Incentives for Information Production in Markets where Prices Affect Real Investment

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Abstract

A fundamental role of financial markets is to gather information on firms’ investment opportunities, and so help guide investment decisions. In this paper we study the incentives for information production when prices perform this allocational role. If firms cancel planned investments following poor stock market response, the value of their shares will become insensitive to information on investment opportunities, so that speculators will be deterred from producing information ex ante. Based on this insight, we derive the following main results. (1) Strategic complementarities in information production may arise, leading to multiple equilibria with different levels of information. (2) The incentive to produce information decreases when economic fundamentals deteriorate, leading to an amplification of shocks to fundamentals. (3) Incentives to produce information on assets in place are stronger than for new investment opportunities. (4) Firms will attract more information production and improve their ex-ante value by committing to overinvest.
1 Introduction

Informational efficiency is a central tenet of financial economics. As Fama and Miller (1972) put it, an efficient market "has a very desirable feature. In particular, at any point in time market prices of securities provide accurate signals for resource allocation; that is, firms can make production-investment decisions ..." (p 335). Yet, although market efficiency has been extensively researched, traditional analysis of secondary financial markets limits attention to assets whose cash flows are unknown, but exogenous. This feature of traditional analysis defies the logic underlying the importance of market efficiency as articulated by Fama and Miller (1972).

We study a model where speculators in a secondary financial market produce information about firms. This information gets reflected in market prices and guides real investment decisions. This feedback from market prices to investment decisions could occur either through managerial learning or through firms’ access to capital (for empirical support, see Baker, Stein, and Wurgler (2003), Luo (2005), Chen, Goldstein, and Jiang (2006), and Bakke and Whited (2006)). A small number of papers in the literature have studied market equilibrium in the presence of this feedback effect (e.g., Leland (1992), Khanna, Slezak, and Bradley (1994), Dow and Gorton (1997), Subrahmanyam and Titman (1999), Dow and Rahi (2003), Goldstein and Guembel (2005)). In this paper, we are interested in the implications that this type of model has for the incentives of speculators to produce information.

We show that the way in which a firm’s investment decisions respond to stock price movements has important implications for information production incentives. Our main results stem from the insight that if a firm is more likely to cancel investment projects following negative price responses, the incentives for speculators to produce information will decrease. This is because, once the investment is cancelled, the security value is less sensitive to information on the project, and thus the information loses its speculative value. This logic exposes a fundamental limitation of the allocational role of price: the fact that investment decisions follow the information in the price may reduce speculators’ incentives to produce this information in the first place.

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Based on this insight, our main results are as follows. First, when a speculator produces private information, he affects the likelihood with which the firm ends up investing. This creates a new kind of externality for other potentially informed traders. For example, information production by one speculator may increase the frequency with which the firm invests. This in turn makes it more profitable for other traders to produce information, so information production may become a strategic complement (in contrast, with exogenous cash flows, information production is always a strategic substitute). As a result, multiple equilibria arise, where different equilibria are associated with different amounts of information production and thus different levels of market efficiency and different firm values. As was argued before, multiple equilibria could help explain the high volatility of financial markets and other phenomena like herds and frenzies, which cannot be explained by traditional models.

Second, in our model, speculators have a stronger incentive to produce information when investments are ex-ante more profitable. This is because high ex-ante profitability implies that the firm is more likely to invest, and this increases the expected speculative profits. Interestingly, this result implies that endogeneity in the level of information production amplifies small changes in fundamentals into large changes in firm values: the increased amount of information associated with improved fundamentals enables more efficient investment decisions, which increase value further. This provides a new explanation for fluctuations over the business cycle.

Third, our analysis has implications for incentives to collect information about assets in place versus new projects. Because new projects may be cancelled following adverse market signals, the incentive to produce information about them is lower than for assets in place (holding other things constant). In Hirshleifer’s (1971) terminology, information on new projects is discovery, while information on assets in place is foreknowledge. He emphasizes that foreknowledge has no social value, while discovery is valuable. Our finding that foreknowledge is more privately profitable than discovery is consistent with his argument that economic forces do not guarantee optimal information production.

Fourth, our analysis implies that firms with a tendency to overinvest will attract more speculative information production. Surprisingly, deviations from ex-post optimal investment decisions
increase ex-ante firm value in our model. Since more investment increases the production of information, and since information increases firm value, it is in the best interest of shareholders to have managers who tend to overinvest. The finance literature has argued that managers are ‘empire builders’ who use free cash flow to overinvest (Jensen (1986)). Our analysis shows that there is a positive side to this phenomenon. Another implication of this is that shareholders could design the firm’s financial structure to control the level of free cash flow in a way that achieves the ex-ante optimal level of overinvestment.

Our results generate an array of interesting empirical implications. In particular, our model predicts that information is more likely to be produced when investments are more profitable ex ante, when firms have more assets in place than investment opportunities, and when firms have a tendency to overinvest due to pre-committed break-up fees, empire-building managers, large amounts of free cash flows, and/or weak governance. As we note in the paper, while some of these results are consistent with existing empirical evidence about differences in the level of analyst coverage across different firms, most aspects of our results provide direction for future empirical research.

Our paper emphasizes the role of information produced by financial markets in firms’ investment decisions. The justification for the usefulness of information in financial markets for firms’ investment decisions is that markets gather information from many different participants, who are too numerous to communicate with the firm outside the trading process (see Subrahmanyam and Titman (1999)). This idea goes back to Hayek (1945), who argues that markets provide an efficient mechanism for information production and aggregation. The ability of financial markets to produce information that accurately predicts future events has also been demonstrated empirically. For example, the literature on prediction markets shows that markets provide better forecasts than polls and other devices (see Wolfers and Zitzewitz (2004)). Roll (1984) shows that private information of citrus futures traders regarding weather conditions gets impounded into citrus futures’ prices, so that prices improve even public predictions of the weather. By focusing only on the information produced in financial markets, we do not try to deny the importance of alternative producers of information, such as banks or large shareholders, which have been extensively analyzed in the
corporate finance literature (see Allen and Gale (2000), for an excellent review). Rather, we try to extend the analysis to a class of information providers, which has been somewhat neglected in the corporate finance literature.

Finally, many of our modelling assumptions are similar to Fulghieri and Lukin (2001). Their model analyzes a primary financial market, where the firm uses the proceeds from issuing securities to make an investment. They study the choice between debt and equity in such a setting. A more informationally sensitive security, such as equity, increases the incentive for speculators to acquire information. A firm that wants to mitigate the Myers and Majluf (1984) lemons problem can reduce the informational asymmetry between informed shareholders and the market by issuing securities that encourage information production. Our model analyzes the particular implications that the feedback effect in a secondary equity market has for the nature of information production. Fulghieri and Lukin (2001) do not analyze the implications of the feedback effect, and thus the questions that we address, as outlined above, are different.\footnote{Dow and Gorton (1997) also consider information production in a model with feedback effect. Their model has one speculator and focuses on comparing stock markets and banks as alternative information production systems. As such, they do not study the issues analyzed in our paper.}

The remainder of the paper is organized as follows. In Section 2, we describe the basic model. Section 3 derives the results on the amount of information production in equilibrium. In Section 4, we analyze the effect of differences in fundamentals on information production, and show that this amplifies shocks to fundamentals. Section 5 considers the differences between investment opportunities and assets in place. In Section 6, we show that firms benefit from deviating from ex-post optimal investment decisions. Section 7 concludes. All proofs are relegated to the appendix.

2 A Model of Feedback

2.1 Modelling assumptions

There is a firm with an investment opportunity. The investment requires a fixed amount $I$. The final payoff of the investment $R$ is binary and takes realizations $R_h$ and $R_l$ with equal probability, depending on the underlying state of the world $\omega \in \{l, h\}$. Assume that $R_h > I > R_l$, i.e., the
investment is worthwhile undertaking when the state of the world is \( h \) but not when it is \( l \).

The shares of the firm are traded in the financial market, where three types of agents are present: noise traders, speculators, and a market maker. Speculators are atomistic, risk neutral, and indexed by \( i \in [0, \infty) \). Each speculator can choose to become informed about \( \omega \) at cost \( c > 0 \), in which case he receives a fully-revealing signal. This assumption is made to simplify the analysis; assuming that speculators receive noisy signals would not change the results qualitatively. After deciding whether to acquire information or not, each speculator can trade \( x_i \), where \( x_i \in [-1, 1] \). Denote by \( \alpha \) the measure of speculators that become informed about \( \omega \). Noise trade \( \tilde{n} \) is normally distributed with 0 mean and variance \( \sigma^2 \). We use \( X \) to denote the total order flow. It is given by:

\[
X = \tilde{n} + \int_0^\alpha x_i di.
\]

The total order flow is submitted to a risk neutral market maker, who observes \( X \), but not its components. He then sets the price equal to the expected value of the firm conditional on the information contained in the order flow. As in Kyle (1985), this can be justified as a result of a perfectly-competitive market-making industry. Unlike Kyle (1985), here the value of the firm is not exogenous, but rather depends on the information revealed in the trading process – i.e., there is a feedback effect from the financial market to the value of the firm. This is because the decision on whether to take the investment or not is conditioned on this information.

Specifically, for most of our analysis, we assume that the firm’s objective is to maximize expected value. Its investment decision is made after observing the order flow and price. Clearly, if \( \alpha > 0 \), these will contain information about the profitability of the project. The firm will use this information and undertake the investment if and only if the updated NPV is at least 0. (In Section 6, we consider the case where the investment decision is not necessarily optimal based on the available information.) To make the analysis simpler we assumed that the firm’s manager does not receive a signal on the profitability of the investment. Allowing the manager to acquire noisy information will not affect the results qualitatively.

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3 That is, there are frictions (such as limited wealth) that constrain trade size to a maximum of 1.

4 Clearly, uninformed speculators optimally choose not to trade.
It is important to note that while we write this paper to describe a firm that learns from its own stock price, there is an alternative interpretation of our model that does not involve this assumption. According to this alternative interpretation, the firm does not have capital to pursue the investment, and relies on external providers of capital, who learn the information from the market. They will provide capital to finance the investment if and only if, based on the available information, they at least break even. If there is perfect competition among external providers of capital (i.e., when they exactly break even), the analysis of our model will remain exactly the same. In particular, the investment will be undertaken if and only if its NPV is at least zero, and the value of the firm will reflect the full profit from the investment if it is undertaken.

2.2 Trading decisions and investment policy

From risk neutrality we know that if speculators acquire information, they will trade the maximum size possible. So, when the true state is $\omega = h$ all informed speculators optimally choose to submit buy orders of size 1 and total order flow is then $X = \bar{n} + \alpha$. Conversely, when $\omega = l$ informed traders submit sell orders and total order flow is $X = \bar{n} - \alpha$.

Suppose that the belief of the market maker and the firm is that $\alpha^m$ speculators acquired information. We define $\theta(X, \alpha^m) \equiv \Pr(\omega = h|X)$ – the probability that the state of the world is $h$ given order flow $X$ and measure of informed speculators $\alpha^m$. We can write

$$\theta(X, \alpha^m) = \frac{\varphi(X - \alpha^m)}{\varphi(X - \alpha^m) + \varphi(X + \alpha^m)}, \quad (2)$$

where $\varphi(n) = \frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{1}{2}(\frac{n}{\sigma})^2}$ is the density function of the normal distribution.

An investment policy is a mapping from the firm’s belief about the high state $\omega = h$ onto its decision to invest. If the firm maximizes value conditional on $\theta$, then it will invest if and only if it believes that doing so generates a NPV of at least zero. Thus, the firm will invest if and only if

$$\theta(X, \alpha^m) \geq \delta \equiv \frac{I - R_l}{R_h - R_l}. \quad (3)$$

We will use $\delta$ as a measure of the profitability of the investment. A high $\delta$ indicates low ex-ante NPV. In particular, when $\delta > \frac{1}{2}$, the ex-ante NPV is negative, whereas when $\delta < \frac{1}{2}$, the ex-ante NPV is positive.
Since the normal distribution function satisfies the monotone likelihood ratio property, we know that $\theta(X, \alpha^m)$ is strictly increasing in $X$. Thus, we can define a cut-off value $\overline{X}$ for total order flow, such that the investment is undertaken if $X$ is above $\overline{X}$ and rejected if $X$ is below $\overline{X}$. Threshold $\overline{X}$ is determined as a function of $\alpha^m$ by $\theta(\overline{X}, \alpha^m) = \delta$. Hence, using the properties of the normal distribution function, we get:

$$\overline{X}(\alpha^m) = \frac{\sigma^2}{2\alpha^m} \ln \frac{\delta}{1 - \delta}. \quad (4)$$

The price that is set by the market maker is then given as a function of $X$ and $\alpha^m$ as follows:

$$P(X, \alpha^m) = \begin{cases} 
R_h \theta(X, \alpha^m) + R_l (1 - \theta(X, \alpha^m)) - I & \text{if} \quad X \geq \overline{X}(\alpha^m) \\
0 & \text{if} \quad X < \overline{X}(\alpha^m) 
\end{cases}. \quad (5)$$

That is, when the order flow is below $\overline{X}$, the firm does not invest so its value is 0. On the other hand, when the order flow is above $\overline{X}$, the firm invests, and its expected value is the NPV of the project conditional on the information contained in the order flow.

2.3 Trading profits

We define a function $\pi(\alpha, \alpha^m)$, which gives the expected trading profits of speculators who choose to become informed as a function of the actual mass of informed speculators $\alpha$ and the mass $\alpha^m$ that the market maker and the firm believe is present. We will require that in equilibrium $\alpha = \alpha^m$.

To confirm the equilibrium, however, it will be important to make a distinction between $\alpha$ and $\alpha^m$. This is because we will need to consider potential deviations by speculators, and this requires calculating the derivative of $\pi(\alpha, \alpha^m)$ with respect to $\alpha$.

To derive the function $\pi(\alpha, \alpha^m)$ note that when $\omega = h$, $X = \bar{n} + \alpha$, and thus the investment will be undertaken if and only if $n \geq \overline{X}(\alpha^m) - \alpha$. Similarly, when $\omega = l$, $X = \bar{n} - \alpha$, and thus the investment will be undertaken if and only if $n \geq \overline{X}(\alpha^m) + \alpha$. Then, the expected trading profits can be written as:

$$\pi(\alpha, \alpha^m) = \frac{1}{2} \int_{\overline{X}(\alpha^m) - \alpha}^{\infty} \varphi(n) (R_h - I - P((n + \alpha), \alpha^m)) \ dn \\
+ \frac{1}{2} \int_{\overline{X}(\alpha^m) + \alpha}^{\infty} \varphi(n) (P((n - \alpha), \alpha^m) - R_l + I) \ dn. \quad (6)$$
Here, if an informed speculator gets good news and buys (with probability $\frac{1}{2}$), he will make a profit if the noise traders’ order is high enough ($n \geq X(\alpha^m) - \alpha$) for the firm to invest. In this case, for each realization of $n$, his profit is the difference between the true value of the firm $R_h - I$ and the price $P((n + \alpha), \alpha^m)$. On the other hand, if the noise traders’ order is low ($n < X(\alpha^m) - \alpha$), then the investment will not be made, and the speculator ends up buying an asset with liquidation value 0 at price 0, so he makes no profit. A parallel explanation applies for a speculator who sells on bad news.

Using the price function (5), we can write:

$$
\int_{-X(\alpha^m) - \alpha}^{\infty} \varphi(n) (R_h - I - P((n + \alpha), \alpha^m)) \, dn
= (R_h - R_l) \int_{-X(\alpha^m) - \alpha}^{\infty} \varphi(n) \frac{\varphi(n + \alpha + \alpha^m)}{\varphi(n + \alpha - \alpha^m) + \varphi(n + \alpha + \alpha^m)} \, dn
= (R_h - R_l) \int_{-X(\alpha^m)}^{\infty} \frac{\varphi(x - \alpha) \varphi(x + \alpha^m)}{\varphi(x - \alpha^m) + \varphi(x + \alpha^m)} \, dx.
$$

(7)

where the second equality follows from the change of variable $x = n + \alpha$. Similarly (and using a change of variable $x = n - \alpha$) we can write:

$$
\int_{X(\alpha^m) + \alpha}^{\infty} \varphi(n) (P((n - \alpha), \alpha^m) - R_l + I) \, dn
= (R_h - R_l) \int_{X(\alpha^m)}^{\infty} \frac{\varphi(x + \alpha) \varphi(x - \alpha^m)}{\varphi(x - \alpha^m) + \varphi(x + \alpha^m)} \, dx.
$$

(8)

Then, we can rewrite $\pi(\alpha, \alpha^m)$ as follows:

$$
\pi(\alpha, \alpha^m) = \frac{1}{2} (R_h - R_l) \int_{X(\alpha^m)}^{\infty} \frac{\varphi(x - \alpha) \varphi(x + \alpha^m)}{\varphi(x - \alpha^m) + \varphi(x + \alpha^m)} \, dx
+ \frac{1}{2} (R_h - R_l) \int_{X(\alpha^m)}^{\infty} \frac{\varphi(x + \alpha) \varphi(x - \alpha^m)}{\varphi(x - \alpha^m) + \varphi(x + \alpha^m)} \, dx.
$$

(9)

2.4 Equilibrium

In equilibrium, $\alpha = \alpha^m$. That is, the mass of informed speculators that the market maker and the firm believe is present – on the basis of which the real-investment threshold and the price are set (see (4) and (5)) – is equal to the actual mass. Moreover, at the equilibrium level of $\alpha$, no further speculator has an incentive to acquire information. Let us define a function $\pi(\alpha) \equiv \pi(\alpha, \alpha)$, which
gives the expected trading profits of each trader if the equilibrium mass of speculators who have become informed is \( \alpha \). Following (9), we get:

\[
\pi(\alpha) = (R_h - R_l) \int_{X(\alpha)}^{\infty} \frac{\varphi(x-\alpha) \varphi(x+\alpha)}{\varphi(x-\alpha) + \varphi(x+\alpha)} \, dx.
\]  

(10)

Using \( \hat{\alpha} \) to denote the equilibrium level of \( \alpha \), there are two sets of conditions that may determine \( \hat{\alpha} \). First, an equilibrium with no production of information (\( \hat{\alpha} = 0 \)) is obtained when the cost to produce information is strictly greater than the expected trading profit given that no speculator produces information, i.e.,

\[
\pi(0) < c.
\]  

(11)

Second, an information with positive production of information (\( \hat{\alpha} > 0 \)) is obtained when, given that \( \hat{\alpha} \) speculators choose to produce information, each speculator who acquires information breaks even, and no further speculator has an incentive to acquire information, i.e.,

\[
\pi(\hat{\alpha}) = c
\]

and

\[
\left. \frac{d\pi(\alpha, \hat{\alpha})}{d\alpha} \right|_{\alpha=\hat{\alpha}} < 0.
\]  

(12)

2.5 Firm value

Our paper studies the interaction between the information in financial markets and real investment decisions. Ultimately, we are interested in the effect of stock price informativeness on the value of the firm. We can compute the value of the firm as a function of \( \hat{\alpha} \) as follows:

\[
\frac{1}{2} \int_{X(\hat{\alpha})}^{\infty} (R_h - I) \varphi(x - \hat{\alpha}) + (R_l - I) \varphi(x + \hat{\alpha}) \, dx.
\]  

(13)

Intuitively, when the state of the world is high (\( \omega = h \)), the firm’s investment generates a net payoff of \( (R_h - I) > 0 \), while investment takes place if and only if the realization of noise trade \( n \) is above \( X(\hat{\alpha}) - \hat{\alpha} \) (so that total order flow is above \( X(\hat{\alpha}) \)). Similarly, when \( \omega = l \), the firm’s investment generates a net payoff of \( (R_l - I) < 0 \), while investment takes place if and only if the realization of noise trade \( n \) is above \( X(\hat{\alpha}) + \hat{\alpha} \).
3 The Amount of Information in Equilibrium

3.1 Positive NPV Investment

In analyzing our model we find that the characterization of equilibrium outcomes is distinctly different for the case where the NPV of the investment is ex-ante positive than for the case where it is ex-ante negative. We first analyze the case where the investment project has a positive NPV ex ante. In this case, if no information arrives, the firm chooses to invest. This means that $I \leq \frac{1}{2}(R_h + R_l)$, or in other words $\delta \leq \frac{1}{2}$. Proposition 1 characterizes the equilibrium outcomes for this case. It says that in this case there is a unique equilibrium: if the cost of information production is high, no information is produced, whereas if it is not high, a positive measure of speculators choose to become informed.

**Proposition 1** When $\delta \leq \frac{1}{2}$, there exists a unique equilibrium. For $c < \pi(0)$, a positive measure of speculators become informed, i.e., $\hat{\alpha} > 0$, and for $c \geq \pi(0)$, no information is produced, i.e., $\hat{\alpha} = 0$.

3.2 Negative NPV Investment

Consider now the case where $\delta > \frac{1}{2}$. Proposition 2 characterizes the equilibrium outcomes for this case. It says that in this case there may be multiple equilibria. There is always an equilibrium with no production of information. If the cost of information production is high, this is the only equilibrium, whereas if it is not high, there are additional equilibria (more than one) with positive measures of speculators that choose to become informed.

**Proposition 2** When $\delta > \frac{1}{2}$:

(i) For any $c > 0$, there exists an equilibrium with $\hat{\alpha} = 0$.

(ii) For $c \leq \max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$, there also exist equilibria with $\hat{\alpha} > 0$.

(iii) For $c > \max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$, the equilibrium with $\hat{\alpha} = 0$ is unique.
Figure 1: The figure shows trading profits as a function of $\alpha$ for the case of $\delta = 0.45$ (dotted line) and for the case of $\delta = 0.55$ (solid line). The other parameters are set at $\sigma = 1$ and $R_h - R_l = 1$. The figure also shows two different costs of information production $c'$ and $c''$. $\alpha_1$ and $\alpha_2$ are two equilibrium values of the measure of informed traders when $\delta > \frac{1}{2}$ and the cost of information production is $c'$.

3.3 Discussion

Figure 1 depicts the expected trading profits as a function of the measure of speculators who choose to acquire information. The solid curve is for the case where the investment has a negative NPV ex ante (here, $\delta = 0.55$), while the dotted curve is for the case where the investment has a positive NPV ex ante (here, $\delta = 0.45$). We can see that when the ex-ante NPV is negative, the profit function is hump-shaped, whereas when the ex-ante NPV is positive, the profit function is monotonically decreasing. This illustrates why the negative NPV case may have multiple equilibria, while the positive NPV case has a unique equilibrium.

To understand the differences between the two cases, it is useful to isolate the different un-
derlying economic effects. First, there is the standard effect in models of informed trading with exogenous investment (e.g., Grossman and Stiglitz (1980)). As more speculators become informed, the equilibrium price becomes closer to the value of the stock, and profits are reduced. This causes a downward slope in the profit function. We call this the \textit{competitive effect}. In our model, it generates strategic substitutabilities in agents’ incentive to produce information.

Second, there is a new effect caused by the endogeneity of the firm’s investment decision. The direction of this effect depends on whether the project has a positive or a negative NPV ex ante. In case of a positive ex-ante NPV, without any information, the firm makes the investment, and more information decreases the probability of the investment being undertaken. This reinforces the competitive effect because as more speculators produce information, the investment is undertaken less often and the value of the stock becomes less sensitive to the information, so the trading profit decreases. This is why in the positive NPV case, the profit function is downward sloping and the equilibrium is unique.

In case of a negative ex-ante NPV, this effect is reversed to produce strategic complementarity in information production. In this case, without any information, the firm does not make the investment. As more speculators produce information, the investment is undertaken more often and the value of the stock becomes more sensitive to the information. There is an \textit{informational leverage effect},\footnote{We thank Rohit Rahi for suggesting this terminology.} where information becomes more valuable as more agents produce it. The interaction between the standard competitive effect and the informational leverage effect causes the profit function to be non monotone.

To see the effects mathematically, it is useful to look at equation (16). The first line on the right-hand side of the equation is negative (see the proof of Proposition 1). This reflects the competitive effect: holding the threshold $X(\alpha)$ – above which the firm invests – fixed, the expected trading profits decrease in the amount of informed trading. The second line on the right-hand side of the equation reflects the effect due to the change in $X(\alpha)$. When the ex-ante NPV is positive, $\frac{dX(\alpha)}{d\alpha}$ is positive. For $\alpha = 0$, the investment is always undertaken ($\lim_{\alpha \to 0} X(\alpha) = -\infty$), and more information makes the investment less likely to be undertaken. Thus, when the ex-ante NPV is
positive, the second line is negative, reinforcing the competitive effect. On the other hand, when the ex-ante NPV is negative, $\frac{\Delta \pi(\alpha)}{d\alpha}$ is negative (For $\alpha = 0$, the investment is never undertaken), and the second line is positive, generating a counter force to the competitive effect.

As a result of the non monotonicity of the pricing function in the case of an ex-ante negative NPV, we have multiple equilibria. First, there always exists an equilibrium in which no information is produced. This happens for the following reason. When nobody produces information, the firm does not invest. Then, it does not pay for an individual to become informed, since the firm’s securities never gain exposure to the information that the speculator collected. Second, when the cost of information production is not too high, there are equilibria with a positive amount of information. From Figure 1, we can see that for $c < \max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$, the profit function will intersect twice with the cost of producing information, generating two equilibria with positive amount of information. For example, if $c = c'$, we can see in the figure that one equilibrium ($\alpha_1$) is obtained at the upward sloping part of the profit function, representing less information than the other equilibrium ($\alpha_2$) that is obtained at the downward sloping part of the profit function. Essentially, there is a coordination problem in information production among multiple speculators. A coordination failure may obtain if they coordinate on producing no information or if the amount of information is $\alpha_1$ rather than $\alpha_2$.

Dow and Gorton (1997) model the feedback effect with one speculator. Their model generates two equilibria when the project has a negative NPV. In one equilibrium information is produced and the firm learns from the price, and in the other equilibrium information is not produced. Because the price is uninformative, the firm does not learn from market prices and never invests. This justifies the decision of the speculator not to produce information. The source for multiplicity in our model is different. Here, speculators’ decisions on whether to produce information depend on how much information they believe other speculators will produce. Thus, the lack of information in financial markets may be merely a result of a coordination failure among speculators.

Two other models in the literature generate strategic complementarities and multiple equilibria in information production. In Veldkamp (2006a, b), this arises because of fixed costs in the production of information. In her model, information is produced and then sold to agents who trade
on it. When demand for the information is high, the fixed cost can be distributed among many agents, and thus the price of the information is low. The low price, in turn, reinforces the high demand. Based on the same logic, an equilibrium with low demand and high price can also be sustained. In Froot, Scharfstein and Stein (1992), the source for strategic complementarities is the short-termism of speculators. A speculator in their model wants to gather the same information as other speculators because he wishes to unwind his position at a price that reflects the information on which the position is acquired.

These models of strategic complementarities and multiple equilibria are appealing because they can explain market volatility and other phenomena like herds and frenzies, which cannot be explained by traditional models and are thus often attributed to irrationality. In models of strategic complementarities, jumps between equilibria and the arbitrariness with which one equilibrium is played for some firms and another equilibrium is played for other firms generate these phenomena.

Given that our model also has strategic complementarities and multiple equilibria, it also contributes to the understanding of these phenomena. Importantly, in our model, strategic complementarities are based on a totally different mechanism. Here, it is just the feedback effect from financial markets to real investment decisions that generates complementarities. As such, our model also generates different implications than the models mentioned above. For example, our model implies that firms, for which the feedback effect from financial markets to real investments is more important, will be more likely to exhibit such multiple equilibria. In addition, as we discussed, in our model, strategic complementarities and multiple equilibria arise only when the NPV of investments is ex-ante negative. Finally, aside from the issue of strategic complementarities, our model has a whole array of other implications resulting from the feedback effect. We now turn to study these implications.
4 Differences in Fundamentals, Information Production, and Firm Value

In our model, differences in fundamentals are amplified by the endogenous production of speculative information. As we show below, firms that have more profitable projects will attract more production of speculative information. Since information improves the efficiency of ex-post investment decisions, this effect acts to amplify differences in ex-ante profitability. This result can be related to findings on amplification of shocks across stages of the business cycle and on differences in the amount of information produced for different firms.

4.1 Differences in fundamentals and information production

To analyze the effect of differences in fundamentals on information production, we study the effect of $\delta$ on the equilibrium amount of information $\hat{\alpha}$. Recall that $\delta \equiv \frac{I-R_l}{R_h-R_l}$ is a measure for the ex-ante profitability of the investment; a high $\delta$ indicates a high ex-post threshold for undertaking the investment and thus a low ex-ante NPV. In varying $\delta$, we wish to consider only the effect of the profitability of the investment without changing anything else in the factors that determine $\hat{\alpha}$. Inspecting the profit function in (10), which is the main determinant of equilibrium, we can see that this amounts either to changing $I$ or to changing $R_h$ and $R_l$ by the same amount. Thus, an increase in $\delta$ can be interpreted as an increase in $I$ or as a decrease in $R_h$ and $R_l$ while holding $(R_h - R_l)$ constant.

Another issue to consider is how to analyze the effect of $\delta$ on the equilibrium amount of information when there are multiple equilibria. In our analysis, in case of multiple equilibria, we will focus on the most informative equilibrium, i.e., the equilibrium that features the highest $\hat{\alpha}$. We will sometime use the notation $\hat{\alpha}_{\text{max}}$ to denote the highest $\hat{\alpha}$. Note that the most informative equilibrium Pareto dominates the others when we consider the value of the firm, the market maker, and the speculators. This is because, as will become clear later, the value of the firm increases in the amount of information, while the speculators and the market maker always make a profit of 0.

Proposition 3 establishes the effect of $\delta$ on $\hat{\alpha}$ (or $\hat{\alpha}_{\text{max}}$).
Proposition 3  (i) When $\delta \leq \frac{1}{2}$, if the amount of information produced in equilibrium $\hat{\alpha}$ is strictly positive, then it decreases in $\delta$.

(ii) When $\delta > \frac{1}{2}$, if the amount of information produced in the most informative equilibrium $\hat{\alpha}_{\text{max}}$ is strictly positive, then it decreases in $\delta$.

The intuition for this result is as follows. As economic fundamentals deteriorate, for each level of information production, the firm invests less frequently. Then, speculators’ expected trading profits are reduced because the value of the firm is less exposed to the information about the profitability of the investment. As a result, in equilibrium, fewer speculators find it worthwhile to pay the cost of information, and the equilibrium amount of information decreases.

One manifestation of this result is shown in Figure 1. As we see there, the profit function $\pi(\alpha)$ for the case of a positive NPV investment (the dotted curve) lies above the profit function for the case of a negative NPV investment (the solid curve). As a result, the equilibrium amount of information in case of a positive NPV investment (low $\delta$) is higher than the amount in even the most informative equilibrium in case of a negative NPV investment (high $\delta$). For example, the intersection between the dotted curve and the cost $c'$ is obtained at $\alpha > \alpha_2$, where $\alpha$ ($\alpha_2$) is the equilibrium amount of information when the NPV is positive (negative – considering the most informative equilibrium) and the cost is $c'$. Proposition 3 establishes that the increase in information holds not only for the shift from a negative to a positive NPV, but rather for any increase in profitability.

The result in Proposition 3 has two empirical implications. First, it implies that the amount of information produced will vary over time in response to aggregate fluctuations in investment prospects. When prospects are poor, firms are more likely to cancel investments and this reduces available trading profits and information production incentives. One way to test this hypothesis is to look at changes in market microstructure measures of informed trading – for example the PIN measure (see Easley, Hvidkjaer, and O’Hara (2002)) – across stages of the business cycle. Another potential proxy for the amount of information produced in financial markets is analyst activity. We are not aware of any empirical studies that have related analyst activity to the business cycle, although anecdotal evidence suggests that financial firms’ employment policies are highly cyclical.
In fact, they seem to be much more cyclical than employment policies of other firms, and thus the pattern cannot be completely explained by the changing fundamentals.

Second, the result suggests that information production should vary cross-sectionally with firms’ investment prospects. Taking analyst activity as a proxy for information production in financial markets, there is some support for this hypothesis in the empirical literature. McNichols and O’Brien (1997) investigate analysts’ decisions to initiate or drop coverage of specific stocks. They find that analysts bias their coverage towards those firms about which they have more favorable expectations. Building on these findings, Sun (2003) shows that the initiation or dropping decision itself predicts future firm performance. Das, Guoh and Zhang (2006) find that among newly listed firms, analysts selectively cover those firms for which they have more positive expectations. Firms that receive more coverage perform better afterwards.

In citing these results, we do not wish to overstate the fit of our model to the data. Clearly, there may be alternative explanations for these results. One that has been put forward in the literature is that analysts attempt to please firms, and that a negative forecast reduces a firm’s willingness to communicate with an analyst and raises the cost of producing information. It would be interesting to conduct an analysis of the relation between fundamentals and information production, using more direct measures of speculative private information in price, which are not exposed to this alternative explanation. The PIN measure, which we mentioned above, is a good candidate for such analysis. It would also be interesting to extend the existing empirical work and relate it more directly to our model by relating information not only to future stock returns of the firms, but also to their future investment behavior. Our model predicts that firms for which less information is produced (for example, firms that are dropped from coverage) will invest less in the future.

4.2 Implications for firm value

Having studied the effect of ex-ante investment profitability on the amount of information produced in equilibrium, we now turn to analyze the effect that this has on the value of the firm. The next proposition shows that, with endogenous information acquisition, the change in the value of the firm caused by a change in fundamentals is amplified compared to a model with fixed information
production. For this comparison, let \( \hat{\alpha}(\delta) \) be the equilibrium amount of information production given the threshold \( \delta \). In case of multiple equilibria, let \( \hat{\alpha}(\delta) \) represent the amount of information in the most informative equilibrium. Next, define \( V(\alpha, \delta) \) to be the ex-ante value of the firm as a function of the amount of information production \( \alpha \) and the threshold \( \delta \), where \( \alpha \) is not necessarily the equilibrium value \( \hat{\alpha}(\delta) \). Using (13), this is given by:

\[
\frac{1}{2} \int_{X(\alpha, \delta)}^{\infty} (R_0 - I) \varphi(x - \alpha) + (R_1 - I) \varphi(x + \alpha) \, dx,
\]

where \( X(\alpha, \delta) \) is derived from (4) as \( \frac{\sigma^2}{2\alpha} \ln \frac{\delta}{1 - \delta} \).

Suppose that \( \delta \) increases from \( \delta_1 \) to \( \delta_2 \). This has two effects on firm value. First, keeping the level of information production fixed, the firm’s project is less profitable (recall that a high \( \delta \) indicates low profitability) and this reduces firm value. The reduction in firm value due to this effect can be measured by \( \frac{V(\hat{\alpha}(\delta_1), \delta_2)}{V(\hat{\alpha}(\delta_1), \delta_1)} \) (where a lower number indicates a larger reduction). Second, the level of information production changes endogenously, so that the total reduction in firm value that actually occurs can be measured by \( \frac{V(\hat{\alpha}(\delta_2), \delta_2)}{V(\hat{\alpha}(\delta_1), \delta_1)} \). The information effect exacerbates the direct effect of an increase in \( \delta \) if \( \frac{V(\hat{\alpha}(\delta_1), \delta_2)}{V(\hat{\alpha}(\delta_1), \delta_1)} > \frac{V(\hat{\alpha}(\delta_2), \delta_2)}{V(\hat{\alpha}(\delta_1), \delta_1)} \). This is indeed the case, as we show in Proposition 4.

**Proposition 4** Consider two different values of \( \delta \): \( \delta_1 < \delta_2 \). Then, \( \frac{V(\hat{\alpha}(\delta_1), \delta_2)}{V(\hat{\alpha}(\delta_1), \delta_1)} > \frac{V(\hat{\alpha}(\delta_2), \delta_2)}{V(\hat{\alpha}(\delta_1), \delta_1)} \).

This result is based on the fact that the information produced by speculators increases the value of the firm. As a result, the decrease in information production caused by lower profitability amplifies the reduction in firm value. To see why information increases firm value, it is useful to inspect equation (14). Analyzing the expression inside the integral, we can see that as \( \alpha \) increases, the firm ends up undertaking the investment more frequently in the high state of the world and less frequently in the low state of the world. That is, an increase in \( \alpha \) improves the efficiency of the firm’s investment decision, and thus increases firm value. We can also see that \( \alpha \) affects the boundaries of the integral via its effect on \( X(\alpha, \delta) \). However, given that \( X(\alpha, \delta) \) is determined optimally to maximize the value of the firm, this has no effect on firm value in equilibrium (i.e., the derivative of \( V(\alpha, \delta) \) with respect to \( X(\alpha, \delta) \) is 0).

The effect of \( \delta \) on firm value is demonstrated in Figure 2. Here, the dotted line shows the effect of \( \delta \) when the amount of information remains constant, while the solid line shows the effect of \( \delta \) with
endogenous information production. Consistent with Proposition 4, the solid line is steeper, and thus the change in firm value as a result of a change in $\delta$ is amplified by the endogenous production of information. Interestingly, Figure 2 shows that there is a point, at which a small change in $\delta$ causes a discrete jump in firm value due to the endogenous response of information production. This happens when a change in $\delta$ shifts speculators from an equilibrium with no production of information to an equilibrium with positive production of information (or vice versa). Consider, for example, Figure 1 and suppose that the profit function is given by the solid hump-shaped curve and the cost of producing information is $c''$. In this case, since $c'' > \max_{\alpha \in \mathbb{R}^+} \pi (\alpha)$, there is a unique equilibrium with no information production: $\hat{\alpha} = 0$. The value of the firm is also 0 since no investment occurs. Now, since $c''$ is just slightly above $\max_{\alpha \in \mathbb{R}^+} \pi (\alpha)$, a very small decrease in $\delta$ is needed to shift the profit function upwards so that it will intersect with $c''$. This will generate an equilibrium with a large positive amount of information and a significantly positive firm value.

Overall, a small change in fundamentals here causes a discrete jump in the equilibrium behavior of speculators and consequently in the value of the firm. This is a result of the non-monotonicity of the price function, and thus it is expected to occur when the ex-ante NPV of the investment is negative.

The amplification of small changes in fundamentals into large changes in firm value, which is identified in Proposition 4, is related to the large literature on fluctuations over the business cycle (see for example, Bernanke and Gertler (1989), Greenwald and Stiglitz (1993), Kiyotaki and Moore (1997), and Suarez and Sussman (1997)). This literature typically links these fluctuations to capital market imperfections, which limit firms’ access to capital in downturns of the business cycle. One explanation in the literature (the balance-sheet channel) is that during a bust a firm’s collateral is less valuable and therefore it has more restricted access to external finance. An alternative explanation (the credit channel) is that banks’ ability to lend is reduced in recessions.

We identify a different mechanism for sharply reduced investment levels. In our setting a firm’s ability to identify good investment projects is weakened during a recession because speculators’ incentives to produce information are reduced. Another way in which our result can operate – if, as we suggest in Section 2.1, we interpreted our model to have outside capital providers instead of firm
Figure 2: The figure shows the value of the firm as a function of $\delta$ for the case where $\alpha$ is exogenous (dotted line) and for the case where $\alpha$ is endogenous (solid line). In the second case, $\alpha = \tilde{\alpha}(\delta)$, while in the first case $\alpha = \tilde{\alpha}(0.4)$, i.e., the two lines intersect when $\delta = 0.4$. The other parameters are set at $\sigma = 1$, $R_h - R_l = 1$, and $c = 0.45$. 
managers learning from the price – is that outside capital providers will be unable to identify good investments and may cut off access to capital. In our view, it is natural to think about changing access to external capital as arising from changes in the information environment since information problems are one of the fundamental reasons for firms’ limited access to external capital. To our knowledge, the model proposed in this paper is the first that links changes in the economic outlook to endogenous changes in information production and investment behavior.

Our result is also consistent with the empirical evidence on cluster periods in IPO activity (e.g., Ibbotson and Ritter (1995), Jenkinson and Ljungqvist (2000)). This clustering seems too extreme to be explained only by variations in average project profitability. Our amplification mechanism, in which lower profitability is associated with less information production, weakens the incentives of firms to carry out an IPO in bad times. In a bust, an IPO will not lead to an informative stock price\[^6\] and in addition there is no need to raise capital for investment.

5 Information Production on Assets in Place vs. Investment Opportunities

Another interesting implication of our model is the difference in information production on assets in place vs. investment opportunities. Is the stock market biased towards producing information on existing projects or on proposed new projects? To analyze this question, we compare the amount of information produced on an investment opportunity, as described thus far in the paper, with the amount of information produced on an investment that has already been undertaken although the returns have not been realized yet. This means that the amount \(I\) has been invested, while the expected return is still \(R_h\) or \(R_l\) with equal probability. Proposition 5 shows that, holding other parameters constant, the amount of information produced on assets in place is greater than the amount of information produced on an investment opportunity.

**Proposition 5** If \(c < \frac{1}{2}(R_h - R_l)\), then the equilibrium level of information production is higher for assets in place than for an investment opportunity. Otherwise, the amount of information

\[^6\]Subrahmanyam and Titman (1999) argue that obtaining an informative stock price is a major motive for IPO’s.
produced is 0 for either the assets in place or the investment opportunity.

The intuition behind this result is that for assets in place, there is no possibility that the project will be canceled and the value of the firm will lose exposure to the information on the profitability of the project. Thus, speculators have a greater incentive to produce information on assets in place.\(^7\)

We can derive an empirical prediction from this result by using book to market ratio as a proxy for the importance of assets in place relative to investment opportunities.\(^8\) Our model predicts that more information will be produced on firms with higher book to market ratios. Indeed, Hong, Lim and Stein (2000) find that, controlling for firm size and a number of other variables, analyst coverage, which is a measure of information production, depends positively and significantly on the book to market ratio. It would be interesting to relate the book to market ratio to more direct measures of private information in price, such as \(PIN\).

Finally, we wish to relate the result in this section to Hirshleifer (1971). Information on new projects is an example of what he calls discovery, while information on assets in place is foreknowledge. Discovery means learning information that will not necessarily be revealed otherwise, such as inventing a new technology. Foreknowledge means learning information that will in any case be revealed later on, such as learning a firm’s earnings a few days in advance. His model shows that the private and social rewards to either kind of information production may diverge. In particular, there may be a private benefit from socially useless foreknowledge. Our finding that foreknowledge is more privately profitable than discovery is consistent with his argument that economic forces do not guarantee optimal information production.

\(^7\)By holding other parameters constant, we focus on the difference between information production on assets in place and on investment opportunities that is caused by the mechanism in our model. In the real world, it is likely that other differences between assets in place and investment opportunities affect the amounts of information. For example, the cost of producing information \(c\) and the uncertainty \((R_h - R_i)\) are likely to be higher for investment opportunities. These two forces may affect the amount of information in opposite directions, and thus the overall effect of introducing them is unclear.

\(^8\)This is a valid proxy after the profitability of future projects is controlled for.
6 Deviating from Ex-Post Optimal Investment Policy

Our analysis so far assumed that the firm takes the ex-post optimal investment decision, given the information contained in market prices and order flows. A straightforward implication of Proposition 3 is that there would be more information produced in the financial market if the firm was expected to invest more than is ex-post optimal, i.e., if the firm was expected to overinvest.

Formally, let us use $\delta_d$ to denote the threshold probability applied ex post to decide whether to undertake the investment or not (the subscript $d$ stands for deviation because the investment decision deviates from the ex-post optimal rule). That is, the firm invests if and only if $\theta(X, \alpha) > \delta_d$. Unlike $\delta$, $\delta_d$ is not constrained to satisfy ex-post optimality, so we do not require $\delta_d$ to equal $\frac{I - R_L - R_h}{R_h - R_L}$.

Given $\delta_d$, the equilibrium amount of information $\hat{\alpha}(\delta_d)$ is determined as before as the quantity of information such that no more speculators have an incentive to become informed; see (11) and (12). The threshold order flow above which the firm invests is then $X(\hat{\alpha}(\delta_d), \delta_d) = \frac{\sigma^2}{2\alpha(\delta_d)} \ln \frac{\delta_d}{1 - \delta_d}$ (see (4)).

Based on Proposition 3, if $\delta_d < \delta$, i.e., if the firm invests more often than is ex-post optimal, the equilibrium amount of information $\hat{\alpha}(\delta_d)$ will be higher than that under optimal ex-post investment decisions $\hat{\alpha}(\delta)$ (as before, in case of multiple equilibria, we consider the most informative equilibrium). This is because when the firm invests more often, the value of the firm ends up being more correlated with the information about the profitability of the investment, and thus the speculative value of the information increases, and speculators choose to produce more information. Note that the exercise in Proposition 3 was based on shifting parameters, such that $\delta$ changes but everything else that determines the equilibrium remains the same. Thus the application of the proposition to the analysis of deviations from $\delta$ to $\delta_d$ is immediate.

The idea that more information is produced on firms that end up overinvesting is very relevant to corporate-finance theory. Indeed, many corporate-finance settings give rise to too much investment ex post. One example is when a firm is committed to pay a fee if it cancels a pre-announced investment. Such fees are very common in acquisitions and are known as break-up fees.\footnote{Often, break-up fees refer to fees payable by the target in the event of another bidder taking it over. Here, we refer to fees payable by the bidder in case it decides to cancel. Such fees have also become common in recent years.} When the
bidding firm is committed to paying a break-up fee, it may go ahead with an acquisition rather than rejecting it even when the financial markets do not react favorably to the announcement. Another example is when the firm is run by a manager who is an empire builder. Jensen’s (1986) free cash flow theory posits that managers generally want to overinvest. Overinvestment will be more pronounced in firms where shareholders have less control over the manager’s actions, for example when the manager has a lot of free cash flow – i.e., because the firm has little debt – or when corporate governance is weak.

Our paper provides a new and interesting implication about such settings. It says that when the firm has a tendency to overinvest – due to pre-committed cancellation fees, empire building managers, abundance of free cash flow, and/or weak corporate governance – speculators will have stronger incentives to produce information on its investment opportunities. Such predictions can be tested by studying the relation between information in stock price – for example, using the PIN measure – and parameters that affect the tendency to overinvest. We believe this is a promising direction for future empirical research.

Another interesting question is whether investing more often than is ex-post optimal can increase the ex-ante value of the firm. On the one hand, the analysis so far shows that information is valuable to the firm and that the firm could benefit from more information if it invested more often. However, there would be a cost to investing more often because it implies deviations from ex-post optimality. To answer this question, we investigate whether committing to deviate from $\delta$ can increase the ex-ante firm value. Using (13), we write the value of the firm as a function of $\delta_d$:

$$V(\delta_d) = \frac{1}{2} \int_{X(\tilde{\alpha}(\delta_d),\delta_d)}^{\infty} (R_h - I) \varphi(x - \tilde{\alpha}(\delta_d)) + (R_I - I) \varphi(x + \tilde{\alpha}(\delta_d)) \, dx. \quad (15)$$

Proposition 6 establishes that, to maximize ex-ante firm value, the firm always wants to commit to set $\delta_d$ lower than the ex-post optimal level $\delta$, i.e., it is optimal to commit ex ante to overinvest.

**Proposition 6** In the most informative equilibrium, the value of the firm is maximized by choosing $\delta_d < \delta$.

For example, in the HP-Compaq takeover, the merger agreement stipulated that either party would be liable to pay compensation of US$675 million if it were responsible for the failure of the transaction.
Intuitively, deviating from the ex-post optimal investment rule by committing to invest more often has two effects. First, the value of the firm falls because the investment rule no longer utilizes the information from the market in the optimal way. Second, speculators are induced to produce more information, which raises the value of the firm. However, the first effect is a second-order effect precisely because the value of the firm is maximized ex-post at that point. On the other hand, the second effect creates a first-order increase in firm value. Hence, it is always ex-ante optimal for the firm to commit to overinvest.

Importantly, the value of committing to a $\delta_d$ below the ex-post efficient level $\delta$ is particularly large when doing so allows the firm to switch from an equilibrium in which no information is acquired to one where a strictly positive amount is acquired. One example is in Figure 1, where the profit function is given by the solid hump-shaped curve and the cost of producing information is $c''$. In this case, since $c'' > \max_{\alpha \in \mathbb{R}^+} \pi (\alpha)$, there is a unique equilibrium with no information production: $\hat{\alpha} = 0$. Since $c''$ is just slightly above $\max_{\alpha \in \mathbb{R}^+} \pi (\alpha)$, the firm could commit to a $\delta_d$ that is just slightly below $\delta$ to enable an equilibrium $\hat{\alpha} (\delta_d) = \arg \max \pi (\alpha)$. This small commitment would lead to a discrete jump in the value of the firm from 0 to a significant positive number, because the amount of information produced jumps from 0 to $\hat{\alpha} (\delta_d) >> 0$.

As we discussed above, there are several ways by which the firm can commit to an ex-post inefficient investment policy. One simple way is to set a break-up fee to be paid in case the investment is canceled. Another, perhaps more natural, way is for the firm to be run by a manager who is an empire builder. As we discussed above, Jensen’s (1986) free cash flow theory posits that managers generally want to overinvest. He argues that leverage can be used to commit the firm to interest payments that reduce free cash flow and control the tendency to overinvest. Our model highlights a positive role for managerial overinvestment. In fact, our results imply that shareholders may want to leave some cash flow for the manager to overinvest in order to benefit from the informational advantage that overinvestment generates. Thus, our theory can be developed further to study how financial structure can be used as a tool to achieve the ex-ante optimal level of overinvestment.

The tension we identify here is one between interim efficiency and ex ante incentives. This
tension exists in a variety of other settings. Brander and Lewis (1986) and Fershtman and Judd (1987) show that it is ex-ante optimal for firms in Cournot competition to create incentives for managers for aggressive behavior that is ex-post inefficient. Cremer (1995) shows that a principal may not wish to fire a high ability manager, even though he performed poorly. This reduces incentives for the manager to exert effort ex ante. Thus, the principal may wish to commit to a tougher interim rule. Other papers have shown that the principal's interim efficient action may be too tough (e.g., Shleifer and Summers (1988), Burkart, Gromb and Panunzi (1997), Almazan and Suarez (2003), and Kihlstrom and Wachter (2005)). In these papers, it may be ex ante optimal to retain a manager who should be sacked from the point of view of interim efficiency. In Rotemberg and Saloner (2000), top management commits to allow middle managers, who obtain private benefits from running their pet projects, to continue with marginally unprofitable projects in order to encourage them to initiate new projects. Guembel and White (2005) show that ex-ante monitoring incentives can be improved by an interim inefficient liquidation policy.

In contrast to these papers, we show that a similar tension may apply to ex ante incentives for financial market traders to acquire information for their speculative trading and the interim efficient investment decision by a firm. Our model is distinctive in that the communication between firm and speculators takes place via the stock market price. In our model, the firm would like the speculators to produce information about a random variable, when the stock price may not end up being sensitive to this random variable. The firm therefore has an incentive to commit to making the stock price reflect the variable more often. This induces the speculators to produce more information.10

Our result can be interpreted in terms of the incompleteness of the securities market. There are relevant states of the world for which there is no state security. These states concern the value of a potential investment. If the firm does not make the investment, then the market is incomplete with respect to these states. But because the firm benefits from having a market for these securities it commits to making the investment and thereby makes the market more complete. Notice that it

10 Strobl (2006) argues that committing to overinvest makes a firm’s securities more informationally sensitive, and this can be used to improve managerial incentives under stock-based compensation.
is impossible for a third party (such as a financial futures exchange) to create this state security because its value does not depend on public information. One cannot design a security whose payoff is a function of the returns on an investment opportunity that may never be undertaken.\footnote{One could imagine creating a futures contract whose value depends on the signals received by the speculators, but it would not be incentive compatible for them to reveal their signals truthfully.}

7 Conclusions

We study the incentives for information production in a financial market where prices influence real investment decisions. We derive the following main results. First, strategic complementarities in information production may arise, as one speculator’s information may increase the chance of investment occurring and so make other speculators’ information more valuable. This leads to multiple equilibria, which may explain stock market volatility and other related phenomena. Second, the incentive to produce information decreases when economic fundamentals deteriorate. As a result, shocks to fundamentals will have an amplified effect on investment and firm value. We relate this to the literature on amplification mechanisms across the business cycle. Third, incentives to produce information on assets in place are stronger than for new investment opportunities. Yet information on projects that have not yet been undertaken is more socially valuable, because information can only affect decisions that have not already been made. Fourth, firms with a tendency to overinvest (for example, due to managerial empire building) will attract more production of speculative information. As a result, firms can improve their ex-ante value by committing to overinvest.

Our model opens several directions for future research. First and foremost, as we noted throughout the paper, there are many empirical implications of our model that may guide future empirical investigations. Our model predicts that information is more likely to be produced when investments are more profitable ex ante, when firms have more assets in place than investment opportunities, and when firms have a tendency to overinvest due to pre-committed break-up fees, empire-building managers, lots of free cash flows, and/or weak governance. As we noted in the paper, existing empirical work provides evidence consistent with the first two of these predictions, using analyst
coverage as a measure of information production. This work can be extended by looking at the relation between analyst coverage and the other variables that induce information production in our model, by looking at more direct measures of private information in financial markets, such as $PIN$, and by relating information production to real investments – a relation that constitutes a key feature of our model.

Second, according to our model, firms always benefit from having some commitment to overinvest ex post. One way to have this commitment in place is for the firm to be run by a manager who is an empire builder. Jensen’s (1986) free cash flow theory posits that managers generally want to overinvest. He argues that leverage can be used to commit the firm to interest payments that reduce free cash flow and control the tendency to overinvest. Our model highlights a positive role for managerial overinvestment, and implies that it may be worthwhile for the firm to leave some free cash flow that will enable the manager to overinvest. This will allow the firm to benefit from the increased information production. This insight suggests that financial structure can be designed optimally to trade off the benefit of overinvestment against its cost. Studying optimal financial structure in this light is an interesting direction for future research.

Third, our model shows that the feedback effect from the financial market to the firm’s investment decision may create strategic complementarities among speculators, generating multiple equilibria with different levels of information production and different firm values. As we noted in the paper, equilibria with low levels of information production will also be associated with low firm value. Thus, they can be interpreted as a coordination failure among speculators. Extending the theoretical analysis in this paper, it would be interesting to explore when such coordination failures will occur, i.e., what causes speculators to coordinate on an equilibrium with little information production. This analysis has first-order implications for the functioning of financial markets and the efficiency of real investment decisions.

Finally, to simplify the analysis and focus on the results that are derived in the paper, we assumed that firm managers who make real investment decisions do not have access to information regarding the profitability of their firms’ investments. It would be interesting to extend the model and allow for managerial information to exist alongside speculators’ information. Such a setting
raises many interesting questions; for example, will managers and speculators choose to acquire the same type or different types of information? The first possibility would be socially wasteful while the second one would not. We plan to explore these issues in future research.

8 Appendix

Proof of Proposition 1. We first show that when \( \delta \leq \frac{1}{2} \), \( \pi(\alpha) \) is a strictly decreasing function. We can write

\[
\frac{d\pi(\alpha)}{d\alpha} = (R_h - R_l) \int_{X(\alpha)}^{\infty} \frac{\varphi(x - \alpha) \varphi(x + \alpha) (\frac{x-\alpha}{\sigma^2} \varphi(x + \alpha) - \frac{x+\alpha}{\sigma^2} \varphi(x - \alpha))}{(\varphi(x - \alpha) + \varphi(x + \alpha))^2} dx
\]

\[
- (R_h - R_l) \frac{dX(\alpha)}{d\alpha} \varphi(X(\alpha) - \alpha) \varphi(X(\alpha) + \alpha)
\]

Here, we used the fact that \( \varphi'(n) = -\frac{n}{\sigma^2} \varphi(n) \).

From (4) it is clear that when \( \delta \leq \frac{1}{2} \), \( \frac{dX(\alpha)}{d\alpha} > 0 \). Thus, the second term in (16) is negative. To show that the first term is also negative, we need to show that

\[
x(\varphi(x + \alpha) - \varphi(x - \alpha)) < \alpha (\varphi(x + \alpha) + \varphi(x - \alpha)).
\]

If \( x < 0 \), then, because \( \varphi(\cdot) \) is the density function of a normal distribution with mean 0, \( \varphi(x + \alpha) > \varphi(x - \alpha) \), and thus the LHS of (17) is negative while the RHS is positive, so the inequality in (17) holds. Similarly, if \( x > 0 \), then \( \varphi(x + \alpha) < \varphi(x - \alpha) \), and again the LHS of (17) is negative while the RHS is positive, so the inequality holds. It follows that \( \frac{d\pi(\alpha)}{d\alpha} < 0 \).

Next, we argue that \( \lim_{\alpha \to \infty} \pi(\alpha) = 0 \). To see this note that because \( \varphi(n) \) approaches 0, as \( n \) approaches either \(-\infty\) or \( \infty \),

\[
\lim_{\alpha \to \infty} \frac{\varphi(x - \alpha) \varphi(x + \alpha)}{\varphi(x - \alpha) + \varphi(x + \alpha)} = 0.
\]

Thus, since \( \pi(\alpha) \) is strictly decreasing and since it approaches 0 as \( \alpha \) approaches \( \infty \), there are two possible scenarios: either (i) there is a unique intersection \( \pi(\alpha) = c \), or (ii) \( \pi(0) < c \). Case (i) will hold when \( c < \pi(0) \), whereas Case (ii) will hold when \( c \geq \pi(0) \). From (11) and (12), we know
that in Case (ii), the unique equilibrium is that there is no information production, i.e., $\alpha = 0$.

In Case (i), there is a unique candidate $\alpha > 0$ that satisfies $\pi(\alpha) = c$. To verify that this is an equilibrium, we need to check that $\frac{d\pi}{d\alpha} \bigg|_{\alpha = \hat{\alpha}} < 0$. Using (9) we can calculate the derivative and evaluate it at $\hat{\alpha}$. This yields

$$
\frac{d\pi}{d\alpha} \bigg|_{\alpha = \hat{\alpha}} = \frac{1}{2} (R_h - R_l) \int_{X(\hat{\alpha})}^{\infty} \frac{-\varphi(x - \alpha) \varphi(x + \alpha) + \varphi'(x + \alpha) \varphi(x - \hat{\alpha})}{\varphi(x - \alpha) + \varphi(x + \hat{\alpha})} dx \quad (19)
$$

which is clearly negative.

**Proof of Proposition 2.** (i) We need to show that if $\hat{\alpha} = 0$, the profit from producing information is 0. From (4), we can see that, for $\delta > \frac{1}{2}$, $\lim_{\alpha \to 0} X(\alpha) = \infty$. Plugging this in the profit function (10), and noting that $\lim_{\alpha \to 0} \frac{\varphi(x - \alpha) \varphi(x + \alpha)}{\varphi(x - \alpha) + \varphi(x + \alpha)} = \frac{1}{2} \varphi(x)$, we know that $\lim_{\alpha \to 0} \pi(\alpha) = 0$.

(ii) From (10) it is clear that $\pi(\alpha) > 0$ for all $\alpha > 0$. We showed in (18) that $\lim_{\alpha \to \infty} \pi(\alpha) = 0$, and in part (i) of this proof that (for $\delta > \frac{1}{2}$) $\lim_{\alpha \to 0} \pi(\alpha) = 0$. It follows that $\pi(\alpha)$ must have a global maximum $\max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$. Consider a cost $c \leq \max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$. Since $\pi(\alpha)$ is a continuous function, it follows that there is at least one point $\alpha > 0$ such that $\pi(\alpha) = c$ (note that when $c < \max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$, there will be at least two such points). Moreover from (12) and (19), we know that each such $\alpha$ constitutes an equilibrium.

(iii) When $c > \max_{\alpha \in \mathbb{R}^+} \pi(\alpha)$, there is no $\alpha > 0$ such that $\pi(\alpha) = c$. Thus, following (12), there is no equilibrium with $\hat{\alpha} > 0$. This means that the equilibrium $\hat{\alpha} = 0$ identified in part (i) of this proof is unique.

**Proof of Proposition 3.** (i) Expected trading profits (see (10)) depend on $\delta$ and $\hat{\alpha}$. The dependence on $\delta$ is due to the effect of $\delta$ on $X(\hat{\alpha})$ (see (4)). In an equilibrium with a strictly positive $\hat{\alpha}$, the dependence of $\hat{\alpha}$ on $\delta$ is implicitly given by $\pi(\hat{\alpha}) = c$. From the implicit function theorem we know that

$$
\frac{\partial \hat{\alpha}}{\partial \delta} = -\frac{\frac{\partial \pi(\hat{\alpha})}{\partial \delta}}{\frac{\partial \pi(\alpha)}{\partial \alpha}}. \quad (20)
$$
From Proposition 1, we know that $\frac{\partial \pi(\hat{\alpha})}{\partial \delta} < 0$. Moreover, we can calculate
\[
\frac{\partial \pi(\hat{\alpha})}{\partial \delta} = (R_h - R_l) \int_{X(\hat{\alpha})}^{\infty} \frac{\partial \varphi(x - \hat{\alpha}) \varphi(x + \hat{\alpha})}{\varphi(x - \alpha) + \varphi(x + \alpha)} \, dx
\]
\[
- (R_h - R_l) \frac{\partial \varphi(X(\hat{\alpha}) - \hat{\alpha})}{\varphi(X(\hat{\alpha}) - \hat{\alpha}) + \varphi(X(\hat{\alpha}) + \hat{\alpha})}.
\]
(21)

The first line on the RHS is 0. From (4), it follows that $\frac{\partial \varphi(X(\hat{\alpha}))}{\partial \delta} > 0$. Hence, $\frac{\partial \pi(\hat{\alpha})}{\partial \delta} < 0$ and therefore $\frac{\partial \alpha}{\partial \delta} < 0$.

(ii) First note that at the point $\pi(\hat{\alpha}_{\text{max}}) = c$, $\pi(\alpha)$ cannot be strictly increasing. Suppose to the contrary that it is strictly increasing, then, because $\pi(\alpha)$ is continuous and $\lim_{\alpha\to\infty} \pi(\alpha) = 0$, there must be $\alpha > \hat{\alpha}_{\text{max}}$, for which $\pi(\alpha) = c$. Then, by (19), $\alpha$ constitutes another equilibrium, contradicting the fact that $\hat{\alpha}_{\text{max}}$ is the most informative equilibrium.

Thus, we have two possible cases to consider. First, if $\pi(\alpha)$ is strictly decreasing at the point $\pi(\hat{\alpha}_{\text{max}}) = c$, we know from the proof in part (i) that $\hat{\alpha}_{\text{max}}$ is decreasing in $\delta$. Second, if $\pi(\alpha)$ is flat at the point $\pi(\hat{\alpha}_{\text{max}}) = c$, then an increase in $\delta$ will shift the function $\pi$ down and $\hat{\alpha}_{\text{max}}$ will fall by a discrete amount.

**Proof of Proposition 4.** We need to show that $V(\hat{\alpha}(\delta_1), \delta_2) > V(\hat{\alpha}(\delta_2), \delta_2)$. From Proposition 3, we know that $\hat{\alpha}(\delta_1) > \hat{\alpha}(\delta_2)$. Thus, we need to show that $V(\alpha, \delta)$ is strictly increasing in $\alpha$. Differentiating $V(\alpha, \delta)$ in (14) with respect to $\alpha$, we get:
\[
\frac{1}{2} \int_{X(\alpha, \delta)}^{\infty} \left[ -(R_h - I) \varphi'(x - \alpha) + (R_l - I) \varphi'(x + \alpha) \right] \, dx
\]
\[
- \frac{1}{2} \frac{\partial \varphi(X(\alpha, \delta))}{\partial \alpha} \cdot \left[ (R_h - I) \varphi(X(\alpha, \delta) - \varphi(X(\alpha, \delta) + \alpha) \right].
\]
(22)

This can be rewritten as
\[
= \frac{1}{2} [(R_h - I) \varphi(X(\alpha, \delta) - \alpha) - (R_l - I) \varphi(X(\alpha, \delta) + \alpha)]
\]
\[
- \frac{1}{2} \frac{\partial \varphi(X(\alpha, \delta))}{\partial \alpha} \cdot [(R_h - R_l) \varphi(X(\alpha, \delta) - \alpha) + (R_l - I) [\varphi(X(\alpha, \delta) + \alpha) + \varphi(X(\alpha, \delta) - \alpha)]].
\]
(23)

The expression in the first line is positive, while, using (4) and (3), we can see that the expression in the brackets in the second line is 0. Thus, the derivative of $V(\alpha, \delta)$ with respect to $\alpha$ is positive.
Proof of Proposition 5. Adapting the profit function $\pi(\alpha)$ in (10) to the case of assets in place, we get:

$$\pi_{AP}(\alpha) = (R_h - R_l) \int_{-\infty}^{\infty} \frac{\varphi(x - \alpha) \varphi(x + \alpha)}{\varphi(x - \alpha) + \varphi(x + \alpha)} dx.$$  \hspace{1cm} (24)

Essentially, since the project has already been undertaken, there is no threshold value of order flow below which the project is rejected.

The function $\pi_{AP}(\alpha)$ is downward sloping. Thus, following (11) and (12), we know that for the case of assets in place there is a unique equilibrium $\widehat{\alpha}_{AP}$, which is greater than 0 and given by $\pi_{AP}(\widehat{\alpha}_{AP}) = c$ as long as $c < \pi_{AP}(0) = \frac{1}{2} (R_h - R_l)$. Otherwise, $\widehat{\alpha}_{AP} = 0$.

Comparing (24) with (10), we can see that $\pi_{AP}(\alpha) > \pi(\alpha)$ for all $\alpha$. This implies that, as long as $c < \frac{1}{2} (R_h - R_l)$, $\widehat{\alpha}_{AP} > \alpha$ (in case $\alpha$ is not unique, the inequality is true for all of the solutions). When $c \geq \frac{1}{2} (R_h - R_l)$, there is no information produced for either the assets in place or the investment opportunity. \hfill \blacksquare

Proof of Proposition 6. First note that the firm never wants to commit to a $\delta_d > \delta$. This is because having $\delta_d > \delta$ implies less information (by Proposition 3) and deviation from ex-post optimal investment; both forces reduce the ex-ante value of the firm. Thus, to prove the proposition, it suffices to show that $\frac{dV(\delta_d)}{d\delta_d}\big|_{\delta_d=\delta} < 0$. We can write:

$$\frac{dV(\delta_d)}{d\delta_d} = \frac{1}{2} \int_{\bar{X}(\widehat{\alpha}(\delta_d), \delta_d)}^{\infty} \frac{\partial \widehat{\alpha}(\delta_d)}{\partial \delta_d} \left[ (R_h - I) \varphi' (x - \widehat{\alpha}(\delta_d)) - (R_l - I) \varphi' (x + \widehat{\alpha}(\delta_d)) \right] dx$$

$$- \frac{1}{2} \frac{\partial \bar{X}(\widehat{\alpha}(\delta_d), \delta_d)}{\partial \delta_d} \cdot \left[ (R_h - I) \varphi \left( \bar{X}(\widehat{\alpha}(\delta_d), \delta_d) - \widehat{\alpha}(\delta_d) \right) + (R_l - I) \varphi \left( \bar{X}(\widehat{\alpha}(\delta_d), \delta_d) + \widehat{\alpha}(\delta_d) \right) \right].$$  \hspace{1cm} (25)

Using the derivations in the proof of Proposition 4, we know that the term in the square brackets at the RHS of (25) is 0 when $\delta_d = \delta$. Then, we can write:

$$\frac{dV(\delta_d)}{d\delta_d} \big|_{\delta_d=\delta} = \frac{1}{2} \frac{\partial \widehat{\alpha}(\delta_d)}{\partial \delta_d} \left( (R_h - I) \varphi \left( \bar{X}(\widehat{\alpha}(\delta_d), \delta_d) - \widehat{\alpha}(\delta_d) \right) \right.$$ \hspace{1cm} (26)

$$- (R_l - I) \varphi \left( \bar{X}(\widehat{\alpha}(\delta_d), \delta_d) + \widehat{\alpha}(\delta_d) \right) \big).$$

Clearly, $(R_h - I) \varphi \left( \bar{X} - \widehat{\alpha}(\delta_d) \right) - (R_l - I) \varphi \left( \bar{X} + \widehat{\alpha}(\delta_d) \right) > 0$. Moreover, from Proposition 3, we know that $\frac{\partial \widehat{\alpha}(\delta_d)}{\partial \delta_d} < 0$ and hence $\frac{dV(\delta_d)}{d\delta_d} \big|_{\delta_d=\delta} < 0$. \hfill \blacksquare
References


