Journal of Finance and Economics, 2016, Vol. 4, No. 5, 156-165
Available online at http://pubs.sciepub.com/jfe/4/5/5

DOI:10.12691/jfe-4-5-5

Learning from Peers' Prices and Corporate Investment under the Influence of Shocks

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Abstract This paper presents a model with endogenous information acquisition when peers' valuation matters for investments. It is shown that peers' stock prices guide private investments but become less informative when decision makers trade on private information. Private information production and trading in the secondary market reduce market liquidity and thus aggravate the impact of noise-creating participation shocks on price informativeness. However, noise also provides camouflage and enables decision makers to generate trading profits at the expense of uninformed traders. There is a tradeoff between trading profit as a source for liquidity and investment efficiency.

Keywords: *information acquisition, informational feedback, peers, noise, price informativeness, investment efficiency*

Cite This Article: Marco Bade, "Learning from Peers' Prices and Corporate Investment under the Influence of Shocks." *Journal of Finance and Economics*, vol. 4, no. 5 (2016): 156-165. doi: 10.12691/jfe-4-5-5.

1. Introduction

This paper investigates the information acquisition of decision makers when learning from peers' market valuation matters for investment efficiency. The analysis suggests that private learning and informed trading by decision makers reduce market liquidity and aggravate the negative impact of noise-creating shocks on the informativeness of stock prices feeding back into corporate investments.

Basically, the concept of share prices aggregating information dates back to [1,2], and [3]. The latter two propose the most well-known models on informed trading and information aggregation of prices.[1] There is empirical evidence on the informational feedback effect on investment decisions. For instance, [14] show that firm managers condition their investment decisions on private information in the firm's own stock price. In particular, they find a relation between the informational content of prices and the sensitivity of investment to prices. However, all previous studies concentrate on feedback effects on investments of firms learning about one-dimensional uncertainty from their own stock price. However, little research has been done on learning about multi-dimensional uncertainty affecting cash flows of multiple related firms. Indeed, in reality, cash flows depend on multiple sources of uncertainty, such as macroeconomic or non-fundamental shocks. Stock prices reflect expectations of a variety of future economic developments. For example, technology shocks may exogenously affect the productivity of incumbent peer firms and thus impact their market valuation. Other firms may use the peer firms' stock prices as an indicator for future demand to guide their investment decisions. Thus, learning from peers' prices is crucial when investment efficiency matters.

According to [15], there is a positive correlation between the returns of a firm and the value of a peer firm's stock. Based on the concept of such cross-predicting stock prices, recent literature provides empirical evidence that there is a positive relation between peers' stock price movements and corporate investments (e.g., [16]). [17] consider a model in which information from peers' stock prices complements the information set of decision makers about their investment opportunities. This is the case when a firm operates in the same market segment as the peer, for example, they sell a substituting or a complementing product.

However, the participation of uninformed investors (noise traders) in the market causes an exogenous effect on demand. This may be regarded as a "participation shock" ([18]) creating noise which makes it difficult for decision makers to filter out relevant information when trying to learn from prices. In the literature, the effects of noise-creating shocks on firms' investments have received very little attention. Research in this field considers the effect of noise on secondary market trading and trading profits of insiders (e.g., [2,3,19]) as is also incorporated in this model.

More recently, [20] show that a decision maker learning from his own stock price faces a tradeoff between liquidity cost and investment efficiency determining his optimal information acquisition. Because of noise, the

1 Based on these models, subsequent studies analyze stock prices in different contexts, for example, in terms of efficiency measures (e.g., [4,5]), or investment decisions (e.g., [6]). More recent works explicitly refer to this as informational feedback from a firm's share price to its internal decision makers (e.g., [7-13]).

decision maker is unable to completely filter out information from the price. The authors argue that the negative effect on investment efficiency is caused by a crowding out effect among informed traders which reduces price informativeness and thus harms the decision maker's investment efficiency. The described setting is bound with strong restrictions concerning the trading structure. In particular, the model assumes discrete variables and a binary trading structure to solve a fixed point problem emerging from the tradability of investment opportunities.[2] This results in a high level of complexity since there are eight different trading cases that have to be considered. In fact, two of the eight cases induce a stock price revealing both the speculator's and the entrepreneur's private information totally. This is an undesired consequence as learning from prices is the primary objective studying feedback effects. In addition, limiting the positions of traders to $+1$ or -1 unit of the traded asset cannot be justified by endogenous reasons because the market participants are risk neutral. Because of limiting the demand, the aforementioned crowding out effect less intuitively expresses itself through a reduction of information quality instead of trading volume.

The present paper refers to the model of [20] by creating a similar setting. Yet, this paper focuses on the more current "learning-from-peers-hypothesis" and, in addition, relaxes the aforementioned restrictions by assuming that the relevant random variables are continuously distributed. This allows for quantitative crowding out among informed traders with respect to trading volume. Additionally, considering continuously distributed random variables allows for examining the effects of informed trading on market liquidity and prices. As a result, the model identifies a completely different reason for the negative effect of private information acquisition and trading by a decision maker on investment efficiency via market liquidity.

The model considers two-dimensional uncertainty. Consider, for example, the peer's cash flows depend on the production technology and on the demand for the firm's products. By acquiring information about one source of uncertainty of the peer's cash flows, that is, the technology-related shock, and trading in the secondary market, the entrepreneur generates a trading profit. However, it seems reasonable to assume that his investment opportunity, for example, to establish a new firm in the same market as the peer selling a complementary product, rather depends on market risks, such as product demand.[3] Outsiders, like speculators, may have better information with respect to market issues relevant for the investment opportunity. If the entrepreneur wants to skim the speculators' information to enhance investment efficiency, he has to learn from the peer's stock price. However, informed trading by the entrepreneur reduces market liquidity and thus aggravates the impact of noise on price informativeness. This harms investment efficiency. However, noise also provides camouflage in the secondary market and enables decision makers to generate trading profits at the expense of uninformed traders. The model generates a tradeoff between trading profit and investment efficiency affecting the information production of private (third-party) firms learning from peers' stock prices. Most interestingly, the present paper shows that informed trading augments the blurring impact of noise on price informativeness and thus reduces investment efficiency of firms related to the traded peer. Thus, the analysis extends and generalizes recent findings in the literature on feedback effects.

Hence, this model provides a theoretical framework for the hypothesis that learning from peers' stock prices guides real investments. To the best of my knowledge, there is no theoretical study to model the learning-from-peers-hypothesis. In addition, this paper generalizes recent findings in the literature by showing that third-party firms from the private sector face a similar tradeoff as the publicly traded peer firm and that the effect of private learning on investment efficiency is due to noise because of its relation to market liquidity. Thus, the paper highlights the opposing impacts of non-fundamental and, especially, noise-creating shocks on corporate investments, trading profit and information acquisition of firms.

The remainder of this paper is organized as follows. Section 2 describes the model. Section 3 solves the model and presents the main results. Section 4 concludes the paper.

2. The Model

2.1. Timeline

Table 1 illustrates the timeline of events. There are four dates. All market participants are assumed to be risk neutral.

Table 1. Timeline

Date t=0	t=1	t=2	t=3
Entrepreneur chooses optimal quality of private information; peer goes public	Speculator and entrepreneur learn private signals; participation shock is realized; trading in the secondary market	Entrepreneur observes peer's price and makes private investment decision	Cash flows are realized

At date t=0, there is an incumbent peer firm which is publicly traded and an entrepreneur with a private investment opportunity which is related to the peer but not publicly traded. The peer issues shares at date t=0 and produces a cash flow at date t=3. At date t=0, the entrepreneur chooses his optimal effort to acquire private information about the publicly traded peer. This makes him an informed trader in the secondary market. At date t=1, a participation shock (e.g., liquidity-shock) is realized and forces primary market investors to trade. This makes them noise traders in the secondary market. At date t=1, a speculator enters the market and receives private information. At the same time, the entrepreneur learns private information. Then, the secondary market for the peer's shares opens and informed traders, noise traders

2 A fixed point problem emerges when an investment opportunity is traded. That is, in setting the price of the investment opportunity, the market maker has to forecast both, his own belief about profitability and the investing firm's belief about the profitability of the investment. The latter, in turn, is affected by the price. The price both reflects and affects the expected value of the investment opportunity.

3 As [17] point out, a peer is not necessarily a competing firm. Instead, the two firms can complement each other, e.g. a computer manufacturer and a software producer (p. 555).

and a competitive market maker trade in a [3] setting.[4] At date t=2, the entrepreneur observes the peer's price and chooses his optimal investment conditional on his information set. Cash flows are realized in the final stage at date t=3.

2.2. Relation between the Peer and the Investment Opportunity

As motivated in [23] and [20], incumbent firms are typically exposed to multiple sources of uncertainty (i.e., product demand, production technology, idiosyncratic developments, etc.). Essentially, these risks can be grouped into two categories, that is, market-related uncertainty and firm-related uncertainty. In order to properly portray a real situation, this model considers two-dimensional uncertainty as in the models mentioned above.

The cash flow from the peer is given by $F = \mu$ where $\mu = \mu_s + \mu_e$. The two different components, μ_s and μ_e, are independent and normally distributed with means $\frac{\mu_0}{2}$ and variances σ_s^2 and σ_e^2, respectively. Think of a cash flow having market related sources of uncertainty described by μ_s (e.g., product demand shock) and firm related sources of uncertainty represented by μ_e, that is, for example, the technology shock mentioned in the introduction section.

The net cash flow G from the investment opportunity of the entrepreneur is given by:

$$G = \mu_s g I - \frac{1}{2} I^2. \qquad (1)$$

The investment opportunity depends on market related uncertainty but not on firm related uncertainty. Consider an investment opportunity in the same market and building on the same environmental conditions as the peer. I is the volume of investment. g is a measure of profitability and describes the sensitivity of the investment opportunity to the market component μ_s. Put differently, g can be interpreted as the strength of the informational feedback effect from the peer's stock.

2.3. Information Structure

The speculator learns a noisy private signal $s_s = \mu_s + \theta$ with $\theta \sim N(0, \sigma_\theta^2)$ at no cost. In contrast, the entrepreneur can buy a private signal $s_e = \mu_e + \varepsilon$ with $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ at variable cost $C(\tau_e)$. θ and ε are independent biases. Define the quality of private signals as $\tau_s \equiv \sigma_s^2 / \left(\sigma_s^2 + \sigma_\theta^2\right)$ and $\tau_e \equiv \sigma_e^2 / \left(\sigma_e^2 + \sigma_\varepsilon^2\right)$, respectively. The cost function $C(\tau_e)$ is increasing and convex with $C(0) = C'(0) = 0$, $C'(1) = \infty$ and $C''(\tau_e) > 0$.[5]

Unlike the entrepreneur and the speculator, noise traders do not have private information. Their aggregate demand n is normally distributed with mean zero and variance σ_n^2. To better understand the information structure, consider, for example, the speculator is an outsider whereas the entrepreneur is a former manager of the peer who wants to establish a spin-off by investing in a private investment opportunity. Thus, the entrepreneur can be viewed as a (former) insider. His private signal enables him to use his information to trade the peer's shares in the secondary market but does not help him to guide his private investment decision. He has to infer the speculator's information (outsider's market information) about μ_s from the peer's price.

3. Solving the Model

3.1. Investment Decision

At date t=2, the entrepreneur makes an investment decision conditional on his information set which is composed of two ingredients. Recall the investment opportunity $G = \mu_s g I - \frac{1}{2} I^2$. Since the investment opportunity depends on market related information μ_s, the entrepreneur cannot use his firm related signal about μ_e to guide the investment decision. He conditions his expectation of the cash flow from the investment opportunity on the peer's price.

$$E(G|P) = E(\mu_s \mid P) g I - \frac{1}{2} I^2. \qquad (2)$$

The price, however, is driven by information about both private signals. The first order condition determines the optimal investment decision:

$$\frac{dE(G|P)}{dI} \models E(\mu_s \mid P) g - I = 0. \qquad (3)$$

After observing the equilibrium stock price the entrepreneur chooses to invest $I^* = gE(\mu_s|P)$. Substituting I^* into G yields the ex post return:

$$G\left(I^*\right) = g^2 \left(\mu_s E(\mu_s \mid P) - \frac{1}{2} \left(E(\mu_s \mid P)\right)^2 \right). \qquad (4)$$

3.2. Equilibrium in the Secondary Market

At the beginning of stage t=1, the speculator and the entrepreneur become informed. A liquidity shock forces the original investors to trade. In addition, the speculator and the entrepreneur submit orders to the market maker based on their informational advantages. These orders and the aggregate demand of the liquidity-motivated investors add up to the total order flow X. Conditional on the aggregate order flow, the market maker takes the opposite position and sets a price to clear the market.

Because of the assumption that the random variables are normally distributed, the trading game has a tractable linear structure. Based on their information set after receiving private signals, the informed agents maximize their expected trading profits to calculate their optimal demands x_i where index i is either s for the speculator or e for the entrepreneur. As in [3], the market maker does

4 The speculator and the market maker are restricted from participating in the primary market. This is important to avoid that the original investors from the primary market are crowded out before the secondary market opens ([21,22]).

5 The assumptions about $C(\tau_e)$ together with $g < \frac{\sqrt{2\sigma_n \left(\tau_s\sigma_s^2 + \tau_e\sigma_e^2\right)^{\frac{1}{2}} \left(\tau_s\sigma_s^2 + \frac{1}{4}\tau_e\sigma_e^2\right)}}{\tau_s\sigma_s^2}$ ensure the existence of an interior solution τ_e^* maximizing the objective function of the entrepreneur in equilibrium.

not learn a private signal. Instead, he observes the total order flow $X = x_e + x_s + n$ which he cannot break down to its components. Hence, the price the market maker sets is assumed to equal the expected cash flow from the peer, conditional on his information, i.e. $P(X) = E(\mu|X)$.

The equilibrium demands of the informed agents and the share price are derived in appendix A and given by:

$$x_s^* = \frac{\sigma_n \tau_s}{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}} \left(s_s - \frac{\mu_0}{2} \right), \tag{5}$$

$$x_e^* = \frac{\sigma_n \tau_e}{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}} \left(s_e - \frac{\mu_0}{2} \right), \tag{6}$$

$$P^* = \mu_0 + \frac{\tau_s}{2}\left(s_s - \frac{\mu_0}{2} \right) + \frac{\tau_e}{2}\left(s_e - \frac{\mu_0}{2} \right) + \lambda^* n, \tag{7}$$

where

$$\lambda^* = \frac{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}}{2\sigma_n}. \tag{8}$$

(Proof, see appendix A.)

Strictly speaking, λ is a parameter to measure the market's illiquidity. Following [3], the inverse $\frac{1}{\lambda}$, measures market liquidity and can be interpreted as market depth. For ease of reading, in the following, I only use the term "market liquidity" when it comes to the effects on λ.

Ex ante, at date t=0 before any information, informed trader i expects a trading profit which is given by:

$$E(\pi_i) = \frac{\sigma_n \tau_i \sigma_i^2}{\sqrt{\tau_i \sigma_i^2 + \tau_j \sigma_j^2}}. \tag{9}$$

(Proof, see appendix A.)

Increasing his own information quality, informed trader i enhances his expected trading profit, that is, $\frac{dE(\pi_i)}{d\tau_i} > 0.$

3.3. Price Informativeness

In this model, price informativeness is defined as the uncertainty reduction effect of the peer's price concerning the component of the payoff relevant for the investment, that is:

$$\Omega_P \equiv var(\mu_s) - var(\mu_s|P^*) = \frac{1}{2}\left(\frac{(\tau_s \sigma_s^2)^2}{\tau_s \sigma_s^2 + \tau_e \sigma_e^2} \right) \tag{10}$$

(Proof, see appendix B.)

Further, define the informativeness of a private signal s_i as $\Sigma_i \equiv var(\mu) - var(\mu|s_i) = \tau_i \sigma_i^2$. Then, price informativeness can be written as:

$$\Omega_P = \frac{\Sigma_s}{2}\left(\frac{\Sigma_s}{\Sigma_s + \Sigma_e} \right). \tag{11}$$

Price informativeness is positively driven by the speculator's signal informativeness. In contrast, the quality of the information of the entrepreneur does not enhance price informativeness. Instead, precise learning by the entrepreneur about the firm specific fundamental and trading on this information conceals the information about μ_s. As a result, informed trading by the entrepreneur reduces price informativeness and thus harms his own learning and investment efficiency. The reason for that becomes obvious by plugging the variance of the price $\sigma_P^2 = \frac{1}{2}(\Sigma_s + \Sigma_e)$ into Ω_P:

$$\Omega_P = \frac{\Sigma_s^2}{4\sigma_P^2}. \tag{12}$$

Recall that the equilibrium price is a linear function in private signals and noise trading which are random variables. Therefore, price volatility depends on the variance of private signals (incorporated in Σ_i) as well as noise σ_n. This can be seen, when rewriting price volatility:

$$\sigma_P^2 = \frac{1}{4}(\Sigma_s + \Sigma_e) + \lambda^2 \sigma_n^2. \tag{13}$$

Informed demand and thus the quality of private information sensitize the market maker in setting λ, that is, λ increases in τ_i and Σ_i. This means, as an informed trader increases private information quality, the market becomes less liquid. The market maker suspects that there is more informed demand incorporated in the aggregate order flow. Thus, he increases the sensitivity of the price to the total order flow, which corresponds to reduced market liquidity. Moreover, λ augments the concealing impact of noise on price volatility which can be seen from the above expression for σ_P^2. Hence, the entrepreneur's quality of information increases price volatility and thus reduces price informativeness because of the negative impact on market liquidity and the non-observability of the non-fundamental, noise-creating participation shock.

3.4. The Entrepreneur's Objective Function and the Tradeoff

Expected value of the investment opportunity

In the following, the ex ante expected cash flow from the investment opportunity as a proxy for investment efficiency is calculated. Ex post, after private learning and observation of the peer's price, the entrepreneur infers the value of μ_s. His expectation about μ_s, given the market valuation of the peer, is given by:

$$E(\mu_s|P^*) = \frac{\mu_0}{2} + \frac{\Sigma_s}{\Sigma_s + \Sigma_e}\left(P^* - \mu_0 \right). \tag{14}$$

(Proof, see appendix C.)

Substituting $E(\mu_s|P^*)$ into the ex post net cash flow from the investment opportunity

$$G(I^*) = g^2\left(\mu_s E(\mu_s \mid P^*) - \frac{1}{2}\left(E(\mu_s \mid P^*) \right)^2 \right)$$

yields the unconditional net expected value of the investment at date t=0:

$$\Psi \equiv E\left(G\left(I^*\right)\right) = \frac{g^2}{2}\left(\frac{\mu_0^2}{4} + \Omega_P\right). \quad (15)$$

(Proof, see appendix C.)

Using the share price to guide the investment decision, the net expected cash flow from the investment opportunity positively depends on the profitability g of investment and on the informativeness of the peer's stock Ω_P about μ_s.

Expected trading profit

I now turn to the entrepreneur's expected trading profit. Because the entrepreneur has private information about the peer firm, he generates a trading profit at the expense of noise traders. As calculated in section 3.2, the entrepreneur expects a trading profit which is given by:

$$E(\pi_e) = \frac{\sigma_n \tau_e \sigma_e^2}{\sqrt{\tau_e \sigma_e^2 + \tau_s \sigma_s^2}}. \quad (16)$$

His expected trading profit increases in noise because it helps the entrepreneur to camouflage his trading.

Objective function and the tradeoff

With this preparation, one can derive the objective function of the entrepreneur. Anticipating the cash flow from the investment opportunity, the expected trading profit and the cost of acquiring private information, the objective function of the entrepreneur is given by:

$$V_0 = \Psi + E\left(\pi_e\right) - C, \quad (17)$$

where $\Psi, E(\pi_e)$ and C depend on τ_e.

The entrepreneur's information quality has two main effects on his objective function. On one hand, more precise private learning enhances his expected trading profit, that is $\frac{dE\left(\pi_e\right)}{d\tau_e} > 0$. However, as discussed in section 3.3, trading by the entrepreneur causes a negative effect on the peer's price informativeness and thus on investment efficiency, that is $\frac{d\Psi}{d\tau_e} < 0$. As a result, there is a tradeoff between trading profit and investment efficiency.

The tradeoff indicates that there is an optimal information quality τ_e^* of the entrepreneur that maximizes his objective function at t=0. τ_e^* satisfies the first order condition given by:

$$\frac{dV_0}{d\tau_e} = \frac{d\Psi}{d\tau_e} + \frac{dE\left(\pi_e\right)}{d\tau_e} - \frac{dC}{d\tau_e} = 0. \quad (18)$$

In fact, there is an interior solution $\tau_e^* \in (0;1)$ if and only if the profitability g of investment is sufficiently small (proof, see appendix C). This is because the effect on investment efficiency is augmented by the informational feedback effect. As g increases, the investment opportunity becomes more important, from the entrepreneur's perspective. This makes the entrepreneur put more emphasis on an efficient investment. Otherwise, if g decreases, the entrepreneur rather focuses on generating trading profits and accepts a less efficient investment decision.

3.5. Optimal Information Quality of the Entrepreneur

This section analyzes the optimal information quality of the entrepreneur. The tradeoff discussed above indicates that there are two main incentives motivating the entrepreneur to acquire more or less precise private information. Both of the incentives are determined by exogenous parameters. This suggests that the entrepreneur differently reacts to changing conditions represented by the parameters. To analyze the entrepreneur's optimal choice of information quality I compute comparative statics of τ_e^* with respect to g, σ_n and Σ_s (see appendix D).

Parameter g represents the profitability of the new investment opportunity. If the new investment opportunity is valuable, the entrepreneur should focus on an efficient investment decision instead of trading profits. Thus, he should try to get information about μ_s by refraining from private information acquisition and by looking at the share price of the peer. In the course of this, the entrepreneur reduces his effort in private information acquisition to maximize price informativeness and thus increase his expected cash flow from the investment opportunity, that is $\frac{d\tau_e^*}{dg} < 0$.

In contrast, noise σ_n arising from the participation shock encourages informed traders to aggressively utilize information advantages. This increases informed trading profits. Hence, noise causes the entrepreneur to focus on private information production and trading of the peer's shares, that is $\frac{d\tau_e^*}{d\sigma_n} > 0$, although there is a negative impact on price informativeness. This is interesting and can be explained by the fact that σ_n has no direct effect but an indirect effect (via the effect of τ_e on market liquidity and price volatility, as discussed in section 3.3) on Ω_P and Ψ.

The quality of the speculator's information Σ_s influences both of the incentive mechanisms. On one hand, the signal informativeness of the speculator augments the negative effect of τ_e on investment efficiency Ψ, that is $\frac{d^2\Psi}{d\tau_e d\Sigma_s} < 0$. This is hardly surprising given the fact that Σ_s directly increases price informativeness and thus investment efficiency. The resulting incentive for the entrepreneur to reduce private information quality is stronger, the higher the quality of relevant information flowing from the peer's stock price. Hence, if the speculator has high quality information, the entrepreneur decides to privately learn less precise information because the information content of the stock is more promising and relevant for the investment.

On the other hand, the signal quality of the speculator has two countervailing effects on the positive effect of τ_e on expected trading profit $E(\pi_e)$. This is because it simultaneously increases (direct effect) and decreases (indirect effect via reduction of market liquidity) the expected trading profit of the entrepreneur. In fact, $\frac{d^2E\left(\pi_e\right)}{d\tau_e d\Sigma_s} > 0$ if and only if $2\Sigma_s < \Sigma_e$. This means, the signal informativeness of the speculator augments the positive effect of τ_e on expected trading profit $E(\pi_e)$ if and only if the quality of the speculator's information is sufficiently low, compared to the entrepreneur.

In this case, Σ_s weakens the incentive to increase information quality arising from enhanced trading profit and strengthens the incentive to reduce information quality arising from reduced investment efficiency. In contrast, if $2\Sigma_s > \Sigma_e$, there is a augmentation effect of Σ_s on the effect of τ_e on expected trading profit $E(\pi_e)$. Thus, when this effect is stronger than the effect of Σ_s on the effect of τ_e on investment efficiency Ψ, the net effect is positive. This depends on the profitability of investment. If g is sufficiently small, the net effect is positive and the entrepreneur is incentivized to increase private information quality. Otherwise, if g is sufficiently high, the entrepreneur primarily focuses on an efficient investment decision instead of generating trading profits. Hence, he chooses to reduce information quality (for all proofs, see the appendix D).

4. Conclusion

This paper studies the information acquisition of decision makers when peer's valuation matters for real investments. The model is consistent with a good deal of empirical findings from the literature on both feedback effects and the learning-from-peers-hypothesis. Yet, this paper contributes to the literature on both topics as it presents some new findings and predictions.

Indeed, peers' stock prices guide private investments and improve investment efficiency if these prices contain information new to decision makers. However, this model suggests that learning from prices should not be the ultimate goal of decision makers. This is because informed trading based on information which is not relevant for investments, for example, when decision makers aim to generate trading profits, reduces price informativeness. That is, private information acquisition and trading in the secondary market reduce the market's liquidity and hence aggravate the negative impact of noise-creating participation shocks on peers' price informativeness. Nevertheless, noise also provides camouflage and enables privately informed decision makers to generate trading profits. This creates a tradeoff between trading profit as a source for liquidity and investment efficiency. The tradeoff determines the optimal information acquisition of decision makers with private investment opportunities.

The main contribution of this paper is the model's proposition that there is a negative relation between private firms' effort to acquire information and the liquidity of the market. Another contribution is highlighting the opposing impacts of non-fundamental, noise-creating shocks on corporate investments, trading profit and thus on the information acquisition of private firms. In addition, the present paper generalizes recent results of [20] by showing that privately held firms face a similar tradeoff between trading profit (liquidity) and investment efficiency as the publicly traded peer firm learning from its own stock price. Further, the paper is closely related to the learning-from-peers-hypothesis which is empirically tested. This is the first study to model the informational feedback effect from peers' valuation to corporate investment decisions of private firms.

Moreover, the model suggests that there is a negative relation between markets' liquidity and price informativeness and thus investment efficiency. That is, the analysis shows that private learning increases the sensitivity of prices to order flows, which corresponds to reduced market liquidity. This augments the concealing impact of noise on price volatility. Hence, decision makers' quality of information increases price volatility and thus reduces price informativeness because of the negative impact on market liquidity and the non-observability of non-fundamental, noise-creating participation shocks. This finding provides an entirely new explanation for the negative effect of private learning and informed trading by decision makers on investment efficiency.

Yet, this paper has some limitations as it does not cover an empirical study. For example, looking toward future research, it would be interesting to test the relation between markets' liquidity and the informativeness of stock prices as this model predicts a negative relation. It is at least of equal interest to test the relation between markets' liquidity and investment efficiency. On the theoretical level, the paper abstracts from other interesting topics as, for example, the model does not endogenize the information production of the speculator. This could add some deeper insights into the effects of private information acquisition and trading by decision makers on financial markets. In addition, this would nest the setup in the literature referred to in the text (e.g., [20]) and thus help to explain what additional new things the information acquisition behavior of a real decision maker adds to the literature.

Appendices

Appendix A: Trading in the Secondary Market

Proof of the secondary market equilibrium

In Appendix A, I derive the secondary market equilibrium. Prior to this, the conditional expectations of the informed agents about the stochastic payoff μ are calculated, starting with the speculator. Based on his private signal s_s the speculator expects:

$$\begin{aligned} E(\mu|s_s) &= E(\mu) + \frac{cov(\mu, s_s)}{var(s_s)}\left(s_s - E(s_s)\right) \\ &= \mu_0 + \frac{cov(\mu_s, \mu_s + \theta)}{var(\mu_s + \theta)}\left(s_s - \frac{\mu_0}{2}\right) \\ &= \mu_0 + \frac{\sigma_s^2}{\sigma_s^2 + \sigma_\theta^2}\left(s_s - \frac{\mu_0}{2}\right) \end{aligned} \tag{19}$$

Substituting $\tau_s \equiv \frac{\sigma_s^2}{\sigma_s^2 + \sigma_\theta^2}$, the expectation can be rewritten as follows:

$$E(\mu|s_s) = \mu_0 + \tau_s\left(s_s - \frac{\mu_0}{2}\right). \tag{20}$$

Analogous, given his private signal s_e, the entrepreneur expects:

$$E(\mu|s_e) |= E(\mu) + \frac{\text{cov}(\mu, s_e)}{\text{var}(s_e)}(s_e - E(s_e)). \quad (21)$$

Hence, the expectation of the entrepreneur is given by:

$$E(\mu|s_e) |= \mu_0 + \tau_e\left(s_e - \frac{\mu_0}{2}\right). \quad (22)$$

The market maker sets a price conditional on the aggregate order flow $X = x_e + x_s + n$. Anticipating that the informed agents have linear demand functions $x_i = \delta + \gamma E(\mu|s_i)$ his expectation conditional on the total order flow is a linear function as well:

$$\begin{aligned} P(X) &|= E(\mu|X) \\ &|= E(\mu) + \frac{\text{cov}(\mu, X)}{\text{var}(X)}(X - E(X)) \\ &|= \mu_0 + \frac{\text{cov}(\mu, \delta + \gamma E(\mu|s_s) + \delta + \gamma E(\mu|s_u) + n)}{\text{var}(\delta + \gamma E(\mu|s_s) + \delta + \gamma E(\mu|s_u) + n)} \\ &\cdot (X - E(X)). \end{aligned} \quad (23)$$

Thus, the linear pricing rule of the market maker is:

$$P(X) = \phi + \lambda X \quad (24)$$

where $\phi = E(\mu) - \lambda E(X)$ is a constant shift parameter and $\lambda = \frac{\gamma\left(\tau_s \sigma_s^2 + \tau_u \sigma_u^2\right)}{\gamma^2\left(\tau_s \sigma_s^2 + \tau_u \sigma_u^2\right) + \sigma_n^2}$ is the sensitivity of the stock price to the total order flow X.

The informed agents maximize their expected trading profits:

$$\max_{x_s}\left(x_s\left(E(\mu|s_s) - E(P(X))\right)\right). \quad (25)$$

Using (A1) and (A3), the speculator's maximization problem is:

$$\max_{x_s}\left(x_s\left(\mu_0 + \tau_s\left(s_s - \frac{\mu_0}{2}\right) - E(\phi + \lambda X)\right)\right) = 0. \quad (26)$$

Since the private signals of the informed agents contain information about independent parts of the stochastic payoff, the signals are uncorrelated. As a consequence, one informed trader cannot infer any information from his own signal about the signal of the competitor. Furthermore, the demand of the noise traders has zero mean. Thus, $E(\phi + \lambda X) = E(\phi + \lambda x_e + x_s + n) = \phi + \lambda x_s$. Solving the maximization problem yields the linear demand function of the speculator:

$$x_s |= \delta + \gamma E(\mu|s_s), \quad (27)$$

where $\delta = -\frac{\phi}{2\lambda}$ and $\gamma = \frac{1}{2\lambda}$.

Similarly, the demand function of the entrepreneur is:

$$x_e |= \delta + \gamma E(\mu|s_e) \quad (28)$$

with identical parameters δ and γ.

There are four equations to determine equilibrium parameters:

$$\phi = E(\mu) - \lambda E(X), \quad (29)$$

$$\lambda = \frac{\gamma\left(\tau_s \sigma_s^2 + \tau_u \sigma_u^2\right)}{\gamma^2\left(\tau_s \sigma_s^2 + \tau_u \sigma_u^2\right) + \sigma_n^2}, \quad (30)$$

$$\delta = -\frac{\phi}{2\lambda}, \quad (31)$$

$$\gamma = \frac{1}{2\lambda}. \quad (32)$$

From the perspective of the market maker, $E(X) = E(x_e + x_s + n) = 0$ because he cannot observe the private signals of informed traders. Thus, from equation (29) it is straightforward that:

$$\phi^* = E(\mu) = \mu_0. \quad (33)$$

Substituting (31) into (30) leads to:

$$\begin{aligned} \lambda &|= \frac{\frac{1}{2\lambda}\left(\tau_s \sigma_s^2 + \tau_e \sigma_e^2\right)}{\frac{1}{4\lambda^2}\left(\tau_s \sigma_s^2 + \tau_e \sigma_e^2\right) + \sigma_n^2} \\ \lambda&\left(\frac{1}{4\lambda^2}\left(\tau_s \sigma_s^2 + \tau_e \sigma_e^2\right) + \sigma_n^2\right) \\ &|= \frac{1}{2\lambda}\left(\tau_s \sigma_s^2 + \tau_e \sigma_e^2\right) \\ &|= \frac{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}}{2\sigma_n}. \end{aligned} \quad (34)$$

In the last step, I substitute ϕ^* and λ^* into equation (31) and equation (32). This leads to:

$$\delta^* |= -\frac{\mu_0 \sigma_n}{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}}, \quad (35)$$

$$\gamma^* |= \frac{\sigma_n}{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}}. \quad (36)$$

Substituting equilibrium parameters into equation (27) yields the speculators equilibrium demand function:

$$x_s^* |= \frac{\sigma_n \tau_s}{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}}\left(s_s - \frac{\mu_0}{2}\right). \quad (37)$$

The optimal demand of the entrepreneur is given by:

$$x_e^* |= \frac{\sigma_n \tau_e}{\sqrt{\tau_s \sigma_s^2 + \tau_e \sigma_e^2}}\left(s_e - \frac{\mu_0}{2}\right). \quad (38)$$

Using equation (37) and equation (38), the equilibrium price of the peer's stock is given by:

$$P^* = \mu_0 + \frac{\tau_s}{2}\left(s_s - \frac{\mu_0}{2}\right) + \frac{\tau_e}{2}\left(s_e - \frac{\mu_0}{2}\right) + \lambda^* n. \quad (39)$$

Proof of the expected trading profits

After receiving the private signal and observing the equilibrium price, the speculator expects to benefit from trading:

$$\pi_s = x_s^*\left(E\left(\mu|s_s,P^*\right)-P^*\right). \quad (40)$$

The ex post expectation is given by:

$$E\left(\mu|s_s,P^*\right) |= E(\mu)+\frac{\text{cov}(\mu,s_s)}{\text{var}(s_s)}\left(s_s-E(s_s)\right) + \frac{\text{cov}\left(\mu,P^*\right)}{var\left(P^*\right)}\left(P^*-E\left(P^*\right)\right) \quad (41)$$
$$|= P^*+\tau_s\left(s_s-\frac{\mu_0}{2}\right).$$

Using equation (37), the ex post trading profit of the speculator can be rewritten:

$$\pi_s |= \frac{\sigma_n\tau_s}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}\begin{pmatrix} s_s \\ -\frac{\mu_0}{2}\end{pmatrix}\left(P^*+\tau_s\begin{pmatrix} s_s \\ -\frac{\mu_0}{2}\end{pmatrix}-P^*\right) \quad (42)$$
$$|= \frac{\sigma_n\tau_s^2}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}\left(s_s-\frac{\mu_0}{2}\right)^2.$$

Taking unconditional expectation leads to the ex ante expected trading profit of the speculator at date t=0:

$$E(\pi_s) |= \frac{\sigma_n\tau_s^2}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}E\left(\left(s_s-\frac{\mu_0}{2}\right)^2\right)$$
$$|= \frac{\sigma_n\tau_s^2}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}\begin{pmatrix}\text{var}\left(s_s-\frac{\mu_0}{2}\right) \\ +E^2\left(s_s-\frac{\mu_0}{2}\right)\end{pmatrix} \quad (43)$$

where $E\left(s_s-\frac{\mu_0}{2}\right)=0$. Hence:

$$E(\pi_s) = \frac{\sigma_n\tau_s\sigma_s^2}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}. \quad (44)$$

The expected trading profit of the entrepreneur is given by:

$$E(\pi_e) = \frac{\sigma_n\tau_e\sigma_e^2}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}. \quad (45)$$

Appendix B: Price Informativeness

Define the informativeness of a private signal $s_i=\mu_i+\alpha$ about the i-component of the stochastic payoff where α is noise as follows:

$$\Sigma_i |\equiv \text{var}(\mu)-\text{var}(\mu|s_i)$$
$$|= \frac{\left(\frac{\sigma_i^2}{\sigma_i^2+\sigma_\alpha^2}\right)^2}{\sigma_i^2+\sigma_\alpha^2} \quad (46)$$
$$|= \tau_i\sigma_i^2.$$

Now, define price informativeness:

$$\Omega_P \equiv \text{var}(\mu_s)-\text{var}\left(\mu_s|P^*\right). \quad (47)$$

Using $\Sigma_i=\tau_i\sigma_i^2$, price informativeness simplifies to:

$$\Omega_P |= \text{var}(\mu_s)-\left(\text{var}(\mu_s)-\frac{cov^2\left(\mu_s,P^*\right)}{\text{var}\left(P^*\right)}\right) \quad (48)$$
$$|= \frac{1}{2}\left(\frac{\Sigma_s^2}{\Sigma_s+\Sigma_e}\right).$$

In addition, define stock price volatility as the variance of the equilibrium share price:

$$\sigma_P^2 \equiv \text{var}(P) = \text{var}\begin{pmatrix}\mu_0+\frac{\tau_s}{2}\left(s_s-\frac{\mu_0}{2}\right) \\ +\frac{\tau_e}{2}\left(s_e-\frac{\mu_0}{2}\right)+\lambda^*n\end{pmatrix}. \quad (49)$$

Note that the private signals and the demand of the noise traders are independent random variables, that is, $cov(s_s,s_e)=cov(s_s,n)=cov(s_e,n)=0$. Thus,

$$\sigma_P^2 |= \frac{\tau_s^2}{4}\text{var}(s_s)+\frac{\tau_e^2}{4}\text{var}(s_e)+\lambda^{*2}\,\text{var}(n) \quad (50)$$
$$|= \frac{1}{2}(\Sigma_s+\Sigma_e).$$

With the variance of the price, the alternative notation of price informativeness as given in the text is straightforward:

$$\Omega_P = \frac{\Sigma_s^2}{4\sigma_P^2}. \quad (51)$$

Appendix C: The Entrepreneur's Objective Function and the Tradeoff

Objective function

In this appendix, the entrepreneur's objective function as given in the text is derived. As shown in appendix A, the entrepreneur's expected trading profit is given by $E(\pi_e)=\frac{\sigma_n\tau_e\sigma_e^2}{\sqrt{\tau_s\sigma_s^2+\tau_e\sigma_e^2}}$. In order to complete the objective function, I now calculate Ψ.

The entrepreneur's ex post expectation about the payoff μ_s after learning from the peer's price is given by:

$$E\left(\mu_s|P^*\right) |= E(\mu_s)+\frac{\text{cov}\left(\mu_s,P^*\right)}{\text{var}\left(P^*\right)}\left(P^*-E\left(P^*\right)\right) \quad (52)$$
$$|= \frac{\mu_0}{2}+\frac{\Sigma_s}{\Sigma_s+\Sigma_e}\left(P^*-\mu_0\right).$$

The ex post cash flow from the investment opportunity is $G(I^*)=g^2\left(\mu_sE(\mu_s|P^*)-\frac{1}{2}\left(E(\mu_s|P^*)\right)^2\right)$. Define $\Psi\equiv E\big(G(I^*)\big)$ as the ex ante expected cash flow from the investment opportunity as a proxy for investment efficiency. Now, I substitute $E(\mu_s|P^*)$ and take unconditional expectation to calculate the belief of the entrepreneur at date t=0, before he learns any information about the payoff, that is:

$$\Psi = E\left(g^2\left(\mu_s E(\mu_s|P^*) - \frac{1}{2}E^2(\mu_s|P^*)\right)\right) = \frac{g^2}{4}\left(\frac{\mu_0^2}{2} + \frac{\Sigma_s^2}{\Sigma_s + \Sigma_e}\right) \quad (53)$$

Recalling price informativeness Ψ as derived in appendix B, one can rewrite Ψ as follows:

$$\Psi = \frac{g^2}{2}\left(\frac{\mu_0^2}{4} + \Omega_P\right). \quad (54)$$

The tradeoff

In section 3.3, it is shown that the information quality of the entrepreneur has a negative effect on price informativeness and thus on investment efficiency, that is:

$$\frac{d\Psi}{d\tau_e} = -\frac{g^2\sigma_e^2}{4}\left(\frac{\Sigma_s}{\Sigma_s + \tau_e\sigma_e^2}\right)^2 < 0. \quad (55)$$

Furthermore, as stated in section 3.2, there is a positive effect of τ_e on the entrepreneur's expected trading profit, which can be expressed by:

$$\frac{dE(\pi_e)}{d\tau_e} = \frac{\sigma_e^2\sigma_n\left(\tau_e\sigma_e^2 + 2\tau_s\sigma_s^2\right)}{2\left(\tau_e\sigma_e^2 + \tau_s\sigma_s^2\right)^{\frac{3}{2}}} > 0. \quad (56)$$

At date t=0, the entrepreneur seeks to maximize his objective function, given by:

$$V_0 \equiv E(A) + \Psi + E(\pi_e) - C. \quad (57)$$

The first order condition is given by:

$$\frac{dV_0}{d\tau_e} = \frac{d\Psi}{d\tau_e} + \frac{dE(\pi_e)}{d\tau_e} - \frac{dC}{d\tau_e} = 0, \quad (58)$$

where $\frac{dE(\pi_e)}{d\tau_e} > 0$ and $\frac{d\Psi}{d\tau_e} - \frac{dC}{d\tau_e} < 0$. This is the tradeoff of the model.

Proof of the existence of an interior solution τ_e^*

If $\tau_e = 0$, $\frac{dV_0}{d\tau_e} > 0$ if and only if

$$g < 2\sqrt{\frac{\sigma_n}{\sqrt{\Sigma_s}}}. \quad (59)$$

Recall that, by assumption (see footnote 5):

$$g < \frac{\sqrt{2\sigma_n\left(\Sigma_s + \tau_e\sigma_e^2\right)^{\frac{1}{2}}\left(\Sigma_s + \frac{1}{4}\tau_e\sigma_e^2\right)}}{\Sigma_s}. \quad (60)$$

Setting $\tau_e = 0$ yields:

$$g < \sqrt{\frac{2\sigma_n}{\sqrt{\Sigma_s}}}. \quad (61)$$

Note that equation (61) is a stricter condition than equation (59). In addition, $C'(0) = 0$. Thus, if $\tau_e = 0$, $\frac{dV_0}{d\tau_e} > 0.$. Furthermore, if $\tau_e = 1$, $\frac{dV_0}{d\tau_e} < 0$ because $C'(1) = \infty$.

The second order condition is given by:

$$\frac{d^2V_0}{d\tau_e^2} = \frac{\sigma_e^4}{2}\cdot\left(\begin{array}{l}\frac{g^2\Sigma_s^2}{\left(\Sigma_s + \tau_e\sigma_e^2\right)^3} \\ +\sigma_n\left(\begin{array}{l}\frac{1}{\left(\Sigma_s + \tau_e\sigma_e^2\right)^{\frac{3}{2}}} \\ -\left(\frac{3}{2}\right)\frac{2\Sigma_s + \tau_e\sigma_e^2}{\left(\Sigma_s + \tau_e\sigma_e^2\right)^{\frac{5}{2}}}\end{array}\right)\end{array}\right) - \frac{d^2C}{d\tau_e^2} < 0, \quad (62)$$

because $g < \frac{\sqrt{2\sigma_n\left(\Sigma_s + \tau_e\sigma_e^2\right)^{\frac{1}{2}}\left(\Sigma_s + \frac{1}{4}\tau_e\sigma_e^2\right)}}{\Sigma_s}$ and $\frac{d^2C}{d\tau_e^2} > 0$. Therefore, there exists a unique interior solution $\tau_e^* \in (0;1)$, such that $\frac{dV_0}{d\tau_e} = 0$.

Appendix D: Optimal Information Quality of the Entrepreneur

In order to analyze the effects of the parameters g, σ_n and Σ_s on the optimal information quality of the entrepreneur, I compute comparative statics with respect to each parameter.

By the envelope theorem,

$$\frac{d\tau_e^*}{dg} = -\frac{\frac{d^2V_0}{d\tau_e dg}}{\frac{d^2V_0}{d\tau_e^2}}. \quad (63)$$

As shown in appendix C, $\frac{d^2V_0}{d\tau_e^2} < 0.$. Hence, the effect of g on τ_e^* ultimately depends on the cross derivative which is given by:

$$\frac{d^2V_0}{d\tau_e dg} = -\frac{g\sigma_e^2}{2}\left(\frac{\Sigma_s}{\Sigma_s + \Sigma_e}\right)^2 < 0. \quad (64)$$

Similarly, concerning noise σ_n,

$$\frac{d\tau_e^*}{d\sigma_n} = -\frac{\frac{d^2V_0}{d\tau_e d\sigma_n}}{\frac{d^2V_0}{d\tau_e^2}} > 0, \quad (65)$$

because $\frac{d^2V_0}{d\tau_e d\sigma_n} = \frac{\sigma_e^2(2\Sigma_s + \Sigma_e)}{2(\Sigma_s + \Sigma_e)^{\frac{3}{2}}} > 0.$

Finally, $\frac{d\tau_e^*}{d\Sigma_s}$ is given by:

$$\frac{d\tau_e^*}{d\Sigma_s} = -\frac{\frac{d^2 V_0}{d\tau_e d\Sigma_s}}{\frac{d^2 V_0}{d\tau_e^2}}. \tag{66}$$

It is not obvious whether $\frac{d^2 V_0}{d\tau_e d\Sigma_s}$ is greater or less than zero. I now examine this expression in detail:

$$\begin{aligned} \frac{d^2 V_0}{d\tau_e d\Sigma_s} |&= \frac{d^2 \Psi}{d\tau_e d\Sigma_s} - \frac{d^2 E(\pi_e)}{d\tau_e d\Sigma_s} \\ |&= -\frac{g^2 \sigma_e^2 \Sigma_s \Sigma_e}{2(\Sigma_s + \Sigma_e)^3} + \frac{\sigma_n \sigma_e^2}{4(\Sigma_s + \Sigma_e)^{\frac{5}{2}}} (\Sigma_e - 2\Sigma_s). \end{aligned} \tag{67}$$

If $\Sigma_e - 2\Sigma_s < 0$, $\frac{d^2 V_0}{d\tau_e d\Sigma_s} < 0$ and thus $\frac{d\tau_e^*}{d\Sigma_s} < 0$. In contrast, given $\Sigma_e - 2\Sigma_s > 0$, $\frac{d^2 V_0}{d\tau_e d\Sigma_s} < 0$ if and only if:

$$\begin{aligned} &-\frac{g^2 \sigma_e^2 \Sigma_s \Sigma_e}{2(\Sigma_s + \Sigma_e)^3} + \frac{\sigma_n \sigma_e^2}{4(\Sigma_s + \Sigma_e)^{\frac{5}{2}}} (\Sigma_e - 2\Sigma_s) |< 0 \\ &g |> \sqrt{\frac{\sigma_n (\Sigma_s + \Sigma_e)^{\frac{1}{2}}}{2\Sigma_s \Sigma_e} (\Sigma_e - 2\Sigma_s)}. \end{aligned} \tag{68}$$

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