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Feedback from Stock Prices to Cash Flows

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ABSTRACT

Feedback from financial market prices to cash flows arises when a firm's non-financial stakeholders, for example, its customers, employees, and suppliers, make decisions that are contingent on the information revealed by the price. Complementarities across stakeholders result in cascades, wherein relatively small stock price moves trigger substantial changes in asset values. This paper analyzes the relation between such feedback effects and parameters such as the information cost, the volatility of existing projects, the risk aversion of liquidity suppliers, and the precision of managerial information.

TRADITIONAL VALUATION MODELS TAKE AS GIVEN an investment's cash-flow pattern, which, along with a discount rate, determines the price or value of the investment. Based on these models, we expect stock price movements to be associated with news about either future cash flows or discount rates. However, in reality, it is often quite difficult to attach significant economic news to large stock price movements. Indeed, CEOs, especially those of smaller technology companies, often express concerns about their stocks being punished by market movements which are not warranted by their assessment of company fundamentals. In an attempt to mitigate such movements, many firms expend considerable resources on investor relations in order to establish strong relationships with outside analysts, and, in other ways, facilitate the flow of information to investors (see, e.g., Graff (2000) and Mahoney (2000)).

These expenditures on investor relations, however, are difficult to explain with traditional finance models which suggest that if stock prices fall for reasons unrelated to long-run fundamentals, the price change will be quickly reversed. A recent *Wall Street Journal* article by Robert McGough (2000, C1) examines this issue, starting out by discussing the view of Lou Gerstner, CEO of IBM, who spends very little time trying to "sell" his stock to investment an-

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alysts. The article states that "Mr. Gerstner takes the high ground, telling analysts that his time is best spent with customers and employees . . ."

However, the article continues by saying that critics of Gerstner believe that his strategy "doesn't work in the new world of technology stocks . . . If CEOs can succeed in being heard above the marketplace, they can attract momentum investors and their stock price can become a competitive weapon in and of itself." The article also quotes PaineWebber's analyst Don Young as saying, "If you win the minds of investors, it tends to help you win in the marketplace as well . . . Creating a buzz around your company is what the most effective CEOs are doing . . .". A related article by Michael Siconolfi (1998, C1) suggests that technology firms are extremely concerned about their stock prices being affected by "flipping" of shares by institutional customers, the issue being that such trading can "crater new stocks, angering issuers."

This paper seeks to explain why managers are concerned about day-to-day movements in their stock prices. Specifically, we provide a model that illustrates how small changes in stock prices, caused by either informed or uninformed trades, can trigger permanent changes in fundamental corporate values. As we show, this feedback from stock prices to fundamental values can significantly affect the incentives for firms to facilitate information collection and in other ways encourage investor interest in their stocks.

Our model of feedback contains two key elements. The first element relates to the interdependence among a firm's stakeholders such as its customers, employees, and suppliers. Instances include a computer producer and its customers who rely on the continuing support of their supplier, or the producers of complementary products, such as Microsoft software and Intel chips, who are affected by each other's investment choices.[1] Our model also applies to a firm whose product has inherent network externalities, like the producer of an operating system that becomes more valuable as more people use it. Such complementarities across stakeholders result in coordination problems and self-fulfilling fragile equilibria.[2]

The second feature of our model relates to the way that stock prices convey information, an issue addressed by the rational expectations literature beginning with Grossman (1976). We depart from this literature by explicitly considering how stock prices influence the decisions of the firm's non-investor stakeholders. As we show, because of the interdependence of these stakeholders and the dependence of their decisions on stock prices, relatively small trades can cause dramatic fluctuations in asset values.

To understand the factors that affect feedback, and how feedback is likely to influence managerial choices, we consider a firm with assets in place and a growth opportunity. The value of the growth opportunity is partially de-

[1] See Titman (1984) and Scitovsky (1954) for an elaboration of these arguments.

[2] This aspect of our model is closely related to the bank runs literature (e.g., Diamond and Dybvig (1983)) as well as other models with complementarities and coordination failures (e.g., Shleifer (1986) and Cooper and John (1988)).

termined by the perceived value of the assets in place, which, in turn, is influenced by the firm's stock price. We consider conditions under which changes in stock prices trigger either a positive cascade, where the growth opportunity becomes extremely valuable, or a negative cascade, where the growth opportunity is lost. We find that since the perceived value of the assets in place is correlated with their actual value, a cascade is more likely to be triggered when the value of the assets in place is very volatile. In addition, a cascade is more likely when there are greater complementarities across the firm's stakeholders.

The firm's information and trading environment also affects the importance of feedback and the probability of triggering a cascade. With a fixed number of informed investors, these feedback effects are less likely to arise if liquidity providers are very risk averse, or if the variance of uninformed trading is high. However, if the number of informed investors is determined endogenously, this result can be reversed. Specifically, we show that when liquidity providers are risk neutral, that increasing the volume of liquidity trading stimulates the entry of informed investors, which makes the price more informative and increases the importance of the feedback effect. For a similar reason, decreasing the cost of information acquisition increases feedback effects.

Our model also demonstrates how managers can influence feedback effects by changing the precision of public information releases or reducing the cost of information acquisition, for example, by easing the access of outside analysts to their firm. We show that managers of relatively mature firms with well-established work forces and customer relationships, such as IBM, will seek to make public information less transparent and increase information acquisition costs to reduce the likelihood of a negative cascade. However, young firms with nascent work forces and customer relations, such as the high technology companies mentioned earlier, will try to increase the likelihood of a positive cascade by making information releases more transparent and increasing their accessibility to outside analysts.

The paper is organized as follows. Sections I and II analyze the stakeholders' decision in a fully revealing and a noisy financial market, respectively. Section III considers transparency as a managerial choice, and Section IV concludes.

I. The Basic Model

We first consider a single firm with symbiotic relationships with other agents that we will call stakeholders. These stakeholders make decisions that affect the firm's value, and then receive a payoff that is contingent on that value. The term stakeholder is generically taken to apply to agents who receive a benefit from being associated with the firm, such as the firm's employees, customers, lenders, and suppliers. We illustrate the case for positive feedback with an example where the relevant stakeholders are potential consumers who are interested in purchasing a product with network externalities, that is, a product whose value increases when more of the product is purchased,[3] and the case of negative feedback with employees who can leave the firm for outside employment opportunities.

As we will show, the externalities associated with stakeholder decisions create situations where firm values are fragile, meaning that an initial shock to cash flows can have a substantial economic effect by triggering a cascade.[4] In a positive cascade, "success breeds success," in that favorable information induces new stakeholders to do business with the firm at favorable terms, creating additional increases in value. On the other hand, in the negative cascade, bad news leads one of the stakeholders to terminate its relation with the firm, which in turn lowers the value to the other stakeholders, leading some of them to also defect, further reducing firm values and triggering further rounds of defection.

The firm consists of "assets in place" and a "growth opportunity," whose value is determined by the value of the assets in place as well as the availability of its key employees or other stakeholders such as customers and suppliers. Production choices are made in Period 1, and in Period 2, the payoffs from the assets in place and the growth opportunity are realized. The Period 2 payoff on the assets in place is given by $\bar{F} + \delta$, where $\bar{F}$ is the ex ante mean and δ is a zero mean, normally distributed random variable and the payoff from the growth opportunity is G. Outside investors can become informed by collecting information about δ.

For concreteness, consider a firm with N stakeholders who have specific human capital that is difficult to replicate. Each stakeholder, who is ex ante identical, obtains ρ_1 times the payoff from the assets in place and ρ_2 times the payoff from the growth opportunity, G; their payoff, denoted by Π, is thus given by

$$\Pi = \rho_1(\bar{F} + \delta) + \rho_2 G. \tag{1}$$

The stakeholders make a strategic decision of whether to associate themselves with the firm or not, which we analyze in detail below. To simplify our analysis, we assume that the entrepreneur issues public claims on the cash flow of the firm's assets in place rather than the whole firm (i.e., the assets in place plus the growth opportunity). This implies that only the assets in place are publicly traded. This assumption has no substantive effect on the

[3] For discussions of adoption externalities, see Dybvig and Spatt (1983) and Milgrom and Roberts (1995). Fletcher (1996), Hutheesing (1994), and Cusumano, Mylonadis, and Rosenbloom (1992) discuss the network externalities that allowed the VHS format to become the industry standard over the technologically superior betamax.

[4] Becker (1991) also discusses a model with network externalities in which cascades result from small changes in product prices, but he does not focus on financial market prices. Further, Teoh (1997) presents a related model in which information disclosure triggers a similar type of cascade. In contrast to Teoh (1997), we explicitly incorporate securities market trading, which allows us to shed light on the role of partially informative stock prices in inducing cascades (in particular, cascades can be triggered by noise, and managers have incentives to take actions that affect price informativeness).

results since there is a deterministic relation in this model between the cash flows of the assets in place and the cash flows of the entire firm.[5] However, as we will see, this relation is nonlinear, which implies that the cash flow of the total firm is not normally distributed, precluding the possibility of obtaining a closed-form solution to the security market equilibrium in a model where a claim on the firm's total cash flow is sold.

In our setting, the stakeholders' future payoffs are contingent on the firm's future profits. We thus consider a situation where the N stakeholders are ordered by their reservation wages $\bar{w}_m$, $m = 1,\ldots,N$, with $\bar{w}_1$ being the highest reservation wage. As already mentioned, the parameter G is influenced by how many stakeholders associate themselves with the firm. In particular, if all N stakeholders are involved in the firm, $G = \bar{G}$. If m stakeholders do not associate with the firm, $G = \bar{G} - mr$, where r is positive, and $\bar{G} > mr$. We assume in this section that δ is directly observed by a competitive market maker, who thus sets the price of the assets in place equal to $\bar{F} + \delta$.

A. Positive Cascades

In this subsection we present a case where a positive cascade arises. We will assume that our interdependent stakeholders are consumers of a product with network externalities rather than employees whose marginal productivities require the inputs of their coworkers.

For illustrative purposes, we assume that the firm has two divisions: one that produces an operating system and the second that produces a software product that is used with the operating system. There are N potential users of this software combination whose utility obtained from the software increases with the number of other users adopting the product as well as with the reliability of the operating system. Let us interpret the variable $\bar{F} + \delta$ as an index of the reliability of the operating system, so that $\rho_1(\bar{F} + \delta)$ in (1) measures that portion of the users gain that is associated with using an operating system with a specified level of quality. In this setting, $G = \bar{G} - mr$ measures that portion of the utility from using the software that depends on the number of other users. In addition, the quantities $\bar{w}_i$, $i = 1,\ldots,N$, can be interpreted as the utility from adopting an alternative product, which we assume can be different for different individuals.

Now, consider the condition

$$\rho_1(\bar{F} + \delta) + \rho_2[\bar{G} - (N-1)r] < \bar{w}_m \tag{2}$$

for $m = 1,\ldots,N-1$ so that none of the agents with reservation gains $\bar{w}_1$ through $\bar{w}_{N-1}$ want to adopt the product. Then, if the conditions

$$\rho_1(\bar{F} + \delta) + \rho_2[\bar{G} - (N-1)r] > \bar{w}_N, \tag{3}$$

[5] In our structure, we assume that the growth opportunity depends on the realization of δ only through the actions of stakeholders. Although this simplifies the exposition, allowing the growth opportunity to also depend directly on δ will not alter our main results.

and

$$\rho_1(\bar{F} + \delta) + \rho_2[\bar{G} - (N - k - 1)r] > \bar{w}_{N-k}, \tag{4}$$

for $k = 1,\ldots,N - 1$ hold, we have an equilibrium where the agent with the reservation gain w_N adopts the product, which allows the other $N - 1$ agents to also adopt the product because of the positive externality induced by the first agent's adoption.

Thus, a realization of δ, which signals an increased expected quality of the operating system, triggers a positive cascade, where some individuals are initially led to buy the software product based on the increase in the expected reliability of the operating system, and then others are induced to buy the software as its user base grows from these initial purchases. In general, an initial favorable stock price movement helps a firm attract the best employees, enhance its reputation with customers, and make it a more attractive joint venture partner.[6]

B. Negative Cascades

In this subsection, we provide an instance of a negative cascade. We assume that the stakeholders are employees of the firm. For exogenous reasons (e.g., cash constraints) the firm cannot commit to paying the stakeholders a fixed wage, but must instead offer them a wage contract that is contingent on the future opportunities of the business. Specifically, both future pay and advancement opportunities are better if the firm is growing and prospering. We assume that agents have equal productivity and have unobservable reservation wages that have identical ex ante expected values but which differ ex post.[7] Since the employees are identical ex ante as well as ex post on all observable dimensions, they must be paid the same.

The firm in this case has a retention problem if future profits are expected to decline. In particular, depending on their reservation wage rates, some employees will quit if sufficiently unfavorable information about the firm is revealed, and by doing so, create costs that are borne by the employees that remain. As we show, these costs can potentially create a negative cascade where all employees quit in response to the defection of one employee.

[6] Tom Meredith, the former CFO of Dell Computer Corporation, claimed in a recent discussion with one of the authors that Dell's rising stock price was one of its sources of comparative advantage for precisely these reasons. Another analogy here is the recent Linux phenomenon where the success of Red Hat's IPO positively affected the sales of Corel software that uses the Linux operating system.

[7] This assumption rules out the possibility that the employee with a higher reservation price can credibly signal his reservation price to his employer in an effort to increase his compensation, for instance, by revealing an outside offer, and then asking for additional compensation. In reality, although it may be possible to reveal an outside wage offer, an employee's reservation wage is determined by other considerations (e.g., location and work conditions) that are more difficult to observe. Of course, in a setting where the relevant stakeholders are customers rather than employees, it is more natural to assume that the reservation prices are unobservable. For instance, we would not expect a Windows customer to be able to obtain a discount from Microsoft by demonstrating that many of his or her colleagues have switched to Linux.

We now characterize several possible equilibria that arise in this setting. One equilibrium arises when

$$\rho_1(\bar{F} + \delta) + \rho_2 \bar{G} > \bar{w}_1. \tag{5}$$

In this case, all employees continue to work for the firm. However, if the condition

$$\rho_1(\bar{F} + \delta) + \rho_2[\bar{G} - (N - 1)r] < \bar{w}_N \tag{6}$$

holds, we have an equilibrium in which all N employees quit the firm. Thus, if (5) and (6) hold simultaneously, multiple equilibria exist. The value of the firm in the equilibrium where employees quit ($\bar{F} + \delta + G - (N - 1)r$) is smaller than the equilibrium where all employees continue to work for the firm ($\bar{F} + \delta + \bar{G}$).

For most of the analysis that follows, we assume that if there are two possible equilibria, the good equilibrium prevails. However, since employees ignore the negative externalities associated with their decisions, the fragility illustrated by these multiple equilibria still exist when we restrict the analysis to only the Pareto dominant equilibria. To understand this, note that if δ is sufficiently low the highest reservation wage employee quits,

$$\rho_1(\bar{F} + \delta) + \rho_2 \bar{G} < \bar{w}_1, \tag{7}$$

even if all other employees prefer staying with the firm conditioned on all others staying, that is, if

$$\rho_1(\bar{F} + \delta) + \rho_2 \bar{G} > \bar{w}_m \tag{8}$$

and

$$\rho_1(\bar{F} + \delta) + \rho_2[\bar{G} - (m - 1)r] < \bar{w}_m \tag{9}$$

for $m = 2,\ldots,N$, we have an equilibrium in which the employees all quit even though all except the first employee would be better off if they could commit to staying with the firm. Indeed, ex ante, before the employees observe their reservation wages, they will, in this case, want to commit not to quit.[8]

[8] It is easily checked that (7), (8), and (9) simultaneously hold under a large parameter set. Consider, for instance, the case where $N = 2$. Then these conditions are satisfied by choosing $\rho_1 = \rho_2 = 1$, $\bar{w}_1 = 10$, $\bar{w}_2 = 3$, $\bar{F} = 0$, $\delta = 0$, $\bar{G} = 5$, and $r = 3$.

If we assume that employees are unable to make binding commitments, then the observability of δ plays an important role. Thus, if δ is not observable, and if the following inequality holds

$$\rho_1 \bar{F} + \rho_2 \bar{G} > \overline{w}_m \tag{10}$$

for all m, the kind of cascade described above will not occur. Hence, in this situation, individuals can be made worse off as a result of information conveyed by financial market prices about δ. Indeed, *all* of the employees may prefer to commit not to see δ to avoid a possible cascade when δ is observed (see the Appendix for a formal argument that demonstrates the above point).

C. The Likelihood of Cascades and Volatility

As the following proposition demonstrates, the parameter set under which either positive or negative cascades obtain is larger when the externalities associated with an employee of a firm quitting (or a customer buying) is higher. Further, the presence of network externalities magnifies fluctuations in asset values.

PROPOSITION 1:

1. *Consider two values of r, r_1 and r_2, with $r_2 > r_1$. For any given realization of δ, the equilibria with positive and negative cascades obtain under a larger parameter set when $r = r_2$ than when $r = r_1$.*
2. *The value of the firm is more volatile when network externalities across stakeholders are present* ($r > 0$) *than when they are not present* ($r = 0$).

For both positive and negative cascades, perceptions of success affect success, and as we will show, stock prices create as well as reflect those perceptions.

II. The Stakeholders' Decision and Partially Revealing Stock Prices

In this section, we show that stock prices play an important role in initiating the kind of cascades discussed in the prior sections. We consider a setting where the information generated in financial markets is conveyed to the firm's nonfinancial stakeholders as well as to its investors. We first analyze a partially revealing rational expectations equilibrium with a fixed number of informed agents (Section II.A) and then consider the implications of endogenizing the entry decision of these agents (Section II.B). Our analysis allows us to address how managers and investment bankers can take actions to affect the likelihood of such cascades by influencing market parameters that determine the informativeness of the stock price.

A. Equilibrium with Exogenously Informed Agents

We begin by considering the case where the investment choices of firms and the decisions of stakeholders are fixed. We consider the valuation of the firm's assets in place, which trade separately from its growth opportunities. In this model, stock prices are set by competitive market makers who may or may not be risk averse. These market makers expect to earn zero expected utility conditional on their information set. Other individuals trade either because they have information, or because they have exogenous liquidity needs, or possibly for irrational reasons such as those in Black (1986). We assume that the total liquidity or noise demand in Period 1 is a zero-mean normally distributed random variable, z. For tractability, we assume that the informed traders are risk neutral. There are k informed traders who learn the realization of δ just prior to trade in Period 1. All random variables are independently normally distributed with zero mean. Throughout the paper, we assume that at least one agent trades on information. Market makers observe only the total (net) order flow from the informed and liquidity traders, which is denoted by Q. We assume that the market makers are risk averse and possess CARA utility with a risk aversion coefficient of A. We assume that a single market maker takes the entire order flow and impose the condition that he earns the "autarky" utility (the utility he would obtain by not making the market), which is normalized to zero for convenience.

In this market, it can be shown using standard microstructure techniques that there exists a unique linear equilibrium in which the price takes the form $P = \bar{F} + \zeta Q$, where Q is the total order flow and the value of ζ is given by

$$\zeta = \frac{Av_\delta}{4} + \sqrt{\left(\frac{Av_\delta}{4}\right)^2 + \frac{kv_\delta}{(k+1)^2 v_z}}. \tag{11}$$

The volatility of the price is given by

$$\operatorname{var}(P) = \frac{kv_\delta}{k+1} + \frac{R^2 v_\delta^2 v_z}{8} + \frac{Rv_\delta}{2}\left[\frac{R^2 v_\delta^2 v_z^2}{16} + \frac{kv_\delta v_z}{(k+1)^2}\right]^{1/2}. \tag{12}$$

We now consider how information conveyed by the financial market price influences stakeholder decisions and how, in turn, this affects the value of growth opportunities. To simplify the stakeholders' problem, consider the case where the following inequality holds

$$\bar{w}_1 < \bar{w}_2 + \rho_2 r < \bar{w}_3 + 2\rho_2 r < \ldots < \bar{w}_N + \rho_2(N-1)r. \tag{13}$$

Under the above condition, if the stakeholder with the reservation wage $\bar{w}_1$ quits, a cascade is triggered where the firm's other stakeholders also leave the firm. Examining this case simplifies the exposition, since it allows us to analyze only the decision of one stakeholder who leaves the firm if the expected payoff is less than his reservation wage $\overline{w}_1$. The additional condition for the cascade to be triggered is if the market price is sufficiently low, that is,

$$\rho_1[\bar{F} + E(\delta|P)] + \rho_2 \bar{G} < \overline{w}_1, \tag{14}$$

which ensures that the stakeholder with reservation wage $\overline{w}_1$ leaves the firm.

The analogous conditions for a positive cascade are

$$\overline{w}_N + \rho_2 Nr > \overline{w}_{N-1} + \rho_2(N-1)r > \ldots > \overline{w}_1 + r, \tag{15}$$

and

$$\rho_1[\bar{F} + E(\delta|P)] + \rho_2(\bar{G} - Nr) > \overline{w}_N, \tag{16}$$

which ensures that the stakeholder with the reservation wage $\overline{w}_N$ joins the firm and all others do so as well.

Denote $(\overline{w}_1 - \rho_2 \bar{G})/\rho_1 \equiv \overline{w}$ and $E(\delta|P) \equiv Y$, with $\bar{F} - \overline{w} > 0$. Then condition (14) can be written as

$$Y < \overline{w} - \bar{F}. \tag{17}$$

The ex ante probability of a negative cascade, denoted by p, is given by

$$p = N\left[\frac{\overline{w} - \bar{F}}{\mathrm{std}(Y)}\right]. \tag{18}$$

Further, defining $\overline{w}' \equiv (\overline{w}_N + \rho_2 Nr - \rho_2 \bar{G})/\rho_1$, with $\overline{w}' - \bar{F} > 0$, the equivalent condition for a positive cascade is obtained by simply reversing the direction of inequality (17) and replacing $\overline{w}$ by $\overline{w}'$. Thus, the corresponding probability p' for a positive cascade is

$$p' = N\left[\frac{\bar{F} - \overline{w}'}{\mathrm{std}(Y)}\right].$$

Thus, given the reservation wages and the unconditional asset value $\bar{F}$, the probability of a cascade of either type depends on $\mathrm{std}(Y)$. The following proposition relating the probability of a cascade to exogenous parameters is proved in the Appendix.

PROPOSITION 2:

1. *The probability of a cascade is increasing in the variance of the stock payoff, v_δ.*
2. *An increase in the variance of noise trading, v_z, or an increase in market maker risk aversion, R, decreases the ex ante probability of a cascade for all $R > 0$. However, for $R = 0$ (risk neutrality of market makers), changes in v_z do not affect the probability of a cascade.*

The first item of the proposition indicates that an increase in the volatility of asset value, δ, increases the sensitivity of prices to information and thus increases the probability of a cascade. This result suggests that the cascades are more likely to obtain for firms whose stocks are more volatile, such as firms in nascent economies or firms in growth-oriented industries.

The second item of the proposition describes how changes in the expected volume of noise trading affect the stakeholders' decision.[9] When market makers are risk neutral, an increase in the variance of noise trading causes informed traders to scale up their trades to exactly offset the increased magnitude of the noise trades, so that price volatility remains unchanged. As a result, an increase in v_z has no influence on the probability of a cascade. When market makers are risk averse, however, an increase in the variance of noise trading is not exactly offset, so price volatility does increase. In this case, prices become less informative, which reduces the probability of a cascade. An increase in market maker risk aversion also makes prices less informative, which decreases the probability of a cascade.

To further elaborate on these last points, consider a firm whose stock is currently priced at 20. Given the current variance of the noise trades and the risk aversion of the market maker, a negative cascade is triggered if the price drops below 15. In this setting, what happens when either the variance of noise trades increase or the market maker risk aversion increases?

In this case, the price variance increases implying that the probability of the price falling below 15 increases. However, *if the stakeholders recognize that the price is less informative, a cascade will no longer be triggered when the price falls below 15*. Therefore, the price must fall below some endogenous lower barrier before a cascade is triggered. What our proposition demonstrates is that when the noise trading volatility or market maker risk aversion increases, this lower barrier falls sufficiently so that the probability that the price crosses the barrier to trigger a cascade decreases.

B. Endogenous Entry by Informed Traders

In the analysis thus far, we have taken the number of informed traders to be fixed. We now analyze how endogenous entry of informed traders affects the stakeholders' decision. As we show, in our setting more informative se-

[9] Note that the variable v_z is related to the volume of noise trade, $|z|$, through the relationship $E(|z|) = \sqrt{2v_z/\pi}$.

curity prices make the stakeholder's decision more sensitive to the stock price and increase the ex ante probability of a cascade. Therefore, factors that stimulate the collection of information increase the impact of feedback on asset values.

We endogenize the number of informed investors by assuming that each informed investor can observe δ at a cost of c. Thus, the number of informed traders is determined endogenously as that number that makes the per capita profits from becoming informed equal the cost of collecting information.

Consider now the effect of an increase in the variance of uninformed trading on the probability of a cascade. The increase in the number of informed traders that occurs in response to an increase in v_z tends to increase the probability of a cascade. However, v_z now has a direct effect on the noisiness of the conditional expectation, as discussed in the previous section, and this effect tends to reduce the probability of a cascade. Thus, under risk aversion of market makers, the effect of an increase in v_z on the probability of a cascade is ambiguous. When market maker risk aversion is small, the effect of an increase in the number of informed agents dominates so that an increase in the amount of noise trading increases the number of informed agents and thus increases the probability of a cascade.

We also consider how the cost of information acquisition affects the probability of a cascade. Increasing the cost of information acquisition, c, will decrease the number of informed agents, which always decreases the probability of a cascade regardless of whether market makers are risk averse or not.

The above discussion can be summarized by the following proposition, which is proved in the Appendix.

Proposition 3: *Under endogenous information acquisition, the following results hold:*

1. *The probability of a cascade is decreasing in the cost of information acquisition, c.*
2. *In general, the effect of an increase in the variance of noise trading on the probability of a cascade is ambiguous. However, for sufficiently small values of market maker risk aversion, the probability of a cascade is increasing in the variance of noise trading.*

Thus, with endogenous entry of informed agents, an increase in the variance of uninformed trading increases the probability of a cascade if market maker risk aversion is sufficiently small. Negative cascades will ensue when conditions (13) and (14) hold, whereas positive ones will occur when (15) and (16) hold. The discussion in Sections I.A and I.B on when negative or positive cascades will occur applies here as well.

Overall, the results of this section suggest that cascades are likely to be positively related to changes in the variance of noise trading and that this relation is likely to be especially strong when market makers are well capitalized. The cost of acquiring information also affects the probability of a cascade; when information costs are low, prices are more informative and the probability of a cascade is higher. The latter result suggests that if managers of nascent firms wish to increase the likelihood of a positive cascade, they will adopt strategies that decrease the cost of information acquisition, such as facilitating analyst access to the firm. We discuss this issue further in Section III.

III. Transparency

In this section, we explore ways in which feedback can potentially affect managerial choices. Specifically, we consider various choices that can affect what we will call the transparency of a firm. These choices include the quality of the auditors the firm may use and the degree of access they may provide to outside analysts, thereby influencing the precision or informativeness of its public announcements. As we show, a manager can influence the likelihood that a cascade will occur by his or her choice of the precision of information releases.

We extend the model developed in Section II by assuming that at date 1, the firm reveals a public signal, $\delta + \epsilon$, where ϵ is a zero-mean, normally distributed variable that is independent of all other random variables. To obtain closed-form solutions, we assume that market makers are risk neutral, though numerical simulations indicate that our results continue to obtain for the case of a risk-averse market maker.

In this setting with a public signal, it can be shown that there exists a unique linear equilibrium where the price is given by $P = \bar{F} + \xi(\delta + \epsilon) + \zeta Q$, where Q is the order flow. The constants ξ and ζ are given by

$$\xi = \frac{v_\delta}{v_\delta + (k+1)v_\epsilon}, \tag{19}$$

and

$$\zeta = \frac{v_\epsilon}{v_\delta + (k+1)v_\epsilon}\sqrt{\frac{kv_\delta}{v_z}}. \tag{20}$$

The next result we state describes the probability of a cascade in terms of the variance of noise in the public signal.

PROPOSITION 4: *The probability of the cascade is decreasing in the variance of the noise in public information v_ϵ.*

Intuitively, when v_ϵ increases, the stock price provides a noisier signal of δ and thereby decreases the probability of a cascade. This intuition is basically correct, but it ignores the fact that an increase in v_ϵ increases the incentive to collect information, implying that the number of informed investors will increase. However, as the Appendix shows, the increase in the number of informed investors dampens the effect of an increase in v_ϵ, but does not reverse the effect.

Now, suppose the manager of the firm can control the precision of the public signal. For example, the manager may have some leeway in the choice of accounting information systems as well as the quality of the auditors that are hired. Under what conditions will the managers choose a system that results in more versus less precise signals?

Whether the manager wants more or less precision depends on whether the expected costs of a negative cascade outweigh the expected benefits of a positive cascade. Within the context of our model, this is determined by whether the conditions for a negative cascade ((13) and (14)) or those for a positive cascade ((15) and (16)) hold. When the conditions for a positive cascade hold, the manager would like the public signal to be more precise in order to increase the likelihood that the feedback effect will occur. When the conditions for a negative cascade hold, the manager would prefer a less precise signal.

To formalize this notion, define $\tau_\epsilon \equiv 1/v_\epsilon$ as the precision of the public information signal. Suppose the manager can increase the precision of the public signal at a cost given by a continuous function $C(\tau_\epsilon)$, with $C'(\tau_\epsilon) > 0$, $C''(\tau_\epsilon) > 0$, $C'(0) = 0$, and $C'(\infty) = \infty$. The following proposition is proved in the Appendix.

PROPOSITION 5:

1. *Suppose that the condition $\rho_1\bar{F} + \rho_2[\bar{G} - (N-1)r] < \bar{w}_N$ holds so that the firm is in an equilibrium where none of the stakeholders joins the firm. Then, if the network externality between stakeholders, measured by the parameter r, is sufficiently high, there exists a unique level of the precision of public information τ_ϵ, which maximizes the ex ante value of the firm. This choice of τ_ϵ optimizes the trade-offs that increasing precision is costly but increases the probability that the firm will move to an equilibrium where all N stakeholders work for the firm.*
2. *Alternatively, suppose that the condition $\rho_1\bar{F} + \rho_2\bar{G}' > \bar{w}_1$ holds so that the firm is in an equilibrium where all stakeholders work for the firm. If r is sufficiently high, in order to avoid a negative cascade the manager optimally sets $\tau_\epsilon = 0$, that is, does not release a public signal. This choice of τ_ϵ maximizes the ex ante value of the firm.*
3. *When $r = 0$ (network externalities are not present), the only consideration is that increasing precision is costly, so the manager optimally sets $\tau_\epsilon = 0$.*

The above analysis can easily be extended to examine the incentives of managers to be either more or less accessible to outside analysts. If managers are more accessible, then the cost of acquiring information about the firm is lower and, in equilibrium, more analysts will cover the firm, increasing the precision of the stock-price signal. Again, a firm's incentive to im-

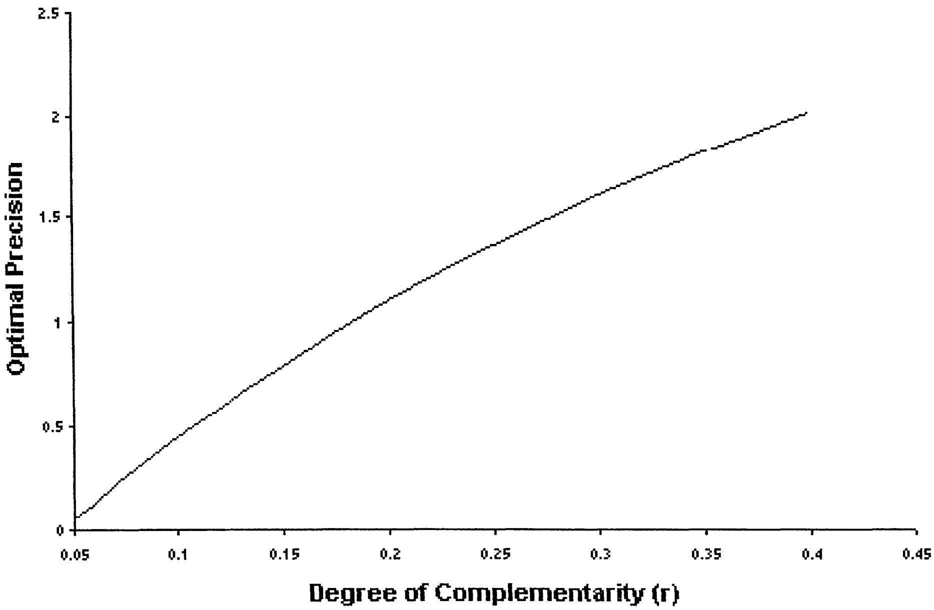

Figure 1. Equilibrium precision versus the degree of complementarity, *r*. The equilibrium level of the precision of public information release by the manager is plotted as a function of the complementarity parameter *r*.

prove the precision of the stock-price signal depends on the likelihood of positive and negative cascades, which in turn, are determined by the maturity of the firm and the importance of network externalities. The Appendix shows that results similar to those in Proposition 5 can be obtained for the cost of information acquisition. Specifically, under reasonable restrictions on the cost function, there exists a level of information acquisition cost that maximizes firm value when the condition in Part 1 of the proposition holds. Under the condition in Part 2, the firm has an incentive to keep the cost of information acquisition as high as possible.

Our results indicate that strategies to reveal public information can vary considerably across firms and even across the life of a firm depending on whether the firm is concerned about a positive cascade or a negative cascade. For example, a nascent firm concerned about attracting stakeholders may increase the precision of public information and increase analyst access to the firm, whereas a mature firm that is very concerned about retaining existing stakeholders may choose to reduce this precision.

The incentive for managers to use the precision of public information releases to affect the likelihood of a cascade is higher, the stronger the complementarities across stakeholders, and the larger the number of stakeholders. This is illustrated in Figures 1 and 2, which show that under the condition in Part 1 of Proposition 5, the optimal precision chosen by the manager is

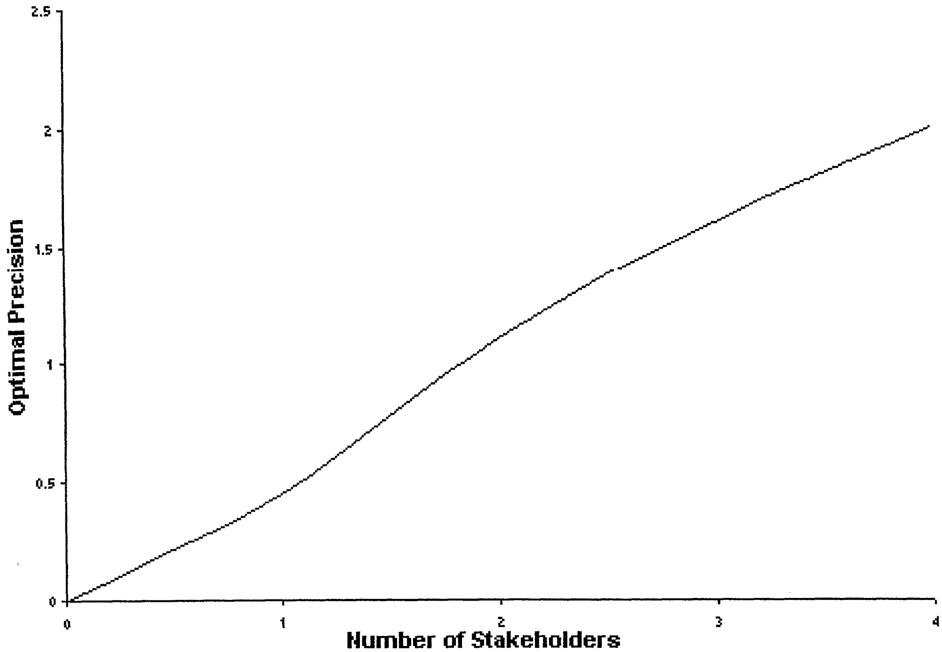

Figure 2. Equilibrium precision versus the number of stakeholders, N. The equilibrium level of the precision of public information release by the manager is plotted as a function of the number of stakeholders, N.

increasing in the degree of complementarity, r, and the number of stakeholders, N.[10]

IV. Conclusion

Economists have become increasingly interested in models with increasing returns to scale and network externalities. An important implication of many of these models is that equilibria can be fragile, and minor differences between firms, or just luck, can be responsible for major successes as well as major failures. This fragility arises because perceptions can be self-fulfilling. The perception of success can generate success and vice versa.

Given the substantial literature on the information content of stock prices, it seems natural to consider how a firm's stock price can affect how the firm is perceived by its customers, suppliers, and employees and how this, in turn, influences their decisions. As we show, in the presence of complementarities, stock prices can directly influence a firm's cash flows, and this has

[10] The base parameter values for the figures are $v_\delta = k = \bar{G} = \bar{w}_N = \rho_1 = 1$, $\bar{F} = 0.1$, and $\rho_2 = 0.3$. The cost function used is $C(\tau_\epsilon) = g\tau_\epsilon^{1.1}$ with $g = 0.01$. For Figure 1, N is fixed at 3 and for Figure 2, r is fixed at 0.3. Qualitatively similar results were obtained for different parameter ranges around the assumed values.

a number of important implications that we consider in detail. The main implications of our analysis are as follows:

- Our analysis indicates that feedback is likely to be most important when complementarities or network externalities are high, but relationships between a firm and its stakeholders are not well established, and when uncertainty about the cash flows of existing projects is high. Hence, the emerging e-commerce and Internet industries should be especially sensitive to the effect of feedback, which is consistent with the anecdotal evidence we mentioned in the introduction.
- The likelihood of feedback is increasing in the risk tolerance of liquidity providers and decreasing in the variance of uninformed noise trading. This result has implications for entrepreneurs and investment bankers of newly public firms. In particular, the result implies that the likelihood of positive feedback is enhanced by choosing relatively well-capitalized market makers to make markets in new issues, and by placing a greater proportion of an IPO with sophisticated institutional investors versus relatively less well-informed retail investors.
- Since the feedback effect is related to the informativeness of the firm's stock price, concerns about feedback influence the quality of a firm's financial statements and the degree of access provided to outside analysts that cover the firm. As we show, young firms, wishing to attract stakeholders, have an incentive to increase the precision of their information releases as well as analyst access. However, our analysis also indicates that more mature firms wishing to avoid losing key stakeholders such as customers and employees want to expend fewer resources to increase the transparency of their financial statements. This is consistent with the anecdotal evidence mentioned in the introduction that less-established companies like Sun have a greater incentive to provide access to outside analysts than mature firms like IBM.

Our analysis also raises a number of additional questions about how feedback can affect managerial choices that provides possible avenues for new research. In particular, feedback may have important implications that relate to the following strands of literature:

- Managerial myopia and financial signaling: If managers believe that feedback is important, they may choose projects that pay off more quickly in the hopes of reporting higher earnings numbers, thereby either preventing a negative cascade or creating a positive cascade. The signaling models that address these issues require that managers have a direct incentive to increase their firms' current share prices, (e.g., the firm is issuing shares or the manager is selling some of his or her shares).[11] With feedback, a firm's current share price directly affects its intrinsic value, so that managers have an incentive to signal even when acting in the long-term interests of their firms.

[11] See, for example, Miller and Rock (1985), Stein (1989), and Brennan (1990).

- The role played by investment banks in taking firms public: Recent research has explored the three separate roles that investment banks play for newly public firms. In addition to taking the firm public, they serve as the market maker for the firm's stock and provide analyst coverage.[12] In particular, our model provides a framework for examining why underwriters who can provide better capitalized market making are more attractive to issuers, and why investment bankers wish to attract possibly uninformed trading volume by publicizing the stock.
- When firms go public and how the new issues are priced: An interesting recent book by Lewis (1999) provides anecdotes that suggest that the possibility of generating the kind of positive cascade described in our model may explain the recent trend to take Silicon Valley companies public very early in their life cycles and substantially underprice the new issues. The idea is that by substantially underpricing the IPOs, the underwriter draws attention to the potential wealth being created by these firms, thereby attracting individuals and firms with complementary products and skills. Recent evidence of the extreme underpricing of Internet IPOs tends to support this argument. Such a theory of IPO underpricing may be worth pursuing formally, since it could potentially generate much clearer empirical tests than existing information-based models of underpricing. Evidence of a relation between the extent to which a new issue is underpriced and the importance of network externalities for the business would provide strong evidence that feedback plays an important role in the new issues market.

Appendix

Discussion of Precommitment to not Observe δ: Suppose there are two employees and that $r = \bar{w}_1 - \bar{w}_2$. Consider a case where δ is observed and assume convenience that $\sigma_\delta = 1$. Then, the first employee leaves if $\delta < \bar{w}_1 - \bar{F}$, and stays otherwise. His payoff is given by $\bar{F} + \delta$ if $\delta \geq \bar{w}_1 - \bar{F}$, and $\bar{w}_1$ otherwise. Now suppose that information about δ is not observed. In this case, the employee receives $\bar{F} + \delta$. The difference between the payoff when δ is not and is observed is a random variable that equals zero if $\delta \geq \bar{w}_1 - \bar{F}$ and $\bar{F} + \delta - \bar{w}_1$ otherwise. Denote this random variable as $f_1(\delta)$ (note that the variable is nonpositive), and its expectation as μ_1. It follows from Johnson and Kotz (1970, p. 81) that

$$\mu_1 = (\bar{F} - \bar{w}_1)\Phi(\bar{w}_1 - \bar{F}) - \frac{1}{\sqrt{2\pi}} \exp[-0.5(\bar{w}_1 - \bar{F})^2], \tag{A1}$$

where Φ denotes the standard normal distribution.

[12] See Ellis, Michaely, and O'Hara (2000) for a discussion of issues that arise when the underwriter is also the market maker and Michaely and Womack (2000) for a discussion of issues that arise when the underwriter provides analyst coverage.

Now consider the second employee. His payoff differential when δ is not and is observed is given by $\bar{F} + \delta - \bar{w}_2$ if $\delta < \bar{w}_1 - \bar{F}$ and zero otherwise. This variable can be positive or negative (it is negative if $\delta < \bar{w}_2 - \bar{F}$ and positive if $\bar{F} - \bar{w}_2 < \delta < \bar{F} - \bar{w}_1$). Denote this variable as $f_2(\delta)$. The expected payoff differential is the expectation of $f_2(\delta)$ (denoted by μ_2). As in (A1), μ_2 is given by

$$\mu_2 = (\bar{F} - \bar{w}_2)\Phi(\bar{w}_1 - \bar{F}) - \frac{1}{\sqrt{2\pi}} \exp[-0.5(\bar{w}_1 - \bar{F})^2]. \tag{A2}$$

When $\bar{w}_1 = \bar{F}$, the above expression equals $0.5(\bar{F} - w_2) - (1/\sqrt{2\pi})$. Since all the functions in (A2) are continuous, μ_2 is positive if $\bar{F}$ is sufficiently large relative to $\bar{w}_2$, and $\bar{w}_1$ is sufficiently close to $\bar{F}$. Thus, the second employee prefers that information about δ not be observed under a nonnull parameter set. Suppose that ex ante, an employee does not know whether he will obtain a reservation wage $\bar{w}_1$ or $\bar{w}_2$ and that the two outcomes are equally likely. Then the ex ante expected payoff differential of each employee will be

$$\begin{aligned} 0.5(\mu_1 + \mu_2) = {} & [\bar{F} - 0.5(w_1 + w_2)]\Phi(\bar{w}_1 - \bar{F}) \\ & - \frac{1}{\sqrt{2\pi}} \exp[-0.5(\bar{w}_1 - \bar{F})^2]. \end{aligned} \tag{A3}$$

Again, this expectation will also be positive if $\bar{F}$ is sufficiently large relative to w_2 and if $\bar{F}$ is sufficiently close to w_1. Thus, if $\bar{F} = w_1$, the right-hand side of (A3) reduces to $0.25(\bar{F} - \bar{w}_2) - (1/\sqrt{2\pi})$, which is positive if $\bar{F} - w_2$ is sufficiently large. Thus, both employees prefer that information about δ not be released under a nonnull parameter set and, under this parameter set, they will, therefore, be willing to precommit to not observe δ.

Proof of Proposition 1: The first part of the proposition follows directly from the observation that (5) and (9), as well as (2) and (4) hold under a larger parameter set for any given δ when $r = r_2$ than when $r = r_1$. The second part of the proposition can be proved as follows. When $r = 0$, the variance of firm value is always v_δ. Now, since δ is normally distributed, for any nonzero value of r, at least one of the probabilities p_i attached to the events that the growth opportunity will be worth $\bar{G} - ir$, $i = 1, \ldots, N$ must be nonzero. The variance of asset values in this case is

$$v_\delta + r^2\left[\left\{\sum_{i=2}^{N+1} (i-1)^2 p_i^2\right\} + \left\{\sum_{i=2}^{N+1} (i-1)p_i\right\}^2\right], \tag{A4}$$

which is greater than v_δ. Q.E.D.

Proof of Proposition 2: Substituting for $P = \bar{F} + \zeta Q$ where Q is the total order flow, we find that condition (17) becomes

$$\frac{k(k+1)v_\delta}{k^2 v_\delta + \zeta^2(k+1)^2 v_z}\left(\frac{k\delta}{k+1} + \zeta z\right) < \bar{w} - \bar{F}. \tag{A5}$$

Now, it is evident that both p and p' are increasing in std(Y), which is given by taking the standard deviation of the left-hand side of (A5), and can therefore be written as

$$\operatorname{std}(Y) = \left[\frac{k^2 v_\delta^2}{k^2 v_\delta + \zeta^2 (k+1)^2 v_z}\right]^{1/2}. \tag{A6}$$

The first part of the proposition follows by substituting writing the reciprocal of the right-hand side of (A6) as

$$\left[\frac{1}{v_\delta} + \frac{\zeta^2 (k+1)^2 v_z}{k^2 v_\delta^2}\right]^{1/2}. \tag{A7}$$

Substituting for ζ from (11) into the above expression shows that the expression is decreasing in v_δ so that std(Y) is increasing in v_δ. Also, when $R = 0$, $\zeta^2 v_z$ is independent of z since ζ then equals $[kv_\delta/(k+1)^2 v_z]^{1/2}$. Noting that $\zeta^2 v_z$ is increasing in v_z and R (from (11)), we obtain the second part of the proposition. Q.E.D.

Proof of Proposition 3: For proving Part 1 of the proposition, first note that the expected profit of each informed agent is given by $\pi = E[\kappa\delta(\delta - \zeta k \kappa \delta)]$, which equals $v_\delta/(k+1)^2\zeta$. Substituting for ζ from equation (11), we find that the profits are decreasing in k. So, given the entry condition where $\pi = c$, the effect of increasing the cost of information acquisition is to decrease the number of informed agents.

It remains to be shown that V is increasing in k. To see this, note from (A6) that the sign of the derivative of V with respect to k is the negative of the sign of $\zeta(k+1)/k$. Substituting for ζ from equation (11), $\zeta(k+1)/k$ equals

$$\frac{Av_\delta(k+1)}{4k} + \sqrt{\left(\frac{Av_\delta(k+1)}{4k}\right)^2 + \frac{v_\delta}{kv_z}}. \tag{A8}$$

Since all of the individual terms in the above expression are decreasing in k, the probability of a cascade is increasing in k, and in turn, decreasing in the cost of information acquisition, c.

Now, consider Part 2 of the proposition and the case where $R = 0$. Recall that the probability of the stakeholder leaving the firm is monotonically increasing in std(Y) where $Y = E(\delta|P)$. Since the market makers are risk neutral, they set the price P equal to the expectation of δ conditional on all available information, so that $Y = P$. For notational convenience, let $V \equiv \operatorname{var}(Y)$. When market makers are risk neutral, V is given by substituting $R = 0$ in (12):

$$V = \frac{kv_\delta}{k+1}. \tag{A9}$$

From (11), we have

$$\zeta = \left[\frac{kv_\delta}{(k+1)^2 v_z}\right]^{1/2}. \tag{A10}$$

Now, the ex ante expected profit of each informed trader is given by $\pi = E[(\bar{F} + \delta - P)x]$, where $x = \kappa\delta$ is the order of the informed trader. Substituting $P = \bar{F} + \zeta Q$ where Q is given by $k\kappa\delta + z$, we have $\pi = v_\delta/(k+1)^2\zeta$. The equilibrium-entry condition is $\pi = c$. Letting $\sigma_\delta = v_\delta^{1/2}$, $\sigma_z = v_z^{1/2}$, and substituting for ζ from above, the entry condition becomes

$$\frac{\sigma_z \sigma_\delta}{(k+1)\sqrt{k}} = c. \tag{A11}$$

In this case, the probability of a cascade is monotonically related to the variance of the price. Now, we can write the derivative of the variance of the price with respect to σ_z as

$$\frac{dV}{d\sigma_z} = \frac{\partial V}{\partial k}\frac{dk}{d\sigma_z} + \frac{\partial V}{\partial \sigma_z}. \tag{A12}$$

From (A11), we have

$$\frac{dk}{d\sigma_z} = -\frac{\partial\pi/\partial\sigma_z}{\partial\pi/\partial k} = \frac{2k(k+1)}{1+3k}. \tag{A13}$$

Since, from (A9), $\partial V/\partial\sigma_z = 0$ and $\partial V/\partial k > 0$, we have $dV/d\sigma_z > 0$. From (18), the probability of a cascade is increasing in std(Y), which equals $V^{1/2}$. The probability of a cascade is therefore increasing in v_z.

Now consider the case of $R > 0$ and again denote $V \equiv \text{var}(Y)$, and observe from (11) and (A6) that

$$\begin{aligned} V^{-1} = \text{var}(Y)^{-1} = 1 &+ \frac{(k+1)^2 v_\delta^2 A^2 v_z}{8k^2} + \frac{v_\delta}{k} \\ &+ \frac{Av_\delta}{2}\sqrt{\frac{(k+1)^4}{k^4}\frac{A^2 v_\delta^2 v_z}{16} + \frac{(k+1)^2}{k^3} v_\delta v_z}, \end{aligned} \tag{A14}$$

which is decreasing in k and increasing in σ_z, so that $\partial V/\partial\sigma_z < 0$, whereas $\partial V/\partial k > 0$. Further, $dk/d\sigma_z = -(\partial\pi/\partial\sigma_z)/(\partial\pi/\partial k)$, where

$$\pi = \frac{v_\delta}{(k+1)^2\zeta}. \tag{A15}$$

Substituting for ζ from (11), it follows that $dk/d\sigma_z > 0$. Now, we know that

$$\frac{dV}{d\sigma_z} = \frac{\partial V}{\partial k}\frac{dk}{d\sigma_z} + \frac{dV}{d\sigma_z}. \tag{A16}$$

From (A14), we have $\partial V/\partial\sigma_z < 0$ and $\partial V/\partial k > 0$. From (A15) and (11), we have $dk/d\sigma_z > 0$. Thus, the right-hand side of (A16) is of ambiguous sign because the first term of this expression is positive whereas the second term is negative. As $A \to 0$, the second term goes to zero, whereas the first term remains positive. This indicates that for sufficiently small values of market maker risk aversion, the entry effect will dominate and increases in v_z will increase the probability of a cascade. Q.E.D.

Proof of Proposition 4: The probability of a cascade is monotonically related to $\mathrm{var}[E(\delta|\delta + \epsilon, k\kappa\delta + z)]$. Now,

$$\begin{aligned}\mathrm{var}[E(\delta|\delta + \epsilon, k\kappa\delta + z)] &= \mathrm{var}[\xi(\delta + \epsilon) + \zeta(k\kappa\delta + z)] \\ &= v_\delta(1 + k\zeta\kappa)^2 + \xi^2 v_\epsilon + \zeta^2 v_z.\end{aligned} \tag{A17}$$

Substituting for ξ and ζ from (19) and (20), we have

$$\mathrm{var}[E(\delta|\delta + \epsilon, k\kappa\delta + z)] = \frac{v_\delta(kv_\epsilon + v_\delta)}{v_\delta + (k+1)v_\epsilon}, \tag{A18}$$

which is monotonically decreasing in v_ϵ.

Now, the above case is that where the informed agents is held fixed. Under endogenous information acquisition, one also has to account for the effect of v_ϵ on the equilibrium number of informed agents.

The ex ante expected profits per informed agent, π, are given by $\pi = E[(\kappa\delta(\delta - \xi(\delta + \epsilon) - \zeta(k\kappa\delta + z)))]$, and, after substituting for the equilibrium parameters from (19) and (20), can be shown to equal the following closed-form expression

$$\pi = \frac{v_\epsilon}{v_\delta + (k+1)v_\epsilon}\sqrt{\frac{v_\delta v_z}{k}}. \tag{A19}$$

The derivative of the number of informed agents with respect to v_ϵ is given by $dk/dv_\epsilon = -(\partial\pi/\partial v_\epsilon)/(\partial\pi/\partial k)$, and substituting for the various partial derivatives, we have

$$\frac{dk}{dv_\epsilon} = \frac{2kv_\delta}{v_\epsilon[v_\delta + (3k+1)v_\epsilon]}. \tag{A20}$$

Now, the derivative of $V \equiv \text{var}[E(\delta|\delta + \epsilon, k\kappa\delta + z)]$ with respect to v_ϵ, which is monotonically related to the probability of a cascade, equals

$$dV/dv_\epsilon = \frac{\partial V}{\partial k}\frac{dk}{dv_\epsilon} + \frac{\partial V}{\partial v_\epsilon}.$$

Substituting for the various derivatives, we have

$$\frac{dV}{dv_\epsilon} = -\frac{v_\delta^2}{[v_\delta + (k+1)v_\epsilon][v_\delta + (3k+1)v_\epsilon]}, \tag{A21}$$

which is negative, completing the proof. Q.E.D.

Proof of Proposition 5: If the condition in the proposition holds, then in Period zero, the firm is in an equilibrium where none of the N stakeholders joins the firm. Consider two mutually exclusive possibilities at the time of trade in Period 1. First consider the possibility that

$$\rho_1(\bar{F} + E(\delta|P, \delta + \epsilon) + \rho_2(\bar{G} - (N-1)r) < \bar{w}_N. \tag{A22}$$

In this case, the firm remains in the bad equilibrium. If the reverse is true, then at least the stakeholder with reservation wage $\bar{w}_N$ joins the firm. But if the conditions

$$\rho_1(\bar{F} + E(\delta|P, \delta + \epsilon)) + \rho_2(\bar{G} - (N-i)r) < \bar{w}_{N-i+1} \tag{A23}$$

hold for $i = 2, \ldots, N$ then all others join the firm as well. Define $\Delta w_j = \bar{w}_j - \bar{w}_{j-1}$ for $j = 1, \ldots, N$. Then the above conditions are equivalent to the condition $r > \Delta w_j$ for $j = 1, \ldots, N$, which will be true if r is sufficiently high. The control variable for the firm manager is τ_ϵ. The manager thus maximizes $V_f(\tau_\epsilon) - C(\tau_\epsilon)$, where V_f is the value of the firm, and therefore sets $V_f'(\tau_\epsilon) = C'(\tau_\epsilon)$. Using (1), it follows that

$$V_f'(\tau_\epsilon) = \frac{Nr\phi(\beta/V)V'(\tau_\epsilon)}{V^2}, \tag{A24}$$

where $\phi(\cdot)$ is the standard normal density evaluated at $\cdot$, and β is a positive constant independent of τ_ϵ. This implies that $V_f'(\tau_\epsilon)$ is nonnegative. From (A21), we have

$$V_f'(\tau_\epsilon) = \frac{v_\delta^2}{[\tau_\epsilon v_\delta + (k+1)][\tau_\epsilon v_\delta + (3k+1)]}. \tag{A25}$$

It follows then that $V_f'(0) > C'(0) = 0$ and $V_f'(\infty) = 0 < C'(\infty)$. Further, $V_f''(\tau_\epsilon) - C''(\tau_\epsilon < 0)$. This implies that the equation $V_f'(\tau_\epsilon) = C'(\tau_\epsilon)$ has a unique solution, which is a maximum of the function $V_f(\tau_\epsilon) - C(\tau_\epsilon)$. The proposition thus follows. In the case of Part 2 of the proposition, it follows that $V_f'(\tau_\epsilon)$ is nonpositive. Hence the optimal solution is to set $\tau_\epsilon = 0$. When $r = 0$, the firm value is always $\bar{F} + \delta + \bar{G}$, so the manager cannot influence ex ante firm value by changing τ_ϵ; hence the third part follows.

Assume, alternatively, that the control variable is the cost of information acquisition, as opposed to the precision of the public signal. Specifically, define $\alpha = 1/c$ and assume a cost function $C(\alpha)$ with $C'(\alpha) > 0$, $C''(\alpha) > 0$, $C'(0) = 0$ and $C'(\infty) = \infty$. This captures the notion that decreasing the cost of information acquisition by increasing analyst coverage, for example, requires an investment in effort at an increasing rate as the cost of information acquisition drops. Now, we have

$$\frac{dV}{dc} = \frac{\partial V}{\partial k}\frac{dk}{dc}. \tag{A26}$$

From (A19) and (A18), and noting that

$$dk/dc = -\frac{\partial(\pi - c)/\partial c}{\partial(\pi - c)/\partial k}, \tag{A27}$$

equation (A26) reduces to

$$\frac{dV}{dc} = -\frac{2v_\delta^{1/2} v_\epsilon k^{3/2}}{v_z^{1/2}[v_\delta + (3k + 1)v_\epsilon]}. \tag{A28}$$

Since $\alpha = 1/c$, from the above expression, it can easily be shown that $V'(\alpha) < 0$ and $V''(\alpha) < 0$. The rest of the proof that there exists a unique level of α that maximizes firm value when the condition in Part 1 of Proposition 5 and that the optimal $\alpha = 0$ for the case in Part 2 of Proposition 5 follows that in the case where τ_ϵ is the control variable for the manager. Q.E.D.

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