms are restricted to choosing long-term compensation contracts. While the first comparison reveals how market competition affects efficiency, the second one illustrates the effect of strategic short-term compensation contracts on efficiency. Proposition 4 summarizes the comparison results. Meanwhile, Figure 2 graphically illustrates them: The solid, dotted, and dashed lines correspond to the equilibrium outcome, the single-firm benchmark, and the economy in which firms only use long-term compensation contracts, respectively.

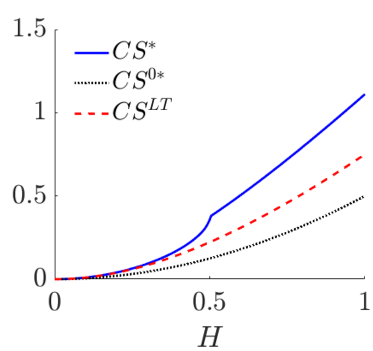
Proposition 4 (Social welfare)**.** *As for social welfare, we have the followings:*

(1) *Compared to the single-firm benchmark, under market competition, in equilibrium: (i) expected industry profits are higher (i.e., $\pi_i^* + \pi_j^* > \pi^{0*}$) if $0 \leq H < \tilde{H} \approx 0.3427$, and are lower otherwise; (ii) expected consumer surplus is higher (i.e., $CS^* > CS^{0*}$); and (iii) expected social welfare is higher (i.e., $SW^* > SW^{0*}$).*

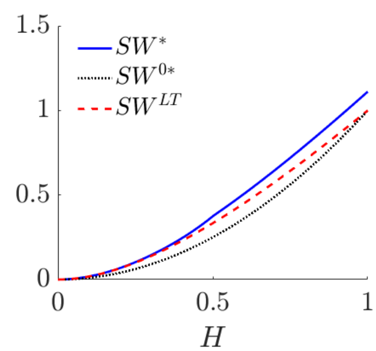
(2) *Compared to the economy in which firms are restricted to choosing long-term compensation contracts, under market competition, in equilibrium: (i) expected industry profits are lower (i.e., $\pi_i^* + \pi_j^* < \pi_i^{LT} + \pi_j^{LT}$); (ii) expected consumer surplus is higher (i.e., $CS^* > CS^{LT}$); and (iii) expected social welfare is higher (i.e., $SW^* > SW^{LT}$).*



(a) Industry profits



(b) Consumer surplus



(c) Social welfare

Figure 2: Efficiency analysis

Part (1) of Proposition 4 states that, compared to the single-firm benchmark, in equilibrium, market competition increases industry profits when the project has a low potential, but lowers them when the project has a high potential. Why can competition increase industry profits? Here, the role of competition is two-fold: On the one hand, competition squeezes the profit of an individual firm. But on the other hand, under competition, the more efficient firm (i.e., the firm with the lower fixed cost) is more likely to invest and the less efficient firm is more likely to stay away from the project, which only benefits industry profits. When the project has a high potential, competition becomes so fierce that the former effect prevails, resulting in lowered industry profits. When the project has a low potential, however, the latter effect dominates and industry profits become higher. Meanwhile, consumer surplus is always higher since competition drives down product prices. Accordingly, social welfare is also higher under market competition.

The second part of Proposition 4 contrasts efficiency in equilibrium versus in the economy in which firms are restricted to choosing long-term compensation contracts. Industry profits are lower in the former case, because competition becomes fiercer under short-term compensation contracts. However, consumer surplus and social welfare are higher, because the fierce competition drives down product prices and increases demand.

Taken together, under market competition, while short-term compensation contracts induce short-termist investment actions, which intensifies market competition and undermines long-term firm values, they actually benefit consumers and social welfare. Although this efficiency result should be viewed with care as it depends on special features of my model, it suggests that an economy with managerial short-termism can be associated with higher consumer surplus and social welfare under certain circumstances.

5.2 Voluntary Disclosure

The basic model assumes that the competing firms' managers cannot credibly disclose their cost information to their respective investors; therefore, the investors must infer the costs from the firms' investment decisions. In this case, the managers use their investment decisions to communicate the firms' fixed costs to the investors, thereby influencing short-term stock prices. Naturally, if firms were to disclose their cost information credibly, investors would no longer need to infer the cost from the investment decisions, which would reduce the strategic effect of aggressive investment and help solve the prisoner's dilemma. However, the exchange of cost information may facilitate oligopolistic coordination, thereby impairing consumer surplus, a topic that is extensively debated in the literature on information sharing (e.g., Vives, 1984, 2008; Gal-Or, 1986; Darrough, 1993; Raith, 1996).

I now investigate the game under the condition that the firms can pre-commit themselves to a particular disclosure policy ex ante before acquiring private cost information. Consider the following extended economy. At $t = 0$, each firm's shareholders choose compensation contracts for their respective managers and disclosure policies, $\lambda_i, \lambda_j \in \{0, 1\}$, for their firm, with $\lambda_i = 1$ representing disclosure and $\lambda_i = 0$ representing nondisclosure.[14] Both firms commit to their disclosure policies and cannot change them in the future. This corresponds to an ex ante disclosure, which is commonly studied (see Goldstein and Yang (2017) for a comprehensive survey).

At $t = 1$, both managers privately observe their firms' fixed costs, C_i and C_j. Then, they make their investment decisions. Note that they disclose cost information if and only if their firms commit to doing so at $t = 0$. If a firm chose to disclose its fixed cost, all investors will now observe it and incorporate it into the short-term stock price. Otherwise, the investors must infer the cost from the firms' investment decision, as they did in the basic model. Finally, at $t = 2$, the firms' profits are realized and managers receive their compensation.

Again, I solve the model using backward induction and present the results in the following proposition.

Proposition 5 (Voluntary disclosure)**.** *Suppose that the firms can disclose their cost information to investors. In equilibrium, neither firm will choose to disclose its cost information, i.e., $\lambda_i = \lambda_j = 0$. This equilibrium outcome mimics that of the basic model, which shows that both firms choose short-term contracts for their managers to encourage aggressive investment decisions.*

Proposition 5 states that, including the option to disclose has no effect on the equilibrium outcome: The firms will never choose to disclose. Here is the intuition. If firm i discloses its cost information, i.e., $\lambda_i = 1$, investors learn its fixed cost directly and have no need to deduce it from manager i's investment decision. Now, whatever the compensation contract is, manager i has no incentive to invest aggressively since it will not boost the firm's short-term stock price. Therefore, if firm i chooses to disclose, it has no means to commit its manager to an aggressive

[14] I assume that shareholders make disclosure policies, even though, at $t = 1$, it is the manager who observes the fixed cost. This is because the optimal contracting ensures that the manager will truthfully report her private information to the shareholders (revelation principal); thus, shareholders are able to make disclosure policies.

investment strategy and, therefore, cannot establish a competitive edge in the market. As such, to take advantage of the commitment role of the short-term contract, the firms must conceal their cost information.

The above finding reveals that, under market competition, competing firms will intentionally conceal their information and write short-term compensation contracts to induce short-termist behavior in their managers. By doing so, their managers make aggressive investment decisions that will benefit their firms in market competition.

Moreover, the above analysis suggests that mandatory disclosure policies (i.e., both firms are mandated to disclose: $\lambda_i = \lambda_j = 1$) is necessary to eliminate short-termist behavior in managers. However, it is important to note that, while such mandatory disclosure policies reduces market competitiveness and improves firm profits, they do leave consumers and social welfare worse off. Therefore, policy makers must take short-termism and market competition into account when implementing such mandatory disclosure policies.

5.3 Intensity of Product Competition

In the basic model, I assumed that, when both firms invest in the project, the competition drives the firm revenue down to $L = 0$. This occurs when firms that offer undifferentiated products engage in price (Bertrand) competition.

In this section, I extend the model by considering other forms of competition, e.g., price/quantity competition with differentiated products (competition is lower in markets where goods are more differentiated; see Singh and Vives, 1984). I maintain the sequence of the basic model and continue to let H represent the monopoly revenue when only one firm launches the project and introduce L to denote the revenue of each firm when two invest in the project. Note both H and L are reduced-form gains earned by firms. I focus on the more general case in which $0 \leq L \leq H$. The basic model is thus the special case $L = 0$.

Ceteris paribus, the intensity of product competition, is captured by L: The more revenue one firm can earn under competition (larger L), the less fierce the competition between the firms becomes. To see the micro-foundation of the model, consider the following example: Assume that the two firms provide differentiated products and compete on prices (differentiated Bertrand competition). When both firms invest in the project, the demand for firm i's products is

$$Q_i = 2\sqrt{H} - P_i + k(P_j - P_i),$$

where P_i is its price and P_j is the price of firm j's product. H stands for the project potential, and $k \in [0, +\infty)$ captures the degree of product substitutability; the more substitutable the two firms' products (larger k), the fiercer the product market competition.

It is easy to show that the equilibrium product prices are $P_i = P_j = \frac{2\sqrt{H}}{2+k}$, and each firm makes a revenue $L = \frac{4H(1+k)}{(2+k)^2}$, which decreases in k (i.e., $\frac{\partial L}{\partial k} < 0$). When k is sufficiently large (i.e., $k = +\infty$), competition is extremely fierce (as in the basic model) and each firm earns a revenue $L = 0$. When $k = 0$, the demands for the two products are independent and there is virtually no competition. In this case, $L = H$. Therefore, given H, the intensity of product market competition is inversely related to L.

In the extended economy, I continue to use ω_i (ω_j) as the weight that is placed on short-term stock performance in a manager's contract. Again, I focus on the symmetric Bayesian Nash equilibrium in pure strategies. The following proposition summarizes the optimal contracting.

Proposition 6 (Intensity of competition)**.** *Under market competition, long-term compensation contracts cannot be sustained in equilibrium. Specifically, for* $0 \leq L \leq H \leq 1$*,*

(1) *if* $L \geq \max\{0, g(H)\}$*, where* $g(H)$ *is given by (B37), the equilibrium compensation contracts are uniquely characterized by* $\omega_i^* = \omega_j^* = \omega^* = 1 - \sqrt{1 - 4(H - L)^2}$*. Moreover, as competition becomes fiercer, the equilibrium contracts load more on the short-term stock price (i.e.,* ω^* *increases as* L *decreases, or as* H *increases); that is, the duration of compensation contracts becomes shorter;*

(2) *if* $0 \leq L \leq \sqrt{2H} - 1$*, the equilibrium compensation contracts are uniquely characterized by* $\omega_i^* = \omega_j^* = \omega^* = 1$*;*

(3) *if* $\sqrt{2H} - 1 < L < g(H)$, *there is no pure strategy equilibrium.*

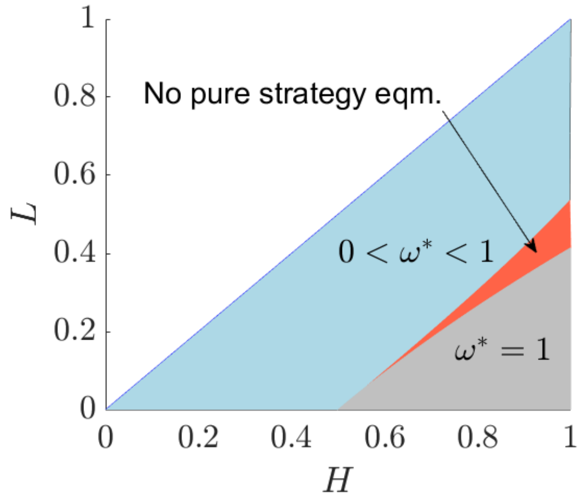


Figure 3: Equilibrium compensation contracts

To begin with, Proposition 6 replicates the main finding of the basic model: Under competition, there is no equilibrium in which both firms will choose long-term contracts for their managers. Again, this is because, if one firm chooses a long-term compensation contract, the other firm will always find it profitable to deviate and choose a short-term contract, thereby inducing its manager's aggressive investment behavior and deterring its rival firm. Figure 3 illustrates the regions for each type of equilibrium compensation contracts.

Part (1) of Proposition 6 states that, when the project has a low potential (i.e., $0 \leq H < \frac{1}{2}$) or when the project has a high potential but the product competition is mild (i.e., $\frac{1}{2} \leq H \leq 1$ and $L \geq g(H)$), there exists a unique pure strategy equilibrium in which both firms' shareholders choose short-term compensation contracts for their respective managers. Moreover, as competition increases (i.e., H increases or L decreases),[15] firms will shorten the duration of their compensation contracts, i.e., $\frac{\partial \omega^*}{\partial H} > 0$ and $\frac{\partial \omega^*}{\partial L} < 0$. This is because, as competition becomes more

[15]Note my model is featured with endogenous product market structure, and competition can encompass several dimensions, including fixed (entry) costs, project potential, and product substitutability. Since I normalize the uncertain fixed cost to a uniform distribution over the unit interval, the project potential is measured relative to the fixed cost, and competition in my setting is about the latter two dimensions. Consistent with Raith (2003), in my model competition can be said to increase when the project potential increases (H increases), or products become more substitutable (L decreases, or k increases).

intense, the commitment effect of short-termism is strengthened, and firms find it more profitable to tie compensation to short-term stock prices. In Section 6, I find empirical evidence consistent with this prediction.

Part (2) shows that, if the project has a high potential and the product competition is fierce (i.e., $\frac{1}{2} \leq H \leq 1$ and $L \leq \sqrt{2H} - 1$), each firm will want to choose a compensation contract with a shorter duration (i.e., larger ω). As a result, the firms engage in a race to increase the weight accorded to short-term stock prices in their managers' compensation contracts. The unique pure-strategy equilibrium features that both managers' pay is tied exclusively to short-term stock performance ($\omega_i^* = \omega_j^* = \omega^* = 1$).

Part (3) of Proposition 6 shows that, if the project has a high potential and the product competition is moderate (i.e., $\frac{1}{2} \leq H \leq 1$ and $\sqrt{2H} - 1 < L < g(H)$), no equilibrium exists in pure strategies. The intuition is as follows. If a firm emphasizes the long-term firm value in its compensation contract, a rival firm will choose a compensation contract with a shorter duration to induce its own manager's aggressiveness and gain a competitive edge. However, if the former firm emphasizes short-term stock performance in its compensation contract, the rival firm will prefer to revert back to the long-term compensation contract, because the product competition is now moderate and the duopoly revenue is neither too good nor too bad for this rival firm. Thus, no pure strategy equilibrium exists.

5.4 Policy Implications

There exists a long-standing debate over short-termism's (often negative) effect. In fact, there are a number of proposals aiming to curb short-termism, and some of them have proven to be quite influential in policy-making. For example, Bebchuk and Fried (2010) propose to escrow the CEO's equity until the long-term, and the UK government has indeed proposed an increase in the minimum vesting period of equity from three to five years.[16] More recently, Dimon and Buffet criticize quarterly earnings guidance as a major driver of firms' unhealthy focus on short-term

[16] The Investment Association Principles of Remuneration, 2017.

profits and suggest reducing or eliminating the practices of estimating quarterly earnings.[17]

As suggested in my paper, if firms are already stuck in the prisoner's dilemma, it would be difficult for them to choose a long-term compensation contract for their managers or to abandon the quarterly earnings guidance. While government regulation can help firms escape the dilemma and eliminate short-termism, market competition will consequently decrease, thereby hurting consumers and social welfare. Therefore, in this context, whether or not the government should intervene remains an open question.

Another type of proposal advocates long-term share holding. For example, the U.S. Securities and Exchange Commission (SEC) privileges long-term holding for tax purposes.[18] Meanwhile, France has a formal requirement that all shares that are held for over two years receive double voting rights.[19] These proposals should work if managerial short-termism were arising as a result of myopic shareholders and investors; however, my model suggests that, when facing inter-firm competition, long-term shareholders are the ones who induce short-termist managerial behavior. For such cases, these policies would not help curb short-termism.

6 Empirical Evidence

As stated in Proposition 6, the optimal contracts that firms offer depend on the extent of product market competition between the firms. Specifically, firms facing fiercer competition are more likely to offer compensation contracts with shorter duration (i.e., larger ω) to take advantage of the commitment effect.[20] I now investigate the relation between the duration of compensation contracts and product market competition empirically.

The main data sources are ISS Incentive Lab (July 2018 version), Hoberg-Phillips Data Library, Compustat, and the Center for Research in Security Prices (CRSP). Following Gopalan et al. (2014),

[17] "Short-termism is harming the economy," *Wall Street Journal*, June 6, 2018.

[18] "Activism, short-termism, and the SEC: Remarks at the 21st Annual Stanford Directorsfi College," Commissioner Daniel M. Gallagher, June 23, 2015.

[19] "French companies fight back against Florange double-vote law," *Financial Times*, April 16, 2015.

[20] See Part (1) of Proposition 6. Note Part (2) specifies a region featured with extreme short-termism, which is very unlikely to be observed in reality; the region specified by Part (3) only makes up a small fraction of the whole parameter space and yields no clear empirical predictions.

I measure executive pay duration using the weighted average vesting length of different compensation components and then compute the average pay duration (*AvgDuration*) across executives in a firm in a given year. Next, I have two proxies for product market competition. First, following Karuna (2007), I employ *industry sales* as a proxy for product market competition, which corresponds to the project potential H in my model. The higher the project potential, the more attractive the project is to potential firms, and the more competitive the product market is. The second proxy is *total similarity* from Hoberg-Phillips TNIC Data, which is the sum of the pairwise similarities between the given firm and all other firms in Hoberg-Phillips sample in the given year. This represents product substitutability k (and thus is inversely related to L) in Section 5.3. The higher the product similarity, the more competitive pressures are faced by the firm. In addition, following Gopalan et al. (2014), I include as control variables basic firm characteristics and factors that affect pay duration. A more detailed description of the data and sample construction can be found in Appendix C.

I obtain 17,843 firm-year observations, covering 1,845 unique U.S. companies. The sample period is from 1998 to 2017. Table 2 reports summary statistics of the variables used in my analysis. The average pay duration in my sample is 1.24 years, and the standard deviation is 1.23 years, which are comparable to Gopalan et al. (2014). Thus, the executive pay vests about one year after it is granted.

[Insert Table 2 Here]

I perform multivariate tests by estimating the following model:

$$AvgDuration_{it} = \alpha + \beta \times Product\ Market\ Competition_{it} + \delta \times Z_{it} + \gamma_t + \varepsilon_{it}, \tag{21}$$

where i indicates the firm, t is the time (fiscal year), Z_{it} are control variables, and γ_t captures year fixed effects. I also include industry fixed effects in some specifications and cluster standard errors at the firm and year level.[21] My model predicts a negative relationship between firms'

[21] The results remain statistically significant if I cluster standard errors at the industry and year level.

average pay duration and their competitive pressures; that is, $\beta < 0$.

[Insert Table 3 Here]

Table 3 reports the results of the regression. In Panel A, I use industry sales (*Log(Industry sales)*) as a proxy for product market competition. I start the empirical analysis in column (1) by including basic firm characteristics as control variables. Consistent with my theory, I find a significantly negative correlation between pay duration and industry sales after controlling for firm size, leverage, and firm growth opportunity. The coefficient estimate is also economically significant: For a one standard deviation increase in *Log(Industry sales)*, pay duration decreases by 0.48 years on average, which is about 40% of the mean of pay duration. In addition, Gopalan et al. (2014) find that firm risk, past stock performance, corporate governance, and project length affect executive pay duration. Therefore, in columns (2)-(5) of Panel A, I include sales volatility, abnormal stock returns over the previous fiscal year, the Entrenchment index (E-index) introduced by Bebchuk, Cohen, and Ferrell (2009), or the proportion of long-term assets as a control variable, respectively.[22] Finally, in column (6) I include all control variables. Overall, the negative relation between pay duration and industry sales remains significant.

In Panel B of Table 3, I use *total similarity* as a proxy for product market competition. As in Panel A, I find a significantly negative correlation between pay duration and product similarity under different sets of control variables. Moreover, the negative relation remains significant along with year and industry fixed effects.[23] The coefficient estimate is also economically significant. For example, in column (2), for a one standard deviation increase in *total similarity*, pay duration decreases by 0.06 years (or 0.78 month) on average, which is around 5% of the mean of

[22] The results are similar if, following Gopalan et al. (2014), I replace sales volatility with stock return volatility or cash flow volatility as a proxy for firm risk, and if I replace abnormal stock returns over the previous year with those over the previous three years as a proxy for past stock performance.

[23] Throughout Panel A and B of Table 3, the coefficients of control variables are consistent with Gopalan et al. (2014) except that of *S.D. Sales* in Panel B. Pay duration is longer for larger firms, firms with lower leverage, and firms with more growth opportunities. In addition, pay duration is shorter for firms with higher risk, firms with higher past stock returns, and firms with longer project length. Finally, there is no consistent relationship between firm governance and pay duration.

pay duration.

The preliminary empirical analysis suggests that the mechanism highlighted in my model is plausible and hints towards the importance of product market competition in determining pay duration. The correlation results I report here have not been documented in the literature and are of interest in and of themselves. However, a more thorough analysis of the relation between pay duration and product market competition, though interesting, is beyond the scope of this paper.

7 Conclusion

In this paper, I study managerial short-termism in an imperfectly competitive market. I show that, when faced with inter-firm competition, firms will induce their managers to behave myopically by, for example,x tying their managers' pay to short-term stock prices. The key friction here is the information asymmetry between managers and investors: Under a short-term compensation contract, a firm's manager will take aggressive actions (e.g., to launch a new project even if it is unprofitable to do so) to signal high profitability to investors, which raises their expectations and boosts the firm's short-term stock price. This, then, gives the firm a competitive advantage. Thus, managerial short-termism is often deliberately induced by firms under market competition.

It is worth mentioning that the theme of my analysis is very general: As long as managers' short-term concerns lead to overinvestment distortions, firms may intentionally induce short-termist behavior in their managers to remain competitive in inter-firm competition. This applies to all types of investments that can be credibly communicated to the financial market.

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Table 2: Summary statistics

This table reports descriptive statistics of the variables used in Section 6. Definitions of the variables in this table are provided in Appendix C. The sample period is from 1998 to 2017. All control variables are winsorized at the 99% level.

	N	**Mean**	**SD**	**Min**	**p25**	**p50**	**p75**	**Max**
Pay duration (years)	17,843	1.24	1.23	0.00	0.27	1.00	1.80	19.93
Total similarity	17,843	6.18	11.42	1.00	1.41	2.42	5.06	127.16
Log(Industry sales)	17,841	11.00	1.54	4.45	10.02	11.23	12.29	13.90
Firm size	17,826	8.52	1.54	5.04	7.51	8.41	9.51	12.92
Leverage	17,750	5.18	19.65	0.00	0.27	0.68	1.42	110.06
Stock return volatility	17,452	0.38	0.21	0.13	0.24	0.33	0.46	1.21
Abnormal return-1 year	17,452	-0.01	0.31	-0.64	-0.19	-0.04	0.10	1.44
Abnormal return-3 year	17,452	-0.05	0.44	-0.84	-0.32	-0.12	0.13	1.78
S.D. Sales	17,826	0.33	0.62	0.00	0.09	0.17	0.31	4.67
S.D. Cashflow	17,826	0.13	0.28	0.00	0.02	0.05	0.11	1.88
Market to Book	16,976	3.69	4.60	0.44	1.52	2.36	3.93	33.45
E-index	14,302	2.99	1.35	0	2	3	4	6
Long-term assets	14,919	0.42	0.25	0.00	0.24	0.43	0.60	0.92

Table 3: Pay duration and product market competition

This table reports results of the regression relating executive pay duration to firms' competitive pressures controlling for several firm characteristics. Specifically, I estimate the OLS regression: $AvgDuration_{it} = \alpha + \beta \times Product\ Market\ Competition_{it} + \delta \times Z_{it} + \gamma_t + \varepsilon_{it}$. Definitions of the variables in this table are provided in Appendix C. Robust standard errors are reported in parentheses and are clustered at year and firm level. Industry classifications are based on SIC3. The dependent variable is scaled by multiplying it by 100 for ease of exposition. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Industry sales

	Dependent variable: *Average pay duration* $\times 100$					
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Industry sales)	-4.184***	-3.727**	-4.304***	-5.692***	-3.996**	-5.238***
	(1.352)	(1.357)	(1.365)	(1.540)	(1.380)	(1.620)
S.D. Sales		-9.700***				-5.704
		(2.444)				(3.838)
Abnormal return-1 year			1.577			0.994
			(4.465)			(3.991)
E-index				1.037		0.645
				(1.661)		(1.727)
Long-term assets					18.85*	18.60*
					(9.538)	(10.45)
Firm size	8.001***	7.330***	7.974***	8.701***	8.128***	8.668***
	(1.363)	(1.425)	(1.397)	(1.474)	(1.362)	(1.552)
Leverage	-0.507**	-0.497**	-0.518**	-0.369	-0.457*	-0.366
	(0.223)	(0.222)	(0.228)	(0.256)	(0.237)	(0.272)
Market to Book	0.671	0.694	0.716	0.685	0.605	0.836
	(0.413)	(0.411)	(0.425)	(0.544)	(0.450)	(0.605)
Observations	16,917	16,917	16,581	13,674	14,110	11,348
R-squared	0.015	0.017	0.015	0.017	0.021	0.024
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm

Panel B: Product similarity

	Dependent variable: *Average pay duration* $\times 100$											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Total similarity	-0.468***	-0.567**	-0.468***	-0.568**	-0.473***	-0.570**	-0.624***	-0.658**	-0.302*	-0.517*	-0.494**	-0.675**
	(0.140)	(0.240)	(0.140)	(0.239)	(0.140)	(0.241)	(0.161)	(0.260)	(0.156)	(0.265)	(0.177)	(0.309)
S.D. Sales			0.0643	0.0708							0.0860***	0.0950***
			(0.0411)	(0.0477)							(0.0275)	(0.0302)
Abnormal return-1 year					2.073	1.088					1.448	-0.939
					(4.443)	(3.732)					(4.232)	(2.644)
E-index							1.376	-1.924			1.077	-1.559
							(1.672)	(1.626)			(1.737)	(1.730)
Long-term assets									17.49*	11.56	15.10	4.144
									(10.05)	(12.15)	(10.86)	(12.95)
Firm size	7.578***	4.912**	7.587***	4.921**	7.517***	4.720**	7.960***	5.450***	7.589***	5.711***	8.074***	6.059***
	(1.406)	(1.711)	(1.406)	(1.712)	(1.442)	(1.768)	(1.610)	(1.768)	(1.391)	(1.662)	(1.613)	(1.814)
Leverage	-0.436*	-0.203	-0.435*	-0.200	-0.446*	-0.215	-0.280	-0.0523	-0.392	-0.182	-0.289	-0.0223
	(0.224)	(0.237)	(0.224)	(0.237)	(0.228)	(0.243)	(0.255)	(0.266)	(0.238)	(0.255)	(0.272)	(0.289)
Market to Book	0.593	0.399	0.591	0.393	0.641	0.432	0.604	0.470	0.523	0.419	0.737	0.571
	(0.409)	(0.419)	(0.409)	(0.420)	(0.420)	(0.441)	(0.539)	(0.605)	(0.447)	(0.457)	(0.601)	(0.703)
Observations	16,919	16,917	16,919	16,917	16,583	16,581	13,674	13,673	14,112	14,109	11,348	11,345
R-squared	0.014	0.131	0.014	0.131	0.014	0.133	0.016	0.149	0.019	0.139	0.021	0.163
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Cluster	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm	Yr, Firm

Appendix A: List of Model Variables

Variables	Description
Basic Model	
	Exogenous Variables
H	Monopoly revenue, or project potential, $H \in [0, 1]$
L	Duopoly revenue, $L = 0$ in the basic model
Π_i	The revenue when firm i invests: $\Pi_i \in \{H, L\}$
C_i	Firm i's fixed cost, uniformly distributed: $C_i \sim U[0, 1]$
	Endogenous Variables
A_i	Manager i's investment decision, $A_i \in \{0, 1\}$
W_i, $\hat{W}_i$	Manager i's compensation: $\hat{W}_i = \hat{a}_i\hat{S}_i + \hat{b}_i\hat{V}_i + \hat{d}_i$ and $W_i = \frac{\hat{W}_i - d_i}{a_i + b_i}$, where $a_i = \frac{\hat{a}_i}{1+\hat{a}_i+\hat{b}_i}$, $b_i = \frac{\hat{b}_i}{1+\hat{a}_i+\hat{b}_i}$, and $d_i = \frac{\hat{d}_i}{1+\hat{a}_i+\hat{b}_i}$
$\hat{W}_0$	Managers' reservation utility (outside option)
V_i, $\hat{V}_i$	The value of firm i at $t = 2$; $V_i = \hat{V}_i + \hat{W}_i$
S_i, $\hat{S}_i$	The stock price of firm i at $t = 1$; $S_i = \hat{S}_i + \hat{W}_i$
π_i, $\hat{\pi}_i$	Firm i's expected long-term profit at $t = 0$, $\pi_i = \mathbb{E}[V_i]$ and $\hat{\pi}_i = \mathbb{E}[\hat{V}_i]$
ω_i	The weight that manager i's compensation places on short-term stock price, $\omega_i \in [0, 1]$
$\bar{C}_i$	The investment cut-off point of firm i, $\bar{C}_i \in [0, 1]$
CS, SW	Welfare measure, CS: Consumer surplus, SW: Social welfare
P, Q	Parameter of the demand function for the homogeneous products, P: price, Q: demand
	Supercripts
^{0}	Single-firm benchmark
^{LT}	The case in which both firms are restricted to choosing long-term compensation contracts
*	Equilibrium outcome
Extensions	
	Exogenous Variables
k	The degree of product substitutability, $k \in [0, +\infty]$
	Endogenous Variables
P_i, Q_i	Parameter of the demand function for firm i's products, P_i: price, Q_i: demand
λ_i	Firm i's disclosure policy, $\lambda_i \in \{0, 1\}$

Appendix B: Proofs

Proof of Equivalent Contracts (2) and (4)

I prove that contracts (2) and (4) provide the same incentives for managers. First, note according to (1) and (2), manager i's compensation $\hat{W}_i$ depends on $\hat{S}_i$ and $\hat{V}_i$, both of which are affected by the compensation. I thus present a contract form equivalent to (2) to break the loop and simplify the analysis. It can be shown that (2) is equivalent to the following contract:

$$\hat{W}_i = a_i S_i + b_i V_i + d_i, \tag{B1}$$

where $a_i = \frac{\hat{a}_i}{1+\hat{a}_i+\hat{b}_i}$, $b_i = \frac{\hat{b}_i}{1+\hat{a}_i+\hat{b}_i}$, $d_i = \frac{\hat{d}_i}{1+\hat{a}_i+\hat{b}_i}$, and S_i and V_i are given by (5).

Proof. I discuss the following two cases to determine the equivalent compensation contract to (2). (i) $A_i = 0$, and (ii) $A_i = 1$. When firm i does not invest in the project ($A_i = 0$), based on (1) we know that $S_i = V_i = \hat{W}_i$. Then the compensation contract (2) can be rewritten as

$$\hat{W}_i = \frac{\hat{d}_i}{1+\hat{a}_i+\hat{b}_i}. \tag{B2}$$

When firm i invests ($A_i = 1$), based on (1), $\hat{S}_i = \mathbb{E}(\Pi_i - C_i|A_i) - \hat{W}_i$ and $\hat{V}_i = \Pi_i - C_i - \hat{W}_i$. Plugging $\hat{S}_i$ and $\hat{V}_i$ into the compensation contract (2) yields

$$\hat{W}_i = \frac{1}{1+\hat{a}_i+\hat{b}_i}\left[\hat{a}_i \mathbb{E}(\Pi_i - C_i|A_i) + \hat{b}_i(\Pi_i - C_i) + \hat{d}_i\right]. \tag{B3}$$

Taken together, (B2) and (B3) can be summarized in the form (B1). Thus contracts (2) and (B1) are equivalent. □

Next, what matters when incentivizing managers is the relative sensitivity of the compensation to the short-term versus the long-term component. I thus normalize the contract (B1) to (4). Note as discussed in Bolton, Scheinkman, and Xiong (2006), in practice CEO compensation packages typically satisfy $0 \leq \hat{b}_i < 1$ and $0 < \hat{a}_i < 1 - \hat{b}_i$. That is, managers are not allowed to short the stock of their company and managers do not hold the entire equity of the firm. Accordingly, I focus on the more realistic case in which $\hat{a}_i + \hat{b}_i \neq 0$ (thus $a_i + b_i \neq 0$), which enables the normalization. Furthermore, the fact that $\hat{a}_i, \hat{b}_i > 0$ guarantees that $\omega_i \in [0, 1]$. To sum up, I start from the contract form (2), rewrite it as in the form of (B1), and normalize it to (4). QED.

Proof of Lemma 1

See the main text.

Proof of Proposition 1

Based on (9), if $\omega^0 \leq 2(1 - H)$, $\frac{\partial \pi^0}{\partial \omega^0} = -\frac{2H^2\omega^0}{(2-\omega^0)^3} < 0$, while if $\omega^0 > 2(1 - H)$, $\frac{\partial \pi^0}{\partial \omega^0} = 0$. Thus the optimal contract is $\omega^{0*} = 0$. QED.

Proof of Lemma 2

See the main text.

Proof of Lemma 3

I first examine the case in which $\omega_i \neq \omega_j$, and then the one where $\omega_i = \omega_j$. Assume without loss of generality that $\omega_i > \omega_j$. Given ω_j, the compensation of manager i is given by (12), which can be simplified to the following:

$$W_i(C_i) = H - \frac{1}{2}\omega_i \bar{C}_i - (1 - \omega_i)\, C_i - H\bar{C}_j. \tag{B4}$$

Given $\omega_i > \omega_j$ if there are multiple equilibria, I focus on the equilibrium where $\bar{C}_i \geq \bar{C}_j$. Therefore, we need to consider the following two cases: (I) $\bar{C}_i^*, \bar{C}_j^* < 1$, and (II) $\bar{C}_i^* = 1, \bar{C}_j^* < 1$.

Before proceeding, I first present the conditions that can support the corner cut-off point and the interior one respectively. In equilibrium $\bar{C}_i = 1$ only when $W_i(1) = -1 + H + \frac{\omega_i}{2}(2 - \bar{C}_i) -$

$H\bar{C}_j > 0$. Substituting $\bar{C}_i = 1$ into the inequality yields

$$\bar{C}_j < 1 - \frac{2-\omega_i}{2H}. \tag{B5}$$

Thus, when (B5) holds, the corner solution $\bar{C}_i = 1$ can be supported. And the interior solution $\bar{C}_i < 1$ can be supported when $\bar{C}_j \geq 1 - \frac{2-\omega_i}{2H}$.

Case I: $\bar{C}_i^*, \bar{C}_j^* < 1$ At the interior cut-off point, manager i is indifferent about investing or not. Setting (B4) to zero yields the best response function of manager i: $\bar{C}_i = \frac{2H(1-\bar{C}_j)}{2-\omega_i}$. Similarly, $\bar{C}_j = \frac{2H(1-\bar{C}_i)}{2-\omega_j}$. The intersection of the two best response functions generates the equilibrium cut-off points given by (16). Plugging the equilibrium cut-off points into (14) yields firms' expected profits as given by (17).

Next, I check if the interior solutions can indeed be supported. Based on (16),

$$\bar{C}_i^* - \bar{C}_j^* = -\frac{2H(\omega_i - \omega_j)}{4H^2 - (2-\omega_i)(2-\omega_j)}. \tag{B6}$$

According to the condition supporting interior cut-off points, $\bar{C}_i^*, \bar{C}_j^* < 1$ only when

$$\bar{C}_i^* - \left(1 - \frac{2-\omega_j}{2H}\right) = \frac{(2-\omega_i)(2-\omega_j)(2H+\omega_j-2)}{4H^2-(2-\omega_i)(2-\omega_j)} \geq 0, \tag{B7}$$

$$\bar{C}_j^* - \left(1 - \frac{2-\omega_i}{2H}\right) = \frac{(2-\omega_i)(2-\omega_j)(2H+\omega_i-2)}{4H^2-(2-\omega_i)(2-\omega_j)} \geq 0. \tag{B8}$$

Recall given that $\omega_i > \omega_j$, I consider the case in which $\bar{C}_i^* \geq \bar{C}_j^*$, which is equivalent to a negative denominator in (B6): $4H^2 - (2-\omega_i)(2-\omega_j) < 0$. Then it is easy to check that if (B8) holds, (B7) holds as well. Thus to support interior solutions we only need (B6) and (B8), which are equivalent to the following conditions respectively:

$$4H^2 - (2-\omega_i)(2-\omega_j) < 0, \tag{B9}$$

$$\omega_i \leq 2(1-H). \tag{B10}$$

(B9) can be rewritten as $\omega_i < 2 - \frac{4H^2}{2-\omega_j}$. Since $\left(2 - \frac{4H^2}{2-\omega_j}\right) - 2(1-H) = \frac{2H(2-2H-\omega_j)}{2-\omega_j} > 0$, (B10) alone is sufficient to support interior solutions.

Case II: $\bar{C}_i^* = 1$ and $\bar{C}_j^* < 1$ Based on the best response function derived in Case I, when $\bar{C}_i = 1$, we have $\bar{C}_j = 0$. Based on (14) firms' expected profits are $\pi_i = H - \frac{1}{2}$ and $\pi_j = 0$. In order for the corner solution $\bar{C}_i = 1$ to be supported in equilibrium, (B5) needs to be satisfied, which is equivalent to

$$\omega_i > 2(1-H). \tag{B11}$$

I next consider the case in which $\omega_i = \omega_j \equiv \omega$. According to Lemma 2, both cut-off points are interior solutions. Setting (B4) to zero and imposing $\bar{C}_i = \bar{C}_j$ yields the best response function of manager i as given by (13). The corresponding profits are given by (15). To support the interior solutions, we need $\bar{C}_j - \left(1 - \frac{2-\omega}{2H}\right) = \frac{(2-\omega)^2}{2H(2+2H-\omega)} > 0$, which holds. Therefore the interior solutions (13) can indeed be supported.

Equilibrium Selection I now discuss the potential multiple equilibria in the subgame $\omega_i > \omega_j$. Note in the above discussions, when $\omega_i > \omega_j$, I focus on the subgame equilibrium in which $\bar{C}_i^* \geq \bar{C}_j^*$. Now I study the cases in which $\bar{C}_i^* \leq \bar{C}_j^*$. First, in Case I, $\bar{C}_i^* \leq \bar{C}_j^*$ is equivalent to a positive denominator in (B6): $4H^2 - (2-\omega_i)(2-\omega_j) > 0$. Then it is easy to check that if (B7) holds, (B8) holds as well. Thus, to support interior solutions we only need (B6) and (B7), which are equivalent to the following conditions respectively:

$$\omega_i > 2 - \frac{4H^2}{2-\omega_j} \text{ and } \omega_j \geq 2(1-H).$$

Recall $\omega_i > \omega_j$. Since $2(1-H) - \left(2 - \frac{4H^2}{2-\omega_j}\right) = \frac{2H(\omega_j - 2(1-H))}{2-\omega_j} \geq 0$ given that $\omega_j \geq 2(1-H)$, the conditions to support $\bar{C}_i^*, \bar{C}_j^* \in (0,1)$ and $\bar{C}_i^* \leq \bar{C}_j^*$ boil down to $\omega_j \geq 2(1-H)$. Second, for the case in which $\bar{C}_i^* < 1$ and $\bar{C}_j^* = 1$, based on the best response function derived in Case

I, I derive that $\bar{C}_i^* = 0$. To support $\bar{C}_j^* = 1$ as a corner solution, we need $\bar{C}_i^* < 1 - \frac{2-\omega_j}{2H}$, which can be simplified to $\omega_j > 2(1-H)$. Taken together, for the subgame in which $\omega_i > \omega_j$: 1) when $0 < H < \frac{1}{2}$, there is no such an equilibrium that $\bar{C}_i^* \leq \bar{C}_j^*$; 2) when $\frac{1}{2} \leq H < 1$, if $\omega_j < 2(1-H)$, there is no such an equilibrium that $\bar{C}_i^* \leq \bar{C}_j^*$, and if $\omega_j > 2(1-H)$, there exist two equilibria satisfying $\bar{C}_i^* \leq \bar{C}_j^*$: i) $\bar{C}_i^*, \bar{C}_j^* \in (0,1)$ and $\bar{C}_i^* \leq \bar{C}_j^*$; ii) $\bar{C}_i = 0$ and $\bar{C}_j^*$. To sum,

(1) when i) $0 \leq H < \frac{1}{2}$, or ii) $\frac{1}{2} \leq H \leq 1$ and $\omega_j \leq 2(1-H)$, $\bar{C}_i^* \geq \bar{C}_j^*$ is the unique subgame equilibrium;

(2) when $\frac{1}{2} \leq H \leq 1$ and $\omega_j > 2(1-H)$, there coexist three equilibria: i) $\bar{C}_i^* = 1, \bar{C}_j^* = 0$; ii) $\bar{C}_i^* = 0, \bar{C}_j^* = 1$; and iii) $\bar{C}_i^*, \bar{C}_j^* \in (0,1), \bar{C}_i^* \leq \bar{C}_j^*$.

Therefore, given the behavior of the equilibrium, for $\omega_i > \omega_j$, it is more natural to focus on the subgame equilibrium in which $\bar{C}_i^* \geq \bar{C}_j^*$. QED.

Proof of Proposition 2

I discuss the following two cases: (1) $0 \leq H < \frac{1}{2}$, (2) $\frac{1}{2} \leq H \leq 1$.

(1) $0 \leq H < \frac{1}{2}$. When $0 \leq H < \frac{1}{2}$, $2(1-H) > 1$, firms' expected profits are given by (17). Taking derivative of π_i with respect to ω_i and equating it to zero yields $\omega_i = \frac{4H^2}{2-\omega_j}$. Similarly, the best response of firm j is $\omega_j = \frac{4H^2}{2-\omega_i}$. The intersection of the two best response functions yields the equilibrium contracts: $\omega_i^* = \omega_j^* = \omega^* = 1 - \sqrt{1-4H^2}$. Plugging $\omega_i^* = \omega_j^* = \omega^*$ into (17) yields the equilibrium expected profit $\pi_i^* = \pi_j^* = \frac{2H^2\sqrt{1-4H^2}}{\left(1+2H+\sqrt{1-4H^2}\right)^2}$.

(2) $\frac{1}{2} \leq H \leq 1$. The best response of firm i given ω_j is as follows:

$$\omega_i(\omega_j) = \begin{cases} \frac{4H^2}{2-\omega_j} & \text{if} \quad \omega_j < 2(1-H), \\ \{\omega_i : \omega_i > \omega_j\} & \text{if} \quad \omega_j \geq 2(1-H). \end{cases}$$

Similarly, we can derive the best response $\omega_j(\omega_i)$. The intersection of the two best responses yields $\omega_i^* = \omega_j^* = 1$ (note $\omega_i, \omega_j \in [0,1]$). Plugging $\omega_i^* = \omega_j^* = 1$ into (17) yields the equilibrium expected profit $\pi_i^* = \pi_j^* = 0$. QED.

Proof of Proposition 3

As derived in the text, when $\omega_i = \omega_j = 0$, the expected profits are $\pi^{LT} = \frac{H^2}{2(1+H)^2}$. It is obvious that when $\frac{1}{2} \leq H \leq 1, \pi^{LT} > \pi^* = 0$. When $0 \leq H < \frac{1}{2}$, $\frac{\partial\left(\pi^{LT}/\pi^*\right)}{\partial H} = \frac{H(2H+1)\left(2H\left(\sqrt{1-4H^2}+2\right)-\sqrt{1-4H^2}+1\right)}{(H+1)^3(1-4H^2)^{3/2}} > 0$, and thus the minimum value of $\frac{\pi^{LT}}{\pi^*}$ is achieved when $H = 0$, which is 1. Therefore, $\pi^{LT} > \pi^*$. QED.

Proof of Proposition 4

Substituting the equilibrium cut-off points (18) into (20) yields the equilibrium expected social welfare as follows

$$SW^* = \begin{cases} \frac{2H^2\left(1+4H+3\sqrt{1-4H^2}\right)}{\left(1+2H+\sqrt{1-4H^2}\right)^2} & \text{if } \ 0 \leq H < \frac{1}{2}, \\ \frac{2H^2(4H+1)}{(2H+1)^2} & \text{if } \frac{1}{2} \leq H \leq 1. \end{cases} \tag{B12}$$

Similarly, the expected firm profit and consumer surplus can be as follows:

$$\pi_i^* + \pi_j^* = \begin{cases} \frac{4H^2\sqrt{1-4H^2}}{\left(\sqrt{1-4H^2}+2H+1\right)^2} \\ 0 \end{cases} \text{ and } CS^* = \begin{cases} \frac{2H^2\left(\sqrt{1-4H^2}+4H+1\right)}{\left(\sqrt{1-4H^2}+2H+1\right)^2} & \text{if } \ 0 \leq H < \frac{1}{2}, \\ \frac{2H^2(4H+1)}{(2H+1)^2} & \text{if } \frac{1}{2} \leq H \leq 1. \end{cases}$$

In the single-firm benchmark, social welfare is $SW^{0*} = \int_0^H (\frac{3}{2}H - C_i)dC_i = H^2$, which consists of $\frac{1}{2}H^2$ industry profits and $\frac{1}{2}H^2$ consumer surplus. I then compare each component. If $0 \leq H < \frac{1}{2}$, $SW^* - SW^{0*} = \frac{4H^2\left(H+\sqrt{1-4H^2}-H\sqrt{1-4H^2}\right)}{\left(1+2H+\sqrt{1-4H^2}\right)^2} > 0$, while if $\frac{1}{2} \leq H \leq 1$, $SW^* - SW^{0*} = \frac{H^2(1+4H-4H^2)}{(1+2H)^2} > 0$. Next, for industry profit if $\frac{1}{2} \leq H \leq 1$, obviously $\pi_i^* + \pi_j^* < \pi^{0*}$. If $0 \leq H < \frac{1}{2}$,

$\left(\pi_i^* + \pi_j^*\right) - \pi^{0*} = \frac{1}{2}H^2\left(\frac{8\sqrt{1-4H^2}}{\left(1+2H+\sqrt{1-4H^2}\right)^2} - 1\right) > (<)\ 0$ when $H < (>)\ \tilde{H}$, where

$$\tilde{H} = \frac{1}{6}\left(7 - \frac{1}{\sqrt[3]{53 - 6\sqrt{78}}} - \sqrt[3]{53 - 6\sqrt{78}}\right) \approx 0.3427. \tag{B13}$$

Last, for consumer surplus if $0 \leq H < \frac{1}{2}$, $CS^* - CS^{0*} = \frac{1}{2}H^2\left(\frac{16H(1+2H)+(1-2H)\left(1+2H+\sqrt{1-4H^2}\right)}{(1+2H)\left(1+2H+\sqrt{1-4H^2}\right)^2}\right) > 0$ and if $\frac{1}{2} \leq H \leq 1$, $CS^* - CS^{0*} = \frac{H^2(3+12H-4H^2)}{2(1+2H)^2} > 0$. So $SW^* > SW^{0*}$, $CS^* > CS^{0*}$. And $\pi_i^* + \pi_j^* > (<)\ \pi^{0*}$ when $H < (>)\ \tilde{H}$.

Further, substituting $\omega_i = \omega_j = 0$ into (13) yields the cut-off points in the economy in which firms were restricted to choosing long-term contracts: $\bar{C}_i^{LT} = \bar{C}_j^{LT} = \frac{H}{1+H}$. Replacing $\bar{C}_i^* = \bar{C}_j^*$ with $\bar{C}_i^{LT} = \bar{C}_j^{LT}$, I obtain social welfare in the economy: $SW^{LT} = \frac{2H^2}{1+H}$. And industry profits and consumer surplus are $\frac{H^2}{(1+H)^2}$ and $\frac{H^2(1+2H)}{(1+H)^2}$, respectively. Note in Proposition 3, it has been shown that $\pi_i^* + \pi_j^* < \pi_i^{LT} + \pi_j^{LT}$. Now we examine social welfare and consumer surplus. If $0 \leq H < \frac{1}{2}$, $SW^* - SW^{LT} = 2H^2\frac{H\left(1-\sqrt{1-4H^2}\right)+\left(\sqrt{1-4H^2}-(1-4H^2)\right)}{\left(1+2H+\sqrt{1-4H^2}\right)^2} > 0$, $\frac{CS^*}{CS^{LT}} = \frac{(H+1)^2\left(\sqrt{1-4H^2}+4H+1\right)}{(2H+1)^2\left(\sqrt{1-4H^2}+1\right)}$ and taking derivative with respect to H generates $\frac{\partial CS^*/CS^{LT}}{\partial H} = \frac{4H(H+1)(4H+1)\left(\sqrt{1-4H^2}+2H+1\right)}{(2H+1)^3\sqrt{1-4H^2}\left(\sqrt{1-4H^2}+1\right)^2} > 0$. Since when $H = 0$, $CS^* = CS^{LT}$, we have $CS^* > CS^{LT}$. Next if $\frac{1}{2} \leq H \leq 1$, $SW^* - SW^{LT} = \frac{2H^3}{(1+H)(1+2H)^2} > 0$ and $CS^* - CS^{LT} = \frac{H^2\left(6H^2+6H+1\right)}{(H+1)^2(2H+1)^2} > 0$. So, $SW^* > SW^{LT}$, $CS^* > CS^{LT}$. QED.

Proof of Proposition 5

The idea of the proof is to show that whatever the compensation contract is, as long as the firm chooses to disclose at $t = 0$, the incentive outcome for the manager is equivalent to a long-term compensation contract. Since we already proved in Proposition 2 that given firm j's contract ω_j, firm i optimally chooses not to write the long-term contract ($\omega_i \neq 0$), we then confirm that to disclose is a dominated strategy for firm i. Therefore, in equilibrium that both firms disclose cannot be sustained. Now we show that the long-term contract is equivalent to any contracts with disclosure. Take firm i as an example. Suppose firm i chooses to disclose the information about the fixed cost, for any contracted ω_i manager i's compensation is

$$W_i(C_i) = \left(1 - \bar{C}_j\right) \left(\omega_i \mathbb{E}(H - C_i | C_i) + (1 - \omega_i)(H - C_i)\right) \\ + \bar{C}_j \left(-\omega_i \mathbb{E}(C_i|C_i) - (1-\omega_i)C_i\right), \tag{B14}$$

whereas if firm i chooses the long-term contract, based on (B4), manager i's compensation is $W_i(C_i) = H(1 - \bar{C}_j) - C_i$, which is equivalent to (B14) because $\mathbb{E}(H - C_i|C_i) = H - C_i$ and $\mathbb{E}(C_i|C_i) = C_i$. QED.

Proof of Proposition 6

Given ω_j, the compensation of manager i is

$$\begin{aligned} W_i(C_i) = & \left(1 - \bar{C}_j\right) \left(\omega_i \mathbb{E}(H - C_i | C_i < \bar{C}_i) + (1 - \omega_i)(H - C_i)\right) \\ & + \bar{C}_j \left(\omega_i \mathbb{E}(L - C_i | C_i < \bar{C}_i) + (1 - \omega_i)(L - C_i)\right) \\ = & H - \frac{1}{2}\omega_i \bar{C}_i - (1 - \omega_i) C_i - (H - L)\bar{C}_j. \end{aligned} \tag{B15}$$

When $C_i = 1$, if $W_i(1) = H - \frac{1}{2}\omega_i \bar{C}_i - (1 - \omega_i) - (H - L)\bar{C}_j \geq 0$, then $\bar{C}_i = 1$ and the inequality can be rewritten as

$$\bar{C}_j \leq \frac{2H - 2 + \omega_i}{2(H - L)}. \tag{B16}$$

Therefore, the interior solution $\bar{C}_i < 1$ can be supported only when $\bar{C}_j > \frac{2H-2+\omega_i}{2(H-L)}$.

I first discuss the case in which $\omega_i \neq \omega_j$. Without loss of generality, assume $\omega_i > \omega_j$, I then discuss the following three cases: (1) $\bar{C}_i^*, \bar{C}_j^* < 1$, (2) $\bar{C}_i^* = 1, \bar{C}_j^* < 1$, and (3) $\bar{C}_i^* = \bar{C}_j^* = 1$.

Case 1. $\bar{C}_i^*, \bar{C}_j^* < 1$**.** At $C_i = \bar{C}_i$, manager i is indifferent about investing or not. Setting $C_i = \bar{C}_i$ in (B15) yields the best response of manager i: $\bar{C}_i = \frac{2H-2(H-L)\bar{C}_j}{2-\omega_i}$. Similarly we can derive the best response of manager j and the interaction of the two best responses yields the equilibrium cut-off points:

$$\begin{cases} \bar{C}_i^* = \frac{2H[2(H-L-1)+\omega_j]}{4(H-L)^2-(2-\omega_i)(2-\omega_j)}, \\ \bar{C}_j^* = \frac{2H[2(H-L-1)+\omega_i]}{4(H-L)^2-(2-\omega_i)(2-\omega_j)}. \end{cases} \tag{B17}$$

And the profits are

$$\begin{cases} \pi_i^* = \frac{2H^2(1-\omega_i)(2(H-L-1)+\omega_j)^2}{[4(H-L)^2-(2-\omega_i)(2-\omega_j)]^2}, \\ \pi_j^* = \frac{2H^2(1-\omega_j)(2(H-L-1)+\omega_i)^2}{[4(H-L)^2-(2-\omega_i)(2-\omega_j)]^2}. \end{cases}$$

As in the basic model, With $\omega_i > \omega_j$, I focus the equilibrium that satisfies $\bar{C}_i \geq \bar{C}_j$: $\bar{C}_i^* - \bar{C}_j^* = \frac{-2H(\omega_i-\omega_j)}{4(H-L)^2-(2-\omega_i)(2-\omega_j)} \geq 0$, which is equivalent to a negative denominator

$$4(H-L)^2 - (2-\omega_i)(2-\omega_j) < 0. \tag{B18}$$

We also need to make sure that the interior cut-off points can be supported.

$$\bar{C}_i^* - \frac{2H-2+\omega_j}{2(H-L)} = \frac{(2-\omega_j)\left[4-2H\omega_i-4(1-L)(1+L-H)-(2-\omega_i)(2-\omega_j)\right]}{2(H-L)\left[4(H-L)^2-(2-\omega_i)(2-\omega_j)\right]} \geq 0 \tag{B19}$$

$$\bar{C}_j^* - \frac{2H-2+\omega_i}{2(H-L)} = \frac{(2-\omega_i)\left[4-2H\omega_j-4(1-L)(1+L-H)-(2-\omega_i)(2-\omega_j)\right]}{2(H-L)\left[4(H-L)^2-(2-\omega_i)(2-\omega_j)\right]} \geq 0. \tag{B20}$$

Since (B19)-(B20)= $\frac{-4L(H-L)-(2-\omega_i)(2-\omega_j)}{2(H-L)[4(H-L)^2-(2-\omega_i)(2-\omega_j)]}$, with (B18), we know that if (B20) holds then (B19) holds. Therefore, the conditions to support interior solutions become (B18) and

$$(2-2H-\omega_i)\omega_j + 2\omega_i - 4(1-H+HL-L^2) < 0, \tag{B21}$$

which is equivalent to the part $4-2H\omega_j-4(1-L)(1+L-H)-(2-\omega_i)(2-\omega_j)<0$ in the numerator of (B20). The two conditions thus can be summarized as

$$\omega_i < 2-\frac{4(H-L)^2}{2-\omega_j}, \tag{B22}$$

$$\omega_i < 2(1-H)+\frac{4L(H-L)}{2-\omega_j}. \tag{B23}$$

RHS of (B22) minus RHS of (B23) is $\frac{2H(2(1-H+L)-\omega_j)}{2-\omega_j} > (<)\ 0$ when $\omega_j < (>)\ 2(1-H+L)$.

First, when $\omega_j > 2(1-H+L)$, we only need (B22), which can be simplified to $(2-\omega_i)(2-\omega_j) > 4(H-L)^2 > (2-\omega_j)^2$, where the last inequality follows because $\omega_j > 2(1-H+L)$. The inequality implies that $\omega_i < \omega_j$, which contradicts. Therefore, this case is impossible.

Second, when $\omega_j < 2(1-H+L)$, we only need (B23). Now I prove that $\omega_j \geq 2(1-L)$ is impossible. Suppose not: $\omega_j \geq 2(1-L)$. Then $2(1-H)+\frac{4L(H-L)}{2-\omega_j}-\omega_j = \frac{(\omega_j-2+2L)(\omega_j-2+2H-2L)}{2-\omega_j} < 0$, which contradicts with $\omega_i > \omega_j$ combined with (B23). Therefore, $\omega_j < 2(1-L)$. To sum, the conditions to support the interior cut-off points are

$$\begin{cases} \omega_j < \min\{2(1-L), 2(1+L-H)\}, \\ \omega_i < 2(1-H)+\frac{4L(H-L)}{2-\omega_j}. \end{cases} \tag{B24}$$

Case 2. $\bar{C}_i^* = 1, \bar{C}_j^* < 1$. When $\bar{C}_i^* = 1$, based on the best response of manager j, $\bar{C}_j^* = \frac{2L}{2-\omega_j}$. And the profits are

$$\begin{cases} \pi_i = H - \frac{1}{2} - \frac{2L(H-L)}{2-\omega_j}, \\ \pi_j = \frac{2L^2(1-\omega_j)}{(2-\omega_j)^2}. \end{cases} \tag{B25}$$

To support the boundary $\bar{C}_i^* = 1$ and interior $\bar{C}_j^* < 1$ we need

$$\bar{C}_i^* - \frac{2H-2+\omega_j}{2(H-L)} = \frac{2(1-L)-\omega_j}{2(H-L)} \geq 0, \tag{B26}$$

$$\bar{C}_j^* - \frac{2H-2+\omega_i}{2(H-L)} = \frac{4L(H-L)-(2-\omega_j)(2H-2+\omega_i)}{2(2-\omega_j)(H-L)} < 0, \tag{B27}$$

which are equivalent to

$$\begin{cases} \omega_j < 2(1-L), \\ \omega_i > 2(1-H) + \frac{4L(H-L)}{2-\omega_j}. \end{cases} \tag{B28}$$

Case 3. $\bar{C}_i^* = \bar{C}_j^* = 1$. Based on (B16), to support the corner solutions we need $\omega_i \geq 2(1-L)$ and $\omega_j \geq 2(1-L)$. Firms' profits are $\pi_i = \pi_j = L - \frac{1}{2}$.

I next discuss the case in which $\omega_i = \omega_j$. When $\omega_i = \omega_j = \omega$, based on (B17), if $\omega < 2(1-L)$,

$$\bar{C}_i^* = \bar{C}_j^* = \frac{2H}{2H + 2(1-L) - \omega}, \tag{B29}$$

and if $\omega > 2(1-L)$, $\bar{C}_i^* = \bar{C}_j^* = 1$. Taken together, for $\omega_i \geq \omega_j$, the cut-off points are

$$\left(\bar{C}_i^*, \bar{C}_j^*\right) = \begin{cases} \left(\frac{2H\left[2(H-L-1)+\omega_j\right]}{4(H-L)^2-(2-\omega_i)(2-\omega_j)}, \frac{2H\left[2(H-L-1)+\omega_i\right]}{4(H-L)^2-(2-\omega_i)(2-\omega_j)}\right) & \text{if } \ \omega_j < \min\{2(1-L), 2(1+L-H)\} \\ & \quad \text{and } \omega_i < 2(1-H) + \frac{4L(H-L)}{2-\omega_j}, \\ \left(1, \frac{2L}{2-\omega_j}\right) & \text{if } \ \omega_j < 2(1-L) \text{ and } \omega_i > 2(1-H) + \frac{4L(H-L)}{2-\omega_j}, \\ (1,1) & \text{if } \ \omega_j \geq 2(1-L), \\ \left(\frac{2H}{2H+2(1-L)-\omega}, \frac{2H}{2H+2(1-L)-\omega}\right) & \text{if } \ \omega_i = \omega_j < 2(1-L). \end{cases} \tag{B30}$$

and the profit function is

$$\left(\pi_i^*, \pi_j^*\right) = \begin{cases} \left(\frac{2H^2(1-\omega_i)\left(2(H-L-1)+\omega_j\right)^2}{\left[4(H-L)^2-(2-\omega_i)(2-\omega_j)\right]^2}, \frac{2H^2(1-\omega_j)(2(H-L-1)+\omega_i)^2}{\left[4(H-L)^2-(2-\omega_i)(2-\omega_j)\right]^2}\right) & \text{if } \ \omega_j < \min\{2(1-L), 2(1+L-H)\} \\ & \quad \text{and } \omega_i < 2(1-H) + \frac{4L(H-L)}{2-\omega_j}, \\ \left(H - \frac{1}{2} - \frac{2L(H-L)}{2-\omega_j}, \frac{2L^2(1-\omega_j)}{(2-\omega_j)^2}\right) & \text{if } \ \omega_j < 2(1-L) \text{ and } \omega_i > 2(1-H) + \frac{4L(H-L)}{2-\omega_j}, \\ \left(L - \frac{1}{2}, L - \frac{1}{2}\right) & \text{if } \ \omega_j \geq 2(1-L), \\ \left(\frac{2H^2(1-\omega)}{(\omega-2(1+H-L))^2}, \frac{2H^2(1-\omega)}{(\omega-2(1+H-L))^2}\right) & \text{if } \ \omega_i = \omega_j < 2(1-L). \end{cases} \tag{B31}$$

The case in which $\omega_i \leq \omega_j$ is similar.

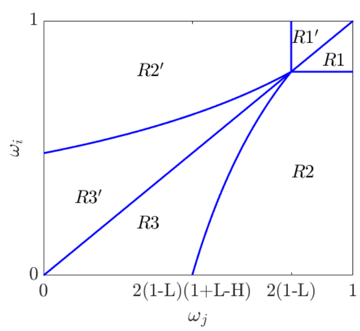
Now we are ready to show that $\omega_i^* = \omega_j^* = \omega^*$ cannot be sustained in equilibrium. With

$0 \leq L \leq H < 1$, the derivative of $\pi_i(\omega_i, \omega_j)$ with respect to ω_i at the point $\omega_j = 0$ is

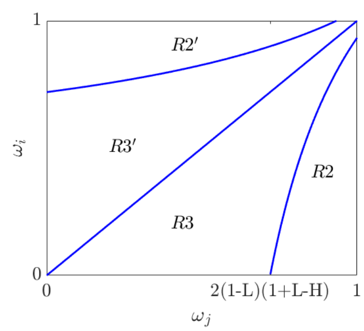
$$\frac{\partial \pi_i}{\partial \omega_i}(0,0) = \frac{H^2(H-L)^2}{2(1+L-H)(1+H-L)^3} > 0. \tag{B32}$$

Therefore $\omega_i = 0$ cannot be firm i's best response and $\omega_i^* = \omega_j^* = 0$ cannot be the equilibrium.

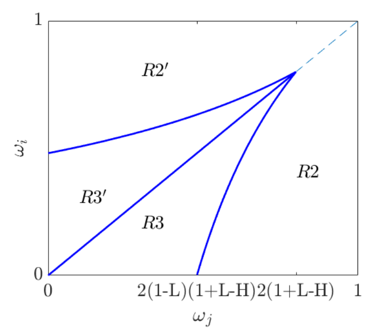
I next discuss the best response of each firm and derive the equilibrium compensation contracts. For ease of exposition, when $\omega_i > \omega_j$, denote the region where $\omega_j < 2(1-L)$ and $\omega_i < 2(1-H) + \frac{4L(H-L)}{2-\omega_j}$ as $R3$, the region where $\omega_j < 2(1-L)$ and $\omega_i > 2(1-H) + \frac{4L(H-L)}{2-\omega_j}$ as $R2$, and the region where $\omega_i \geq 2(1-L)$ as $R1$. The area where $\omega_i < \omega_j$ is similarly denoted. As derived above, firms' payoff function is a piece-wise function, whose domain depends on the sign of $L - \frac{1}{2}$ and $H - 2L$ and is shown in Figure A1.



(a) $L > \frac{1}{2}$ and $H < 2L$



(b) $L < \frac{1}{2}$ and $H < 2L$



(c) $L < \frac{1}{2}$ and $H > 2L$

Figure A1: Regions of profit functions

First, I solve for the pure strategy equilibrium that involves no extreme short-termism ($\omega^* < 1$). This can only happen in $R3$ and $R3'$. In $R3$ and $R3'$ taking derivative of π_i with respect to ω_i yields the potential best response of firm i:

$$\omega_i(\omega_j) = \frac{4(H-L)^2}{2-\omega_j}, \tag{B33}$$

and the interaction of the two best responses generates an equilibrium candidate $\omega_i^* = \omega_j^* = 1 - \sqrt{1-4(H-L)^2}$, which requires that $H - L < \frac{1}{2}$. Now we need to make sure (B33) indeed lies within $R3$ or $R3'$ and it is the best response function. To make sure that (B33) lies in $R3$ or

$R3'$ requires

$$\left(2(1-H)+\frac{4L(H-L)}{2-\omega_j}\right)-\frac{4(H-L)^2}{2-\omega_j}=2\frac{-2(-1+H+H^2-3HL+2L^2)-(1-H)\omega_j}{2-\omega_j}>0, \tag{B34}$$

and it is equivalent to $\omega_j < \frac{2(-1+H+H^2-3HL+2L^2)}{-1+H} \equiv \tilde{\omega}$. It can be shown that when $H < 2L$, $\tilde{\omega} > 2(1-L)$ and when $L > H - \frac{1}{2}$, $\tilde{\omega} > 2(1+L-H)$. Therefore (B33) must lie in $R3$ or $R3'$.

Recall that $0 \leq L \leq H < 1$. Since for all $0 \leq L \leq H < 1$ and $L > H - \frac{1}{2}$, we have $1-\sqrt{1-4(H-L)^2} < 2(1-L)$ and $1-\sqrt{1-4(H-L)^2} < 2(1+L-H)$. Thus in this region $\omega_i^* = \omega_j^* = 1-\sqrt{1-4(H-L)^2}$ indeed lies in $R3$ or $R3'$. Next, we need make sure that (B33) is indeed the best response function. Note based on Figure (A1), as ω_j increases, the best response of firm i may be to choose long-term contract ($\omega_i = 0$). We thus compare the following two terms

$$\pi_i^*\left(\frac{4(H-L)^2}{2-\omega_j},\omega_j\right)-\pi_i^*(0,\omega_j)=\frac{1}{2}\left(\frac{H^2\left(\omega_j-2(1-H+L)\right)^2}{(2-\omega_j)\left(\omega_j-2+4(H-L)^2\right)}-L^2\right)>0, \tag{B35}$$

when $\omega_j < \bar{\omega}$, where

$$\bar{\omega}=-\frac{2\left(H^2+\sqrt{L^2\left(-2H^3+H^2(L+1)^2-2HL^3+L^4\right)}-H\left(L^2+1\right)+L^3-L\right)}{H+L}. \tag{B36}$$

Therefore, $\omega_i^* = \omega_j^* = 1-\sqrt{1-4(H-L)^2}$ is indeed the equilibrium contract when $1-\sqrt{1-4(H-L)^2} < \bar{\omega}$. This holds when $L > g(H)$, where its inverse function $g^{-1}(H)$ is as follows

$$\begin{aligned} H =&\frac{1}{8}(1+4L^2)+\frac{1}{8\sqrt{3}}\Psi_3+\frac{1}{2}\sqrt{2L^4+L^2+\frac{2}{3}\left(-2L^4-4L^3+L\right)+\frac{1}{8}+\frac{1}{2}\Psi_2\Psi_1^{-1/3}-\frac{1}{6}\Psi_1^{1/3}} \\ &+\sqrt{3}\left(\frac{3L^2}{2}+L+\frac{1}{8}\right)\Psi_3^{-1}, \end{aligned} \tag{B37}$$

where

$$
\begin{aligned}
\Psi_1 =& 8L^{12} - 96L^{11} + 420L^{10} - 776L^9 + 492L^8 - 12L^7 - 21L^6 - 6L^5 - L^3, \\
& + 3\sqrt{3}\sqrt{-L^8\left(28L^8 - 240L^7 + 652L^6 - 520L^5 + 10L^4 + 68L^3 + 9L^2 - 6L - 1\right)}, \\
\Psi_2 =& - L^2 + 5L^4 + 40L^5 - 76L^6 + 32L^7 - 4L^8, \\
\Psi_3 =& \sqrt{3\left(4L^2+1\right)^2 + 24\left(-2L^4 - 4L^3 + L\right) + 8L\left(2L^3 + 4L^2 - 1\right) + 8\Psi_2\Psi_1^{-1/3} + 8\Psi_1^{1/3}}.
\end{aligned}
$$

Given that if $0 \leq H < \frac{1}{2}$, $\max\{0, g^{-1}(H)\} = 0$, while if $\frac{1}{2} \leq H \leq 1$, $\max\{H - \frac{1}{2}, g(H)\} = H - \frac{1}{2}$, we know the area that supports the equilibrium $\omega_i^* = \omega_j^* = 1 - \sqrt{1 - 4(H-L)^2}$ is

$$
\max\{0, g^{-1}(H)\} < L < H \leq 1, \tag{B38}
$$

which is given by the blue area in Figure 3. Also, for the comparative statics, given H, $\frac{\partial \omega^*}{\partial L} = -\frac{4(H-L)}{\sqrt{1-4(H-L)^2}} < 0$. Note firms' expected profits are $\pi_i = \pi_j = \int_0^{\bar{C}_i} \left((H - C_i)\left(1 - \bar{C}_j\right) + (L - C_i)\bar{C}_j\right) dC_i$. Plugging $\omega_i^* = \omega_j^* = 1 - \sqrt{1 - 4(H-L)^2}$ into it yields the equilibrium firm profits:

$$
\pi_i^* = \pi_j^* = \pi^* = \frac{2H^2\sqrt{1 - 4(H-L)^2}}{\left(\sqrt{1 - 4(H-L)^2} + 2H - 2L + 1\right)^2}. \tag{B39}
$$

Next, I focus on the area where extreme short compensation contracts are supported. As discussed above, when $L < H - \frac{1}{2}$, (B33) does not lie within $R3$ or $R3'$. Now to pin down the best response function, we only need to compare the following two terms:

$$
\pi_i^*\left(2(1-H) + \frac{4L(H-L)}{2 - \omega_j}, \omega_j\right) - \pi_i^*(0, \omega_j) = \frac{(2H-1)\omega_j + 4H(L-1) - 4L^2 + 2}{2\left(\omega_j - 2\right)} - \frac{L^2}{2} > 0,
$$

when $\omega_j < \frac{4(H(L-2)+1)}{-2H+L^2+1} - 2$. Since when $L < \sqrt{2H} - 1$, $\frac{4(H(L-2)+1)}{-2H+L^2+1} - 2 > 2(1 + L - H)$, the corresponding best response in that area is

$$\omega_i(\omega_j) = \begin{cases} \{\omega_i : \omega_i \geq 2(1-H) + \frac{4L(H-L)}{2-\omega_j}\} & \text{if } \ 0 < \omega_j < 2(1+L-H), \\ \{\omega_j : \omega_i > \omega_j\} & \text{if } 2(1+L-H) \leq \omega_j < 1. \end{cases} \tag{B40}$$

Therefore, the equilibrium is $\omega_i^* = \omega_j^* = 1$ when

$$0 \leq L < \sqrt{2H} - 1 \text{ and } 0 \leq H \leq 1, \tag{B41}$$

which is given by the grey region in Figure 3.

Finally, in the remaining region $\sqrt{2H} - 1 < L < g(H)$ and $0 \leq H \leq 1$, where $g^{-1}(H)$ is given by (B37), there is no pure strategy equilibrium. To see why, we consider firms' best response in the region. As discussed above, when $\sqrt{2H} - 1 < L < H - \frac{1}{2}$ and $0 \leq H \leq 1$, $\frac{4(H(L-2)+1)}{-2H+L^2+1} - 2 > 2(1+L-H)$, thus $\pi_i^*\left(2(1-H) + \frac{4L(H-L)}{2-\omega_j}, \omega_j\right) < \pi_i^*(0, \omega_j)$ and the best response for firm i is

$$\omega_i(\omega_j) = \begin{cases} \{\omega_i : \omega_i \geq 2(1-H) + \frac{4L(H-L)}{2-\omega_j}\} & \text{if } \ 0 < \omega_j < 2(1+L-H), \\ 0 & \text{if } 2(1+L-H) \leq \omega_j < 1. \end{cases} \tag{B42}$$

The best response of firm j is similarly derived and the two best responses cannot interact. So there is no pure strategy equilibrium. Similarly, when $H - \frac{1}{2} < L < g(H)$ and $0 \leq H \leq 1$, as discussed above, although (B33) lies within $R3$ or $R3'$, around the interaction $\pi_i^*\left(\frac{4(H-L)^2}{2-\omega_j}, \omega_j\right) < \pi_i^*(0, \omega_j)$. Thus the best response of firm i is

$$\omega_i(\omega_j) = \begin{cases} \frac{4(H-L)^2}{2-\omega_j} & \text{if } \ 0 < \omega_j < \bar{\omega}, \\ 0 & \text{if } \bar{\omega} \leq \omega_j < 1, \end{cases} \tag{B43}$$

where $\bar{\omega}$ is given by (B36). Again, the two firms' best responses do not interact within $0 \leq L \leq H \leq 1$, so there is no pure strategy equilibrium. QED.

Appendix C: Data Construction and Variable Definitions

ISS Incentive Lab provides detailed grant level compensation data for senior executives of the largest 750 companies in the U.S. (based on market capitalization). I start with a sample of 378,475 pieces of grant level compensation information for 59,004 unique named executives (participants). Since the identity of the set of largest firms changes from year to year, Incentive Lab backward and forward fills data to yield a total number of 2,189 unique companies for the period 1998-2017. I drop grant observations for which I fail to identify the award type,[24] performance type,[25] vesting schedule,[26] starting and ending of the vesting period, and grant-date value, and finally obtain 279,956 participant-year observations.

In untabulated analysis, I examine the distributions of the vesting periods for restricted stocks, options, and cash grants for all executives in my sample. For both stocks and options, the vesting periods cluster around three- to five-year horizon, and for grants with long vesting periods a large fraction of the vesting schedules are graded. These two patterns are consistent with those documented in Gopalan et al. (2014).

To construct pay duration, I follow Gopalan et al. (2014) and compute the weighted average vesting length of different compensation components: Firm i's executive m's pay duration in fiscal year t is

$$Duration_{imt} = \frac{\sum_{l=1}^{n} Grant_{imtl} \times t_l}{\sum_{l=1}^{n} Grant_{imtl}}, \tag{C1}$$

where $Grant_{imtl}$ is the grant-date value of grant l and t_l (years) is the vesting length of this grant. I consider three types of grants: restricted stocks, options, and cash. Then firm i's average duration

[24]There are 12 different grant types in Incentive Lab and I classify them as follows. Type "cash" includes *cashLong*, *cashShort*, *unitCash*, and *Unit Cash*, type "stock" includes *rsu*, *stock*, *phantomStock*, and *Performance Unit*, and type "option" consists of *Option*, *reloadOption*, *phantomOption*, *sarEquity*, and *sarCash*.

[25]There are 4 different performance types in Incentive Lab: *Time*, *Abs*, *Rel*, and *AbsRel*. The first type is time-vesting grant – the number of units granted is fixed and the vesting does not depend on future performance. The last three types are performance-vesting grant – the vesting is contingent on future performance and the number of units granted is either fixed or depends on future performance.

[26]There are 4 different vesting schedules in Incentive Lab: *Cliff*, *Ratable*, *None*, and *Unknown*. In the first type, the entire grant vests at once at the end of the vesting period. The second type is "graded," where the grant vests gradually over time. For the last two types, I assume that the grant has graded vesting schedule as the second type.

in fiscal year t is the average of all its named executives' pay duration in that year:

$$AvgDuration_{it} = \frac{1}{M_{it}} \sum_{m=1}^{M_{it}} Duration_{imt}, \tag{C2}$$

where M_{it} is the number of executives of firm i in year t and *Duration*$_{imt}$ is from equation (C1).

Next, for product similarity, I use *total similarity* from Hoberg-Phillips TNIC data library (Hoberg and Phillips, 2016) as a proxy. The higher a firm's product similarity, the fiercer competition the firm is faced with. The other proxy for product market competition - *Log(Industry sales)* - is computed as the natural logarithm of the sum of firm sales in an industry for a given year. The higher industry sales, the more competitive pressures the firm feels.

I drop grant information that cannot be matched with Hoberg-Phillips TNIC data and finally obtain 17,843 firm-year observations, which cover 1,845 unique companies.

Table C1: Empirical variables definitions

Variables	Definition
AvgDuration	The average executive pay duration for a firm, where pay duration is calculated based on equation (1) in Gopalan et al. (2014). Source: ISS Incentive Lab.
Total similarity	Total similarity data of a firm's products, negatively associated with product differentiation. Source: Hoberg-Phillips Data Library
Log(Industry sales)	Natural logarithm of the sum of sales for firms operating in the SIC3 industry. Source: Compustat.
Firm size	Natural logarithm of total assets. Source: Compustat.
Leverage	The ratio of sum of total long-term debt and total debt in current liabilities to total assets. Source: Compustat.
Market to Book	The ratio of sum of market value of equity and book value of total liabilities to total assets. Source: Compustat.
Stock return volatility	The stock return volatility calculated as the annualized volatility of daily stock returns during the previous fiscal year. Source: CRSP.
S.D. Sales	Standard deviation of the ratio of the firm's annual sales growth during the previous five years. Source: Compustat.
S.D. Cashflow	Standard deviation of the ratio of the ratio of cash flows over lagged total assets over the previous five years. Source: Compustat.
Abnormal return-1 year (-3 year)	The abnormal return on the firm's stock over the previous fiscal year (or three fiscal years) and the Fama-French three-factor model is employed to estimate expected returns. Source: CRSP and Fama-French Data Library.
E-index	Bebchuk, Cohen, and Ferrell (2009) Entrenchment index, calculated as the number of existence of six governance provisions. Source: ISS.
Long-term assets	The ratio of sum of total net property, plant, and equipment and goodwill to sum of total assets less cash and short-term investments. Source: Compustat.