Information Technology, Competition for Attention, and Corporate Efficiency*

Zhiqiang Ye

IESE Business School

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Abstract

I study the effects of information technology (IT) progress in a model where stock prices aggregate speculators' information and guide firms' investments. Speculators with limited attention acquire more information about firms with larger investment capacities. IT progress (i.e., lowering information costs) will improve stock price informativeness and corporate efficiency when information is costly. Yet, when information is inexpensive, speculators will use up attention. Then IT progress can backfire: Firms excessively expand capacities to engage in zero-sum competition for speculators' attention, reducing corporate efficiency and social welfare. Raising firms' growth opportunities can reinforce the undesirable effects of IT progress.

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1 Introduction

One crucial role of security prices in financial markets is aggregating information from different investors and guiding firms' real decisions. Although a firm knows itself better than anyone else, it still needs to learn from the market because investors could have better information on industrial prospects, consumer demand, market conditions, etc.[1] For firms that want to gain insights from the financial market, the encouraging news is that information technology (IT) advances in recent years have significantly enhanced the availability of information for investors. For example, the widespread use of mobile devices and the wireless internet has allowed investors to access real-time information with a few taps. Progress in financial technology (FinTech) has improved financial institutions' information gathering and dissemination, reducing information costs for investors.

However, the increasing availability of information causes the scarcity of investors' attention to be prominent, as was predicted by Herbert A. Simon:

> "*[I]n an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the attention of its recipients.*"

Plenty of evidence has documented that investors' attention is a limited resource (see Nekrasov et al., 2023 for a survey).

How do firms and stock market investors (referred to as speculators) with limited attention react to IT progress? Since the information contained in stock prices can guide corporate decisions, what will firms do to increase the price informativeness of their stocks? How does IT progress interplay with speculators' limited attention? Most importantly, does IT progress improve corporate efficiency and social welfare? To answer those questions and to help explain some empirical facts, I build a tractable model of firm-stock feedback, in which firms make real decisions to maximize their profits, and speculators with limited attention acquire private information and trade firms' stocks. In particular, firms can extract valuable information from stock prices to improve their investment efficiency. My model will help to illuminate the following empirical results:

- Investor attention matters for corporate actions. Firms with distracted shareholders have abnormally low stock returns and are more likely to make value-destroying

[1] Goldstein et al. (2022a) provide survey evidence that 75.2% of the surveyed firms say that stock prices contain helpful information for their investment decisions.

acquisition decisions (Kempf et al., 2017). Firms with greater price informativeness have higher productivity (Bennett et al., 2020).

- An improvement in information availability (i.e., a decrease in information acquisition cost) increases firms' stock price informativeness (Zhu, 2019).
- Investors process more data about large high-growth firms relative to processing data about other firms (Farboodi et al., 2022).
- The broader availability of information can increase firms' investment without significantly increasing their price informativeness (Goldstein et al., 2022b).

Model preview. Firms have mutually unrelated real businesses and must make the following real decisions: building capacities and making investment decisions. A firm's capacity determines the upper bound of the firm's investment (i.e., the maximum scale of the firm's business). After the capacity is determined, a firm chooses its investment, which cannot exceed the capacity limit. The final payoff of a firm's business is uncertain and affected by its random unobservable fundamental. Specifically, if the fundamental is good (resp. bad), the firm will have a positive (resp. negative) marginal investment return. Hence, a firm should ideally invest up to the capacity limit (resp. refrain from investing) when its fundamental is good (resp. bad).

Firms' stocks are traded in a financial market with three types of players: speculators, noise traders, and market makers. Speculators trade stocks for profits. A speculator can acquire private signals about firms' fundamentals and perform informed speculation by paying information acquisition costs. More precise signals incur higher information costs. In my model, information technology inversely measures how costly information acquisition is; an IT improvement refers to a reduction in speculators' information acquisition costs. In addition to costly information acquisition, speculators face attention constraints: The aggregate precision of a speculator's private signals has an upper bound. The attention constraint is interpreted as human resources' limited memory and information processing capacity, which cannot improve as rapidly as information technology.

With private signals, speculators submit market orders for stocks, together with noise traders who submit random orders. Competitive market makers observe aggregate order flows and set fair stock prices to absorb those orders. Such prices are observable to firms before they make investment decisions. Since stock prices contain speculators' private information, they can guide firms' investment decisions. Then a feedback loop arises:

Market makers' pricing will affect firm investment, which in turn affects firms' expected profits and market makers' pricing.

The model set-up just described can easily match the realistic situations of some firms. For example, a manufacturing firm should determine its production capacity (e.g., the scale of factories, the number of production lines, etc.). After that, the firm determines its production, corresponding to its investment decision in the model. Before making the production decision, the firm may get additional information about the market condition, so it may not produce to its capacity limit in the end.

Another example is how a firm makes an acquisition decision: First, the firm needs to determine the scale and scope of the acquisition plan (i.e., how many shares and what businesses of the target to acquire), which corresponds to choosing the capacity. However, the firm may not execute the acquisition plan because new information (e.g., stock market reaction) can change the firm's mind. The decision on plan execution corresponds to the firm's investment decision in the model. A more detailed acquisition example can be seen in Goldstein (2023).[2]

Results preview. Since firms' stock payoffs depend on their uncertain fundamentals, speculators are incentivized to acquire firms' fundamental information and perform speculative trading. Through market makers' pricing, speculators' private information is aggregated (with some noise) by stock prices, which thereby can guide firms' investment decisions. Specifically, a firm can infer from an abnormally high (resp. low) price that its fundamental will be good (resp. bad), so it is optimal to invest up to the capacity limit (resp. refrain from investing). Higher price informativeness makes this guidance more precise and thereby increases the firm's expected profit (i.e., corporate efficiency).

From speculators' perspective, larger-capacity firms are worth more information acquisition. The reason is that a large capacity implies a high dispersion of a firm's final value (i.e., final stock payoff); that is, the firm can make a significant profit or loss, depending on whether its investment decision fits its fundamental. Such a large stock payoff dispersion implies that a speculator can considerably profit if she trades the firm's stocks in the correct direction. Therefore, speculators have higher incentives to acquire information about firms with larger capacities. Knowing speculators' information acquisition preference, firms have *information-attracting incentives* when determining their capac-

[2] Goldstein (2023) provides the following anecdote: On February 4, 2020, The Wall Street Journal reported that Intercontinental Exchange (ICE) made a takeover offer to acquire eBay. Investors then sold the shares of ICE, sending its stock price down by 7.5% on February 4 and another 3% down on February 6. Seeing the market reaction, ICE decided to cease the plan.

ities: A firm would like to build additional capacities to spur speculators' information acquisition. The purpose is to increase the firm's stock price informativeness and improve its investment efficiency.

Firms' information-attracting incentives of building capacities complicate the effect of information technology progress (i.e., a decrease in information acquisition costs) on corporate efficiency. When information acquisition is quite costly, speculators cannot acquire much information, so their attention is abundant (i.e., their attention constraint is not binding). In this case, IT progress will increase firm capacities and induce speculators to acquire more information about all firms, improving firms' stock price informativeness and real efficiency.

However, when IT improves to a certain level, speculators will use up their attention (i.e., their attention constraint becomes binding) because of the increased information availability. In this case, there is no space for speculators to acquire more information about all firms; instead, acquiring more information about one firm means learning less about other firms, giving rise to speculators' attention allocation trade-off. Then firms' building more capacities will induce zero-sum competition for speculators' attention: As a firm increases its capacity, it will increase its stock price informativeness by attracting more attention from speculators, but meanwhile, it will decrease the attention allocated to other firms. Such competition for attention is destructive to corporate efficiency because, in equilibrium, all firms waste some capacities for information-attracting purposes; however, speculators cannot acquire more precise information due to their limited attention.

When speculators' attention constraint becomes binding, firms do not necessarily trigger competition for attention. If information acquisition is not sufficiently cheap (i.e., IT is at an intermediate level), firms will intentionally hold their capacities low to avoid this zero-sum competition because they know that triggering such competition will suddenly decrease the marginal benefit of extending capacities. In this case, IT progress induces firms to build fewer capacities: Firms control their capacities at a level that exactly induces speculators to use up their attention. Since no capacities are wasted, IT progress improves corporate efficiency.

However, when IT improves to a sufficiently advanced level (i.e., information acquisition is sufficiently cheap), firms' information-attracting incentive will be strong enough to dominate their fear of competing for attention. The reason is that very advanced IT makes speculators' learning preferences quite sensitive to firms' capacities: A small increase in a firm's capacity can attract a lot of attention (and hence information) when information is very cheap. Consequently, firms increase their capacities to compete for attention instead of avoiding such competition. In this case, IT improvements will intensify the competition and induce firms to waste more capacities, hurting their efficiency. The decrease in corporate efficiency (caused by IT progress) can even dominate the decrease in speculators' information acquisition costs and thereby reduce social welfare. Increasing firms' growth opportunities can reinforce the undesirable effects of IT progress by strengthening firms' incentives to compete for attention.

With competition for attention, different firms' capacity-building decisions become strategic substitutes, even if their businesses have no fundamental correlation. The reason is that increasing a firm's capacity will reduce other firms' price informativeness, thereby making their capacity-building less profitable. Because of the strategic substitutability, each firm cares about other firms' capacity-building incentives. If a firm can demonstrate a high incentive to increase its capacity (e.g., through its stock price), other firms' capacity-building will be discouraged.

Finally, I relax the hard attention constraint by allowing speculators to extend their attention. In this case, an IT improvement always increases firms' stock price informativeness because cheaper information induces speculators to extend their attention and acquire more information about all firms. However, this need not mean that IT progress increases corporate efficiency because speculators still face the attention allocation tradeoff, although the attention limit is soft (i.e., it can be extended by paying costs). As a result, firms' competition for attention still exists, implying excessively high firm capacities. When developing attention is very costly, the waste of capacities caused by IT progress can dominate the increase in firms' stock price informativeness and the decrease in speculators' information costs, thereby reducing corporate efficiency and social welfare. Again, increasing firms' growth opportunities can reinforce the undesirable effects of IT progress.

Related literature. First of all, this paper contributes to the literature exploring the theoretical implications of the feedback effect, which means the information contained in stock prices can guide firm managers' decisions and hence affect firm values (see Bond et al., 2012 and Goldstein, 2023 for surveys). Plenty of empirical works have justified the existence of the feedback effect.[3] Theoretical works in the field can trace back to Gross-

[3] Luo (2005) shows that merging companies are more likely to close acquisition deals if stock prices react negatively to the initial announcement of those deals. Chen et al. (2007), Foucault and Frésard (2012), Edmans et al. (2017) and Ye et al. (2022) find that a firm will have higher sensitivity of corporate investment to its stock price if more information (not possessed by the firm) is contained in the price. Bakke and Whited (2010) show that managers' investment decisions incorporate investors' private infor-

man and Stiglitz (1980), Hellwig (1980), Kyle (1985) and Glosten and Milgrom (1985), which show in different environments that stock prices can reflect investors' private information. However, those papers focus only on the financial market and do not consider the real decisions of firms.

Fishman and Hagerty (1989) consider firms' real decisions and show that more efficient security prices can lead to more efficient investment decisions. Leland (1992) shows that allowing informed trading can stimulate firms' real investment. Firms in their models care about stock prices simply because firm profits directly depend on the prices, rather than because they need to learn from the prices.[4] In contrast, firms in my model care only about their final values rather than interim stock prices; moreover, they learn from stock prices to correct their beliefs about future fundamentals, which increases their investment efficiency.

Some models consider that a firm learns from its stock price to get helpful information for real decisions (Dow and Gorton, 1997; Subrahmanyam and Titman, 1999, 2001; Goldstein and Guembel, 2008; Bond et al., 2010; Goldstein et al., 2013; Edmans et al., 2015; Dow et al., 2017; Goldstein and Yang, 2019). In particular, Dow et al. (2017) and Goldstein and Yang (2019) study how firms can affect stock market investors' incentives to provide information, which is also a vital issue analyzed in my model. However, those papers consider only a single representative firm in their models, neglecting the potential interplay among firms. In contrast, my model studies the decision-making of multiple firms, of which the interplay is my focus.

The most closely related paper to my model is Dow et al. (2022), where firms compete to attract informed investors by shortening their project maturity. The authors find that in equilibrium, competition for informed investors cannot increase an individual firm's price informativeness, implying a "short-termism trap". Similarly, my model shows that competition for investors' information induces excessive capacity-building, which hurts corporate efficiency. My model differs in three aspects: First, my model is built on the context in which firms with no agency problem make real decisions to maximize final firm values, while the Dow et al. model studies how stock informativeness affects

mation in stock prices but are unaffected by stock market mispricing. Foucault and Fresard (2014) find that firms even learn from their peers' stock prices to guide investment decisions. Jayaraman and Wu (2020) show that firms can use voluntary forecast announcements to elicit information from investors and then adjust their annual capital expenditures based on the market reaction to those announcements. Banerjee et al. (2023) confirm the existence of managerial learning from stock prices, but highlight that CEO overconfidence can weaken the feedback effect.

[4] Medran and Vives (2004) also study firm investment in a rational expectation context. However, in their model, the firm is the insider and has nothing to learn from the market price.

CEO compensation and agency cost, which is an entirely different context. Second, my model's stock investors have no exogenous learning preferences. In contrast, investors in Dow et al. (2022) face exogenous early liquidation risk and prefer learning about firms with short-term projects. Hence, shortening project maturity is firms' way to compete for informed investors. Finally and most importantly, in my paper, whether or not firms compete for investors' information is endogenous and depends on the level of information technology in the market, which is a new finding in the literature. This paper is the first to point out that IT progress can trigger competition for investors' information, reducing real efficiency.

My paper also relates to the literature on limited investor attention (see Nekrasov et al., 2023 for a survey). There is vast literature showing that investors' attention is a limited cognitive resource (Hirshleifer et al., 2009; DellaVigna and Pollet, 2009; Louis and Sun, 2010; Israeli et al., 2021; Brown et al., 2022; Chen et al., 2023), even for sophisticated or institutional investors (Corwin and Coughenour, 2008; Kempf et al., 2017; Harford et al., 2019; Schmidt, 2019; Driskill et al., 2020; Chiu et al., 2021), and analyzing the consequences.[5] My paper contributes to the literature by studying the interaction between investors' limited attention and information technology progress and showing that IT improvements may backfire due to limited investor attention.

Finally, my model relates to the literature on technological progress in information availability and its impact on the market. Dugast and Foucault (2018) develop a model showing that the availability of quick imprecise information might crowd out the processing of slower and more precise information, thereby causing damage to the market. Pavan et al. (2022) show that as the cost of information declines, traders overinvest in information acquisition and trade too much on their private information. Similar to those papers, I also find that a decrease in information acquisition cost may bring unexpected adverse effects; however, my result is driven by a different mechanism: feedback effect and firms' competition for investors' information.

2 The model

My model is built on Kyle (1985) and Edmans et al. (2015) to analyze how the information availability progress affects stock market trading, firms' behavior, and real efficiency. The economy has four types of players: firms, speculators, noise traders, and market makers.

[5] Hirshleifer and Teoh (2003) and Hirshleifer et al. (2011) use theoretical methods to study how limited investor attention affects firms' information disclosure and stock market reactions to information.

All players are risk-neutral. Risk-free (gross) return is normalized to 1 for simplicity.

The game consists of four periods: $t = 0, 1, 2$ and 3. At $t = 0$, each firm determines its business capacity. At $t = 1$, speculators acquire information about firms' fundamentals after observing firms' capacities. At $t = 2$, speculators and noise traders trade firms' stocks by submitting market orders; market makers set the clearing prices after observing the aggregate order for each firm's stocks. Also, at $t = 2$, each firm determines its investment after observing stock prices; a firm's maximum investment cannot exceed its capacity determined at $t = 0$. All uncertainties are resolved at $t = 3$.

Firms and real businesses. The economy has two firms – firm 1 and firm 2 – with unrelated fundamentals. Each firm runs a real business that pays off at $t = 3$. At $t = 0$, firm i ($i = 1, 2$) determines its business capacity K_i (also referred to as business scale), with $K_i \geq 0$. Extending the business capacity is costly for a firm. If firm i chooses a capacity K_i, it must pay a *capacity-building* cost of $C(K_i)$, which is an increasing function with continuous derivatives to at least the third order. I assume the function has the following properties: $C'(0) = 0$, $C'(+\infty) = +\infty$, $C''(\cdot) > 0$ and $C'''(\cdot) \geq 0$.[6]

The payoff of firm i's business is determined by: (a) the firm's investment I_i at $t = 2$, which is constrained by its capacity K_i (i.e., $I_i \in [0, K_i]$); and (b) its fundamental at $t = 3$, denoted by F_i. The firm's fundamental can be either good (denoted by $F_i = H$) or bad (denoted by $F_i = L$). F_i is a random variable with the following prior probability distribution:

$$prob.\,(F_i = H) = prob.\,(F_i = L) = \frac{1}{2}. \tag{1}$$

Given firm i's investment I_i, the firm's business payoff at $t = 3$ is given by:

$$\underset{\text{with } I_i \in [0,K_i]}{R_i(I_i, F_i)} \equiv \begin{cases} I_i\,(\theta + \upsilon) + \iota & \text{if} \quad F_i = H \\ I_i \underbrace{(\theta - \upsilon)}_{<0} - \iota & \text{if} \quad F_i = L \end{cases} \tag{2}$$

with $\iota > 0$ and $\upsilon > \theta > 0$. Equation (2) implies that a good (resp. bad) fundamental corresponds to a high and positive (resp. low and negative) marginal return of investment. Parameter ι represents the basic risk of a firm's business; that is, even if firm i chooses $I_i = 0$ (i.e., the lowest risk exposure), its business payoff still depends on the fundamental and hence is risky.[7] Parameter ι can be viewed as the risk from a firm's asset in place,

[6] To maintain as many generalities as possible, I do not specify the capacity-building cost function $C(\cdot)$. A valid example is $C(K) = cK^2/2$. All numerical illustrations in the model are based on this quadratic cost function.

[7] The model's results are robust to $\iota = 0$. However, with $\iota = 0$, the analyses will be more complex

which is hard to adjust. Investment I_i measures firm i's variable risk exposure in its business: With a higher I_i, firm i's business has a larger positive payoff (resp. induces a larger loss) when the fundamental is good (resp. bad). Capacity K_i determines the maximum level of firm i's investment(i.e., $0 \leq I_i \leq K_i$ must hold). Based on the prior distribution of F_i, $E[R_i(I_i, F_i)] = I_i\theta$ holds, so θ represents the ex-ante profitability of the firm's business. If $F_i = H$ (resp. $F_i = L$), obviously the optimal investment of firm i should be $I_i = K_i$ (resp. $I_i = 0$), which generates the largest profit (resp. avoids as much loss as possible). Parameter v represents the *growth opportunity* of a firm's business – a high v implies an opportunity to earn a high return or avoid large losses by making a correct investment decision.

Finally, I assume the two firms' fundamentals, F_1 and F_2, are mutually independent. This assumption means that for a given I_i, firm i's (random) business payoff $R_i(I_i, F_i)$ cannot be affected by the other firm's decisions or fundamental. Therefore, the two firms are fundamentally unrelated, implying that any potential interplay between them cannot be attributed to the intrinsic correlation between their businesses.

Interpretation of firms' real decisions. I interpret a firm's business (and the related real decisions) in two ways: production interpretation and M&A interpretation.

Production interpretation. In this case, a firm's business is to build production lines and then sell goods. Capacity K_i refers to firm i's maximum production ability. To increase K_i, the firm needs to rent or purchase larger factories, build more production lines, and/or adopt more advanced production technology, which incurs the capacity-building costs $C(K_i)$. At $t = 2$, the investment I_i refers to firm i's actual production. Since the market evaluation of the firm's products is uncertain, the market price of firm i's product minus the marginal production cost (i.e., the profit margin of selling a product) may be positive (i.e., $\theta + v$) or negative (i.e., $\theta - v$). I_i is between 0 and K_i because actual production can neither be negative nor exceed the firm's capacity limit.

M&A interpretation. In this case, the business of firm i – which can be a holding company that does not produce goods or services itself – is to acquire another company. Capacity K_i refers to the scope and scale of the acquisition plan that the acquirer (i.e., firm i) and the target preliminarily agree on. A higher K_i means that the acquirer plans to

because then I must separately discuss the special case with $I_i = 0$ when proceeding. The case with $I_i = 0$ and $\iota = 0$ is special because it means firm i's payoff is certain, thereby eliminating the space for informed stock market trading. Although I can show that $I_i = 0$ will never arise in equilibrium, explaining the result will increase the complexity and length of the paper. Hence, I focus on $\iota > 0$ to ensure that firm payoff is always risky, which simplifies the analyses without changing the key insights of the model.

purchase more shares or/and departments of the target. The capacity-building costs $C(K_i)$ refer to firm i's costs of making a plan and negotiating with the target to reach a preliminary agreement. After reaching the agreement, firm i announces (or informally leaks) the acquisition plan to the market at $t = 0$; however, the plan has not yet been executed at this moment. The return of executing the acquisition plan is risky. If it generates significant synergy, the return is positive (i.e., $K_i(\theta + v)$); otherwise, the return is $K_i(\theta - v)$, which is negative. At $t = 2$, the investment I_i determines whether or not to execute the plan: If firm i executes it, then $I_i = K_i$; otherwise $I_i = 0$, meaning canceling the plan. Note that in the M&A interpretation, I_i takes only two possible values: K_i (execution) or 0 (cancel), which seemingly differs from the previous model set-up. However, later I will show that firm i chooses either $I_i = K_i$ or $I_i = 0$, even if intermediate values in $[0, K_i]$ are allowed. Hence, restricting firm i's investment to the binary set $\{0, K_i\}$ will not change any result of the model.

Firm profit and stock market. At $t = 3$, firm i's final profit is equal to:

$$\Pi_i \equiv R_i(I_i, F_i) - C(K_i).$$

There exists a stock market where firms' shares are traded. The shareholders of firm i have claims on the firm's final profit: A share of firm i's stock pays off Π_i when all uncertainties are resolved at $t = 3$.[8] When making decisions (on K_i and I_i), firm i always maximizes the expected value of Π_i based on its available information; that is, the principal-agent problem is absent in the model.

Speculators and information technology. At $t = 1$, speculators (of mass 1) are present in the stock market and can acquire private information about the two firms' fundamentals. Specifically, a speculator (e.g., speculator j, $j \in [0, 1]$) can acquire a private signal s_i^j, which equals either "h" or "l", about firm i's fundamental. The distribution of s_i^j is as follows:

$$prob(\, s_i^j = h \,|\, F_i = H) = prob(\, s_i^j = l \,|\, F_i = L) = \frac{1}{2} + \tau_i^j,$$

where $\tau_i^j \geq 0$ is the precision of the signal. Conditional on firms' fundamentals, s_i^j is independent across different i's and j's. The cost of acquiring such a private signal equals $S(\tau_i^j) \equiv \gamma(\tau_i^j)^2/2$, where the cost parameter $\gamma > 0$ inversely measures the *information*

[8] My model is robust under a more general assumption that a stock of firm i pays off $(1 - \beta)\Pi_i$, $\beta \in [0, 1)$ (see Goldstein et al., 2013). To ease parameters, I let $\beta = 0$.

technology of the market. That is, information technology represents the availability of information for speculators.

At $t = 2$, speculators trade firms' stocks based on their private information. Speculator j can submit a market order x_i^j for firm i's stocks. Following Edmans et al. (2015), I assume x_i^j can take three possible values: 1, 0, and -1, meaning "long position", "no position", and "short position" respectively.

Market making and feedback effect. There exist noise traders submitting random orders for stocks at $t = 2$. The aggregate order of noise traders for firm i's stocks is u_i, which is uniformly distributed on $[-\epsilon, \epsilon]$ and independent of any other random variable.

Competitive market makers set market clearing prices at $t = 2$ after observing each stock's aggregate order (of speculators and noise traders). Hence, firm i's stock price p_i (set by market makers) is determined by the following equation:

$$p_i = E[\Pi_i | Y_1, Y_2],$$

where $Y_i \equiv \int_0^1 x_i^j dj + u_i$ is the aggregate order flow for firm i's stocks.

Firm i can observe p_1 and p_2 before determining its investment I_i at $t = 2$. As a result, I_i can be affected by the firm's stock price p_i because it aggregates speculators' information about the firm's fundamental.[9] Market makers are aware that firm i's investment depends on the stock price p_i, so a feedback loop arises: Market makers' pricing will determine p_i and hence affect firm profit Π_i by guiding firm i's investment I_i, which in turn affects the pricing of market makers since they can correctly anticipate I_i.

Limited speculator attention. A speculator has limited attention. Following Kacperczyk et al. (2016), I assume that the total precision of speculator j's signals about the two firms satisfies the following constraint:

$$\tau_1^j + \tau_2^j \leq \overline{\tau}, \tag{3}$$

where $\overline{\tau}$ represents a speculator's attention capacity. The attention constraint is interpreted as human resources' limited memory and information processing capacity. In practice, raw information alone cannot guide speculative trading; human work is needed to translate raw information into knowledge that can guide financial investment (see Abis and Veldkamp, 2023). For example, a signal indicating an energy shortage may be either

[9] Since the two firms are fundamentally unrelated, a firm can never get useful information from the other firm's stock price. Therefore, assuming that firm i can observe only p_i is also viable.

good news or bad news for a firm; a speculator must first understand the information and then use her expertise to judge whether it is a positive or negative signal for a certain firm. Although the improvement of information technology can make it cheaper to acquire information (i.e., reduce γ), human-based knowledge production is constrained by limited memory, deadlines for decision-making, the speed of understanding information, and so on, which cannot improve as rapidly as information technology. My model captures such a limitation of human resources using Inequality (3): A speculator can process at most $\overline{\tau}$ precision units of information before submitting her orders. In Section 7.2, I relax the hard attention limit by allowing speculators to extend their attention.

Timeline. Now I can describe the timeline in more detail: At $t = 0$ (*business-starting stage*), the two firms simultaneously determine their business capacities (i.e., firm i chooses K_i). In the later periods, K_i is observable to all market participants. Speculators acquire private information about the two firms' fundamentals at $t = 1$ (*information acquisition stage*). Specifically, speculator j chooses τ_1^j and τ_2^j subject to the attention constraint (3).

At $t = 2$ (*trading stage*), the following events take place in sequence: First, speculators (with private signals) and noise traders submit their orders together. Second, market makers set price p_i for firm i's stocks after observing the aggregate order flows Y_1 and Y_2. Finally, the two firms choose investments subject to their capacity limits (i.e., firm i chooses $I_i \in [0, K_i]$) after observing the stock market prices p_1 and p_2. All uncertainties are resolved at $t = 3$ (*final period*). A share of firm i's stocks pays off Π_i in this final period. Figure 1 summarizes the timeline.

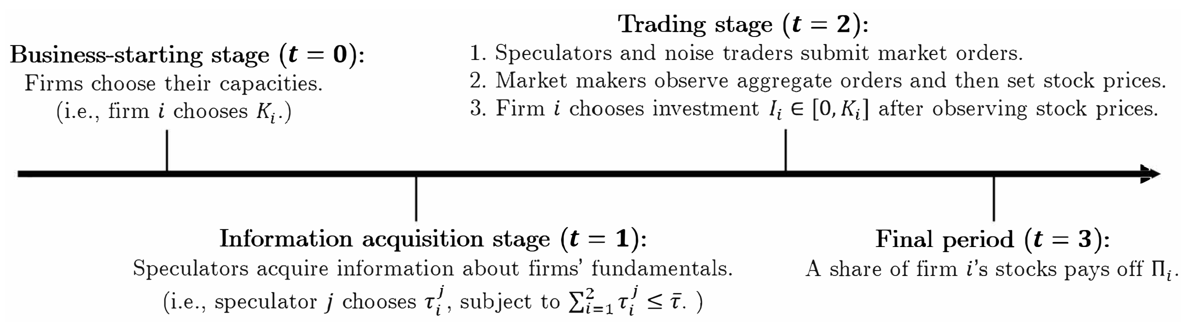

Figure 1: Timeline.

The equilibrium concept my model uses is perfect Bayesian equilibrium, which is defined as follows.

Definition 1. *A perfect Bayesian equilibrium consists of firm i's capacity K_i and investment I_i, speculator j's information precision τ_i^j and market order x_i^j, and market makers' stock price p_i, such that:*

- *Firm i's investment $I_i \in [0, K_i]$ maximizes the (conditional) expected firm profit $E\left[\Pi_i | \, p_1, p_2\right]$.*
- *Market makers set firm i's stock price p_i to be $E[\Pi_i | \, Y_1, Y_2]$.*
- *Speculator j's market order $x_i^j \in \{-1, 0, 1\}$ maximizes the (conditional) expected speculative profit $\sum_{i=1}^2 E\left[x_i^j \left(\Pi_i - p_i\right) \middle| \, s_1^j, s_2^j\right]$.*
- *Speculator j's information precision τ_i^j maximizes the (unconditional) expected net profit $\sum_{i=1}^2 \left(E\left[x_i^j \left(\Pi_i - p_i\right)\right] - \gamma(\tau_i^j)^2/2\right)$.*
- *Firm i's capacity K_i maximizes the (unconditional) expected firm profit $E\left[\Pi_i\right]$.*
- *All players have rational expectations in that each player's belief about the other players' strategies is correct in equilibrium.*

3 Trading stage

The equilibrium will be analyzed by backward induction. In this section, I characterize the equilibrium at $t = 2$ (the trading stage), taking as given the capacity K_i of firm i's business and the precision τ_i^j of speculator j's private information.

Letting $\tau_i \equiv \int_0^1 \tau_i^j dj$ denote the average precision of speculators' signals about firm i's fundamental, I assume that the following inequality holds throughout the paper:

$$\tau_i < \frac{\epsilon}{2}. \tag{4}$$

Inequality (4) ensures that the aggregate order Y_i does not always fully reveal firm i's fundamental F_i. If Inequality (4) is not satisfied, trading firm i's stocks will be unprofitable for speculators because market makers can always perfectly infer F_i from Y_i and then set $p_i = \Pi_i$, which eliminates the profitability of speculative trading. In Section 4 (Proposition 2), it is shown that Inequality (4) must hold endogenously at the information acquisition stage because speculators will acquire information about a firm only if trading the firm's stocks is profitable. The following lemma characterizes speculators' informed trading.

Lemma 1. *At $t = 2$, speculator j submits the order $x_i^j = 1$ (resp. $x_i^j = -1$) for firm i's stocks when $s_i^j = h$ (resp. $s_i^j = l$).*

Firm i's final stock payoff Π_i is high (resp. low) when its fundamental is good (resp. bad). Therefore, the rational strategy of speculator j is to long (resp. short) the firm's stock when she estimates that the final stock payoff will be above (resp. below) the expectation of market makers. From the speculator's perspective, the only available information (besides the prior belief) about firm i's fundamental is the private signal s_i^j. Hence, if this signal is informative (i.e., $\tau_i^j > 0$), the speculator will long (resp. short) firm i's stock when $s_i^j = h$ (resp. $s_i^j = l$) because then the firm's fundamental is more likely to be good (resp. bad). If the signal is not informative (i.e., $\tau_i^j = 0$), speculator j makes zero expected trading profits no matter how she determines the position; in this case, I still let the speculator long (resp. short) firm i's stocks when $s_i^j = h$ (resp. $s_i^j = l$).

According to Lemma 1, the following equations hold:

$$\begin{cases} E\left(x_i^j \middle| F_i = H\right) = \left(\frac{1}{2} + \tau_i^j\right) - \left(\frac{1}{2} - \tau_i^j\right) = 2\tau_i^j \\ E\left(x_i^j \middle| F_i = L\right) = \left(\frac{1}{2} - \tau_i^j\right) - \left(\frac{1}{2} + \tau_i^j\right) = -2\tau_i^j \end{cases}.$$

Based on Chebyshev's law of large numbers, $\int_0^1 x_i^j dj = 2\tau_i$ (resp. $\int_0^1 x_i^j dj = -2\tau_i$) holds if $F_i = H$ (resp. $F_i = L$), so the aggregate order flow Y_i for firm i's stocks is as follows:

$$Y_i = \begin{cases} 2\tau_i + u_i & \text{if} \quad F_i = H \\ -2\tau_i + u_i & \text{if} \quad F_i = L \end{cases}. \tag{5}$$

After observing Y_i, competitive market makers set stock prices, anticipating that those prices will affect firms' investments. The following proposition characterizes the result.

Proposition 1. *At $t = 2$, there exists a unique equilibrium. Firm i's equilibrium stock price p_i is determined by:*

$$p_i + C(K_i) = \begin{cases} K_i(\theta + v) + \iota & \textit{if} \quad Y_i > -2\tau_i + \epsilon & \textit{[positively fully revealing]} \\ K_i\theta & \textit{if} \quad Y_i \in [2\tau_i - \epsilon, -2\tau_i + \epsilon] & \textit{[non-revealing]} \\ -\iota & \textit{if} \quad Y_i < 2\tau_i - \epsilon & \textit{[negatively fully revealing]} \end{cases}.$$

Firm i's equilibrium investment is given by:

$$I_i = \begin{cases} K_i & \textit{if} \quad p_i + C(K_i) > -\iota \\ 0 & \textit{if} \quad p_i + C(K_i) \leq -\iota \end{cases}.$$

First, I explain the inference of market makers. Depending on the value of Y_i, three cases may arise: *positively fully revealing*, *non-revealing*, or *negatively fully revealing* case. If market makers observe $Y_i > -2\tau_i + \epsilon$ (i.e., very high demand for firm i's stocks), they can perfectly infer that $F_i = H$ holds because, according to Equation (5), the upper bound of Y_i under $F_i = L$ is $-2\tau_i + \epsilon$. Hence, Y_i is positively fully revealing when $Y_i > -2\tau_i + \epsilon$. If market makers observe $Y_i < 2\tau_i - \epsilon$ (i.e., very low demand), they can perfectly infer that $F_i = L$ holds because the lower bound of Y_i is $2\tau_i - \epsilon$ if $F_i = H$. Hence, Y_i is negatively fully revealing when $Y_i < 2\tau_i - \epsilon$. If market makers observe $2\tau_i - \epsilon \le Y_i \le -2\tau_i + \epsilon$ (i.e., intermediate demand), they cannot extract any useful information about F_i because of the following equation (Bayes' theorem):

$$prob\left(F_i = H \middle| Y_i \in [2\tau_i - \epsilon, -2\tau_i + \epsilon]\right) = \frac{\frac{\epsilon - 2\tau_i}{\epsilon} prob\left(H\right)}{\frac{\epsilon - 2\tau_i}{\epsilon} prob\left(H\right) + \frac{\epsilon - 2\tau_i}{\epsilon} prob\left(L\right)} = prob\left(H\right),$$

which means the order flow Y_i does not change market makers' prior belief. Therefore, Y_i is non-revealing (or uninformative) in this case. Figure 2 illustrates how Y_i reveals information about firm i's fundamental.

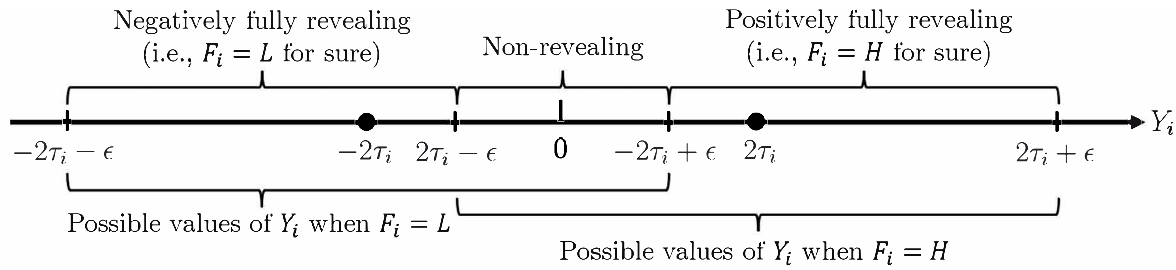

Figure 2: Information contained in the aggregate order Y_i.

Next, I explain market makers' pricing and firms' investments. In the negatively fully revealing case (i.e., $Y_i < 2\tau_i - \epsilon$), the upper bound of firm i's profit Π_i is $-\iota - C(K_i)$, which realizes when firm i chooses $I_i = 0$. Hence, the upper bound of stock price p_i is also $-\iota - C(K_i)$ in the negatively fully revealing case. Reasoning similarly, in the positively fully revealing case (i.e., $Y_i > -2\tau_i + \epsilon$), the lower bound of Π_i is $\iota - C(K_i)$, which is also the lower bound of p_i. In the non-revealing case (i.e., $2\tau_i - \epsilon \le Y_i \le -2\tau_i + \epsilon$), firm i's expected business payoff equals $\left(R_i(I_i, H) + R_i(I_i, L)\right)/2 = I_i\theta$, so the lower bound of Π_i and p_i is $-C(K_i)$. Overall, in the positively fully revealing or the non-revealing case, the lower bound of p_i must be strictly higher than $-\iota - C(K_i)$, which is the upper bound of p_i in the negatively fully revealing case. As a result, observing p_i, firm i can perfectly detect whether or not the negatively fully revealing case arises.

Whenever firm i observes $p_i > -\iota - C(K_i)$, it knows for sure that the negatively fully revealing case does not arise (i.e., either the positively fully revealing or the non-revealing case happens), so it optimally chooses $I_i = K_i$ because the marginal benefit of investment is at least $\theta > 0$. Anticipating this, market makers will set $p_i = K_i(\theta + \upsilon) + \iota - C(K_i)$ in the positively fully revealing case and $p_i = K_i\theta - C(K_i)$ in the non-revealing case. When firm i observes $p_i \leq -\iota - C(K_i)$, it knows for sure that the negatively fully revealing case arises, so it optimally chooses $I_i = 0$. Anticipating this, market makers will set $p_i = -\iota - C(K_i)$ in the negatively fully revealing case.

Now the role of Inequality (4) can be better understood. If Inequality (4) does not hold, the non-revealing case $2\tau_i - \epsilon \leq Y_i \leq -2\tau_i + \epsilon$ will arise with zero probability (see Figure 2). As a result, Y_i is always fully revealing, either positively or negatively. In this case, Proposition 1 still holds with the non-revealing case ignored. However, this means $\Pi_i - p_i = 0$ always holds, so a speculator makes zero expected speculative profit no matter how she trades.[10]

Price informativeness. According to market makers' pricing rule in Proposition 1, in equilibrium firm i can extract the fundamental information contained in Y_i through observing p_i, so stock price informativeness is equivalent to the informativeness of the aggregate order Y_i. Since Y_i is uninformative (resp. fully revealing) about F_i when $Y_i \in [2\tau_i - \epsilon, -2\tau_i + \epsilon]$ (resp. $Y_i \notin [2\tau_i - \epsilon, -2\tau_i + \epsilon]$), the price informativeness of p_i can be measured by the probability that Y_i is (positively or negatively) fully revealing, which is characterized by the following corollary.

Corollary 1. *The probability that Y_i is fully revealing is given by:*

$$prob\,(Y_i \notin [2\tau_i - \epsilon, -2\tau_i + \epsilon]) = \frac{2\tau_i}{\epsilon},$$

so firm i's stock price informativeness can be measured by τ_i/ϵ.

Intuitively, speculators' aggregate order for firm i's stocks is more likely to reveal the firm's fundamental F_i if the average information precision τ_i is higher; hence the informativeness of Y_i and p_i is increasing in τ_i. A higher ϵ means that noise trading

[10] Speculator j's speculative profit from firm i's stocks is $x_i^j(\Pi_i - p_i)$, which equals 0 if $\Pi_i - p_i = 0$. When Y_i is fully revealing, $\Pi_i - p_i = 0$ must hold with certainty because market makers correctly anticipate firms' investments in equilibrium. Therefore, speculators' expected trading profit (for any given τ_i^j) is 0 if the non-revealing case arises with zero probability.

is more volatile and hence can better hide the fundamental information contained in speculators' orders, so the informativeness of Y_i and p_i is decreasing in ϵ.[11]

4 Information acquisition stage

In this section, the capacity K_i of firm i's business is taken as given. I denote speculator j's profit (net of information acquisition costs) from trading firm i's stock by π_i^j, which is characterized in the following lemma.

Lemma 2. *At $t=1$, speculator j's expected profit (net of information acquisition costs) from trading firm i's stock is given by:*

$$E_{t=1}\left[\pi_i^j\right] = \underbrace{2\tau_i^j\left(1-\frac{2\tau_i}{\epsilon}\right)(K_i v+\iota)}_{\textit{speculative profit}} - \underbrace{\frac{\gamma}{2}\left(\tau_i^j\right)^2}_{\textit{information cost}}. \tag{6}$$

Hence, speculator j's total expected profit at $t=1$ equals $E_{t=1}\left[\pi_1^j+\pi_2^j\right]$.

Speculator j's expected profit from trading firm i's stocks has two components: speculative profit and information (acquisition) cost. With Inequality (4), the speculative profit of speculator j is positive if $\tau_i^j>0$; the reason is that the aggregate order Y_i is not always fully revealing (i.e., $\Pi_i - p_i = 0$ does not always hold) when Inequality (4) holds, which makes informed speculation profitable. Better-informed speculators can trade in the correct direction with higher probabilities, so the speculative profit of speculator j is increasing in τ_i^j. However, aggregate informed trading may fully reveal firms' fundamentals to market makers, reducing the profitability of speculative trading. As a result, the speculative profit is decreasing in price informativeness τ_i/ϵ.

What is particularly noteworthy is that, for a given positive τ_i^j, speculator j's profit from trading firm i's stocks is increasing in $K_i v$ (i.e., growth opportunity scaled by capacity). A higher $K_i v$ implies a larger dispersion for firm i's final business payoff, which makes informed speculation on firm i's stocks more profitable for given τ_i^j and τ_i.[12] The

[11] In practice, stock price informativeness is not directly observable, so the empirical literature usually adopts investment-price sensitivity as a proxy. In my model, it is easy to show that the sensitivity of firm i's investment I_i to stock price p_i is increasing in τ_i/ϵ, so investment-price sensitivity is indeed a valid proxy.

[12] If Y_i is fully revealing, then $\Pi_i - p_i = 0$ holds, implying a zero speculative profit. However, if Y_i is non-revealing, then $\Pi_i - p_i$ may be either $K_i v+\iota$ (which happens when $F_i = H$) or $-K_i v-\iota$ (which happens when $F_i = L$). A speculator can earn $K_i v+\iota$ if submitting the correct order in the non-revealing case. Thus informed speculation is more profitable when $K_i v$ is higher.

implication is that a speculator's marginal benefit of acquiring firm i's fundamental information is increasing in the firm's capacity K_i, as is shown in the following equation:

$$\frac{\partial E_{t=1}\left[\pi_i^j\right]}{\partial \tau_i^j} = \underbrace{2\left(1-\frac{2\tau_i}{\epsilon}\right)(K_i v+\iota)}_{\text{marginal information benefit}} - \underbrace{\gamma\tau_i^j}_{\text{marginal information cost}}. \tag{7}$$

At the information acquisition stage, speculator j chooses τ_1^j and τ_2^j to solve the following optimization problem:

$$\max_{\tau_1^j\geq 0,\tau_2^j\geq 0} E_{t=1}\left[\pi_1^j+\pi_2^j\right]$$

$$s.t.\ \tau_1^j+\tau_2^j \leq \overline{\tau}. \tag{8}$$

The following proposition characterizes the result.

Proposition 2. *At $t=1$, all speculators choose the same information precision in equilibrium, that is, $\tau_i^j=\tau_i$. The attention constraint (8) is binding if and only if*

$$\underbrace{\frac{2(K_1 v+\iota)\epsilon}{4(K_1 v+\iota)+\gamma\epsilon}+\frac{2(K_2 v+\iota)\epsilon}{4(K_2 v+\iota)+\gamma\epsilon}}_{\tau_1^*+\tau_2^*} \geq \overline{\tau}. \tag{9}$$

If Inequality (9) does not hold (i.e., attention constraint is not binding), then $\tau_i^j=\tau_i=\tau_i^*$ holds with

$$\tau_i^* \equiv \frac{2(K_i v+\iota)\epsilon}{4(K_i v+\iota)+\gamma\epsilon} < \frac{\epsilon}{2}.$$

If Inequality (9) holds (i.e., attention constraint is binding), then $\tau_i^j=\tau_i=\hat{\tau}_i<\tau_i^*$ holds with

$$\hat{\tau}_1 \equiv \min\left\{\max\left\{\frac{2(K_1-K_2)v\epsilon+\overline{\tau}(4(K_2 v+\iota)+\gamma\epsilon)}{4(K_1+K_2)v+8\iota+2\gamma\epsilon},0\right\},\overline{\tau}\right\}\ \textit{and}\ \hat{\tau}_2\equiv\overline{\tau}-\hat{\tau}_1.$$

Since each individual speculator takes the aggregate precision τ_i as given, all speculators actually face an identical optimization problem at $t=1$ and must make the same information acquisition decision, implying $\tau_i^j=\tau_i$ in equilibrium.

Whether the attention constraint (8) is binding substantially affects the information acquisition trade-off of speculator j. If $\overline{\tau}$ is sufficiently large such that constraint (8) is not binding (which happens when Condition 9 is violated), the choice of τ_1^j is independent of that of τ_2^j. In this case, τ_i^j is simply determined by the first order condition $\partial E_{t=1}\left[\pi_i^j\right]/\partial\tau_i^j = 0$, leading to $\tau_i^j = \tau_i = \tau_i^*$ in equilibrium. Since the two firms are fundamentally unrelated, τ_1^* is unaffected by firm 2's capacity. It is easy to show that τ_i^* is increasing in $K_i v$, because a speculator's marginal benefit of acquiring firm i's information is increasing in $K_i v$ (Equation 7).

If Condition (8) is binding (which happens when $\tau_1^* + \tau_2^* \geq \overline{\tau}$; see Inequality 9), increasing τ_1^j implies a reduction in τ_2^j, so speculator j must decide how to *allocate* her attention between the two firms. In this case, the equilibrium value of τ_i^j – which equals $\hat{\tau}_i$ – depends on both firms' capacities because the speculator must compare the two firms' marginal information values for speculation. The constrained precision $\hat{\tau}_i$ is lower than the unconstrained level τ_i^* because, with a binding attention constraint, increasing τ_i^j incurs an additional cost: acquiring less information about the other firm (i.e., giving up some speculative profits from the other firm's stocks). Since information precision cannot be negative, τ_i^j has an upper bound $\overline{\tau}$ and a lower bound 0. If the marginal value of increasing τ_1^j exceeds that of increasing τ_2^j considerably, speculators will choose the boundary allocation (i.e., $\tau_1^j = \hat{\tau}_1 = \overline{\tau}$ and $\tau_2^j = \hat{\tau}_2 = 0$). If neither firm can take up speculators' entire attention, an interior equilibrium with $\hat{\tau}_i \in (0, \overline{\tau})$ will arise.

Note that $\tau_i^* < \epsilon/2$ always holds, which means Inequality (4) must be endogenously satisfied at the information acquisition stage.[13] The reason is that speculators have incentives to acquire information about a firm (i.e., can make positive profits from informed speculation) only if the firm's stock price is not always fully revealing; such incentives prevent $\tau_i \geq \epsilon/2$ from arising in equilibrium.

The following corollary characterizes the constrained precision $\hat{\tau}_i$ in the interior equilibrium.

Corollary 2. *If $0 < \hat{\tau}_i < \overline{\tau}$ holds, $\hat{\tau}_1$ is increasing in K_1 and decreasing in K_2. A symmetric result holds for $\hat{\tau}_2$.*

In an interior equilibrium, increasing K_1 will raise speculator j's marginal benefit of acquiring firm 1's information (see Equation 7), thereby leading to a higher τ_1^j. An increase in τ_1^j forces the speculator to decrease τ_2^j when the attention constraint is binding.

According to Proposition 2 and Corollary 2, $\tau_1 > \tau_2$ holds if and only if $K_1 > K_2$, no matter whether the attention constraint is binding. The implication is that a firm with

[13]If the attention constraint is not binding, then $\tau_i = \tau_i^* < \epsilon/2$. If the attention constraint is binding, then according to Proposition 2, $\tau_i = \hat{\tau}_i < \tau_i^* < \epsilon/2$ must hold. In sum, $\tau_i < \epsilon/2$ must hold in equilibrium because $\tau_i^* < \epsilon/2$.

a larger business scale will attract more investors to learn about the firm. This result is consistent with Farboodi et al. (2022), who find that investors process more data about large high-growth firms relative to processing data about other firms.[14]

The following corollary shows how information technology (represented by γ) interacts with speculators' attention constraint.

Corollary 3. *If $\overline{\tau} \geq \epsilon$, speculators' attention constraint is never binding. If $\overline{\tau} < \epsilon$, speculators' attention constraint is binding if and only if γ is sufficiently small.*

As γ decreases, the unconstrained precision τ_i^* will increase and gradually approach $\epsilon/2$. Recall that in equilibrium, speculators' endogenous information acquisition always ensures $\tau_i^* < \epsilon/2$ (which means the non-revealing case arises with a positive probability). If $\overline{\tau} \geq \epsilon$, then $\tau_1^* + \tau_2^* < \overline{\tau}$ always holds because $\tau_i^* < \epsilon/2$, implying that speculators' attention constraint is never binding. If $\overline{\tau} < \epsilon$, however, speculators will use up their attention as τ_i^* approaches $\epsilon/2$ (i.e., γ approaches 0).

5 Business-starting stage

For the rest of the paper, I assume $\overline{\tau} < \epsilon$ holds; otherwise, speculators' attention constraint is trivial (Corollary 3). The following lemma characterizes the expected profit of a firm at the business-starting stage $t = 0$.

Lemma 3. *For a given τ_i, the expected profit of firm i at $t = 0$ is given by*

$$E_{t=0}[\Pi_i] = \underbrace{K_i \left(\theta + \frac{\tau_i}{\epsilon} (v - \theta) \right)}_{\textit{expected business return}} - \underbrace{C(K_i)}_{\textit{capacity-building costs}}.$$

Firm i's profit consists of two parts: the expected return of the firm's business and the costs $C(K_i)$ of building up the capacity K_i. Everything else being equal, the expected return of firm i's business is increasing in θ because $\tau_i/\epsilon < 1/2$ holds endogenously (see Proposition 2). The intuition is that θ represents the intrinsic profitability (i.e., ex-ante return) of a firm's business. In addition, the expected business return of firm i is increasing in its stock price informativeness (i.e., increasing in τ_i and decreasing in ϵ). The reason is that p_i provides firm i with useful information about its fundamental, which

[14] The model assumes firms have the same growth opportunity v for simplicity. If I instead let them have different growth opportunities – that is, v_1 for firm 1 and v_2 for firm 2 – then it can be shown that $\tau_1 > \tau_2$ holds if and only if $K_1 v_1 > K_2 v_2$, still consistent with Farboodi et al. (2022).

guides the firm's investment. Higher average information precision τ_i or/and smaller noise trading dispersion ϵ increases the quality of such guidance. This result is consistent with Kempf et al. (2017), who find that a firm with distracted shareholders – which can be viewed as a decrease in τ_i – has abnormally low stock returns and is more likely to make value-destroying acquisition decisions. Similarly, Bennett et al. (2020) document that firms with greater price informativeness have higher productivity.[15]

Information-attracting incentive of building capacity. According to Lemma 3, firm i's marginal benefit of increasing its capacity K_i is given by

$$m_i(K_1,K_2) \equiv \frac{\partial E_{t=0}[\Pi_i + C(K_i)]}{\partial K_i} = \underbrace{\theta + \frac{\tau_i}{\epsilon}(v-\theta)}_{\text{marginal static return } +} + \underbrace{\frac{K_i(v-\theta)}{\epsilon}\frac{\partial \tau_i}{\partial K_i}}_{\text{information attracting } +} > 0, \quad (10)$$

which implies that firm i extends its capacity for two incentives: *chasing the static return* and *attracting information*. The marginal static return of increasing K_i is represented by the first two terms of $m_i(K_1,K_2)$, which means that for a given τ_i, firm i's business itself has a positive marginal return and hence is worth some capacity. The marginal static return is increasing in price informativeness τ_i/ϵ because a more informative stock price can better guide firm i's investment at $t=2$. Even if $\tau_i = 0$, firm i still has the incentive to chase the static return because the ex-ante marginal return of its business is $\theta > 0$.

What is more interesting is firm i's information-attracting incentive, which is reflected by the last term of Equation (10). Proposition 2 can help explain such an incentive: A larger capacity K_i provides speculators with higher benefits of acquiring firm i's information, which increases τ_i and improves the firm's investment efficiency. Hence, firm i is incentivized to increase its capacity K_i in exchange for a higher τ_i.

Firm i's marginal benefit of building up capacity K_i has two possible forms, depending on whether speculators use up their attention:

$$m_i(K_1,K_2) = \begin{cases} m_i^*(K_i) \equiv \theta + \frac{\tau_i^*}{\epsilon}(v-\theta) + \frac{K_i(v-\theta)}{\epsilon}\frac{\partial \tau_i^*}{\partial K_i} & \text{if} \quad \tau_1^j + \tau_2^j < \overline{\tau} \\ \hat{m}_i(K_1,K_2) \equiv \theta + \frac{\hat{\tau}_i}{\epsilon}(v-\theta) + \frac{K_i(v-\theta)}{\epsilon}\frac{\partial \hat{\tau}_i}{\partial K_i} & \text{if} \quad \tau_1^j + \tau_2^j = \overline{\tau} \end{cases}.$$

[15] Specifically, if $F_i = L$ realizes but firm i fails to detect it, then the firm will choose $I_i = K_i$ and finally earn a business payoff of $K_i(\theta - v) - \iota$ (which is lower than $-\iota$ since $\theta - v < 0$). In contrast, if firm i detects $F_i = L$ from its stock price, it will choose $I_i = 0$, and the final business payoff will be $-\iota$. Such a correction (guided by the stock price p_i) will increase the firm's business payoff by $K_i(v-\theta)$ when $F_i = L$. The probability that firm i's bad fundamental occurs together with a negatively fully revealing stock price equals τ_i/ϵ (i.e., $prob(Y_i < 2\tau_i - \epsilon \cap F_i = L) = \tau_i/\epsilon$), so price informativeness improves firm i's expected value by $K_i(v-\theta)\tau_i/\epsilon$.

If $\tau_1^j + \tau_2^j < \overline{\tau}$ (i.e., the attention constraint is not binding), a speculator need not consider how to allocate her attention between the two firms. In this case, $\tau_i^j = \tau_i = \tau_i^*$ holds, so firm i's marginal benefit of increasing K_i is $m_i^*(K_i)$, which is independent of the other firm's capacity. If $\tau_1^j + \tau_2^j = \overline{\tau}$ (i.e., the attention constraint is binding), however, firm i's price informativeness – which equals $\hat{\tau}_i$ now – depends on both K_1 and K_2, so does firm i's marginal benefit (denoted by $\hat{m}_i(K_1, K_2)$ in this case) of increasing K_i.

The following proposition characterizes the symmetric equilibrium at the business-starting stage.

Proposition 3. *At $t = 0$, there exists a λ (with $\lambda \geq 0$) such that a unique symmetric equilibrium exists if and only if $\gamma \geq \lambda$. In the symmetric equilibrium, the two firms choose the same capacity level, denoted by K^e. There exist $\overline{\gamma}$ and $\underline{\gamma}$ (with $\lambda < \underline{\gamma} < \overline{\gamma}$) such that:*

- *If $\gamma > \overline{\gamma}$, then $K^e = K^*$ holds, where K^* is the unique solution of $m_i^*(K^*) = C'(K^*)$. At $t = 1$, the attention constraint is not binding: $\tau_i = \tau_i^*|_{K_i = K^*} < \overline{\tau}/2$.*
- *If $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$, then $K^e = \overline{K}$ holds, where $\overline{K} \equiv \overline{\tau}\gamma\epsilon / (4(\epsilon - \overline{\tau})v) - \iota/v$. At $t = 1$, the attention constraint is binding: $\tau_i = \tau_i^*|_{K_i = \overline{K}} = \overline{\tau}/2$.*
- *If $\lambda \leq \gamma < \underline{\gamma}$, then $K^e = \hat{K} > \overline{K}$ holds, where $\hat{K}$ is the unique solution of $\hat{m}_i\left(\hat{K}, \hat{K}\right) = C'(\hat{K})$. At $t = 1$, the attention constraint is binding: $\tau_i = \hat{\tau}_i|_{K_i = \hat{K}} = \overline{\tau}/2$.*

When information acquisition is very costly (i.e., $\gamma > \overline{\gamma}$), speculators cannot use up their attention, so τ_i equals the unconstrained level τ_i^* (see Proposition 2 to recall the definitions of τ_i^* and $\hat{\tau}_i$). In this case, firm i's marginal benefit of increasing K_i is $m_i^*(K_i)$, so the equilibrium capacity K^e is determined by $m_i^*(K^e) = C'(K^e)$. There is no interaction between the two firms when $\gamma > \overline{\gamma}$.

As γ decreases to $\overline{\gamma}$, speculators will use up their attention. In this case, an increase in K_1 increases τ_1 but decreases τ_2, implying that increasing capacity is a way to *compete for speculators' attention.* Knowing that speculators use up their attention, a firm has two options: (a) controlling its capacity to avoid competition for attention or (b) increasing its capacity to compete for more attention. Proposition 3 shows that when information technology is at an intermediate level (i.e., $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$), firms will choose the former option because triggering competition for attention will suddenly increase the difficulty of attracting speculators' information (i.e., $\partial\tau_i/\partial K_i$ will suddenly jump down when competition for attention is triggered), which discontinuously lowers firms' information-attracting incentives.[16] To avoid competition for attention, firms control their capacities at $\overline{K}$, which exactly induces speculators to use up attention (i.e., with $K_i = \overline{K}$, the unconstrained information precision τ_i^* exactly reaches $\overline{\tau}/2$).[17] As γ further decreases, the competition-avoiding capacity level $\overline{K}$ will decrease because then a smaller capacity can induce speculators to use up attention.

When γ is sufficiently low (i.e., $\lambda \leq \gamma < \underline{\gamma}$), firms will prefer increasing their capacities to compete for speculators' attention rather than avoiding the competition. The reason is that, with sufficiently cheap information, speculators' learning preference is very sensitive to firms' capacities (i.e., $\partial \hat{\tau}_i / \partial K_i$ is high when γ is small enough). As a result, firm i's information-attracting incentive of increasing K_i becomes sufficiently strong when $\gamma < \underline{\gamma}$, inducing the firm to increase K_i above $\overline{K}$ (i.e., to compete for attention). Since such competition cannot break speculators' attention constraint, τ_i is fixed at $\overline{\tau}/2$ in equilibrium.

When $\gamma < \lambda$, a symmetric equilibrium no longer exists, of which the intuition will be explained in Section 6. Figure 3 illustrates the three types of equilibria and their main properties.

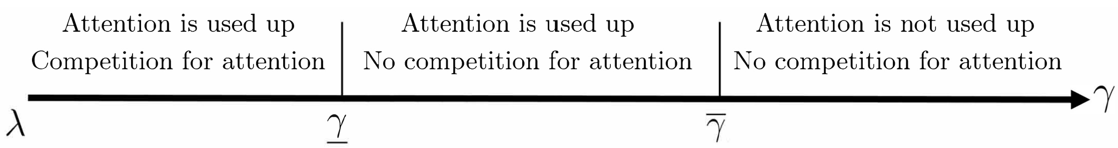

Figure 3: Information Technology and the Type of Equilibrium.

The following corollary characterizes firms' capacity level K^e in the symmetric equilibrium.

Corollary 4. *If $\gamma > \overline{\gamma}$, firm i's equilibrium capacity K^e is decreasing in γ; if $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$, K^e is increasing in γ; if $\lambda \leq \gamma < \underline{\gamma}$, K^e is decreasing in γ.*

[16] When the attention constraint is binding, increasing τ_i^j will incur an additional cost for speculator j: acquiring less information about the other firm. Therefore, the speculator will suddenly become more "reluctant" to increase τ_i^j if an increase in K_i triggers competition for attention. From a firm's perspective, this means the difficulty of attracting speculators' information will discontinuously go up when competition for attention is triggered.

[17] If both firms control their capacities at $\overline{K}$ (i.e., if $\tau_i^* = \overline{\tau}/2$ holds without triggering competition for attention), firm i's marginal benefit of increasing K_i is $m_i^*\left(\overline{K}\right) = \theta + \frac{(v-\theta)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{2v(\epsilon-\overline{\tau})^2}{\gamma\epsilon^2}\right)$. However, if firm i triggers competition for attention by increasing K_i marginally from $\overline{K}$, the firm's marginal benefit of increasing K_i will discontinuously drop to $\hat{m}_i\left(\overline{K}, \overline{K}\right) = \theta + \frac{(v-\theta)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{v(\epsilon-\overline{\tau})^2}{\gamma\epsilon^2}\right)$.

When information is costly (i.e., $\gamma > \overline{\gamma}$), speculators do not use up their attention. In this case, K^e – which equals K^* – is decreasing in γ for two reasons: (a) A lower γ (i.e., lowering information costs) induces speculators to acquire more information (i.e., increase τ_i), which increases a firm's marginal static return of extending capacities (see Equation 10); (b) a lower γ makes it easier for firms to attract information through capacity-building, thereby increasing firms' information-attracting incentives. When information technology is at an intermediate level (i.e., $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$), firms use up speculators' attention while avoiding competition for attention. The resulting equilibrium capacity is $K^e = \overline{K}$, which is increasing in γ because a smaller K^e can induce speculators to use up attention as information becomes cheaper. When information is cheap (i.e., $\lambda \leq \gamma < \underline{\gamma}$), firms will compete for attention by increasing their capacities. In this case, K^e $(= \hat{K})$ is decreasing in γ because lowering information costs makes speculators' learning preference more sensitive to firms' capacities, thereby increasing firms' information-attracting incentives.[18] Figure 4 (the solid curve) illustrates K^e.

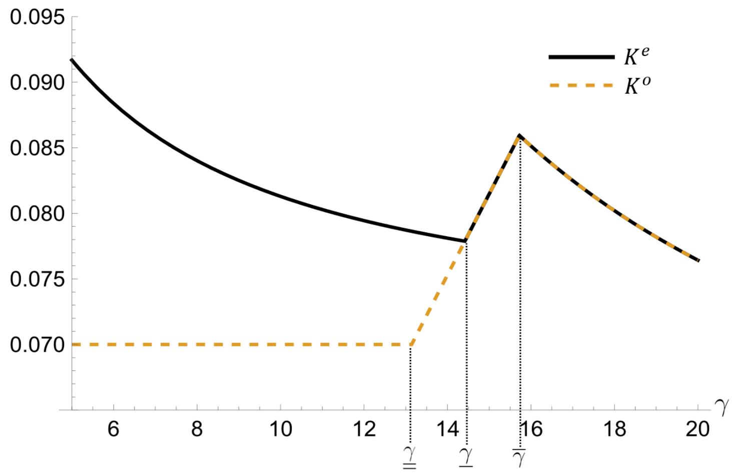

Figure 4: Equilibrium Capacity K^e and Efficient Capacity K^o. This figure plots how information technology (inversely measured by γ) affects firms' equilibrium capacity level K^e (solid; defined in Proposition 3) and the efficient symmetric capacity K^o (dashed; to be defined in Definition 2). The capacity-building cost function is $C(K) \equiv cK^2/2$. The parameter values are $\overline{\tau} = 0.02$, $v = 0.9$, $\epsilon = 0.2$, $c = 2$, $\theta = 0.1$, $\iota = 0.01$.

Note that with competition for attention (i.e., $\lambda \leq \gamma < \underline{\gamma}$), reducing γ will increase a firm's ex-ante expected investment $E_{t=0}[I_i]$ due to the increase in K^e; however, the firm's

[18] In the equilibrium with competition for attention (i.e., $\lambda \leq \gamma < \underline{\gamma}$), it can be shown that $\left.\frac{\partial \hat{\tau}_i}{\partial K_i}\right|_{K_1=K_2=K^e} = \frac{v(\epsilon-\overline{\tau})}{4(K^e v+\iota)+\gamma\epsilon} > 0$, which is decreasing in γ for a given K^e. Hence, a lower γ strengthens firms' information-attracting incentives. In contrast, the marginal static return of a firm's capacity is fixed at $\theta + \frac{\overline{\tau}/2}{\epsilon}(v-\theta)$ and hence unaffected by γ when $\lambda \leq \gamma < \underline{\gamma}$.

stock price informativeness is fixed at $\overline{\tau}/(2\epsilon)$. This result is consistent with Goldstein et al. (2022b), who find that improvement in the availability of information can increase firms' investment without significantly increasing their price informativeness.

Self-reinforcement of the information-attracting incentive. According to Equation (10), the magnitude of firm i's information-attracting incentive is:

$$\text{Information-attracting incentive} = \underbrace{K_i\,(v-\theta)}_{\text{amplifier}} \times \underbrace{\frac{\partial\,(\tau_i/\epsilon)}{\partial K_i}}_{\text{incentive source}} > 0. \tag{11}$$

Such an incentive exists because $\partial\,(\tau_i/\epsilon)\,/\partial K_i > 0$; that is, firm i's price informativeness is increasing in its capacity. Once the incentive exists, its magnitude will be amplified by a coefficient $K_i\,(v-\theta)$. As $K_i\,(v-\theta)$ increases, firm i will suffer a larger loss if it fails to detect the bad fundamental. Hence, improving its price informativeness becomes more important, amplifying the firm's information-attracting incentive.

The amplifier of Equation (11) generates a *self-reinforcement* property for firms' information-attracting incentives: If an exogenous parameter change (e.g., a decrease in γ when $\lambda \leq \gamma < \underline{\gamma}$) increases firm i's information-attracting incentive, the firm will choose a higher K_i (Corollary 4); the increase in K_i enlarges the amplifier $K_i\,(v-\theta)$, reinforcing the increase in firm i's information-attracting incentive. With competition for attention, the self-reinforcement effect will drag firms deeper into the competition as IT improves.

6 Information technology and real efficiency

This section analyzes the relation between information technology (inversely measured by γ) and two types of real efficiency: (a) corporate efficiency and (b) social welfare.

Corporate efficiency and information-attracting externality. This type of efficiency is measured by the sum of both firms' ex-ante profits:

$$\text{Corporate efficiency } = E_{t=0}\left[\Pi_1 + \Pi_2\right].$$

Since my model focuses on the symmetric equilibrium, corporate efficiency can also be represented by firm i's ex-ante profit $E_{t=0}[\Pi_i]$. The following proposition shows how corporate efficiency is affected by information technology.

Proposition 4. *In the symmetric equilibrium, firm i's ex-ante expected profit $E_{t=0}[\Pi_i]$ is decreasing in γ when $\gamma \geq \underline{\gamma}$, while it is increasing in γ when $\lambda \leq \gamma < \underline{\gamma}$.*

When $\gamma > \overline{\gamma}$, speculators do not use up their attention. In this case, a lower γ increases corporate efficiency for two reasons: (a) Speculators' information acquisition incentives become higher; (b) attracting information through capacity-building becomes easier for firms. Both reasons make stock prices more informative (i.e., increase τ_i) and improve firms' profits. When $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$, firms use up speculators' attention without incurring competition for attention, so their capacities are controlled at $\overline{K}$. In this case, a lower γ increases corporate efficiency because firms can sustain their price informativeness using a lower capacity level (i.e., $\overline{K}$ decreases but $\tau_i = \tau_i^* = \overline{\tau}/2$ still holds), implying that fewer capacities are built for information-attracting. In sum, corporate efficiency is decreasing in γ when $\gamma \geq \underline{\gamma}$, no matter whether speculators use up their attention (see the solid curve of Figure 5).

When $\lambda \leq \gamma < \underline{\gamma}$, firms compete for attention through capacity-building. In this case, an *information-attracting externality* arises: Increasing K_1 (resp. K_2) will induce speculators to decrease τ_2 (resp. τ_1), but firm 1 (resp. firm 2) does not internalize this effect. As γ decreases, speculators' learning preference becomes more sensitive to firms' capacities, increasing firms' information-attracting incentives. However, as both firms increase their capacities, neither firm can improve its price informativeness in equilibrium (i.e., τ_i still equals $\overline{\tau}/2$) because of the information-attracting externality. Hence, both firms waste more capacities for information-attracting without injecting more information into their prices, which hurts corporate efficiency (see the solid curve of Figure 5).

To better understand how the information-attracting externality distorts firms' capacity decisions, I will compare firms' symmetric equilibrium capacity at $t = 0$ (i.e., $K_i = K^e$) with the efficient symmetric capacity, which is defined as follows:

Definition 2. *The efficient symmetric capacity K^o maximizes the sum of the two firms' ex-ante expected profits (i.e., $E_{t=0}[\Pi_1 + \Pi_2]$) subject to the following conditions:*

- *Symmetry: $K_1 = K_2 = K^o$.*
- *Given $K_1 = K_2 = K^o$, all market participants choose their equilibrium behavior at $t = 1$ and 2.*

The following lemma characterizes K^o.

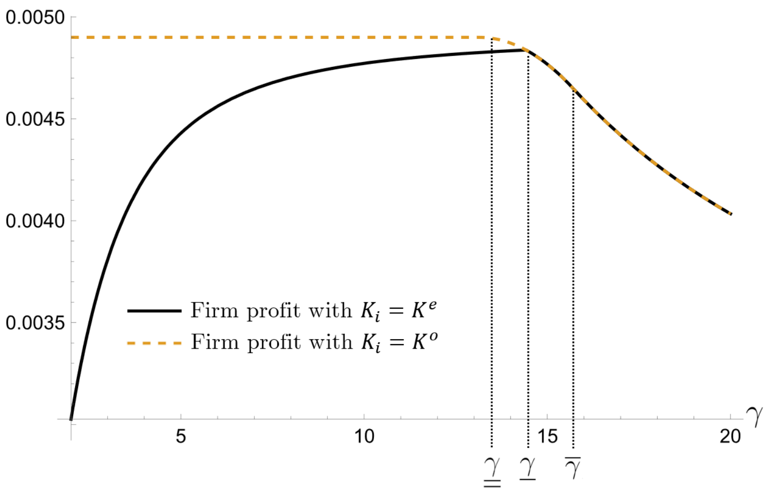

Figure 5: Information Technology and Firm Profit. This figure plots how information technology (inversely measured by γ) affects firm i's profit $E_{t=0}[\Pi_i]$. The solid (resp. dashed) curve describes the case in which firm i's capacity takes the symmetric equilibrium level K^e (resp. efficient level K^o). The capacity-building cost function is $C(K) = cK^2/2$. The parameter values are $\overline{\tau} = 0.02$, $v = 0.9$, $\epsilon = 0.2$, $c = 2$, $\theta = 0.1$, $\iota = 0.01$.

Lemma 4. *There exists $\underline{\underline{\gamma}}$ ($< \underline{\gamma}$) such that*

$$K^o = \begin{cases} K^* & \text{if} \quad \gamma > \overline{\gamma} \\ \overline{K} & \text{if} \quad \underline{\underline{\gamma}} \le \gamma \le \overline{\gamma} \\ \underline{\underline{K}} & \text{if} \quad \gamma < \underline{\underline{\gamma}} \end{cases},$$

where K^* and $\overline{K}$ are given in Proposition 3; $\underline{\underline{K}}$ is the unique solution of

$$\underbrace{\theta + \frac{\overline{\tau}/2}{\epsilon}(v - \theta)}_{\textit{marginal static return}} = C'\left(\underline{\underline{K}}\right). \tag{12}$$

From the perspective of corporate efficiency, the information-attracting externality should be internalized to avoid the "waste" of capacities. Therefore, K^o should ensure that the zero-sum competition for attention does not arise. If $\gamma > \overline{\gamma}$, speculators' attention is abundant, and there is no interaction between firms in equilibrium, so K^o coincides with K^e ($= K^*$). If $\underline{\gamma} \le \gamma \le \overline{\gamma}$, firms control their capacities at $\overline{K}$ to use up speculators' attention without incurring competition for attention, so again K^e ($= \overline{K}$) coincides with K^o.

If $\lambda \le \gamma < \underline{\gamma}$, competition for attention arises in equilibrium, which implies $K^o <$

$K^e = \hat{K}$ since the choice of K^o should avoid such competition. When $\underline{\underline{\gamma}} \leq \gamma < \underline{\gamma}$, the efficient capacity K^o equals $\overline{K}$, which uses up speculators' attention without incurring competition for attention. When γ is very low (i.e., $\gamma < \underline{\underline{\gamma}}$), information is sufficiently cheap such that speculators will use up their attention even if firms do not intentionally use capacities to attract information. In this case, no capacity should be built for information-attracting, so K^o (which equals $\underline{\underline{K}}$ now) is simply determined by balancing the marginal static return and the marginal capacity-building cost, implying Equation (12).[19] The following corollary summarizes the comparison between K^o and K^e (see Figure 4 for an illustration).

Corollary 5. *If $\gamma \geq \underline{\gamma}$ (resp. $\lambda \leq \gamma < \underline{\gamma}$), then $K^e = K^o$ (resp. $K^e > K^o$) holds.*

The dashed curve of Figure 5 illustrates how information technology affects a firm's profit when both firms adopt the efficient capacity K^o. In this case, IT improvements never reduce corporate efficiency because the zero-sum competition for attention is avoided. Note from the figure that when $\gamma < \underline{\underline{\gamma}}$, firm profit with efficient capacity (i.e., $K_i = K^o$) is unaffected by γ. This follows because, with $\gamma < \underline{\underline{\gamma}}$, the efficient capacity K^o $(= \underline{\underline{K}})$ no longer varies with γ. Recall that $\underline{\underline{K}}$ matches the marginal capacity-building cost with a firm's marginal static return (see Equation 12), the latter of which is unaffected by information technology when speculators' attention is used up. As a result, the dashed curve of Figure 5 becomes horizontal when $\gamma < \underline{\underline{\gamma}}$.

What happens when $\gamma < \lambda$? In this case, the symmetric equilibrium with $K^e = \hat{K}$ cannot be sustained because a firm would like to "quit the competition" given that the other firm's capacity is $\hat{K}$. Taking firm 1 as an example, quitting the competition means choosing a very low K_1 and accepting $\tau_1 = 0$. If quitting, firm 1 no longer learns from its stock price; instead, it profits only from the ex-ante investment return θ. In sum, $\gamma < \lambda$ implies that competition for attention would be so harmful to corporate efficiency that a firm prefers to give up learning from stocks.

Sometimes a symmetric equilibrium (described in Proposition 3) always exists, no matter how small γ is. In this case, λ is set to zero, so $\gamma < \lambda$ never happens. A sufficient condition for $\lambda = 0$ is $\overline{\tau} \geq \epsilon/2$, meaning that speculators' attention capacity is sufficiently large to make one firm's stocks always fully revealing. Since fully revealing a firm's fundamental will eliminate the profitability of speculation on the firm, speculators

[19] In the case $\gamma < \underline{\underline{\gamma}}$, although the determination of $\underline{\underline{K}}$ does not incorporate firms' information-attracting incentives, $K_i = \underline{\underline{K}}$ still induces speculators to use up attention because information is sufficiently cheap. Thus, the marginal static return equals $\theta + \frac{\overline{\tau}/2}{\epsilon}(v - \theta)$.

must allocate positive attention to both firms. As a result, a firm will never quit the competition (i.e., give up learning from stocks).[20]

Social welfare. This type of efficiency is measured by the ex-ante profits of all market participants. Hence, the ex-ante social welfare (denoted by W) is given by :

$$W = E_{t=0}[\Pi_1 + \Pi_2] - \int_0^1 \frac{\gamma}{2}\left(\tau_1^j\right)^2 dj - \int_0^1 \frac{\gamma}{2}\left(\tau_2^j\right)^2 dj. \tag{13}$$

Compared with corporate efficiency, social welfare considers speculators' information acquisition costs. The trading profits of players in the stock market are not reflected in Equation (13) because the aggregate expected trading profits (excluding information acquisition costs) of speculators, market makers, and noise traders always equal 0. The following proposition shows how social welfare is affected by information technology.

Numerical Result 1. *Let $C(K) \equiv cK^2/2$. Social welfare W in the symmetric equilibrium is increasing in γ when $\overline{\tau}$ is sufficiently small and γ is sufficiently close to λ.*

Social welfare considers speculators' information acquisition costs, so a decrease in γ will generate a *cost-saving effect* (i.e., information becomes cheaper). Due to the attention limit of speculators, τ_i^j is at most equal to $\overline{\tau}/2$ in the symmetric equilibrium. When $\overline{\tau}$ is very small, a decrease in γ can save only a few information costs for speculators, implying that the cost-saving effect is weak.

However, a small $\overline{\tau}$ does not mean that firms' information-attracting incentives are weak. When γ is sufficiently small, competition for attention will arise; in this case, a decrease in γ strengthens firms' information-attracting incentives (i.e., intensify competition for attention), reducing corporate efficiency (see Proposition 4). In addition, as γ decreases, the corporate efficiency reduction will be accelerated by the self-reinforcement of firms' information-attracting incentives (recall the amplifier of Equation 11). When $\overline{\tau}$ is sufficiently small and γ is sufficiently close to λ, the speed of corporate efficiency reduction will dominate the (weak) cost-saving effect, so IT progress will reduce social welfare (see Panel A of Figure 6 for an illustration). When $\overline{\tau}$ is not small, however, the cost-saving effect of reducing γ can be the dominant effect, thereby improving social welfare (see Panel B of Figure 6).

The following result shows that increasing firms' growth opportunities may also hurt corporate efficiency and social welfare when competition for attention arises.

[20] Quitting the competition is a firm's boundary strategy. If firm 1 quits, it must let $\tau_1 = 0$. However, speculators will never put all attention on only one firm when $\overline{\tau} \geq \epsilon/2$. This means speculators' attention constraint will not be binding when τ_1 is very small, preventing firm 1 from deviating to $\tau_1 = 0$.

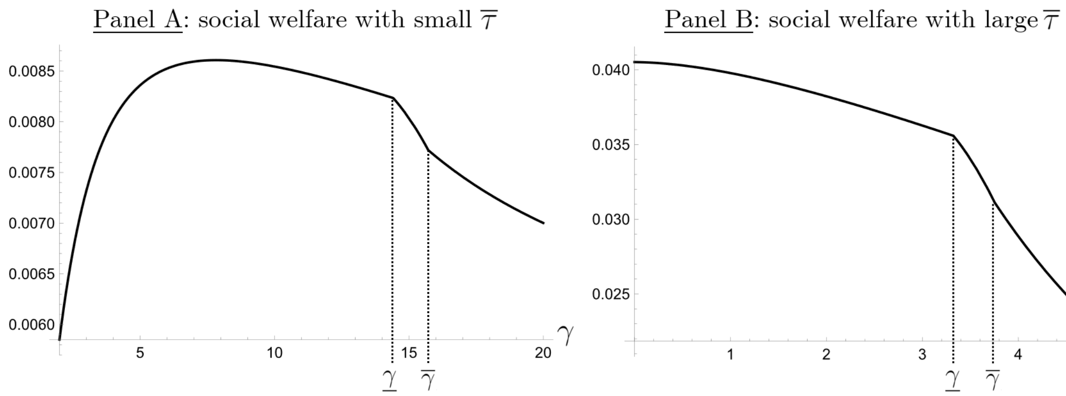

Figure 6: Information Technology and Social Welfare. This figure plots how information technology (inversely measured by γ) affects social welfare. The capacity-building cost function is $C(K) = cK^2/2$. The parameter values are: $v = 0.9$, $\epsilon = 0.2$, $c = 2$, $\theta = 0.1$ and $\iota = 0.01$ for both panels; $\overline{\tau} = 0.02$ for Panel A and $\overline{\tau} = 0.1$ for Panel B.

Numerical Result 2. *Let $C(K) \equiv cK^2/2$ and $\lambda \leq \gamma < \underline{\gamma}$. Firm i's expected profit $E_{t=0}[\Pi_i]$ and social welfare W in the symmetric equilibrium are decreasing in v when v is sufficiently large and $\overline{\tau}$ is sufficiently small.*

With competition for attention, increasing v has two effects: (a) The marginal static return of increasing K_i – which equals $\theta + \overline{\tau}(v - \theta) / (2\epsilon)$ – will increase because firm i can make more profits or avoid larger losses following the guidance of p_i; (b) firms' information-attracting incentives will be stronger (i.e., competition for attention will be more intense, generating a more significant waste of capacities) because a higher v increases the importance of learning from prices. The former effect – which is substantial when $\overline{\tau}$ is high – tends to improve corporate efficiency and social welfare, while the latter tends to hurt them and is strong when v is large.[21] A numerical study finds that the latter effect dominates when v is large and $\overline{\tau}$ is small (see Panel A of Figure 7 for an illustration). When $\overline{\tau}$ is large, however, an increase in v will significantly improve the marginal static return of increasing K_i, which dominates the increasing waste of capacities and thus improves corporate efficiency and social welfare (Panel B of Figure 7).

[21]The self-reinforcement of firms' information-attracting incentives also works here. As v increases, firm i will increase K_i, which implies a larger amplifier of Equation 11. The increase in the amplifier reinforces firms' incentives to compete for attention, accelerating the reduction in corporate efficiency.

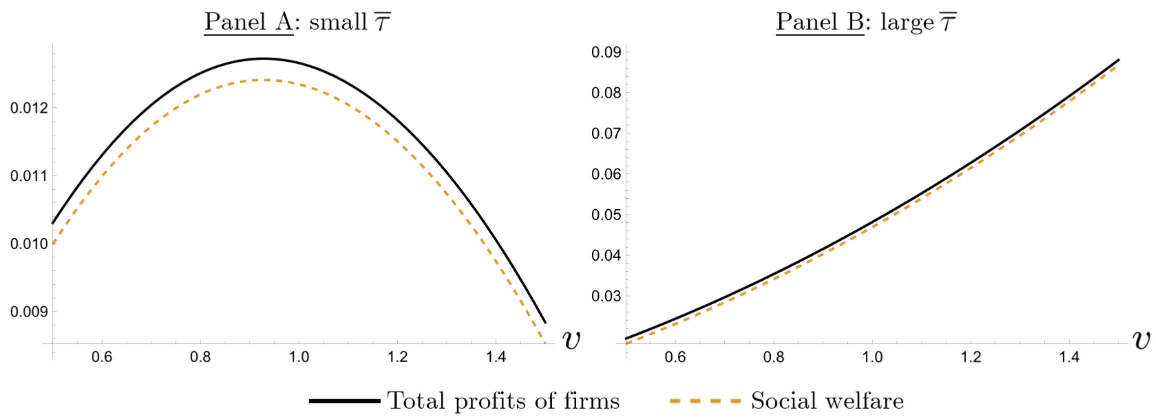

Figure 7: The Effects of Growth Opportunity When $\gamma < \underline{\gamma}$. This figure plots how v affects corporate efficiency (solid curve) and social welfare (dashed curve) in the case with competition for attention (i.e., $\gamma < \underline{\gamma}$). The capacity-building cost function is $C(K) = cK^2/2$. The parameter values are: $\gamma = 0.5$, $\epsilon = 0.2$, $c = 2$, $\theta = 0.1$ and $\iota = 0.01$ for both panels; $\overline{\tau} = 0.05$ for Panel A and $\overline{\tau} = 0.1$ for Panel B.

7 Extensions

In this section, I provide two extensions of the baseline model. First, I analyze the strategic relation of the two firms' capacities when there is competition for attention. To uncover the implications of the strategic relationship, I let firms learn from stocks and make investment decisions also at the business-starting stage $t = 0$. Second, I relax speculators' hard attention constraints by allowing them to acquire attention endogenously.

7.1 Endogenous strategic substitutability and its implications

Before extending the baseline model, I provide the following proposition to characterize the strategic relation of the two firms' capacities when speculators' attention constraint is binding (i.e., when Condition 9 holds).

Proposition 5. *Let speculators' attention constraint be binding (i.e., Condition 9 hold) and $\hat{\tau}_i \in (0, \overline{\tau})$. The two firms' capacity decisions at $t = 0$ are strategic substitutes:*

$$\frac{\partial^2 E_{t=0}[\Pi_1]}{\partial K_1 \partial K_2} = \underbrace{\frac{\partial \left(\theta + \hat{\tau}_1 \left(v - \theta\right)/\epsilon\right)}{\partial K_2}}_{\textit{marginal static return } -} + \underbrace{\frac{K_1 \left(v - \theta\right)}{\epsilon} \frac{\partial^2 \hat{\tau}_1}{\partial K_1 \partial K_2}}_{\textit{information attracting } +/-} < 0.$$

When speculators' attention is used up, the two firms' capacities become strategic substitutes. The reason is that a higher K_2 reduces firm 1's price informativeness, thereby decreasing its marginal static return of extending capacities. Increasing K_2 has an ambiguous effect on firm 1's information-attracting incentive.[22] However, no matter how firm 1's information-attracting incentive is affected, the decrease in its marginal static return always dominates. Hence, firm 1 will have less incentive to increase K_1if K_2 becomes larger, implying strategic substitutability.

Model extension. Previous sections focus on the symmetric equilibrium at $t = 0$, in which the implications of the strategic substitutability displayed in Proposition 5 are unclear. Hence, this section extends the baseline model by adding the following assumptions:

- At $t = 0$, firm i must choose its period-0 investment – denoted by I_{0i} – together with its capacity K_i. The period-0 investment I_{0i} cannot exceed K_i.
- At $t = 0.5$ (i.e., between $t = 0$ and $t = 1$), firm i's period-0 investment generates the following observable payoff:

$$\underset{\text{with } I_{0i}\in[0,K_i]}{R_{0i}(I_{0i}, F_{0i})} \equiv \begin{cases} I_{0i}\,(\theta + v) + \iota & \text{if} \quad F_{0i} = H \\ I_{0i}\,(\theta - v) - \iota & \text{if} \quad F_{0i} = L \end{cases}, \tag{14}$$

  where F_{0i} is firm i's period-0 fundamental, which has the prior probability distribution: $prob.\,(F_{0i} = H) = prob.\,(F_{0i} = L) = 1/2$. Hence, in this section, firm i's business will pay off twice: $R_{0i}(I_{0i}, F_{0i})$ at $t = 0.5$ and $R_i(I_i, F_i)$ at $t = 3$. Firm i's final value (i.e., stock payoff) becomes:

$$\Pi_i \equiv R_{0i}(I_{0i}, F_{0i}) + R_i(I_i, F_i) - C\,(K_i)\,.$$

  I assume that F_{01}, F_{02}, F_1, and F_2 are mutually independent.
- At $t = 0^-$ (i.e., before $t = 0$), market makers observe F_{01} and F_{02} and set price p_{0i} for firm i's stock.[23] The pricing rule is $p_{0i} = E[\Pi_i|\, F_{01}, F_{02}]$. Market makers' belief on the two firms is fair; that is, $p_{01} = p_{02}$ if $F_{01} = F_{02}$.

[22] If $K_1 > K_2$ (resp. $K_1 < K_2$), increasing K_2 will strengthen (resp., weaken) firm 1's information-attracting incentive.

[23] The results in this section will not qualitatively change if I instead assume that: (a) speculators acquire information and then submit orders together with noise traders at $t = 0^-$; (b) market makers observe the period-0^- aggregate order flows and then set p_{0i} for firm i. To convey the main ideas without making the extended model very heavy, I let market makers observe F_{01} and F_{02}.

- The inequality $\overline{\tau} \geq \epsilon/2$ holds and $K_i C''(K_i)/C'(K_i)$ is sufficiently large (i.e., the function $C(K_i)$ is sufficiently convex), ensuring the existence and uniqueness of an interior equilibrium.

All the other set-ups in Section 2 still apply. With the new assumptions above, firm i's capacity K_i affects two rounds of business payoffs – $R_{0i}(I_{0i}, F_{0i})$ at $t = 0.5$ and $R_i(I_i, F_i)$ at $t = 2$. Firms can learn from p_{0i} before making decisions at $t = 0$. Since firms may have different period-0 fundamentals, they do not necessarily make the same real decisions at $t = 0$.[24] The following proposition characterizes the equilibrium.

Proposition 6. *Let γ be sufficiently small. There exists a unique equilibrium, in which $\tau_1 + \tau_2 = \overline{\tau}$ holds and firms compete for speculators' attention. Firms can perfectly infer F_{01} and F_{02} from p_{01} and p_{02}. Firm i chooses $I_{0i} = K_i 1_{\{F_{0i}=H\}}$, with $1_{\{\cdot\}}$ being an indicator function that equals 1 (resp. 0) if the condition in $\{\cdot\}$ holds (resp. does not hold).*

Let $K_i(F_{0i}, F_{0j})$ denote firm i's capacity when the firm's period-0 fundamental is F_{0i}, while the other firm's is F_{0j}. The following relation holds:

$$K_i(H, L) > K_i(H, H) > K_i(L, L) > K_i(L, H).$$

Market makers know that different combinations of F_{01} and F_{02} imply different firm payoffs in the future. As a result, their pricing will reflect the combinations of F_{01} and F_{02}. Knowing this, firms can infer F_{01} and F_{02} from p_{01} and p_{02}. Obviously, firm i will choose $I_{0i} = K_i$ (resp. $I_{0i} = 0$) if $F_{0i} = H$ (resp. $F_{0i} = L$) is inferred.

Given F_{0j}, $K_i(H, F_{0j}) > K_i(L, F_{0j})$ holds because firm i wants to increase I_{0i} to raise its first-round payoff $R_{0i}(I_{0i}, F_{0i})$ when $F_{0i} = H$, which calls for a higher K_i. When $F_{01} = F_{02}$ holds, a symmetric equilibrium with $K_1 = K_2$ will arise (as in Section 5). In this case, $K_i(H, H) > K_i(L, L)$ because both firms' marginal benefits of extending capacities are higher when $F_{01} = F_{02} = H$ than when $F_{01} = F_{02} = L$.

What is more interesting is that $K_i(F_{0i}, H) < K_i(F_{0i}, L)$ for a given F_{0i}, meaning that one firm's "good" period-0 fundamental discourages the other firm's capacity-building. The reason is that, with competition for attention, K_1 and K_2 are strategic substitutes (see Proposition 5).[25] If $F_{01} = H$, firm 2 will believe that firm 1's incentive to increase

[24] After $t = 0.5$, $R_{0i}(I_{0i}, F_{0i})$ becomes observable and hence is simply a constant term added to firm i's final value. Therefore, the new assumptions will not qualitatively change the equilibrium at $t = 1$ and 2.

[25] Proposition 5 is robust with the new assumptions in the section. The strategic substitutability results from speculators' information acquisition preferences at $t = 1$, which is unaffected by those new assumptions because $R_{0i}(I_{0i}, F_{0i})$ has been determined and observable after $t = 0.5$.

K_1 is stronger than when $F_{01} = L$, which – through the strategic substitutability effect – reduces firm 2's incentive to increase K_2. In such an equilibrium, stock prices p_{01} and p_{02} are not only an information source but also credible commitments about firms' capacity-building incentives.

Corollary 6. *Let γ be sufficiently small and $p_{0i}\,(F_{0i}, F_{0j})$ denote firm i's stock price at $t = 0^-$ when the firm's period-0 fundamental is F_{0i}, while the other firm's is F_{0j}. The following relations hold:*

$$\begin{cases} p_{0i}\,(H, F_{0j}) > p_{0i}\,(L, F_{0j}) & \textit{for a given } F_{0j} \\ p_{0i}\,(F_{0i}, L) > p_{0i}\,(F_{0i}, H) & \textit{for a given } F_{0i} \end{cases}.$$

For a given F_{0j}, $p_{0i}\,(H, F_{0j}) > p_{0i}\,(L, F_{0j})$ holds for three reasons. First, there is a *direct reason*: Firm i's first-round business payoff $R_{0i}(I_{0i}, F_{0i})$ is higher when $F_{0i} = H$ than when $F_{0i} = L$. Second, there is an *information-attracting effect*: Everything else being equal, a higher K_i increases τ_i, improving firm i's investment efficiency at $t = 2$. Finally, there is a *strategic substitutability effect*: $F_{0i} = H$ is a commitment that firm i has a strong capacity-building incentive, which reduces the other firm's capacity-building incentive and thereby reinforces the increase in τ_i.

For a given F_{0i}, $p_{0i}\,(F_{0i}, L) > p_{0i}\,(F_{0i}, H)$ holds because of the information-attracting and strategic substitutability effects. Information-attracting effect: As F_{0j} changes from L to H, firm i's period-2 price informativeness τ_i/ϵ will be lower because the other firm's capacity becomes higher. Strategic substitutability effect: Seeing $F_{0j} = H$ (i.e., the other firm's commitment to build up a high capacity), firm i's capacity-building incentive becomes smaller, reinforcing the decrease in τ_i. Both effects reduce firm i's expected value.

7.2 Endogenous attention

In this section, I relax speculators' hard attention constraint by assuming that at $t = 1$ (information acquisition stage), speculator j chooses not only information precision τ_i^j ($i = 1, 2$) but also her maximum attention, denoted by $\overline{\tau}^j$. Therefore, the attention constraint of the speculator is $\tau_1^j + \tau_2^j \leq \overline{\tau}^j$. Both private information and attention are costly to acquire. Specifically, at $t = 1$, the total information and attention costs incurred by speculator j is

$$\underbrace{\frac{\gamma}{2}\left(\tau_1^j\right)^2 + \frac{\gamma}{2}\left(\tau_2^j\right)^2}_{\text{information acquisition costs}} + \underbrace{\frac{\alpha}{2}\left(\overline{\tau}^j\right)^2}_{\text{attention expansion costs}}.$$

Since attention is costly, it is optimal for a speculator to use up all her attention, which means $\tau_1^j + \tau_2^j = \overline{\tau}^j$ must hold. All the other set-ups in Section 2 still apply here. New assumptions in Section 7.1 are not included.

Letting $\tilde{\tau}$ denote the average attention limit of all speculators (i.e., $\tilde{\tau} \equiv \int_0^1 \overline{\tau}^j dj$), the following proposition characterizes the effects of IT improvements.

Proposition 7. *There exists a λ (with $\lambda \geq 0$) such that a unique symmetric equilibrium exists when $\gamma \geq \lambda$. In the symmetric equilibrium, the two firms choose the same capacity level (denoted by K^e) at $t = 0$, and speculator j chooses $\tau_i^j = \tau_i = \tilde{\tau}/2$ at $t = 1$. Both K^e and $\tilde{\tau}$ are decreasing in γ and α.*

As γ decreases, information acquisition becomes less costly, so speculators have higher incentives to acquire information about both firms. Such incentives induce speculators to extend their attention and thereby acquire more precise signals (i.e., τ_i and $\tilde{\tau}$ increase). This result is consistent with Zhu (2019), who documents that improving information availability (i.e., decreasing information acquisition cost) increases firms' stock price informativeness. A decrease in α has a similar effect: When attention extension is less costly, a speculator (e.g., speculator j) will have the incentive to increase $\overline{\tau}^j$, which implies higher $\tilde{\tau}$ and τ_i. Expecting that τ_i will be higher (because of a decrease in γ or/and α), the marginal static return of increasing K_i becomes higher for firm i because it can make investment decisions more efficiently at $t = 2$. As a result, equilibrium firm capacity level K^e is decreasing in γ and α.[26]

Furthermore, as K^e increases (because of a decrease in γ or/and α), informed trading can bring larger speculative profits to speculators (see Lemma 2), which reinforces speculators' incentives to increase $\tilde{\tau}$ and τ_i. Since my model interprets speculators' attention constraints as the limited memory and information processing capacity of human resources, Proposition 7 predicts that the improvement of information technology (i.e., the decrease in γ) will induce institutional investors to increase their stock market analysts' quality and quantity, which can be viewed as an increase in $\tilde{\tau}$.

Although speculators no longer face hard attention constraints, the following proposition shows that competition for attention and information-attracting externality still exist.

[26] A decrease in γ or α also affects firms' information-attracting incentives. A numerical study finds that, in general, firms' information-attracting incentives may be weakened or strengthened as γ or α decreases. However, firms' higher incentives of chasing static returns (due to a higher τ_i) always dominate the variation of firms' information-attracting incentives. Thus K^e will increase if γ or α decreases.

Proposition 8. *If $\alpha > 0$ (resp. $\alpha = 0$), then $K^e > K^o$ (resp. $K^e = K^o$) holds in the symmetric equilibrium.*

When attention is costly to acquire (i.e., $\alpha > 0$), a speculator must decide how to allocate her attention between the two firms, giving rise to a substitutive relation between τ_1^j and τ_2^j. The substitutive relation implies the existence of an information-attracting externality. Firm i, however, will not internalize this externality, so its information-attracting motive must be excessively high from the perspective of corporate efficiency. As a result, a firm's equilibrium capacity level K^e is higher than the efficient symmetric level K^o (see Definition 2) when $\alpha > 0$. In contrast, when $\alpha = 0$ holds, τ_1^j and τ_2^j have no substitutive relation for speculator j, so the information-attracting externality does not exist, implying $K^e = K^o$.

Proposition 8 implies that firms' competition for speculators' attention still exists when $\alpha > 0$. Therefore, decreasing γ can increase firms' capacities through two channels: First, stock prices become more informative (i.e., τ_i and $\tilde{\tau}$ increase), which increases the marginal static return of capacity-building; this channel improves corporate efficiency. Second, competition for attention can be more intense, which hurts corporate efficiency because of the information-attracting externality. The following numerical result shows that the adverse effect of the second channel may dominate.

Numerical Result 3. *Let $C(K) \equiv cK^2/2$. Firm i's equilibrium expected profit $E_{t=0}[\Pi_i]$ and social welfare W are increasing in γ when α is sufficiently large and γ is sufficiently close to λ.*

When attention is very costly to acquire (i.e., α is large), decreasing γ will only slightly increase τ_i, so the increase in the marginal static return of firm i's capacity is weak. In contrast, firms' information-attracting incentives (and the consequent competition for attention) are significant even if α is large. As γ decreases, competition for attention becomes more intense, implying more waste of capacities.[27] When α is large and γ is small, the waste of capacities will dominate the slight increase in firms' marginal static returns, so corporate efficiency (measured by $E_{t=0}[\Pi_i]$) is increasing in γ.

A large α also implies that the equilibrium value of $\overline{\tau}^j$ (and hence $\tilde{\tau}$) must be very low. Then the cost-saving effect of decreasing γ is weak since speculators acquire only a small amount of information. As a result, the decrease in corporate efficiency (caused

[27] In general, the effect of decreasing γ on firms' information-attracting incentives is ambiguous. However, when α is sufficiently large, decreasing γ will increase firms' information-attracting incentives (i.e., increase $\partial\tau_i/\partial K_i$), thereby intensifying competition for attention.

by a decrease in γ) dominates the weak cost-saving effect when α is large and γ is small, thereby reducing social welfare.

The following result characterizes the effects of firms' growth opportunities.

Numerical Result 4. *Let $C(K) \equiv cK^2/2$ and $\gamma \geq \lambda$. Firm i's equilibrium expected profit $E_{t=0}[\Pi_i]$ and social welfare W are decreasing in v when v and α are sufficiently large.*

This result is reminiscent of Numerical Result 2. When v and α are sufficiently large, increasing v only slightly improves the marginal static return of firms' capacities but intensifies competition for attention by a lot, which thereby decreases corporate efficiency and social welfare.

8 Conclusion

A firm's capacity determines the dispersion of the firm's final value, so raising the firm's capacity increases speculators' marginal benefit of acquiring the firm's fundamental information, improving the firm's stock price informativeness. The testable implication is that firms with larger production (or investment) capacities tend to have higher investment-price sensitivity, a classic proxy for stock price informativeness.

Knowing speculators' learning preferences, firms have incentives to attract speculators' information by building additional capacities. The information-attracting motivation of increasing capacities will interact with information technology progress and potentially generate unexpected adverse effects. When information acquisition is expensive, speculators' attention is abundant. In this case, IT progress increases firms' stock price informativeness and improves corporate efficiency because stock prices can better guide firms' investment decisions. As IT improves to a certain level, speculators' attention is used up (i.e., the attention constraint is binding). Then further IT progress will induce firms to reduce their capacities to avoid competition for attention if information acquisition is not sufficiently cheap. Firms' attempt to avoid competition for attention ensures there is no waste of capacities, which benefits corporate efficiency.

However, IT progress will reduce corporate efficiency when information is sufficiently cheap, inducing firms to engage in a zero-sum competition for attention. Firms waste capacities for the information-attracting purpose without increasing either firm's price informativeness because expanding a firm's capacity will reduce the price informativeness of the other firm, which is an externality that firms do not internalize. The decrease in corporate efficiency can even dominate the direct cost-saving effect of lowering information costs, thereby reducing social welfare. The testable prediction is that in developed financial markets with low information acquisition costs, a firm's price informativeness (proxied by investment-price sensitivity) will decrease if other firms increase their capacities (or scales). Moreover, increasing firms' growth opportunities can reinforce firms' information-attracting incentives and the undesirable effects of IT progress.

With competition for attention, the two firms' capacity-building decisions are strategic substitutes. Because of the strategic substitutability, a firm cares about the other firm's capacity-building incentive. If a firm can demonstrate a high incentive to increase capacities (e.g., through its stock price), the other firms' capacity-building will be discouraged. The implication of the finding is that a firm's real decisions can be sensitive to other (unrelated) firms' news. Specifically, a firm may become more conservative in business expansion when other firms announce good fundamental news.

When speculators can extend their attention, IT progress always increases firms' price informativeness. Since speculators' attention constraints are interpreted as the limited memory and information processing capacity of human resources, the empirical prediction is that IT improvements will induce institutional speculators to increase their stock analysts' quality or/and quantity. The IT-induced increase in price informativeness need not improve corporate efficiency because firms' competition for attention still exists. When such competition is intense enough, IT progress will reduce corporate efficiency and social welfare, despite the increase in price informativeness. Thus, through a new mechanism, my model confirms the possible inconsistency between real efficiency and market efficiency (Bond et al., 2012).

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Appendix A: Proofs

Proof of Lemma 1. Given s_i^j, let $\varphi_i^{j+}\left(s_i^j\right)$ (resp. $\varphi_i^{j-}\left(s_i^j\right)$) denote the probability that speculator j submits a long (resp. short) order for firm i's stocks.

When $F_i = H$, speculators' aggregate order for firm i's stocks is

$$X_i\left(H\right) = \int_0^1 \left(\left(\frac{1}{2}+\tau_i^j\right)\left(\varphi_i^{j+}\left(h\right)-\varphi_i^{j-}\left(h\right)\right)+\left(\frac{1}{2}-\tau_i^j\right)\left(\varphi_i^{j+}\left(l\right)-\varphi_i^{j-}\left(l\right)\right)\right)dj.$$

When $F_i = L$, speculators' aggregate order for firm i's stocks is

$$X_i\left(L\right) = \int_0^1 \left(\left(\frac{1}{2}+\tau_i^j\right)\left(\varphi_i^{j+}\left(l\right)-\varphi_i^{j-}\left(l\right)\right)+\left(\frac{1}{2}-\tau_i^j\right)\left(\varphi_i^{j+}\left(h\right)-\varphi_i^{j-}\left(h\right)\right)\right)dj.$$

Then

$$X_i\left(H\right)-X_i\left(L\right) = \int_0^1 \left(2\tau_i^j\left(\varphi_i^{j+}\left(h\right)-\varphi_i^{j-}\left(h\right)\right)-2\tau_i^j\left(\varphi_i^{j+}\left(l\right)-\varphi_i^{j-}\left(l\right)\right)\right)dj \leq 4\tau_i.$$

Therefore, $X_i\left(H\right)-\epsilon < X_i\left(L\right)+\epsilon$ must hold since $4\tau_i < 2\epsilon$.

If $Y_i \in \left[X_i\left(H\right)-\epsilon, X_i\left(L\right)+\epsilon\right]$, Y_i is non-revealing (i.e., uninformative) for market makers due to Bayes' theorem:

$$\begin{aligned} & prob\left(F_i = H \middle| Y_i \in \left[X_i\left(H\right)-\epsilon, X_i\left(L\right)+\epsilon\right]\right) \\ = & \frac{\frac{2\epsilon-\left(X_i(H)-X_i(L)\right)}{2\epsilon}prob\left(H\right)}{\frac{2\epsilon-\left(X_i(H)-X_i(L)\right)}{2\epsilon}prob\left(H\right)+\frac{2\epsilon-\left(X_i(H)-X_i(L)\right)}{2\epsilon}prob\left(L\right)} = prob\left(H\right). \end{aligned}$$

If $Y_i < X_i\left(H\right)-\epsilon$ (negatively fully revealing case), market makers will infer $F_i = L$ and set $p_i = \Pi_i$, implying 0 speculative profit for speculators. If $Y_i > X_i\left(L\right)+\epsilon$ (positively fully revealing case), market makers will infer $F_i = H$ and again set $p_i = \Pi_i$, implying 0 speculative profit. When $Y_i \in \left[X_i\left(H\right)-\epsilon, X_i\left(L\right)+\epsilon\right]$ (non-revealing case), market makers get no information from Y_i, so p_i equals the unconditional expectation of Π_i. In this non-revealing case, the optimal strategy of speculator j is to submit $x_i^j = 1$ (resp. $x_i^j = -1$) when $s_i^j = h$ (resp. $s_i^j = l$). See the proof of Lemma 2 for details about the speculator's trading profit following the strategy.

Since speculator j knows that she cannot make any profits in the positively or negatively fully revealing case, she cares only about her profit in the case $Y_i \in \left[X_i\left(H\right)-\epsilon, X_i\left(L\right)+\epsilon\right]$, which arises with a positive probability. As a result, speculator j will submit $x_i^j = 1$ (resp.

$x_i^j = -1$) when $s_i^j = h$ (resp. $s_i^j = l$).

Proof of Proposition 1. The explanations below Proposition 1 have proven the result.

Proof of Lemma 2. If firm i's fundamental is L, $Y_i = -2\tau_i + u_i$ holds. In this case, if $Y_i < 2\tau_i - \epsilon$ (which occurs with probability $2\tau_i/\epsilon$), the stock price p_i is fully revealing, so the trading profit of a speculator is 0 no matter how she trades. If $Y_i \geq 2\tau_i - \epsilon$ (which happens with probability $(\epsilon - 2\tau_i)/\epsilon$), Y_i is uninformative; in this case, market makers set price $p_i = K_i\theta$, but firm value is $K_i(\theta - v) - \iota$, so the speculative profit of buying a unit of firm i's stock is $-K_i v - \iota$. A speculator with precision τ_i^j will buy (resp. sell) a unit with probability $1/2 - \tau_i^j$ (resp. $1/2 + \tau_i^j$); hence, when $F_i = L$, her expected speculative profit of trading firm i's stock is equal to

$$\frac{\epsilon - 2\tau_i}{\epsilon}\left(\begin{array}{c}\left(\frac{1}{2} + \tau_i^j\right)(K_i v + \iota) \\ + \left(\frac{1}{2} - \tau_i^j\right)(-K_i v - \iota)\end{array}\right) = \underbrace{2\tau_i^j(\epsilon - 2\tau_i)(K_i v + \iota)/\epsilon}_{\text{denoted by } \pi_i^{spec}\left(\tau_i^j\right)}.$$

Reasoning in the same way, her expected speculative profit when $F_i = H$ is also $\pi_i^{spec}\left(\tau_i^j\right)$, so her total profit (net of information costs) is $\pi_i^{spec}\left(\tau_i^j\right) - \gamma\left(\tau_i^j\right)^2/2$.

Proposition 2. Combining $\partial E_{t=1}\left[\pi_i^j\right]/\partial\tau_i^j = 0$ and $\tau_i^j = \tau_i$ yields τ_i^*. If $\tau_1^* + \tau_2^* \leq \overline{\tau}$, speculator j optimally chooses $\tau_i^j = \tau_i^*$. If $\tau_1^* + \tau_2^* > \overline{\tau}$, the first order condition of a speculator is

$$2\frac{\epsilon - 2\tau_1}{\epsilon}(K_1 v + \iota) - \gamma\tau_1^j = 2\frac{\epsilon - 2(\overline{\tau} - \tau_1)}{\epsilon}(K_2 v + \iota) - \gamma\left(\overline{\tau} - \tau_1^j\right),$$

which, combined with $\tau_i^j = \tau_i \in [0, \overline{\tau}]$, yields $\hat{\tau}_1$ in the proposition.

Proof of Lemma 3. Consider the case $F_i = H$, which means $Y_i = 2\tau_i + u_i$. In this case, if $Y_i > -2\tau_i + \epsilon$ (which happens with probability $2\tau_i/\epsilon$), price is fully revealing; the firm's investment is K_i, so the firm value is $K_i(\theta + v) + \iota - C(K_i)$. If $Y_i \leq -2\tau_i + \epsilon$ (which happens with probability $(\epsilon - 2\tau_i)/\epsilon$), market makers set price $p_i = K_i\theta - C(K_i)$, so the firm's investment is still K_i in this non-revealing case; the firm value is $K_i(\theta + v) + \iota - C(K_i)$. In sum, the firm value is $K_i(\theta + v) + \iota - C(K_i)$ when $F_i = H$.

Next, consider the case $F_i = L$, which means $Y_i = -2\tau_i + u_i$. If $Y_i < 2\tau_i - \epsilon$ (which happens with probability $2\tau_i/\epsilon$), price is fully revealing; in this case, the firm's investment is 0, so the firm value is $-\iota - C(K_i)$. If $Y_i \geq 2\tau_i - \epsilon$ (which happens with probability $(\epsilon - 2\tau_i)/\epsilon$), market makers set price $p_i = K_i\theta - C(K_i)$, so the firm's investment is K_i in this non-revealing case; firm value is $K_i(\theta - v) - \iota - C(K_i)$. Overall, the firm value is

$(\epsilon - 2\tau_i) K_i (\theta - v) / \epsilon - \iota - C(K_i)$ when $F_i = L$.

As a result, the unconditional expected firm profit at $t = 0$ is

$$\begin{aligned} E_{t=0}[\Pi_i] &= \frac{1}{2}(K_i(\theta + v) + \iota) + \frac{1}{2}\left(\frac{\epsilon - 2\tau_i}{\epsilon} K_i(\theta - v) - \iota\right) - C(K_i) \\ &= K_i\left(\theta + \frac{\tau_i}{\epsilon}(v - \theta)\right) - C(K_i). \end{aligned}$$

Proof of Proposition 3. In this proof, I first focus on the case where the symmetric equilibrium exists. At the end of the proof, I show that a symmetric equilibrium does not exist when γ is too small (i.e., when $\gamma < \lambda$).

When γ is sufficiently large, obviously $\tau_1^* + \tau_2^* < \overline{\tau}$ holds, so speculators' attention constraint is not binding. In this case, firm i optimal capacity level K^* solves

$$m_i^*(K^*) = \left(\theta + \frac{\tau_i^*}{\epsilon}(v - \theta) + \frac{K_i(v - \theta)}{\epsilon}\frac{\partial \tau_i^*}{\partial K_i}\right)\Bigg|_{K_i = K^*} = C'(K^*). \tag{A.1}$$

According to the definition of τ_i^*, it can be shown that $m_i^*(0) > 0$, $m_i^*(+\infty) = (v + \theta)/2 < +\infty$ and

$$\frac{\partial m_i^*(K_i)}{\partial K_i} = \frac{4v\gamma(v - \theta)\epsilon(4\iota + \gamma\epsilon)}{(4K_i v + 4\iota + \gamma\epsilon)^3},$$

which is decreasing in K_i. Then Equation (A.1) must have a unique positive solution K^* for two reasons: (a) $C'(0) = 0$ and $C'(+\infty) = +\infty$ ensure the existence of at least one positive solution; (b) $C''(\cdot) > 0$ and $C'''(\cdot) \geq 0$ ensure that the smallest positive solution (denoted by $K_i = K^{\downarrow}$) must be the unique solution because

$$C''(K^{\downarrow}) \geq \frac{\partial m_i^*(K_i)}{\partial K_i}\bigg|_{K_i = K^{\downarrow}}$$

must hold, which means $C''(K_i) > \partial m_i^*(K_i)/\partial K_i$ holds for all $K_i > K^{\downarrow}$ (due to $C'''(\cdot) \geq 0$). As a result, $C'(K_i)$ increases faster than $m_i^*(K_i)$ when $K_i > K^{\downarrow}$, implying that $K^{\downarrow}$ is the unique solution (i.e., $K^{\downarrow} = K^*$).

It can be shown that

$$\frac{\partial m_i^*(K_i)}{\partial \gamma} = -\frac{2(v - \theta)\epsilon(4\iota(K_i v + \iota) + \gamma\epsilon(2K_i v + \iota))}{(4K_i v + 4\iota + \gamma\epsilon)^3} < 0,$$

so $m_i^*(K_i)$ will increase as γ decreases, implying that K^* is decreasing in γ. When speculators' attention constraint is not binding, it can be shown that

$$\tau_i^*|_{K_i=K^*} = \frac{2\left(K^*\upsilon+\iota\right)\epsilon}{4\left(K^*\upsilon+\iota\right)+\gamma\epsilon},$$

which is decreasing in γ and will exceed $\overline{\tau}/2$ for γ small enough because $\overline{\tau} < \epsilon$. When $\tau_i^* = \overline{\tau}/2$, it holds that

$$\frac{2\left(K^*\upsilon+\iota\right)\epsilon}{4\left(K^*\upsilon+\iota\right)+\gamma\epsilon} = \frac{\overline{\tau}}{2} \Leftrightarrow K^* = \frac{\overline{\tau}\gamma\epsilon}{4\left(\epsilon-\overline{\tau}\right)\upsilon} - \frac{\iota}{\upsilon} \equiv \overline{K}.$$

Note that $\overline{K}$ is the capacity that induces speculators to exactly use up attention (i.e., $\tau_i^*|_{K_i=\overline{K}} = \overline{\tau}/2$).

Let $\gamma = \overline{\gamma}$ be the threshold such that $\tau_i^*|_{\gamma=\overline{\gamma}} = \overline{\tau}/2$ holds. Since τ_i^* is decreasing in γ, the threshold $\overline{\gamma}$ is unique. At $\gamma = \overline{\gamma}$, K^* exactly equals $\overline{K}$, implying the following firm i's FOC:

$$m_i^*\left(K^*\right)|_{\gamma=\overline{\gamma}} = \left(\theta + \frac{(\upsilon-\theta)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{2\upsilon\left(\epsilon-\overline{\tau}\right)^2}{\gamma\epsilon^2}\right)\right)\Bigg|_{\gamma=\overline{\gamma}} = C'(\overline{K})\big|_{\gamma=\overline{\gamma}}. \tag{A.2}$$

Obviously, $\overline{K}$ is increasing in γ (and recall that K^* is decreasing in γ), so $K^* > \overline{K}$ will hold when $\gamma < \overline{\gamma}$.

When γ decreases from $\overline{\gamma}$ by a little but is sufficiently close to $\overline{\gamma}$, $\tau_1^* + \tau_2^* > \overline{\tau}$ will hold. In this case, it can be shown that $K_i = \overline{K}$ is the symmetric equilibrium capacity, from which neither firm wants to deviate. Suppose that firm i deviates to $\overline{K} - \sigma$ (with $\sigma > 0$), speculators' attention will not be used up (recall $\tau_i^*|_{K_i=\overline{K}} = \overline{\tau}/2$). Then firm i's marginal benefit of extending capacities must be higher than the marginal cost because of the following inequality:

$$m_i^*\left(\overline{K}-\sigma\right) > C'(\overline{K}-\sigma). \tag{A.3}$$

Inequality (A.3) holds because $K^* > \overline{K} > \overline{K} - \sigma$ when $\gamma < \overline{\gamma}$ (recall that K^* is the unique solution of $m_i^*\left(K^*\right) = C'(K^*)$). Thus, firm i has no incentive to deviate to $\overline{K} - \sigma$.

Next I show that firm i will not deviate to $\overline{K}+\sigma$ when γ is lower than but sufficiently close to $\overline{\gamma}$. Suppose that firm 1 deviates to $K_1 = \overline{K} + \sigma$ while firm 2 sticks to $K_2 = \overline{K}$. Then $\tau_i = \hat{\tau}_i$ will hold, so firm 1's marginal benefit of capacity-building is $\hat{m}_1\left(K_1, K_2\right)$

instead of $m_1^*(K_1)$. When γ is sufficiently close to $\overline{\gamma}$, it can be shown that

$$\lim_{\sigma\to 0^+} \hat{m}_1\left(\overline{K}+\sigma, \overline{K}\right) = \theta + \frac{(v-\theta)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{v\left(\epsilon-\overline{\tau}\right)^2}{\gamma\epsilon^2}\right) < C'(\overline{K}) \tag{A.4}$$

because of Equation (A.2). Hence, firm 1 has no incentive to deviate to $\overline{K}+\sigma$ when σ is small. Later I will show that whenever $\hat{m}_1(K_1, K_2) < C'(K_1)$ holds, $C'(K_1)$ will increase with K_1 faster than $\hat{m}_1(K_1, K_2)$ (because $\partial\hat{m}_1(K_1, K_2)/\partial K_1$ is decreasing in K_1, $C''(\cdot) > 0$ and $C'''(\cdot) \geq 0$). Hence, firm 1 has no incentive to deviate to any K_1 that is higher than $\overline{K}$. The same result holds for firm 2. In sum, when γ is lower than but sufficiently close to $\overline{\gamma}$, $K_i = \overline{K}$ is the symmetric equilibrium capacity, from which neither firm wants to deviate.

As γ decreases to a sufficiently low level, the following inequality will hold for firm 1:

$$\lim_{\sigma\to 0^+} \hat{m}_1\left(\overline{K}+\sigma, \overline{K}\right) = \theta + \frac{(v-\theta)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{v\left(\epsilon-\overline{\tau}\right)^2}{\gamma\epsilon^2}\right) > C'(\overline{K}), \tag{A.5}$$

because $\overline{K}$ will approach 0 (i.e., $C'(\overline{K})$ will approach 0) when γ is sufficiently small. In this case, firm 1 has an incentive to increase its capacity from $\overline{K}$; the same result holds for firm 2. Once they increase their capacities from $\overline{K}$, $\tau_i = \hat{\tau}_i$ must hold, so the first order condition in the symmetric equilibrium is $\hat{m}_i(K_i, K_i) = C'(K_i)$. Focusing on firm 1, I will show the existence and uniqueness of the symmetric equilibrium. It can be shown that $\hat{m}_1(0, K_2) > 0$, $\hat{m}_1(+\infty, K_2) = (v+\theta)/2 < C'(+\infty)$ and

$$\frac{\partial\hat{m}_1(K_1, K_2)}{\partial K_1} = \frac{2v(v-\theta)(\epsilon-\overline{\tau})(2K_2v+4\iota+\gamma\epsilon)(4K_2v+4\iota+\gamma\epsilon)}{\epsilon\left(2(K_1+K_2)v+4\iota+\gamma\epsilon\right)^3},$$

which is decreasing in K_1. Then $\hat{m}_1(K_1, K_2) = C'(K_1)$ must have a unique positive solution $K_1 = \hat{K}_1$ for two reasons: (a) $C'(0) = 0$ and $C'(+\infty) = +\infty$ ensure the existence of at least a positive solution; (b) $C''(\cdot) > 0$ and $C'''(\cdot) \geq 0$ ensure that such a solution $\hat{K}_1$ is unique (because when $K_1 > \hat{K}_1$, $C'(K_1)$ will increase with K_1 faster than $\hat{m}_1(K_1, K_2)$). In the symmetric case with $K_1 = K_2$, it can be shown that $\hat{m}_1(0,0) > 0$, $\hat{m}_1(+\infty, +\infty) < C'(+\infty)$, so $\hat{m}_1(K_1, K_1) = C'(K_1)$ must have a solution $K_1 = \hat{K}$. This solution is unique because $\partial\hat{m}_1(K_1, K_2)/\partial K_2 < 0$ (see the proof of Proposition 5), implying a strategic substitutability relation between K_1 and K_2. Given that a symmetric equilibrium exists, the unique solution $\hat{K}$ is the equilibrium capacity when Inequality (A.5) holds. Obviously, $\hat{K} > \overline{K}$ must hold because: (a) $\hat{m}_1(+\infty, +\infty) < C'(+\infty)$ holds, (b) $\hat{m}_1\left(\overline{K}, \overline{K}\right) > C'(\overline{K})$

holds (i.e., Inequality A.5 holds), and (c) $\hat{m}_1\left(\hat{K},\hat{K}\right) = C'(\hat{K})$ has a unique solution $\hat{K}$. As a result, speculators' attention is used up, implying $\tau_i = \hat{\tau}_i|_{K_i=\hat{K}} = \overline{\tau}/2$.

The threshold $\underline{\gamma}$ is determined by the solution of $MB\left(\underline{\gamma}\right) = C'(\overline{K})\big|_{\gamma=\underline{\gamma}}$, where $MB\left(\cdot\right)$ is defined as follows:

$$MB\left(\gamma\right) \equiv \lim_{\sigma\to 0^+} \hat{m}_1\left(\overline{K}+\sigma,\overline{K}\right) = \theta + \frac{(v-\theta)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{v\left(\epsilon-\overline{\tau}\right)^2}{\gamma\epsilon^2}\right). \tag{A.6}$$

That is, $MB\left(\gamma\right)$ is a firm's marginal benefit of capacity-building when the firm deviates to $\overline{K}+\sigma$ (with $\sigma > 0$ infinitesimal), given that the other firm's capacity is controlled at $\overline{K}$. When γ is lower than but sufficiently close to $\overline{\gamma}$, $MB\left(\gamma\right) < C'(\overline{K})$ holds because of Inequality (A.4). As γ decreases, $\overline{K}$ and $C'(\overline{K})$ will approach 0, in which case $MB\left(\gamma\right) > C'(\overline{K})$ must hold. Hence, there exists at least a solution $\underline{\gamma}$ making $MB\left(\underline{\gamma}\right) = C'(\overline{K})\big|_{\gamma=\underline{\gamma}}$ hold. Letting $\underline{\gamma} = \gamma^{\downarrow}$ be the lowest solution of $MB\left(\underline{\gamma}\right) = C'(\overline{K})\big|_{\gamma=\underline{\gamma}}$, next I show that $\underline{\gamma} = \gamma^{\downarrow}$ is the unique solution. It can be shown that

$$\frac{\partial MB\left(\gamma\right)}{\partial\gamma} = \frac{(v-\theta)\,v\left(\epsilon-\overline{\tau}\right)^2}{\epsilon^3}\frac{\iota}{v}\left(\frac{1}{\gamma}\right)^2,$$

which is decreasing in γ. Meanwhile,

$$\frac{\partial C'(\overline{K})}{\partial\gamma} = C''(\overline{K})\frac{\overline{\tau}\epsilon}{4\left(\epsilon-\overline{\tau}\right)v},$$

which is weakly increasing in γ because $C'''(\cdot) \geq 0$ and $\partial\overline{K}/\partial\gamma > 0$. This means $C'(\overline{K})$ must increase with γ faster than $MB\left(\gamma\right)$ for $\gamma \geq \gamma^{\downarrow}$. Hence, $\underline{\gamma} = \gamma^{\downarrow}$ is the unique solution of $MB\left(\underline{\gamma}\right) = C'(\overline{K})\big|_{\gamma=\underline{\gamma}}$. Obviously, $\underline{\gamma} < \overline{\gamma}$ must hold because $MB\left(\overline{\gamma}\right) < C'(\overline{K})\big|_{\gamma=\overline{\gamma}}$ (see Inequality A.4, which holds when $\gamma \to \overline{\gamma}$).

Potential non-existence of a symmetric equilibrium. Next, I show that the symmetric equilibrium may not exist. The previous proof has already shown that given $K_2 = K^e$ (which can be K^*, $\overline{K}$, or $\hat{K}$ depending on γ), firm 1 will not deviate from $K_1 = K^e$ if $\tau_1 \in (0,\overline{\tau})$. To ensure the existence of the symmetric equilibrium, I still need to check if firm 1 would like to deviate to the boundary case $\tau_1 = 0$ or $\tau_1 = \overline{\tau}$, which means $\partial\tau_1/\partial K_1 = 0$ (i.e., firm 1's information-attracting incentive disappears). Obviously, firm 1 will not deviate to $\tau_1 = \overline{\tau}$ because it requires $K_1 > K^e$; without the information-attracting incentive (i.e., if $\partial\tau_1/\partial K_1 = 0$), firm 1 has no incentive to increase K_1 from K^e.

Next, I consider if firm 1 would like to deviate to $\tau_1 = 0$. Given $\tau_1 = 0$ and $\partial\tau_1/\partial K_1 = 0$, firm 1's marginal benefit of capacity-building is simply θ, so its optimal K_1 (given $\tau_1 = 0$) is determined by

$$\theta = C'(K_1) \Leftrightarrow K_1 = K^D \equiv C'^{-1}(\theta),$$

where $C'^{-1}(\cdot)$ is the inverse function of $C'(\cdot)$. Then, two subcases may arise. First, if $\tau_1 > 0$ still holds when $K_1 = K^D$ and $K_2 = K^e > K^D$, then deviating to $K_1 = K^D$ cannot implement the boundary case $\tau_1 = 0$. In this case, firm 1 will not deviate from the $K_1 = K^e$ because $K_1 = K^D$ is still an inner strategy (with $\tau_1 > 0$) and hence dominated by $K_1 = K^e$. To implement the boundary case $\tau_1 = 0$, firm 1 must choose $K_1 < K^D$, which is dominated by $K_1 = K^D$ since the marginal static return $(\theta + \tau_1 (v - \theta)/\epsilon)$ alone calls for $K_1 \geq K^D$.

Next, I consider the subcase that $\tau_1 = 0$ indeed holds when $K_1 = K^D$ and $K_2 = K^e > K^D$. Let $\Pi(\gamma)$ denote a firm's period-0 expected profit when both firms choose the capacity level K^e (which can be K^*, $\overline{K}$, or $\hat{K}$ depending on γ) and when the information cost parameter is γ. Since K^e is a function of γ, $\Pi(\gamma)$ is also a function of γ.

For any γ, if firm 1 deviates to $K_1 = K^D$ and $\tau_1 = 0$, its profit will be equal to $\Pi(+\infty)$. To see this, note that if $\gamma \to +\infty$ (which means speculators' attention constraint is not binding), K^* converges to K^D: Since $\gamma \to +\infty$ implies that $\tau_1^* = 0$ and $\partial\tau_1^*/\partial K_1 = 0$, K^* (under $\gamma \to +\infty$) is also determined by $\theta = C'(K^*)$. As a result, by deviating to $K_1 = K^D$ and $\tau_1 = 0$, firm 1's profit will be $\Pi(+\infty)$. When both firms choose the capacity K^e, firm 1's profit is $\Pi(\gamma)$. Hence, firm 1 will have the incentive to deviate to $K_1 = K^D$ and $\tau_1 = 0$ if and only if $\Pi(\gamma) < \Pi(+\infty)$. Following the proof of Proposition 4, $\Pi(\gamma) > \Pi(+\infty)$ must hold for $\gamma \geq \underline{\gamma}$ because $\Pi(\gamma)$ is decreasing in γ when $\gamma \geq \underline{\gamma}$. As a result, the threshold λ for the nonexistence of a symmetric equilibrium must be strictly lower than $\underline{\gamma}$. If $\Pi(0) \geq \Pi(+\infty)$, then firm 1 will not deviate to $K_1 = K^D$ and $\tau_1 = 0$ for any $\gamma \geq 0$; in this case, I let $\lambda = 0$. If $\Pi(0) < \Pi(+\infty)$, then $\lambda \geq 0$ is determined by $\Pi(\lambda) = \Pi(+\infty)$, which must have the property $0 < \lambda < \underline{\gamma}$. In summary, a symmetric equilibrium does not exist when $\gamma < \lambda$.

Proof of Corollary 4. When $\gamma > \overline{\gamma}$, it can be shown that

$$\frac{\partial m_i^*(K_i)}{\partial\gamma} = -\frac{2(v-\theta)\epsilon(4\iota(K_i v + \iota) + \gamma\epsilon(2K_i v + \iota))}{(4K_i v + 4\iota + \gamma\epsilon)^3} < 0,$$

so $m_i^*(K_i)$ will increase as γ decreases, implying a higher K^*. When $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$, the symmetric equilibrium capacity is $\overline{K} = \overline{\tau}\gamma\epsilon/4\left(\epsilon-\overline{\tau}\right)v - \iota/v$, which is obviously increasing in γ. When $\lambda \leq \gamma < \underline{\gamma}$, it can be shown that

$$\frac{\partial \hat{m}_1\left(K_1, K_1\right)}{\partial \gamma} = -\frac{K_1 v\left(v-\theta\right)\left(\epsilon-\overline{\tau}\right)}{\left(4K_1 v + 4\iota + \gamma\epsilon\right)^2} < 0.$$

Thus $\hat{m}_1\left(K_1, K_1\right)$ will increase as γ decreases, implying a larger solution $\hat{K}$ for $\hat{m}_1\left(\hat{K}, \hat{K}\right) = C'(\hat{K})$.

Proof of Proposition 4. When $\gamma > \overline{\gamma}$, obviously $E_{t=0}[\Pi_i]$ is decreasing in γ because in this case there is no firm interaction. In this case, for any given K_i ($< \overline{K}$) firm i's expected profit is decreasing in γ.

When $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$, $\tau_i = \overline{\tau}/2$ always holds; a decrease in γ will not affect τ_i. Consider a fictitious case with *exogenous* $\tau_i = \overline{\tau}/2$; that is, a case in which firm i takes $\tau_i = \overline{\tau}/2$ as given. In this fictitious case, $\partial\tau_i/\partial K_i = 0$ holds (because firm i takes $\tau_i = \overline{\tau}/2$ as given), implying the non-existence of the information-attracting incentive. Then the firm's optimal capacity, denoted by K_i^{fic}, should be determined by

$$\theta + \frac{\overline{\tau}/2}{\epsilon}\left(v-\theta\right) = C'\left(K_i^{fic}\right). \tag{A.7}$$

K_i^{fic} is a firm's profit-maximizing capacity when τ_i is fixed at $\overline{\tau}/2$. When $\underline{\gamma} \leq \gamma \leq \overline{\gamma}$, Equation (A.7) implies $K_i^{fic} < \overline{K}$ because the following inequality holds:

$$C'\left(K_i^{fic}\right) < \hat{m}_i\left(\overline{K}, \overline{K}\right) = \theta + \frac{\left(v-\theta\right)}{\epsilon}\left(\frac{\overline{\tau}}{2} + \overline{K}\frac{v\left(\epsilon-\overline{\tau}\right)^2}{\gamma\epsilon^2}\right) < C'(\overline{K}). \tag{A.8}$$

This means that $K_i = \overline{K}$ is excessively high for a firm if τ_i is fixed at $\overline{\tau}/2$. Moreover, K_i^{fic} does not depend on γ. As γ decreases, $\overline{K}$ will decrease and hence get closer to K_i^{fic}, while τ_i stays at $\overline{\tau}/2$; hence, firm i's profit will increase.

When $\lambda \leq \gamma < \underline{\gamma}$, τ_i still stays at $\overline{\tau}/2$, while $K_i = \hat{K}$ ($> \overline{K}$) will increase as γ decreases. Therefore, $\hat{K}$ will get farther away from K_i^{fic} without changing $\tau_i = \overline{\tau}/2$, implying a decrease in firm profit.

Proof of Lemma 4. When $\gamma > \overline{\gamma}$, obviously the efficient capacity is determined by $m_i^*\left(K^o\right) = C'\left(K^o\right)$ because speculators' attention is not used up. Hence, the efficient capacity level K^o equals K^*.

When $\gamma \leq \overline{\gamma}$, speculators' attention is used up. Letting $K_1 = K_2 = K^o \geq \overline{K}$, from the perspective of corporate efficiency, the marginal benefit of increasing K^o is

$$\frac{\partial \left(E_{t=0}\left[\Pi_1+\Pi_2\right]\right)|_{K_i=K^o}}{\partial K^o}=2\theta+\frac{\overline{\tau}}{\epsilon}\left(v-\theta\right),$$

because $\tau_i=\overline{\tau}/2$ is unaffected by K^o when $K_1=K_2=K^o\geq\overline{K}$. According to Equation (A.7) and Inequality (A.8), the following inequality must hold when $K^o\geq\overline{K}$:

$$\frac{\partial \left(E_{t=0}\left[\Pi_1+\Pi_2\right]\right)|_{K_i=K^o}}{\partial K^o}<2C'(K^o),$$

implying that $K^o>\overline{K}$ is not optimal for corporate efficiency. Meanwhile, if $\overline{K}>K_i^{fic}$, K^o cannot be lower than $\overline{K}$; otherwise, speculators' attention constraint will not be binding, so $m_i^*\left(K^o\right)>C'\left(K^o\right)$ will hold, which means increasing K^o back to $\overline{K}$ can improve corporate efficiency. As a result, $K^o=\overline{K}$ if $\gamma\leq\overline{\gamma}$ and $\overline{K}>K_i^{fic}$ both hold.

If $\gamma\leq\overline{\gamma}$ and $\overline{K}\leq K_i^{fic}$ both hold, then $\tau_i=\overline{\tau}/2$ will hold if $K^o=K_i^{fic}$, in which case the following equation holds:

$$\frac{\partial \left(E_{t=0}\left[\Pi_1+\Pi_2\right]\right)|_{K_i=K^o=K_i^{fic}}}{\partial K^o}=2\theta+\frac{\overline{\tau}}{\epsilon}\left(v-\theta\right)=2C'(K_i^{fic}).$$

Therefore, $K^o=K_i^{fic}$ is the optimal capacity level for corporate efficiency when $\gamma\leq\overline{\gamma}$ and $\overline{K}\leq K_i^{fic}$ both hold. Note that K_i^{fic} is exactly the same as $\underline{\underline{K}}$. $\gamma=\underline{\underline{\gamma}}$ is the unique solution for $\overline{K}=K_i^{fic}$. Note that $\underline{\underline{\gamma}}<\underline{\gamma}$ must hold because $\overline{K}>K_i^{fic}$ still holds when $\gamma=\underline{\gamma}$ according to Inequality (A.8).

Proof of Proposition 5. With $\tau_i=\hat{\tau}_i\in(0,\overline{\tau})$ and Lemma 3, it can be shown that

$$\frac{\partial^2 E_{t=0}[\Pi_1]}{\partial K_1\partial K_2}=-\frac{v\left(v-\theta\right)\left(\epsilon-\overline{\tau}\right)\left(\left(4\iota+\gamma\epsilon\right)\left(2K_2v+4\iota+\gamma\epsilon\right)+2K_1v\left(8K_2v+12\iota+3\gamma\epsilon\right)\right)}{\epsilon\left(2\left(K_1+K_2\right)v+4\iota+\gamma\epsilon\right)^3},$$

which is negative.

Proofs of Proposition 6 and Corollary 6. In the proof, I let $I_{0i}\left(F_{0i},F_{0j}\right)$ denote firm i's period-0 investment when the firm's period-0 fundamental is F_{0i}, while the other firm's is F_{0j}.

Under assumption $\overline{\tau}\geq\epsilon/2$, firm 1 never deviates to boundary strategy with $\tau_1=0$; the same result holds for firm 2. If firm 1 deviates to $\tau_1=0$, then $\overline{\tau}\geq\epsilon/2$ ensures that $\tau_2<\epsilon/2<\overline{\tau}$ must hold (i.e., with endogenous information acquisition, firm 2's stock price cannot always be fully revealing). Therefore, $\tau_1=0$ implies $\tau_1+\tau_2<\overline{\tau}$, which means that speculators' attention constraint is not binding. However, if $\tau_1 + \tau_2 < \overline{\tau}$, $\tau_1 > 0$ must hold (Proposition 2), so deviation to $\tau_1 = 0$ is impossible. Hence, with $\overline{\tau} \geq \epsilon/2$, I only need to consider the interior equilibria.

When γ is sufficiently close to 0 and $\overline{\tau} < \epsilon$, $\tau_1^* + \tau_2^* > \overline{\tau}$ must hold no matter how firm i chooses K_i. As a result, $\tau_1 + \tau_2 = \overline{\tau}$ must hold in equilibrium. This means firms cannot avoid competition for attention by controlling their capacities; a necessary condition for avoiding such competition is that firms could make speculators' attention constraints non-binding by reducing their capacities.

Regarding the pricing of the market makers, it can be shown that $p_{0i}\left(H,H\right) \neq p_{0i}\left(L,L\right)$. If not (i.e., if $p_{0i}\left(H,H\right) = p_{0i}\left(L,L\right)$), firms cannot distinguish $F_{01} = F_{02} = H$ from $F_{01} = F_{02} = L$ by observing stock prices, so $K_i\left(H,H\right) = K_i\left(L,L\right)$ and $I_{0i}\left(H,H\right) = I_{0i}\left(L,L\right)$ must hold. However, given that $K_i\left(H,H\right) = K_i\left(L,L\right)$ and $I_{0i}\left(H,H\right) = I_{0i}\left(L,L\right)$, $p_{0i}\left(H,H\right) = p_{0i}\left(L,L\right)$ cannot hold because market makers can observe F_{0i}. As a result, $p_{0i}\left(H,H\right) \neq p_{0i}\left(L,L\right)$.

Similarly, it can be shown that $p_{01}\left(H,L\right) = p_{02}\left(L,H\right)$ or $p_{01}\left(L,H\right) = p_{02}\left(H,L\right)$ is impossible; that is, the two firms must have different period-0^- prices when their period-0 fundamentals are different. If not, they will have the same capacity and period-0 investment when $F_{0i} = H$ and $F_{0j} = L$; given this, market makers must set different prices for them, contradicting $p_{0i}\left(H,L\right) = p_{0j}\left(L,H\right)$.

In sum, stock prices p_{01} and p_{02} can fully reveal F_{0i}. When $p_{01} = p_{02}$, firms know that $F_{01} = F_{02} = H$ or $F_{01} = F_{02} = L$ happens. Since $p_{0i}\left(H,H\right) \neq p_{0i}\left(L,L\right)$, $F_{01} = F_{02} = H$ and $F_{01} = F_{02} = L$ can be distinguished. When $p_{01} \neq p_{02}$, firms know that their period-0 fundamentals are different; furthermore, they can infer which firm has period-0 fundamental H because, in equilibrium, they have correct beliefs about market makers' pricing rule. As a result, firm i will choose $I_{0i} = K_i 1_{\{F_{0i}=H\}}$ (the correct investment decision).

After $t = 0.5$, $R_{0i}(I_{0i}, F_{0i})$ becomes observable and hence can be viewed as a constant, which will not affect speculators' information acquisition decisions at $t = 1$. Therefore, Proposition 2 is robust to those new assumptions. Hence, firm i's expected value at $t = 0$ is

$$E_{t=0}[\Pi_i] = \underbrace{E\left[R_{0i}(I_{0i}, F_{0i})\right| F_{01}, F_{02}]}_{\text{given } I_{0i}=K_i 1_{\{F_{0i}=H\}}} + \underbrace{K_i\left(\theta + \frac{\tau_i}{\epsilon}\left(v - \theta\right)\right)}_{=E[R_i(I_i,F_i)]} - C\left(K_i\right).$$

For firm 1, note that $E\left[R_{01}(I_{01},F_{01})\right| F_{01},F_{02}]$ is independent of F_{02}, so

$$\frac{\partial^2 E_{t=0}[\Pi_1]}{\partial K_1 \partial K_2} = -\frac{v\left(v-\theta\right)\left(\epsilon-\overline{\tau}\right)\left(\left(4\iota+\gamma\epsilon\right)\left(2K_2 v+4\iota+\gamma\epsilon\right)+2K_1 v\left(8K_2 v+12\iota+3\gamma\epsilon\right)\right)}{\epsilon\left(2\left(K_1+K_2\right)v+4\iota+\gamma\epsilon\right)^3},$$

implying that Proposition 5 is robust.

An interior equilibrium with $\tau_i \in (0,\overline{\tau})$ must be determined by the following first-order conditions (FOC) about K_i:

$$\begin{cases} \frac{\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})}{\partial K_1} + \hat{m}_1\left(K_1,K_2\right) = C'\left(K_1\right) \\ \frac{\partial R_{02}(K_2 1_{\{F_{02}=H\}},F_{02})}{\partial K_2} + \hat{m}_2\left(K_1,K_2\right) = C'\left(K_2\right) \end{cases}. \tag{A.9}$$

When $K_i C''\left(K_i\right)/C'\left(K_i\right)$ is sufficiently large (i.e., the function $C\left(K_i\right)$ is sufficiently convex), the FOC system has a unique solution. $K_i\left(H,H\right) > K_i\left(L,L\right)$ holds because

$$\frac{\partial R_{0i}(K_i 1_{\{F_{0i}=H\}},H)}{\partial K_i} > \frac{\partial R_{0i}(K_i 1_{\{F_{0i}=H\}},L)}{\partial K_i} \tag{A.10}$$

holds for a given K_i.

Given the strategic substitutability between K_1 and K_2, $K_1\left(H,L\right) > K_1\left(L,L\right)$ and $K_1\left(H,H\right) > K_1\left(L,H\right)$ must hold because K_1 will increase (and meanwhile K_2 will decrease) to keep the FOC (A.9) holding if $\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})/\partial K_1$ increases. Symmetrically, K_1 will decrease (and K_2 will increase) if $\partial R_{02}(K_2 1_{\{F_{02}=H\}},F_{02})/\partial K_2$ increases, meaning that $K_1\left(H,L\right) > K_1\left(H,H\right)$ and $K_1\left(L,L\right) > K_1\left(L,H\right)$.

Given K_2, firm 1's expected firm value must increase if $\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})/\partial K_1$ increases (Envelope Theorem). Given $\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})/\partial K_1$, firm 1's expected firm value must increase if K_2 decreases, because a lower K_2 increases τ_1. In equilibrium, an increase in $\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})/\partial K_1$ decreases K_2, so firm 1's expected value must increase because: (a) $\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})/\partial K_1$ becomes higher, and (b) K_2 becomes lower. Thus, $p_{01}\left(H,F_{02}\right) > p_{01}\left(L,F_{02}\right)$ holds for a given F_{02}. Symmetrically, $p_{02}\left(H,F_{01}\right) > p_{02}\left(L,F_{01}\right)$ holds for a given F_{01}.

Since an increase in $\partial R_{01}(K_1 1_{\{F_{01}=H\}},F_{01})/\partial K_1$ increases K_1, firm 2's expected value will decrease due to the Envelope theorem:

$$\frac{E_{t=0}[\Pi_2]}{\partial K_1} = K_2 \frac{\left(v-\theta\right)}{\epsilon}\frac{\partial \tau_2}{\partial K_1} < 0.$$

The Envelope Theorem is applicable because firm 2 makes real decisions taking K_1 as given. Thus, $p_{0i}(F_{0i}, L) > p_{0i}(F_{0i}, H)$ holds for a given F_{0i}.

Proof of Proposition 7. As in the proof of Proposition 3, I first focus on the case where the symmetric equilibrium exists. At the end of the proof, I show that a symmetric equilibrium exists when γ is higher than a threshold (i.e., when $\gamma \geq \lambda$).

For given K_1 and K_2, speculator j's ex-ante profit with endogenous attention is

$$2\tau_1^j \frac{\epsilon - 2\tau_1}{\epsilon}(K_1 v + \iota) - \frac{\gamma}{2}\left(\tau_1^j\right)^2 + 2\tau_2^j \frac{\epsilon - 2\tau_2}{\epsilon}(K_2 v + \iota) - \frac{\gamma}{2}\left(\tau_2^j\right)^2 - \frac{\alpha}{2}\left(\tau_1^j + \tau_2^j\right)^2.$$

FOCs with respect to τ_1^j and τ_2^j are respectively

$$\begin{cases} 2\frac{\epsilon-2\tau_1}{\epsilon}(K_1 v + \iota) - \gamma\tau_1^j - \alpha\left(\tau_1^j + \tau_2^j\right) = 0, \\ 2\frac{\epsilon-2\tau_2}{\epsilon}(K_2 v + \iota) - \gamma\tau_2^j - \alpha\left(\tau_1^j + \tau_2^j\right) = 0. \end{cases} \tag{A.11}$$

In a symmetric equilibrium, $\tau_1^j = \tau_1$ and $\tau_2^j = \tau_2$ hold. Combining $\tau_1^j = \tau_1$, $\tau_2^j = \tau_2$, and Equation (A.11), it can be shown that

$$\frac{\partial \tau_1}{\partial K_1} = \frac{2\frac{\epsilon-2\tau_1}{\epsilon}v - \alpha\frac{\partial \tau_2}{\partial K_1}}{\frac{4}{\epsilon}(K_1 v + \iota) + \gamma + \alpha} > 0 \text{ and } \frac{\partial \tau_2}{\partial K_1} < 0. \tag{A.12}$$

Let τ_1^{Δ} and τ_2^{Δ} denote the equilibrium average information precision for firms 1 and 2, respectively. In the symmetric case with $K_1 = K_2$, it can be shown that

$$\tau_1^{\Delta}\Big|_{K_1=K_2} = \frac{2(K_1 v + \iota)\epsilon}{4(K_1 v + \iota) + (2\alpha + \gamma)\epsilon}. \tag{A.13}$$

Let $m_1^{\Delta}(K_1, K_2)$ denote firm 1's marginal benefit of increasing K_1 for given K_1 and K_2. It can be shown that $\partial m_1^{\Delta}(K_1, K_2)/\partial K_2 < 0$, $m_1^{\Delta}(0,0) > m_1^{\Delta}(0, K_2) > C'(0)$, $m_1^{\Delta}(+\infty, +\infty) < m_1^{\Delta}(+\infty, K_2) = (v + \theta)/2 < C'(+\infty)$, and $\partial^2 m_1^{\Delta}(K_1, K_2)/(\partial K_1)^2 < 0$, which ensures the existence and uniqueness of the solution to $m_1^{\Delta}(K^e, K^e) = C'(K^e)$ (The proof of Proposition 3 has shown why such conditions can ensure the existence and uniqueness of a symmetric solution). Therefore, if a symmetric equilibrium exists, it must be unique and represented by K^e.

After some calculation, it can be shown that

$$\frac{\partial m_1^{\Delta}(K_1, K_2)}{\partial \gamma} < 0 \text{ and } \frac{\partial m_1^{\Delta}(K_1, K_2)}{\partial \alpha} < 0$$

hold when $K_1 = K_2$. Thus, in the symmetric equilibrium, K^e is decreasing in γ and α.

As γ and α decrease (which increases K^e), $\tau_1^{\Delta}\big|_{K_1=K_2}$ will increase according to Equation (A.13).

Existence of a symmetric equilibrium. Next, I show that the symmetric capacity decisions $K_1 = K_2 = K^e$ indeed sustain an equilibrium under certain conditions. First, I show that firm profit (with $K_1 = K_2 = K^e$) is decreasing in γ when γ is large enough. In the interior case with $\tau_1 > 0$ and $\tau_2 > 0$, the derivative of firm 1's expected profit $E_{t=0}[\Pi_1]$ with respect to γ is as follows (Envelope theorem is used):

$$\frac{\partial E_{t=0}[\Pi_1]}{\partial \gamma} = K_1 \left(\frac{(v-\theta)}{\epsilon} \left(\frac{\partial \tau_1}{\partial \gamma} + \frac{\partial \tau_1}{\partial K_2} \frac{\partial K_2}{\partial \gamma} \right) \right).$$

In the symmetric case with $K_1 = K_2 = K^e$, it can be shown that

$$\left. \frac{\partial \tau_1}{\partial \gamma} + \frac{\partial \tau_1}{\partial K_2} \frac{\partial K_2}{\partial \gamma} \right|_{K_1=K_2=K^e} = -\frac{2\left((K^e v + \iota)\,\epsilon^2 + \frac{v\alpha(2\alpha+\gamma)\epsilon^3}{(4K^e v + 4\iota + \gamma\epsilon)} \frac{\partial K^e}{\partial \gamma} \right)}{\left(4K^e v + 4\iota + (2\alpha+\gamma)\,\epsilon\right)^2} \tag{A.14}$$

According to the proof of Proposition 8, K^e is determined by

$$m_1^{\Delta}(K^e, K^e) = \left(\begin{array}{c} \theta + \frac{(v-\theta)}{\epsilon} \frac{2(K^e v+\iota)\epsilon}{4(K^e v+\iota)+(2\alpha+\gamma)\epsilon} \\ + \frac{K^e(v-\theta)}{\epsilon} \frac{(4(K^e v+\iota)+(\alpha+\gamma)\epsilon)}{(4(K^e v+\iota)+\gamma\epsilon)} \frac{2v(2\alpha+\gamma)\epsilon^2}{(4(K^e v+\iota)+(2\alpha+\gamma)\epsilon)^2} \end{array} \right) = C'(K^e), \tag{A.15}$$

which implies $\lim_{\gamma\to+\infty} \partial K^e/\partial\gamma = 0$. As a result, $\partial K^e/\partial\gamma$ is close to 0 when γ is large, which means $\partial\tau_1/\partial\gamma + (\partial\tau_1/\partial K_2)(\partial K_2/\partial\gamma) < 0$ holds (see Equation A.14) when γ is large and $K_1 = K_2 = K^e$. As a result, $\partial E_{t=0}[\Pi_1]/\partial\gamma < 0$ when γ is large and $K_1 = K_2 = K^e$.

As in the proof of Proposition 3, the unique symmetric solution $K_1 = K_2 = K^e$ is indeed an equilibrium if a firm (e.g., firm 1) has no incentive to deviate to the boundary case $\tau_1 = 0$ or $\tau_1 = \tilde{\tau}$. If $\tau_1 = \tilde{\tau}$, speculators do not acquire information about firm 2, so Equation (A.11) no longer holds; instead, the FOC with respect to τ_1^j should be

$$2\frac{\epsilon - 2\tau_1}{\epsilon}(K_1 v + \iota) - \gamma\tau_1^j - \alpha\tau_1^j = 0,$$

which implies

$$\left. \frac{\partial \tau_1}{\partial K_1} \right|_{\tau_1=\tilde{\tau}} = \frac{2\frac{\epsilon-2\tau_1}{\epsilon} v}{\frac{4}{\epsilon}(K_1 v + \iota) + \gamma + \alpha}. \tag{A.16}$$

Recall that when $\tau_1 \in (0, \tilde{\tau})$, $\partial\tau_1/\partial K_1$ is given by Equation (A.12), where $\partial\tau_2/\partial K_1 < 0$ contributes to the (positive) value of $\partial\tau_1/\partial K_1$. When τ_1 reaches $\tilde{\tau}$, $\partial\tau_2/\partial K_1$ becomes zero and hence no longer contributes to $\partial\tau_1/\partial K_1$, yielding $\partial\tau_1/\partial K_1|_{\tau_1=\tilde{\tau}}$ (see Equation A.16).

Hence, firm 1 will not deviate to $\tau_1 = \tilde{\tau}$ because it requires $K_1 > K^e$; however, with $\partial \tau_2 / \partial K_1 = 0$, the value of $\partial \tau_1 / \partial K_1 |_{\tau_1 = \tilde{\tau}}$ cannot sustain $K_1 > K^e$.

Next, I consider if firm 1 would like to deviate to $\tau_1 = 0$; in this case, $\partial \tau_1 / \partial K_1 = 0$ holds (i.e., firm 1's information-attracting incentive disappears). Given $\tau_1 = 0$ and $\partial \tau_1 / \partial K_1 = 0$, firm 1's marginal benefit of capacity-building is simply θ, so its optimal K_1 (given $\tau_1 = 0$) is determined by

$$\theta = C' (K_1) \Leftrightarrow K_1 = K^D \equiv C'^{-1} (\theta),$$

Then, two subcases may arise. First, if $\tau_1 > 0$ still holds when $K_1 = K^D$ and $K_2 = K^e > K^D$, then deviating to $K_1 = K^D$ cannot implement the boundary case $\tau_1 = 0$. In this case, firm 1 will not deviate from $K_1 = K^e$ because $K_1 = K^D$ is still an inner strategy (with $\tau_1 > 0$) and hence dominated by $K_1 = K^e$. To implement the boundary case $\tau_1 = 0$, firm 1 must choose $K_1 < K^D$, which is dominated by $K_1 = K^D$ since the marginal static return $(\theta + \tau_1 (v - \theta) / \epsilon)$ alone calls for $K_1 \geq K^D$.

Next, I consider the subcase that $\tau_1 = 0$ indeed holds when $K_1 = K^D$ and $K_2 = K^e > K^D$. Let $\Pi (\gamma)$ denote a firm's period-0 expected profit when both firms choose the capacity level K^e (which is the unique symmetric solution to $m_1^{\Delta} (K^e, K^e) = C' (K^e)$) and when the information cost parameter is γ. Since K^e is a function of γ, $\Pi (\gamma)$ is also a function of γ. For any γ, if firm 1 deviates to $K_1 = K^D$ and $\tau_1 = 0$, its profit will be equal to $\Pi (+\infty)$. To see this, note that if $\gamma \to +\infty$, K^e converges to K^D: If $\gamma \to +\infty$, it holds that $\tau_1^{\Delta} \to 0$ and $\partial \tau_1^{\Delta} / \partial K_1 \to 0$, so K^e (under $\gamma \to +\infty$) is determined by $\theta = C' (K^e)$. As a result, by deviating to $K_1 = K^D$ and $\tau_1 = 0$, firm 1's profit will be $\Pi (+\infty)$. When both firms choose the capacity K^e, firm 1's profit is $\Pi (\gamma)$. Hence, firm 1 will have the incentive to deviate to $K_1 = K^D$ and $\tau_1 = 0$ if and only if $\Pi (\gamma) < \Pi (+\infty)$.

According to the previous analysis, $\partial E_{t=0} [\Pi_1] / \partial \gamma < 0$ holds when γ is large and $K_1 = K_2 = K^e$ (because then $\partial \tau_1 / \partial \gamma + (\partial \tau_1 / \partial K_2) (\partial K_2 / \partial \gamma) < 0$ holds; see Equation A.14). Therefore, $\Pi (\gamma)$ is decreasing in γ when γ is large, which means that $\Pi (\gamma) > \Pi (+\infty)$ must hold when γ is sufficiently large. As a result, the symmetric solution $K_1 = K_2 = K^e$ is indeed an equilibrium when γ is sufficiently large (i.e., there exists $\lambda \geq 0$ such that a unique symmetric equilibrium exists when $\gamma \geq \lambda$). If $\Pi (\gamma) > \Pi (+\infty)$ holds for all $\gamma \geq 0$, I let $\lambda = 0$.

Proof of Proposition 8. For a firm, the marginal benefit of increasing both K_1 and

K_2 together (with $K_1 = K_2$) is:

$$m_1^o(K_1) \equiv \underbrace{\theta + \frac{\tau_1^\Delta\big|_{K_2=K_1}}{\epsilon}(v-\theta) + \frac{K_1(v-\theta)}{\epsilon}\frac{\partial\left(\tau_1^\Delta\big|_{K_2=K_1}\right)}{\partial K_1}}_{\text{Letting } K_2=K_1 \text{ before taking derivative wrt } K_1}. \tag{A.17}$$

In the symmetric case with $K_1 = K_2$, firm 1's marginal benefit of increasing K_1 (without changing K_2) is

$$m_1^\Delta(K_1, K_1) = \underbrace{\theta + \frac{\tau_1^\Delta\big|_{K_1=K_2}}{\epsilon}(v-\theta) + \frac{K_1(v-\theta)}{\epsilon}\left.\frac{\partial\tau_1^\Delta}{\partial K_1}\right|_{K_2=K_1}}_{\text{Taking derivative wrt } K_1 \text{ first (without considering } K_2=K_1\text{), then letting } K_2=K_1}$$

It can be shown that

$$\frac{\partial\left(\tau_1^\Delta\big|_{K_2=K_1}\right)}{\partial K_1} = \frac{2v(2\alpha+\gamma)\epsilon^2}{(4(K_1 v+\iota)+(2\alpha+\gamma)\epsilon)^2};$$

$$\left.\frac{\partial\tau_1^\Delta}{\partial K_1}\right|_{K_2=K_1} = \frac{(4(K_1 v+\iota)+(\alpha+\gamma)\epsilon)}{(4(K_1 v+\iota)+\gamma\epsilon)}\frac{2v(2\alpha+\gamma)\epsilon^2}{(4(K_1 v+\iota)+(2\alpha+\gamma)\epsilon)^2} > \frac{\partial\left(\tau_1^\Delta\big|_{K_2=K_1}\right)}{\partial K_1}.$$

Thus $m_1^\Delta(K_1, K_1) > m_1^o(K_1)$, meaning that, in equilibrium, K^e must be higher than K^o.