Optimal Contracting with Moral Hazard and Cascading

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In this article I identify optimal incentive contracts for managers of firms competing in the product market. Such firms often confront similar decisions and uncertainties. Managers can improve decision quality by generating private signals through costly effort. However, since signals are likely to be correlated, firms that decide later get additional information from the actions of earlier firms. This impacts effort choice. Decision quality is also affected if later managers disregard their own signals and blindly imitate preceding decisions. In a competitive environment, such cascading hurts profits. Contracts that solve both moral hazard and cascading problems typically put more weight on firm profits, making them expensive. Contacts with more weight on decision quality are less expensive but result in cascades. Shareholders choose contracts that maximize their net surplus. This results in testable implications about which industries may have more convergence in investment choices, greater pay-for-profit sensitivity, larger differences in observed contracts, more innovation, larger-size firms, and potential for overcompensation.

Cascading occurs when agents blindly imitate preceding decisions in a sequential decision-making environment. This phenomenon is well researched in diverse fields like zoology, political science, and social

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psychology.[1] Recently scholars have begun documenting its presence in economic decisions of firms. Since firms function under more readily identifiable contracts, organizational forms, and payoff interactions, this provides an opportunity to investigate such behavior in a more structured setting.

A body of research exists on imitative behavior by firms in the presence of positive payoff externalities, that is, a firm's return from an action improves as more firms choose the same action [see, e.g., Akerlof (1980), Katz and Shapiro (1985), and Becker (1991)]. In such a framework, it is not surprising that imitation can be shown to be rational. However, recent articles like Chang, Chaudhuri, and Jayaratne (1997) and Kennedy (1997) document examples where managers of different firms imitate each other's decisions even when the resulting competition reduces firm profits. Such mutually destructive imitation in managerial decisions is harder to explain as a rational response and Porter (1994) brands it as "disastrous" because it triggers "a mutually destructive battle no firm is likely to win."

This raises an important question. If cascading is indeed harmful, why do stockholders not prevent it? Is it because mechanisms like incentive contracts, which stockholders use to influence managerial behavior, are inadequate in preventing cascades; or is it that the necessary mechanisms are too costly to implement, so shareholders rationally permit their managers to imitate the decisions of other managers?

This article examines the question in a setting with the necessary ingredients for cascading to occur: a number of competing firms faced with a similar investment decision and a common uncertain future. This is especially representative of an industry facing an opportunity in the form of a new product, technology, or markets.[2] Shareholders of the different competing firms need their managers to perform two tasks: initially expend an optimal amount of effort researching the opportunity, and subsequently take the optimal decision on the basis of all available information. Depending on their contract, managers will rationally choose their unobservable effort level. However, the contracting issue is complicated by the presence of multiple firms. As managers of all firms are unlikely to decide simultaneously, those who decide later observe the preceding decisions. Since these convey the private information of earlier managers, the possibility of getting free information influences the initial effort choice of managers and the resulting decision quality. There is also a more direct effect. If early managers make similar decisions, later managers may choose to imitate the earlier

[1] Bikhchandani, Hirshleifer, and Welch (1992) and Hirshleifer (1998) provide illustrations and an insightful discussion of imitative behavior in social, political, and economic settings. Also see Bannerjee (1992) and Welch (1992).

[2] Examples include auto companies deciding whether to produce electric cars, film and camera manufacturers deciding about digital cameras, TV and cable companies studying web boxes for TVs, computer companies deciding whether to enter the sub-$1000 computer market, long-distance carriers looking to enter local markets, and U.S. companies viewing emerging markets in Asia and South America.

decisions even when their private information supports a different action. In an environment with negative payoff externality, such cascading hurts shareholders.

To prevent these losses, shareholders can offer contracts that solve both the moral hazard and the cascading problem. These contacts can be based on the verifiable observables in this framework: firm's ex post profits and decision quality, that is, whether ex post the decision turns out to be right (or wrong). Since all agents are assumed to be risk neutral, there is a locus of optimal contracts that solves the effort choice problem. Included are contracts based on only profits or only decision quality, as well as a continuum of contracts based on both. However, not all these contracts solve the cascading problem. Because of the negative payoff externality, managers face a tension between maximizing profits and being good forecasters. As more firms decide to accept, their expected profits decrease and the opportunity becomes less attractive (possibly negative NPV) for firms that decide later. However, since managers' private information is correlated, later managers can increase the probability of being right by imitating earlier decisions. Thus, depending on their contract, managers either cascade even when it reduces firm profits, or focus on profit maximization at the expense of being worse forecasters.

Contracts that solve both moral hazard and cascading problems do so by ensuring that the expected loss to managers from cascading dominates their expected gain from being good forecasters. Thus, these contracts typically put more weight on firm profits and less on decision quality. However, if managers are wealth constrained, such contracts are less likely to be feasible. Contracts with more weight on decision quality are more likely to be feasible, but increase the probability of cascades as they induce the managers' to care more about being good forecasters. Shareholders choose contracts that maximize their surplus net of manager's compensation. Thus, depending on the set of optimal and feasible contracts, shareholders either choose to solve both problems (even if it necessitates overcompensating the manager) or, if that is too expensive, choose to solve only the moral hazard problem and rationally permit cascading. The problem is worse for larger investment decisions as feasibility constraints become more binding.

Cascading is not always undesirable. Since managers' private information is correlated, shareholders may gain from cascading behavior when both the negative impact of excessive entry and the positive impact of innovation (being the only manager to invest in a potentially good project) are low. For these parameters a variety of contracts (both high and low profit sharing) give the desired outcome. A number of testable implications emerge about which industries may have more convergence in investment choices, greater pay-for-profit sensitivity, greater reliance on decision quality, more innovation, larger-size firms, potential for overcompensation, etc. These are discussed in more detail later on in this article.

This article extends the multitasking work of Holmstrom and Milgrom (1991) to a multifirm setting. It also extends the multifirm work of Brander and Lewis (1986), Fershtman and Judd (1987), and Maksimovic (1988) by allowing managerial decisions to provide information to other managers and potentially influence their decisions. The article is based on the multifirm framework (with cascading) of Bikhchandani, Hirshleifer, and Welch (1992) with managers of similar and known ability facing identical investments with state-dependent payoffs.[3] Following Khanna and Slezak (1997), the article extends the model in a number of dimensions. It allows each manager to exert costly and unobservable effort to generate private signals about the future state before taking the decision. It introduces payoff interaction between firms from similar decisions. In addition, shareholders as residual claimants offer optimal contracts to maximize their net residual. These extensions generate some of the more interesting results in this article.

The article is organized as follows. Section 1 provides the structure of the model. Section 2 identifies the optimal contracts, the optimal effort choice, and the equilibrium payoffs to the shareholders and managers. Section 3 performs a numerical analysis for a set of parameters. Section 4 studies the robustness of the conclusions by looking at larger project sizes, penalties like manager's reputation loss and search costs which can be only partially captured by the firm, and contractibility of order in the sequence. Section 5 looks at empirical implications and related issues. This is followed by a conclusion.

1. The Model

Consider an industry with three symmetric firms owned by risk-neutral stockholders and run by risk-neutral managers of equal and known ability. There are three time periods $t = 0, 1, 2$. At $t = 0$, stockholders of each firm give their manager a contract. Based on the contract, each manager chooses an effort level to collect a private signal about identical risky investments whose payoff depends on two equally likely states, H and L. Greater effort results in higher quality signals and, since managers investigate identical projects, signals are correlated. Since there are negative payoff externalities between firms, each firm's expected profit is reduced as more firms accept. This effect is captured through the variable d. The state and firm profits are revealed with certainty at $t = 2$. At $t = 1$, after the effort choice but before states are realized, each manager decides whether to accept or reject

[3] Other models where cascading/herding can occur are Scharfstein and Stein (1990) and Zwiebel (1995) which extend Harris and Holmstrom's (1982) reputation building article to a multifirm setting. In contrast to this article, they assume that managers' quality is unknown and their actions determine their reputation and future wages. These reputation concerns are shown to possibly result in inefficient herding. In multifirm models like Brander and Lewis (1986), Fershtman and Judd (1987), and Maksimovic (1988), cascading is not an issue because there is neither learning from other's actions nor reputation effects.

t = 0	t = 1	t = 2
contract given and effort choice made	order revealed and decisions taken sequentially	state and payoffs revealed

Figure 1
Sequence of events

the investment. Firms decide sequentially, and managers who make their investment decision later can observe both the order and the decisions of earlier managers. For the basic model I assume that the order in the sequence is determined randomly after the managers' effort choice, and while observable is not contractible.[4] Since each manager is getting a correlated signal about a common uncertainty, earlier managers' decisions provide further information (for free) to managers deciding later and may influence their decision to invest. Whether managers cascade (as also their effort choice) will be determined by the contract shareholders give them at $t = 0$. Thus the time line is as shown in Figure 1.

If the project is adopted, it will generate, at $t = 2$, a state- and competition-dependent random payoff, k, as follows:[5]

$k = 1$	for each firm if H and no more than two firms invest.
$k = 1 - d$	for each firm if H and three firms invest.
$k = 0$	for each firm if L and no more than two firms invest.
$k = -d$	for each firm if L and three firms invest.

The cost for each firm to undertake the project is $c > .5$, so that the unconditioned expected value is negative. The discount rate is zero. For d large enough, the third manager's entry can make the new investment value reducing (negative NPV) for all firms. This situation is referred to as overcapacity.

At $t = 0$, managers can expend costly effort to get an imperfect private signal, θ, about the future state. Since managers are assumed to be symmetric, the same amount of effort will result in a signal of similar quality for each one of them. Similar to Bikhchandani, Hirshleifer, and Welch, the signal has the following properties:

If H, then $\theta = H$ with probability $p(e) \in [.5, 1]$, and $\theta = L$ with probability $1 - p(e)$.

[4] One justification is that earlier firms have an incentive to hide their decision for as long as possible, or make misleading statements. Thus it is unlikely that the timing of their decisions (especially rejections) will be verifiable, at least without costly monitoring. Managers are assumed to observe the timing because they are constantly monitoring each other's moves. Later I relax this assumption and derive optimal effort choice and optimal contracts under the assumption that managers know their order in the sequence before their effort choice and that the order is contractible. Major conclusions are not affected.

[5] More rigorous models of joint production with imperfect competition should not qualitatively change the results. The necessary condition is that a new entrant reduce the expected profits of all competitors.

If L, then $\theta = L$ with probability $p(e) \in [.5, 1]$, and $\theta = H$ with probability $1 - p(e)$.

For simplicity, I assume p is linearly related to effort, e, according to $p(e) = \alpha + \beta e$, with α and β positive and $\alpha \geq .5$. Thus a higher level of effort leads to a more accurate signal about the future state. The cost of effort to a manager is assumed to be $.5e^2$.

Stockholders give the manager an optimal contract based on all verifiable observables at $t = 1$ and 2: a firm's ex post profit, a manager's decision (whether he invested or not), and the ex post realization of the state. As long as a manager only partially owns the firm, a contract based solely on profits will not be optimal [see Holmstrom (1982)]. This free-rider problem also drives Jensen and Meckling (1976). Since managers with partial ownership lose less than \$1 in remuneration per \$1 loss in gross profits, they will underinvest in effort (or overconsume perquisites in Jensen and Meckling). As Holmstrom shows, this problem can be solved through a contract that also has a penalty such that, at the optimal effort level, a \$1 amount of shirking translates into a \$1 expected loss to the manager.[6]

Let D^i denote the decision of the ith manager, $i = 1, 2, 3$. If $D^i = A$, manager i accepts the project and incurs cost c; if $D^i = R$, he rejects and does not incur c. When managers decide sequentially, later managers can observe the decisions of earlier managers and infer their signals. There are two cases: when they optimally condition on these decisions (and potentially ignore their own signal), and when they optimally decide only on the basis of their own signal. The latter is referred to as a no-cascade (nc) scenario and the former as a cascade (c) scenario. At $t = 0$, shareholders have to anticipate which scenario will occur and give the contract that is optimal for that scenario.

Given the observables in the model, manager i is compensated according to the following contract: $W^i = \omega + \lambda\pi^i - \gamma I^i$, where ω is a constant, π^i is the gross profit of firm i (for which manager i works), and I^i is an indicator variable. $\pi^i = a(k - c)$, where $a = 1$ if $D^i = A$ and $a = 0$ if $D^i = R$, while I^i is 0 if manager i's decision turns out correct ex post and 1 if it turns out to be wrong. Thus this contract gives the manager a stake in firm profits along with a penalty if his decision turns out to be incorrect. W^i is a random variable which, for example, equals $\omega + \lambda(1 - d - c)$ if all three managers accept and the state turns out to be H; and when two managers, $i = 1$ and 2, accept, the third manager, $i = 3$, rejects and the state is L ex post, $W^i = \omega - \lambda c - \gamma$ for $i = 1, 2$ and $W^i = \omega$ for $i = 3$.

A discussion of why this particular form has been selected is instructive. Other contractual forms based on profits and decision quality are also likely

[6] Such a contract trivially solves the problem in Jensen and Meckling since there is no uncertainty in payoffs. However, as Holmstrom (1982) demonstrates, the problem posed in Jensen and Meckling can be solved through such a contract even if payoffs are uncertain.

to result in a set of optimal contracts. For instance, one candidate is a contract consisting of a portion of firm profits along with a bonus for the right decision. However, the form with the penalty has an advantage. Since the penalty is a potential inflow into the firm (from the manager), such contracts are more likely to have $\omega > 0$. Thus fewer contracts of this form are likely to run into the manager's wealth constraint, making the set of feasible contracts larger. The same trade-off holds for contracts with other forms, possibly with nonlinear components. Contracts that load up on profits are more likely to solve both moral hazard and cascading problems, but are also potentially more expensive. Those that load up on decision quality are more likely to result in cascading but are also more likely to be feasible.[7]

Given the compensation contract, I look at the shareholders' problem first under the no-cascade scenario and then separately under the cascade scenario. Separating it in this fashion allows me to identify a manager's decision at $t = 1$ (accept or reject), conditional on his order in the sequence, effort choice, and the strategies of competing managers. After fixing the decision, I can identify the manager's optimal effort choice (at $t = 0$) for a given contract. The shareholders' problem then reduces to identifying the optimal contract for the effort level that maximizes their expected surplus net of manager's compensation, given strategies of competing managers. Thus the shareholders' optimization problem under the no-cascade scenario for firm i is

$$\max_{\omega,\lambda,\gamma} E[\pi^i - (\omega + \lambda\pi^i - \gamma I^i) \mid p^i(e^{i*}), \{p^j(e^{j*}), j \neq i\},$$
$$D^{ig*}(e^{i*}), \{D^{j*}(e^{j*}); j \neq i\}], \quad \text{s.t.:}$$

(i) $\pi^i = a(k - c)$, where $a = 1$ if $D^i = A$, $a = 0$ if $D^i = R$, and k is as defined above.

(ii) Given effort e^{i*} and firm i enters the sequence at position g, D^{ig*} solves

$$\max_{D^{ig}} E[U(\omega + \lambda\pi^i - \gamma I^i, e^i) \mid p^i(e^{i*}), D^{ig}, \theta^i, \{D^{jg*}(e^{j*})\forall j; j \neq i\},$$
$$\{p^j(e^{j*}); j \neq i\}] \equiv M_{\text{nc}}(\theta^i, g),$$

where $E[U(\omega + \lambda\pi^i - \gamma I^i, e^i))] = E(\omega + \lambda\pi^i - \gamma I^i) - .5(e^i)^2$; and $D^{ig*}(\theta^i)$ represents the optimal decision of i if he enters at position g,

[7] Another contract that may appear attractive is one with punishment based not on decision quality but on failure to achieve a critical profit level. This has the merit that by not conditioning on decision quality it reduces the manager's incentive to cascade. However, such a contract would require multiple critical levels, each conditioned on realized state, competition, and order. When order is not contractible, such contracts are unlikely to be effective. Even with contractible order, given the large set of potential payoffs it is unlikely that effective contracts can be identified.

(iii) and e^{i*} solves

$$\max E[M_{\text{nc}}(\theta^i, g) \mid p^i(e^i), D^i(\theta^i), \{D^{j*}(e^{j*}); j \neq i\}, \{p^j(e^{j*}); j \neq i\}] \equiv N_{\text{nc}}, \text{ and}$$

(iv) $N_{\text{nc}} \geq 0$.

The objective function is the expected amount of the surplus that accrues to shareholders (gross payoff minus manager's compensation) of firm i given their manager's effort choice, e^{i*}, decision rule when order in the sequence is g, $D^{ig*}(e^{i*})$, the optimal decision rule of all other managers, $\{D^{j*}(e^{j*}); j \neq i\}$, and the quality of other managers' signals $\{p^j(e^{j*}); j \neq i\}$. Constraint (i) defines the gross payoff conditional on the decision. Constraint (ii) states that manager i takes the decision that maximizes his expected utility given his signal (θ^i), the quality of his signal $p^i(e^i)$, and other managers' strategies. Though the expression for the maximized value $M_{\text{nc}}(\theta^i, g)$ for manager i depends on his position g in the decision process, it does not play a significant role in the no-cascade case since managers ignore the information contained in the decisions of earlier managers. In this case $M_{\text{nc}}(\theta^i, g)$ is equal for $g = 1, 2, 3$; each occur with probability 1/3. Constraint (iii) states that the effort level maximizes the expectation of M_{nc}, the expected utility level given g. Constraint (iv) is the participation constraint that the managers be given their expected reservation utility, which here is normalized to zero.[8]

The program under the cascade scenario is different only to the extent that constraints (ii)–(iv) need to be conditioned on the decisions of the managers who decide before manager i, that is, $\{D^{j*}; j < g\}$.[9]

Given constraint (iv), i's shareholders will set ω such that the manager's expected utility at $t = 0$ (before the effort choice and before knowing g) is zero at the optimal effort level. Since managers observe g but stockholders do not, stockholders can condition only on expected profit and the expected probability that the manager's decision will be wrong ex post. Thus i's shareholders will set

$$\omega = .5e^{*^2} - \lambda E(\pi^i \mid (.)) + \gamma E(I^i \mid (.)), \tag{1}$$

[8] While this normalization has no incentive effects, as pointed out by a referee it is relevant for which contracts are feasible when the manager is wealth constrained. In fact if the reservation utility is high enough, then all contracts will be feasible and there will be no issue of overcompensating managers.

[9] In effect conditions (ii)–(iv) are replaced by conditions (ii′)–(iv′):
(ii′) Given a level of effort e^{i*} and firm i enters the decision sequence at position g, D^{ig*} solves

$$\max E[U(\omega + \lambda\pi^i - \gamma I^i, e^i) \mid p^i(e^{i*}), D^{ig}, \theta^i, \{D^{j*}; j < g\}, \{D^{j*}(e^{j*}); j \neq i\}, \{p^j(e^{j*}); j \neq i\}],$$

(iii′) e^{i*} solves

$$\max E[M_c(\theta^i, \{D^{j*}; j < g\}, g) \mid p^i(e^i), D^i(\theta^i), \{D^{j*}(e^{j*}); j \neq i\}, \{p^j(e^{j*}); j \neq i] \equiv N_c,$$

and
(iv′) $N_c \geq 0$.

where $E(I^i \mid (.))$ is the $t = 0$ expected probability that the manager i will be wrong ex post when he chooses the optimal effort level e^* and decides optimally via $D^*(e^*)$, given the strategies of other managers. Since this is before a manager observes g, this expectation is equal for all managers and shareholders. Thus subscript i can be dropped.

Substituting the expression for ω in the shareholders' maximization problem in the two programs gives the following intuitive expression: i's shareholders maximize

$$E(\pi \mid \{(.), \kappa\}) - .5e^{*^2} \mid \kappa, \text{ where } \kappa = \text{nc, c}. \tag{2}$$

Thus the shareholders' problem is solved in two steps. In step 1, the shareholders solve for the e^* which satisfies Equation (2), given κ, while the second part consists of identifying λ_κ and γ_κ in the manager's contract such that the manager's welfare is also optimized at an identical e^*.[10] The next task is to identify expressions for $E(\pi \mid \{(.), \kappa\})$ and $E(I \mid \{(.), \kappa\})$.

2. The Equilibrium

A firm's gross profit π depends on the extent of negative competitive externality, d, the manager's effort choice, e, and whether, given the optimal contract, there is cascading or not, κ. I deal with the optimal contracting problem first. As shown later, the optimal contract is not unique given a set of parameters. In fact λ_κ and γ_κ are substitutes. Contracts with high pay-profit sensitivity require a low penalty, while those with lower sensitivity need a higher penalty. Higher penalties will increase the probability of cascading, but these contracts are more likely to have $\omega_\kappa > 0$. Contracts with higher sensitivity are less likely to lead to cascading; however since they pay a larger share of the profit to the manager they are more likely to have $\omega_\kappa < 0$. If managers are wealth constrained ex ante, then the contracts with $\omega_\kappa < 0$, which requires the manager to pay for the privilege of getting the job, may not be feasible.

Since the manager's signal is not observable, whether there is cascading is not contractible even ex post. However, optimal contracts can be identified under the assumption of cascades or no cascades. For instance, shareholders can identify the optimal contract and the resultant effort choice assuming managers do not cascade. Next they must confirm whether, given the contract, not cascading is indeed optimal for the manager. If it is, then this contract is optimal and may achieve first best.[11] However, given the no-

[10] See Harris and Raviv (1979) and Holmstrom (1979) for this approach to moral hazard problems, though for risk-averse agents. With risk neutrality, their problem has a trivial solution: put all the risk on the agent, say, through a forcing contract. This "big stick" solution is not optimal in this article, because it increases the probability of cascading.

[11] Cascading is not always undesirable. As discussed later, gross profits can be higher with cascading for

cascading optimal contract, if managers are better off cascading, then the outcome is necessarily inferior as this contract is not optimal with cascading. Now stockholders can either try another no-cascading optimal contract or not try to prevent cascading and offer the optimal contract for the cascading environment. Stockholders will rationally choose the contract and the environment that provides the highest surplus.

The next step is to identify the optimal contracts, optimal decision rule, optimal effort choice, and the shareholders' surplus for each scenario separately. Since cascading is not contractible, a triplet of optimal contracts, decision rules, and effort choice will constitute a Nash equilibrium only if it is self-enforcing. That is, a triplet identified under the assumption of no cascading will constitute an equilibrium only if managers, when presented with the opportunity, do not switch to the cascading scenario.

Since ex ante managers are identical, I search for a symmetric Nash equilibrium. Thus each manager facing an identical contract will, in equilibrium, respond with the same effort choice at $t = 0$ and, at $t = 1$, a decision rule that spells out the same action (across managers) for each possible signal and each possible order in the sequence. Stockholders, anticipating at $t = 0$ how managers will react, pick the contract that maximizes their expected net surplus.

I start my search for the equilibrium by first fixing the decision rule under each scenario. For the no-cascade scenario it is trivial: all managers pick $D = A$ if $\theta = H$, and $D = R$ if $\theta = L$, in every order in the sequence. For the cascade scenario, the following decision rule appears to be a good candidate: the manager picks $D = A$ if $\theta = H$, and $D = R$ if $\theta = L$ in all positions except those where he strictly reduces the probability of being wrong by ignoring his own signal and imitating the decisions of managers before him. To identify such positions the following proposition is useful.

Proposition 1. *Given any effort choice e (and the resultant signal quality p) and the above decision rule for the cascade scenario, only the manager who goes third can improve the probability of being right by imitating the decision of managers before him.*

Proof. See Appendix.

The proof of Proposition 1 shows that the manager in the third position can lower his probability of being wrong by conditioning on previous decisions. This occurs when the previous two decisions convey information that is contrary to his signal. Since signals are correlated, when he updates using Bayes' rule he realizes that the probability of his decision being wrong ex post is lower if he ignores his own signal. Thus his expected probability

parameter spaces with low negative externalities.

of being wrong before he knows which order he will play in is lower if he conditions on the managers who will decide before him. The next proposition identifies the expected probabilities (at $t = 0$) of being wrong when the manager does not ever imitate and when he does according to the above decision rule.[12]

Proposition 2. *Given p, κ, and the above decision rule, before the manager knows his order in the sequence his expected probability of being wrong is $E(I_{nc}(p(e))) = 1 - p$ when $\kappa =$ no-cascade, and $E(I_c(p(e))) = (1/3)(1 - p)(3 + p - 2p^2)$ when $\kappa =$ cascade. Also, $E(I_c(p(e))) < E(I_{nc}(p(e)))$, for all $p > .5$.*

Proof. From Proposition 1, the probability of being wrong in all positions except third is $1 - p$. At the third it is $1 - p$ if no cascading and $(1 - p)^2(1 + 2p)$ if the manager conditions on previous decisions. Thus $E(I_{\text{nc}}(p(e))) = 1 - p$ while $E(I_{\text{c}}(p(e))) = (2/3)(1 - p) + (1/3)(1 - p)^2(1 + 2p) = (1/3)(1 - p)(3 + p - 2p^2)$. It is straightforward to show that $E(I_{\text{c}}(p(e))) < E(I_{\text{nc}}(p(e)))$. ∎

The symmetric Nash equilibrium to be tested is the no-cascading one. This assumes that, in equilibrium, each manager accepts if the signal is H and rejects if the signal is L. Given, all managers play the same strategy, an effort level, e, and a contract represented by the pair (λ, γ), expressions for the expected gross profit of each firm, expected payoff to the managers and the expected surplus to the stockholders are identified. The next step is to identify the optimal e, denoted by q^* for convenience, which supports the symmetric Nash equilibrium for some given λ and γ. That is, given a (λ, γ) pair, and that the other two managers choose effort level p, q^* both maximizes the manager's wealth and is equal to the effort level p of the other managers. The (λ, γ) pairs that result in a q^* that maximizes shareholders expected wealth are then identified. Finally, it is necessary to check whether, given (λ, γ) pairs that are optimal for the proposed no-cascading equilibrium, the third manager is not better off using the cascading strategy. For that it is necessary to develop expressions for the optimal effort choice and the expected wealth of the manager if he chooses to cascade for the given (λ, γ) pair. Thus the regime $\kappa =$ no cascades implies that managers in all positions in the sequence decide in accordance with their private signal, and $\kappa =$ cascades implies that the third manager ignores his own signal whenever both managers before him accept. Corollary 2 develops conditions that ensure that managers in the first and second positions do not gain from ignoring their own signal for both $\kappa =$ no cascades and $\kappa =$ cascades. Since, unlike the third manager, both these managers decrease

[12] I later establish conditions that make this belief system consistent with the equilibrium proposed below.

the probability of being right by ignoring their own signal, these conditions are not onerous and do not bind in the parameter spaces investigated in the numerical analysis.

I start by identifying the expected gross profits for the firm if the manager were selected in the first, second, or third positions, respectively, in the sequence. Since the order is imposed randomly after the manager's effort choice, the variable of interest for the manager is the ex ante expected gross profit. To develop an expression for these profits, it is necessary to find the expected gross profits in each of the three positions. Since the ex ante probability of the manager to be in any particular position is one-third, the ex ante expected gross profit is one-third the sum of the expected profits in each position. Also, since the ex ante expected profit is different for the no-cascade and cascade strategies, the expected profits in each of these positions conditional on the regime need to be identified.

Proposition 3. *Given c, d, and the belief system, the expected gross profit for a given p is $E(\pi(p, \kappa = \text{no-cascades})) = .5(p - d + 3pd - 3p^2d - c)$ for the manager's no-cascade strategy and $E(\pi(p, \kappa = \text{cascades})) = (1/6)(2p - 3d + 6pd - 6p^2d + 3p^2 - 2p^3 - 3c)$ for the cascade strategy.*

Proof. See Appendix.

The following corollary establishes the condition under which the expected gross profit under no cascade is higher than under cascade. As distinct from other articles where cascades are necessarily bad, for example, Scharfstein and Stein (1990) and Zwiebel (1995), here it is parameter specific. Since signals are correlated, there is useful information in the actions of previous managers. For small competitive externalities, managers' decision to cascade would increase shareholder wealth. This is because the value from making the right decision exceeds the loss from overcapacity. When d is large, however, the no-cascade scenario dominates. Now the negative externality swamps the gains of getting a better forecast of the future state.

Corollary 1. *Given managers choose same p under both regimes, for $3d > 2p - 1$ the expected gross profit is higher when the third manager does not cascade.*[13]

Proof. From Proposition 3, $.5(p - d + 3pd - 3p^2d - 3c) - (1/6)(2p - 3d + 6pd - 6p^2d + 3p^2 - 2p^3 - 3c) = p(1 - p)(3d + 1 - 2p)$. This is positive when $3d > 2p - 1$. ■

[13] The conditions for when $p_c^* \neq p_{nc}^*$ need to be developed numerically since p_c^* is a nonsimplifiable expression of the solution to a quadratic equation.

Having found expressions for $E(\pi(p,\kappa))$ and $E(I(p,\kappa))$ under the conjectured equilibrium, I need to identify conditions that ensure that the proposed strategy of deciding according to their private signals constitutes optimal responses for managers at the first and second positions. This is obvious for the manager chosen to go first, since by not following the equilibrium strategy of A if $\theta_1 = H$ and R if $\theta_1 = L$, he increases his probability of penalty without increasing expected profits. However, the proposed equilibrium and the resulting belief system is not unconditionally supported at the second position. The second manager may not decide according to his signal if it is the same as the first manager's if he knows that two same decisions will start a cascade. If the expected externality from the cascade is larger than the expected increase in the penalty, he may choose to accept the penalty increase. Corollary 2 in the Appendix identifies the conditions needed to sustain the equilibrium. Note that these conditions hold for high γ and not large d. The intuition is that for high γ, avoiding penalty is more important, and for not high d, the advantage of avoiding a cascade is less.

Next it is necessary to identify the optimal effort choice of a manager given that other managers pick p. This permits me to identify the fixed point, that is, the q^* which both solves this managers optimization problem and is equal to p. As expected this will be a function of λ, γ and the other parameters of the model. Also, for given λ, γ, the optimal effort choice q^* is a function of whether the manager plays the no-cascade or cascade strategy.

Proposition 4. *Given $\alpha, \beta, \lambda, \gamma, d$ and that the other two managers choose the effort level resulting in signal quality p, the optimal effort choice of the remaining manager in the symmetric Nash equilibrium results in signal quality q^* given by $q^*_{nc} = (.5\lambda\beta^2(1+d) + \beta^2\gamma + \alpha)/(1 + \lambda\beta^2 d)$ when all managers use no-cascade strategy; and q^*_c which is a solution to $q_c^2(-\lambda\beta^2/3 - 2\beta^2\gamma) + q_c(\lambda\beta^2(1-2d)/3 + 2\beta^2\gamma - 1) + \lambda\beta^2(1+d)/3 + \alpha = 0$ when managers use the cascade strategy.*

Proof. See Appendix.

The proof is done in two parts. First the optimal q^* for the manager given the others choose p, is identified. Then, the fixed point is found by equating this q^* to p. This is done separately for the cascade strategy and the no-cascade strategy.

As is obvious from Proposition 4, the manager's effort choice is determined by the parameters λ and γ of his compensation contract. Thus shareholders can affect the manager's effort level through their choice of λ and γ. The next step is to identify the p^* that maximizes the expected net surplus of the stockholders. For this it is necessary to solve the shareholders' optimization problem as laid down in Equation (2). The next proposition establishes the respective p^*'s that optimize shareholder welfare for manager's no-cascade and cascade strategies.

Proposition 5. *When managers follow the no-cascade strategy in equilibrium, the shareholders' net expected surplus is maximized when the effort choice of the manager is* $p^*_{nc} = (.5(1+3d) + \alpha/\beta^2)/(3d + 1/\beta^2)$*, and when they follow the cascade strategy in equilibrium,* p^*_c *is a solution to* $-p^2 + p(1 - 2d - 1/\beta^2) + (1/3 + d + \alpha/\beta^2) = 0$.

Proof. The shareholders' $\max_p .5[p - d + 3pd - 3p^2d - c] - .5((p-\alpha)/\beta)^2$ when managers follow the no-cascade strategy. The p^* that solves this is $(.5(1+3d)+\alpha/\beta^2)/(3d+1/\beta^2)$. For the cascade strategy, the shareholders' $\max_p (1/6)[2p - 3d + 6pd - 6p^2d + 3p^2 - 2p^3 - 3c] - .5((p-\alpha)/\beta)^2$. The p^*_c that solves this is the solution to $-p^2 + p(1-2d-1/\beta^2) + (1/3 + d + \alpha/\beta^2) = 0$. ■

In the no-cascade equilibrium, shareholders would like to offer a contract such that $q^*_{nc} = p^*_{nc}$. Note that p^*_{nc} is independent of λ and γ. The reason is that the managers are paid the competitive wage, that is, they are compensated only to the extent of their cost of effort.[14] This is ensured by setting ω such that the manager's rent is zero. ω provides the shareholders with the ability to provide the necessary incentives to the manager without overpaying him. ω also allows for a multiple of optimal contracts. The next proposition establishes the set of (λ, γ) pairs which ensure that the effort choice of the managers optimizes shareholder surplus. There is a locus of such pairs.[15]

Proposition 6. *The locus of* λ *and* γ *pairs that satisfies the condition* $q^*_{nc} = p^*_{nc}$ *is defined by*

$$1 + 3d - 6d\alpha = \lambda(2\beta^2 d - 2\alpha d + d + 1) + \gamma(2 + 6\beta^2 d).$$

Proof. Simply equate q^*_{nc} from Proposition 4 to p^*_{nc} from Proposition 5. ■

Since α, β, and d are exogenously determined, the terms in the brackets are constant. Thus λ and γ are substitutes in that a higher λ implies a lower γ. This means that when managers have higher ownership positions they require smaller penalties to motivate them to make the required effort. However, when their holdings are small, the penalties have to be large. This, in turn, has implications for the constant ω in the wage. With higher ownership position, to ensure that the manager gets only the competitive wage, ω will be negative more often. Thus a manager's capital constraint may put an upper

[14] This holds for any constant reservation wage.

[15] This occurs because of the risk neutrality assumption. Khanna and Slezak (1997) study a related problem with risk aversion and demonstrate the existence of an optimal contract. This problem gets more involved because of the value of hedging to managers.

bound on the amount of ownership that can be given to him. In larger firms, in particular, this capital constraint may limit manager's ownership to an extremely small proportion, putting a large weight on potential penalties. The numerical analysis shows this increases the probability of managers copying decisions of other managers even when it means selecting negative NPV projects.

3. Numerical Analysis

There are only four exogenous variables in this model α, β, c, and d. A high α reduces the contribution of effort e, and a high β increases it. High c lowers the profitability of the project while a high d makes cascading more expensive for all firms. λ, γ, q_c^*, q_{nc}^*, p_c^*, p_{nc}^*, ω_{nc}, and expected gross profit, $E\pi_{nc}$, are all determined endogenously. For the example I choose $\alpha = .75$, $\beta = .35$, $c = .5$, and $d \in [0, .35]$.[16] From Proposition 6, the locus of λ and γ pairs that maximizes both managers' expected wealth and shareholder expected surplus is a function of α, β, and d and is tabulated in columns 1 and 2 (Table 1). For any pair (λ, γ), from Propositions 4 and 5, p_{nc}^*, q_{nc}^* are calculated in columns 3 and 4. As expected they are all equal. Column 5 lists the appropriate ω for different (λ, γ) pairs that makes the expected utility of the manager equal to zero. This can be calculated from Proposition 5 by substituting $q_{nc}^* = p_{nc}^*$ for $p(e^*)$. ω varies with (λ, γ) pairs since higher λ means higher sensitivity to profit. Since γ is inversely related to λ, the manager's ω becomes smaller and then negative for still higher λ. For higher weight on profit, the manager needs to pay to get the job. If he is capital constrained, these pairs may be feasible only if he is overcompensated to some extent. Column 6 lists the optimal effort choice of manager q_c^* (denoted q^{**}), if the manager decides to cascade given the (λ, γ) pair of the no-cascade contract. Column 7 gives the expected utility of the manager if he decides to cascade given λ, γ and ω of the no-cascade contract. This is a pivotal column since it identifies when it is profitable for the manager to cascade given the no-cascade contract.

For the first table with $d = .30$, the manager will cascade for weight on profit of less than 35% since his expected utility, $Eu(M, \omega, q^{**})$, is greater than zero if he cascades. Comparing column 8 to column 9 shows that stockholders are worse off whenever the manager cascades. Notice also that $q_c^* < q_{nc}^*$, that is, the effort choice of the manager if he may cascade (column 6) is less than the effort choice of the manager if he knows he will not cascade (column 4). This is true for all parameters I look at and the reason is that when the manager knows he may use others' correlated signals, he free rides to some extent. Columns 10 and 11 are also quite

[16] For the sake of robustness, I can show that the results hold for many reasonable values of α, β, and c.

Table 1
Shareholders solve both moral hazard and cascading problems

1 λ	2 γ	3 $p^*(w/o, sh)$	4 $q^*(w/o, M)$	5 ω	6 $q^{**}(w, M, \lambda, \gamma)$	7 $Eu(M, \omega, q^{**})$	8 $E\pi(sh, q^*, \omega)$	9 $E\pi(sh, q^{**}, \omega)$	10 $p^\wedge(w)$	11 $E\pi(sh, p^\wedge, \omega^\wedge)$
0.05	0.23	0.780	0.780	0.05	0.762	0.005	0.064	0.045	0.790	0.054
0.1	0.21	0.780	0.780	0.042	0.763	0.005	0.064	0.046	0.790	0.054
0.15	0.19	0.780	0.780	0.034	0.764	0.004	0.064	0.048	0.790	0.054
0.2	0.16	0.780	0.780	0.026	0.766	0.003	0.064	0.049	0.790	0.054
0.25	0.14	0.780	0.780	0.019	0.767	0.002	0.064	0.050	0.790	0.054
0.3	0.12	0.780	0.780	0.011	0.768	0.001	0.064	0.051	0.791	0.054
0.35	0.1	0.780	0.780	0.003	0.769	0.000	0.064	0.053	0.790	0.054
0.4	0.08	0.780	0.780	−0.005	0.770	−0.001	0.064	0.054	0.790	0.054
0.45	0.06	0.780	0.780	−0.013	0.771	−0.002	0.064	0.055	0.790	0.054
0.5	0.04	0.780	0.780	−0.021	0.772	−0.004	0.064	0.056	0.790	0.054

Columns 1 and 2 give the different λ, γ pairs for the optimal contract without (w/o) cascade. p^* and q^* are the optimal effort choices of shareholders and managers, respectively. In equilibrium these are equal. ω in column 5 is the cash payment to the manager which makes $E(u(M, \omega, q^*)) = 0$. Given λ and γ under the no cascade assumption, q^{**} in column 6 is the manager's optimal effort choice if he intends to cascade (w) and $E(u(M, \omega, q^{**}))$ is his resultant utility. Column 8 gives the shareholders' surplus if the manager does not cascade and chooses optimal effort level q^*. Column 9 gives the shareholders' surplus if the manager cascades and takes effort q^{**}, and the contract is under the assumption of no cascade. Column 10 is the manager's optimal effort $p^\wedge$ if he cascades, given the optimal contract assumes cascades. Column 11 is the shareholders' surplus when they give the optimal contract under the assumption of cascades and the manager chooses $p^\wedge$ and cascades. The pivotal columns are 5 and 7. Whenever $\omega < 0$, the contract is nonaffordable for the manager. Managers cascade whenever $E(u(M, \omega, q^{**})) > 0$.
$\alpha = 0.75$, $\beta = 0.35$, $d = 0.3$, $c = 0.5$

instructive. Column 10 is the optimal effort choice $p^\wedge(w)$ of the manager when he knows he may cascade and the shareholders give him an optimal contract knowing he may cascade. The γ's for this contract are higher than in column 2, as is $p^\wedge$ as compared to p^*. When the manager is expected to cascade, shareholders require a higher effort level and get it with higher punishment. For this set of parameters though, shareholders prefer that the manager not cascade since their surplus then is .064 instead of .054 if he cascades (column 11).[17] Thus they will give a contract with 35% weight on profit and penalty of .102.[18]

Table 2 is for $d = .22$. Again p^* is higher, as is γ. Managers will cascade for $\lambda < 60\%$. What is more striking is that ω becomes negative for $\lambda > 35\%$. Thus if managers are wealth constrained, then preventing cascades is not feasible without overcompensating the manager. The overcompensation, though, must be provided through an increase in the weight on profit and not through an increase in ω. An increase in ω will only increase the expected utility of the manager if he cascades but will not prevent cascading. However, if the manager needs to be overcompensated to the full extent of the negative

Table 2
Shareholders rationally permit cascading

1 λ	2 γ	3 p^*(w/o, sh)	4 ω	5 q^{**}(w, M, λ, γ)	6 Eu(M, ω, q^{**})	7 Eπ(sh, q^*, ω)	8 Eπ(sh, $p^\wedge$, $\omega^\wedge$)
0.05	0.288	0.788	0.063	0.765	0.007	0.083	0.081
0.1	0.266	0.788	0.053	0.766	0.006	0.083	0.081
0.15	0.244	0.788	0.044	0.767	0.006	0.083	0.081
0.2	0.223	0.788	0.035	0.768	0.005	0.083	0.081
0.25	0.201	0.788	0.026	0.770	0.005	0.083	0.081
0.3	0.179	0.788	0.017	0.771	0.004	0.083	0.081
0.35	0.157	0.788	0.008	0.772	0.003	0.083	0.081
0.4	0.135	0.788	−0.001	0.773	0.003	0.083	0.081
0.45	0.113	0.788	−0.01	0.774	0.002	0.083	0.081
0.5	0.092	0.788	−0.019	0.775	0.001	0.083	0.081
0.55	0.07	0.788	−0.028	0.777	0.001	0.083	0.081
0.6	0.048	0.788	−0.037	0.778	0.000	0.083	0.081
0.65	0.026	0.788	−0.047	0.779	−0.001	0.083	0.081

Columns 1 and 2 give the different λ, γ pairs for the optimal contract without (w/o) cascade. p^* is the optimal effort choice shareholders desires and, in equilibrium, the manager delivers. ω in column 4 is the cash payment to the manager which makes $E(u(M, \omega, q^*)) = 0$. Given λ and γ under the no cascade assumption, q^{**} in column 5 is the manager's optimal effort choice if he intends to cascade (w) and $E(u(M, \omega, q^{**}))$ his resultant utility. Column 7 and 8 give, respectively, shareholders' surplus without the possibility of cascades and with, given the optimal contract for each scenario.
$\alpha = 0.75$, $\beta = 0.35$, $d = 0.22$, $c = 0.5$

[17] Also note that $\gamma = 0$ for λ close to .6 and not 1 as may be expected. The reason is $d > 0$. When $d > 0$, it acts like a penalty in the sense that the probability of penalty is reduced, but at the expense of reduced profits and thus lower return from profit sharing. For $d = 0$, $\lambda = 1$ implies $\gamma = 0$ as expected. This is because there is no hidden penalty in expected gross profit.

[18] In more conventional terms, the expected wage, $E(W) = \omega + \lambda E(\pi) - \gamma E(I) = .003 + .0236 - .022 = .0042 \equiv .5e^2$, the disutility from effort. This is under the assumption that the manager's net utility is zero. Dependence on punishment allows the contract to be feasible since $\omega > 0$. The numbers can be derived from Table 1.

ω, then shareholders are worse off than if they allow managers to cascade under an optimal contract for cascading. This is because the difference between columns 7 and 8 is $.083 - .081 = .002$ and the minimum amount of overcompensation needed to prevent cascading is .037 (for a pay-profit sensitivity of 60%), bigger than the difference of .002. Thus they are better off letting managers cascade under an optimal contract with cascading, and low pay-profit contracts will suffice.

For lower negative externalities, say $d = .1$, managers will cascade at even higher weights on profit. However, now cascading is the preferred outcome for the shareholders. The reason is that for low payoff externality, the benefit from using earlier managers information to get a better forecast dominates the profit-loss from cascading. By Corollary 1, this occurs whenever $3d < 2p - 1$. For $d = .1$, it can be shown that $p^* = .8$, and this condition is satisfied. For such low d's, shareholders are worse off if they prevent cascading. Thus contracts with a low weight on profits (and a high weight on decision quality) can be used to solve only the moral hazard problem.

4. Robustness

4.1 Manager's penalty not fully accruing to firm

The analysis in this article assumes that the manager's penalty accrues to the firm. This is the case when the penalty is in the form of lost bonuses or demotion to lower positions with lesser pay, or direct contingent transfers from the manager to the firm. However, the firm may get only some of the penalty incurred by the manager if the latter faces cost like reputation loss or search costs for new job. The analysis below extends the article to incorporate this aspect.

It may be noted that the optimization problem of the manager remains the same since the cost of the penalty is the same to him whether the firm recovers it or not, but that of the shareholders changes to

$$(1 - \lambda_\kappa)E(\pi \mid \{(.), \kappa\}) + a\gamma_\kappa(E(I \mid \{(.), \kappa\}) - \omega,$$

where $a \in [0, 1]$ is the proportion of the expected penalty recovered by the firm. Substituting for ω from Equation (1), the shareholders' optimization problem reduces to identifying the e^* which solves

$$\max_e E(\pi \mid \{(.), \kappa\}) + (a - 1)\gamma_\kappa E(I \mid \{(.), \kappa\}) - .5e^2,$$
$$\text{s.t. this } e^* \text{ also solves the manager's optimization problem.} \quad (3)$$

For $\kappa =$ no cascade, from Propositions 2 and 3, Equation (3) becomes

$$\max_e .5(p - d + 3pd - 3p^2d - c) + (a - 1)\gamma(1 - p) - .5e^2 \quad (3')$$

Table 3
Penalty not fully accruing to firm

1 λ	2 γ	3 p^*(w/o, sh)	4 ω	5 q^{**}(w, M, λ, γ)	6 Eu(M, q^{**}, ω)	7 Eπ(sh, q^*, ω)	8 Eπ(sh, p^, ω^)
0.05	0.28	0.786	0.061	0.764	0.006	0.052	0.045
0.1	0.25	0.786	0.052	0.765	0.006	0.053	0.045
0.15	0.23	0.785	0.043	0.766	0.005	0.054	0.046
0.2	0.20	0.785	0.035	0.767	0.004	0.055	0.047
0.25	0.18	0.784	0.026	0.768	0.003	0.056	0.048
0.3	0.15	0.784	0.017	0.769	0.001	0.057	0.049
0.35	0.12	0.783	0.008	0.770	0.000	0.058	0.050
0.4	0.10	0.783	−0.001	0.771	−0.001	0.059	0.051
0.45	0.07	0.782	−0.01	0.772	−0.002	0.060	0.052
0.5	0.05	0.781	−0.019	0.773	−0.003	0.061	0.053

Columns 1 and 2 give the different λ, γ pairs for the optimal contract without (w/o) cascade. p^* is the optimal effort choice shareholders desires and, in equilibrium, the manager delivers. ω in column 4 is the cash payment to the manager which makes $E(u(M, \omega, q^*)) = 0$. Given λ and γ under the no-cascade assumption, q^{**} in column 5 is the manager's optimal effort choice if he intends to cascade (w) and $E(u(M, \omega, q^{**}))$ his resultant utility. Columns 7 and 8 give, respectively, shareholders' surplus without the possibility of cascades and with, given the optimal contract for each scenario. The additional parameter a implies that only 0.8 of the manager's penalty is captured by the firm.
$\alpha = 0.75$, $\beta = 0.35$, $d = 0.3$, $c = 0.5$, $a = 0.8$

and $(p')^* = (.5(1+3d)-\gamma(a-1)+\alpha/\beta^2)/(3d+1/\beta^2)$. $(p')^*$ is higher than p^* since the penalty hurts both managers and stockholders, and stockholders prefer to reduce the probability of penalty. As in Proposition 6, shareholders will choose λ and γ which equate $(p')^*$ to q^*_{nc} from Proposition 4. The locus of such pairs of λ and γ is the solution to

$$\begin{aligned}(.5(1+3d) - \gamma(a-1) + \alpha/\beta^2)/(3d + 1/\beta^2)\\ = (.5\lambda\beta^2(1+d) + \beta^2\gamma + \alpha)/(1+\lambda\beta^2 d),\end{aligned}$$

which is

$$\begin{aligned}1 + 3d - 6d\alpha \;=\; &\lambda(2\beta^2 d - 2\alpha d + d + 1) + \gamma(2 + 6\beta^2 d - 2(a-1))\\ &- 2\gamma\lambda\beta^2 d(a-1).\end{aligned}$$

Table 3 shows that the earlier results are maintained. However, now the desired effort levels are higher. The weight on profit to prevent cascading does not necessarily change (remains at 35%), but there is greater dependence on punishment. The surplus to the stockholders with and without cascading (columns 7 and 8) is naturally lower than in Table 1 (columns 8 and 11).

4.2 When size of investment is increased

For this analysis I assume that all payoffs and the cost are multiplied by a factor of m. That is, for a cost mc, the output will be $m(1-d)$ per firm if all three enter and the state is H, m if two or less enter and state is H, 0 if state is L and two or less enter, and $-md$ if state is L and all three enter.

Proposition 7. *When the size of the project is increased to m, the locus of (λ, γ) pairs that satisfy the condition $q^*_{nc} = p^*_{nc}$, is defined by*

$$m + 3md - 6md\alpha = \lambda(2m^2\beta^2 d - 2m\alpha d + md + m) + \gamma(2 + 6m\beta^2 d).$$

Proof. See Appendix.

As m becomes larger (say twice as big: that is, $m = 2$ in Table 4), not surprisingly the optimal effort desired by shareholders increases. Thus for the same level of ownership as when $m = 1$, the size of penalty is higher. However, this increases the managers' benefit from cascading (see column 6 of Table 4). Managers now earn more of their compensation through pay-profit sensitivity, which makes the fixed component of their wage negative for lower λ and by larger amounts. Thus if the manager is wealth constrained, the amount of overcompensation needed to avoid cascades is .007, with pay-profit sensitivity of 35% and penalty of .16.[19] If compared to Table 1, it can be seen that for smaller projects cascading could be stopped without any overcompensation, since for $\lambda = 35\%$, ω is positive. For the parameters of Table 4, it turns out that shareholders will choose to overcompensate as the difference between columns 7 and 8 is $.014 > .007$. However, with higher m, or other parameters, it is easy to give examples where preventing cascades becomes too expensive for firms. Then they will permit cascades and give optimal contracts under the assumption that cascades will occur. Thus, for larger size projects or firms, overcompensation will be higher as will the incidence of cascades. As a result, larger firms that wish to avoid cascades will on average offer higher compensation than if they were smaller, both because of higher desired effort and the higher amount of overcompensation needed.

4.3 Introducing debt into capital structure

Since all agents are risk neutral and there is no limited liability, debt serves to reduce the size of the project.[20] Thus a lower level of effort will be optimal. Also, the manager can be given higher pay for profit without triggering the feasibility constraint. Thus highly levered industries will see less copycat behavior and less overcompensation. The algebra is the same as in Section 4.2.

[19] $E(W) = -.007 + .0512 - .0321 = .0124 \equiv .5e^2$, the disutility from effort. The numbers can be derived from Table 4. When compared to note 18, the optimal effort required is higher, as is the intensity of incentives. However, since higher weight on punishment would result in cascading, a larger weight is needed on profit. This runs into the feasibility constraint. However, as discussed in the text, in this case shareholders prefer to overcompensate to avoid cascades.

[20] Because of risk neutrality and unlimited liability, in this model debt is nonstrategic and merely reduces equity. In that sense its role is similar to that in Jensen and Meckling (1976) and Stulz (1988). A more strategic role of debt [see Harris and Raviv (1991)], though desirable, is not attempted here.

Table 4
Size of project is bigger

1 λ	2 γ	3 p*(w/o, sh)	4 ω	5 q**(w, M, λ, γ)	6 Eu(M, q**, ω)	7 Eπ(sh, q*, ω)	8 Eπ(sh, p^, ω^)
0.05	0.41	0.805	0.085	0.772	0.008	0.134	0.120
0.1	0.37	0.805	0.07	0.774	0.007	0.134	0.120
0.15	0.33	0.805	0.054	0.776	0.006	0.134	0.120
0.2	0.29	0.805	0.039	0.779	0.004	0.134	0.120
0.25	0.25	0.805	0.024	0.781	0.003	0.134	0.120
0.3	0.21	0.805	0.009	0.783	0.001	0.134	0.120
0.35	0.16	0.805	−0.007	0.785	0.000	0.134	0.120
0.4	0.12	0.805	−0.022	0.788	−0.002	0.134	0.120
0.45	0.08	0.805	−0.037	0.790	−0.004	0.134	0.120
0.5	0.04	0.805	−0.053	0.792	−0.006	0.134	0.120

Columns 1 and 2 give the different λ, γ pairs for the optimal contract without (w/o) cascade. p^* is the optimal effort choice shareholders desire and, in equilibrium, the manager delivers. ω in column 4 is the cash payment to the manager which makes $E(u(M, \omega, q^*)) = 0$. Given λ and γ under the no-cascade assumption, q^{**} in column 5 is the manager's optimal effort choice if he intends to cascade (w) and $E(u(M, \omega, q^{**}))$ his resultant utility. Columns 7 and 8 give, respectively, shareholders' surplus without the possibility of cascades and with, given the optimal contract for each scenario. The additional parameter m implies that the project is twice the original size.
$\alpha = 0.75$, $\beta = 0.35$, $d = 0.3$, $c = 0.5$, $m = 2$

4.4 Firm's order in the sequence common knowledge and contractible

The analysis is now extended to the scenario where at $t = 0$ shareholders and managers know their firm's order in the sequence and the contract can be conditioned on it. This should improve shareholder welfare by making contracts more efficient especially for the cascading case. Since the third manager is expected to ignore his signal in some cases, shareholders can reduce wasted effort by requiring a lower effort choice. Also one would expect that the punishment component will be generally higher for the first two positions since these do not cascade. At the third position one would expect the punishment component to be even larger in the cascade case, as this ensures a higher probability that the manager will cascade. Higher weights on the punishment component have a secondary benefit as well. Now more contracts will be feasible, reducing the frequency of overcompensation. Since the efficiency gains should be captured by the shareholders, they should be better off under both scenarios. All these hypothesis are borne out in Table 5.

The analysis for this section is more involved because the effort choices and contracts will depend on the order. Thus I need to find optimal effort choice and optimal contracts for each position. This needs to be solved simultaneously as each manager takes the optimal effort choice of the other as given before choosing his own. I give the analysis in some detail for the no-cascade case, but only the results for the cascade case.

4.4.1 The no-cascade case. The notation used is the same as in Proposition 4, as is some of the logic. However, now I search for an asymmetric Nash equilibrium. As in the earlier case, the manager in position 2 will make

Table 5
Firms' order in sequence known and contractible at $t = 0$

Cascades							No-Cascades						Switching	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$\lambda 3$	$\gamma 3$(w)	$\gamma 2(\omega)$	p*(M)	q*(M)	$\pi 3$(sh)	$\pi 2$(sh)	$\gamma 2$(w/o)	p*(M)	$\gamma 3$(w/o)	q*(M)	$\pi 3$(sh)	$\pi 2$(sh)	ω(M, w/o, q*)	Eu(M, ω, q**)
0.05	0.48	0.35	0.795	0.77	0.116	0.065	0.35	0.795	0.41	0.803	0.083	0.082	0.088	0.044
0.1	0.45	0.33	0.795	0.77	0.116	0.065	0.33	0.795	0.39	0.803	0.083	0.082	0.079	0.036
0.15	0.43	0.31	0.795	0.77	0.116	0.065	0.31	0.795	0.37	0.803	0.083	0.082	0.070	0.027
0.2	0.4	0.30	0.795	0.77	0.116	0.065	0.30	0.795	0.35	0.803	0.083	0.082	0.061	0.019
0.25	0.38	0.28	0.795	0.77	0.116	0.065	0.28	0.795	0.33	0.803	0.083	0.082	0.052	0.010
0.3	0.35	0.26	0.795	0.77	0.116	0.065	0.26	0.795	0.30	0.803	0.083	0.082	0.043	0.002
0.35	0.33	0.24	0.795	0.77	0.116	0.065	0.24	0.795	0.28	0.803	0.083	0.082	0.034	−0.006
0.4	0.3	0.22	0.795	0.77	0.116	0.065	0.22	0.795	0.26	0.803	0.083	0.082	0.025	−0.015
0.45	0.28	0.20	0.795	0.77	0.116	0.065	0.20	0.795	0.24	0.803	0.083	0.082	0.016	−0.023
0.5	0.25	0.19	0.795	0.77	0.116	0.065	0.19	0.795	0.22	0.803	0.083	0.082	0.007	−0.032

Columns 1–7 represent the cascade scenario, 8–13 the no-cascade scenario, and 14 and 15 check whether managers have incentive to cascade. Columns 2 and 3 give the weight on the punishment component for positions three and two, respectively. Column 4 is the optimal effort choice for managers in first and second positions, while column 5 is that for the manager in third position. Columns 6 and 7 are the shareholders' expected surplus from the third and first two firms, respectively. Columns 8–13 give similar parameters for the no-cascade scenario. Column 14 gives the feasibility constraint, while column 15 is the manager's surplus if he cascades and chooses his effort assuming he will cascade, when the contract assumes no cascade.
$\alpha = 0.75$, $\beta = 0.35$, $d = 0.22$, $c = 0.5$

the same equilibrium choices as manager 1, since he does not gain from observing manager 1's action. Assume that both make an effort to generate a signal of quality p. Also assume that the manager coming in position 3 selects signal quality q, and that manager 3's contract is represented by $\{\omega_3, \lambda_3, \gamma_3\}$ and that of managers 1 and 2 is represented by $\{\omega_2, \lambda_2, \gamma_2\}$. The solution is identified through backward induction. First solve for q^* as a function of p and the contracts. Then solve for p^* given that manager 3 chooses q^*, given the contracts. (One is essentially looking for an intersection point of two response functions to simultaneously identify q^* and p^*.) Thus manager 3's problem is

$$\begin{aligned}\max_q \omega_3 + .5\lambda_3[p^2q(1-d) + (1-p)^2(1-q)(-d) + 2p(1-p)q \\ + \ q(1-p)^2 - c] \\ - \gamma_3(1-q) - .5((q-\alpha)/\beta)^2,\end{aligned}$$

where the second term is the profit component of contract given that managers 1 and 2 choose p and manager 3 chooses q, the third term is the penalty component, and the fourth term is the disutility of effort. The solution is

$$q^*(m, \text{nc}) = \beta^2[.5\lambda_3(1 + d - 2pd) + \gamma_3] + \alpha. \tag{S1}$$

Next look at the optimization problem of the shareholders of firm 3. As in Equation 2, shareholders would like to get a signal of quality q that maximizes expected gross profits minus disutility of effort. Thus their problem is

$$\begin{aligned}\max_q .5[p^2q(1-d) + (1-p)^2(1-q)(-d) + 2p(1-p)q \\ + \ q(1-p)^2 - c] - \ .5((q-\alpha)/\beta)^2\end{aligned}$$

and the solution is

$$q^*(s/h, \text{nc}) = .5\beta^2(1 + d - 2pd) + \alpha. \tag{S2}$$

Notice that this is a function of p, d, α, and β. Only p is endogenous and yet unknown.

Equating $q^*(m, \text{nc})$ to $q^*(s/h, \text{nc})$ as in Proposition 5 gives the locus of (λ_3, γ_3) pairs that get the desired q^*. The locus is

$$.5(1 - \lambda_3)(1 + d - 2pd) = \gamma_3.$$

The next step is to find the optimal p as a function of only exogenous variables to substitute into Equation (S2). Manager 2's optimization is as follows. Given Equation (S2), he solves

$$\max_p \omega_2 + .5\lambda_2[p^2q(1-d) + (1-p)^2(1-q)(-d) + p(1-q) + pq(1-p) - c] - \gamma_2(1-q) - .5((p-\alpha)/\beta)^2.$$

Substituting q^* for q and solving I get

$$p^*(m, \text{nc}) = [.5\lambda_2\beta^2(-2\beta^2d^2 + 1 + 2d - \beta^2d - 2d\alpha) + \beta^2\gamma_2 + \alpha]/(1 + \lambda_2\beta^2d - 2\lambda_2\beta^4d^2). \tag{S3}$$

The shareholders' optimization is

$$\max_p .5[p^2q(1-d) + (1-p)^2(1-q)(-d) + pq(1-p) + p(1-q) - c] - .5((p-\alpha)/\beta)^2. \tag{S4}$$

Again substituting q^* for q and solving I get

$$p^*(s/h, \text{nc}) = [.5\beta^2(-2\beta^2d^2 + 1 + 2d - \beta^2d - 2d\alpha) + \alpha]/(1 + \beta^2d - 2\beta^4d^2). \tag{S5}$$

Notice this is a function of only exogenous variables. Thus we can calculate q^* and p^*.

Equating $p^*(s/h, \text{nc})$ and $p^*(m, \text{nc})$ gives the locus of contracts that get the desired effort, under assumption of no cascades. The locus is

$$(1-\lambda_2)(-2\beta^2d^2 + 1 + 2d - \beta^2d - 4d\alpha + 4\beta^2d^2\alpha) - 2\gamma_2(1 + \beta^2d - 2\beta^4d^2) = 0.$$

4.4.2 The Cascade case. Manager 3's optimization is

$$\max_q \omega_3 + .5\lambda_3[p^2q(1-d) + (1-p)^2(1-q)(-d) + p^2(1-q)(1-d) + q(1-p)^2(-d) + 2pq(1-p) - c] - \gamma_3(1-p)(1+p-2pq) - .5((q-\alpha)/\beta)^2$$

and the solution is

$$q^*(m, c) = \alpha + \beta^2[2p(1-p)(.5\lambda_3 + \gamma_3)]. \tag{S6}$$

Shareholders of the firm in the third position solve

$$\max_q .5[p^2q(1-d) + (1-p)^2(1-q)(-d) + p^2(1-q)(1-d) + q(1-p)^2(-d) + 2pq(1-p) - c] - .5((q-\alpha)/\beta)^2$$

and the solution is

$$q^*(s/h, c) = \alpha + \beta^2p(1-p). \tag{S7}$$

The locus of contracts that gets the desired effort is

$$.5\lambda_3 + \gamma_3 = .5. \tag{S8}$$

Similarly the optimal quality signal at the second position and the locus of contracts is

$$p^*(m, \text{nc}) = (\lambda_2\beta^2 d + .5\lambda_2\beta^2 + \beta^2\gamma_2 + \alpha)/(1 + 2\lambda_2\beta^2 d); \tag{S9}$$

$$p^*(s/h, \text{c}) = (\beta^2 d + .5\beta^2 + \alpha)/(1 + 2\beta^2 d); \tag{S10}$$

and the locus of contracts is

$$.5 + d - 2\alpha d = \lambda_2(.5 + d - 2\alpha d) + \gamma_2(1 + 2\beta^2 d). \tag{S11}$$

As before, I numerically check which of the optimal contracts under the no-cascade scenario remain optimal when managers are permitted to cascade. In Table 5, columns 1–7 represent the cascade scenario, 8–13 represent the no-cascade scenario, and 14 and 15 check whether, given the optimal contract under assumption of no-cascade, managers have the incentive to cascade. The parameters α, β, c, and d are the same as for Table 2 so results can be compared. I start with the cascade scenario. Since managerial contracts now depend on the position in the sequence, the weights on expected probability of punishment will be different for a given λ. These are represented by $\gamma 3(c)$ (third position) and $\gamma 2(c)$ (first and second position) with the one in third position being higher because, in the cascade scenario, since the third manager is going to cascade more weight can be put on punishment.[21] Also, as expected, the effort by the third manager, $q^*(m)$ in column 5, is lower than that in positions 1 and 2, $p^*(m)$ in column 4. This represents expected efficiency gains from knowing the order at the time of contracting, which enables shareholders to offer different contracts for different positions. Since the manager in the third position is expected to ignore his information in certain situations, lesser effort leads to smaller waste. The expected efficiency gain should accrue to the shareholders and this can be seen by comparing $2/3(\pi 2) + 1/3(\pi 3) = .082$ to column 11 of Table 2, .081.

For the no-cascade scenario, punishment is higher in the third position [$\gamma 3$(nc) in column 10] than in positions 1 and 2 [$\gamma 2$ (nc) in column 8], but not as high as in the cascade case (column 2). In contrast to the cascade case, $q^*(m)$ in column 11 is now higher than $p^*(m)$ in column 9. There are two reasons. One, because of the no-cascade assumption, the manager does

[21] Positions 1 and 2 are similar because of the particular nature of the externality: when the second enters, profits of neither firm are affected. However, when the third enters, that reduces profitability for all. Thus the third will be generally different.

not ignore his information and, two, since his decision to enter imposes an externality on all (including himself) he has a reason to search more.

The other interesting comparisons are (i) the third firm's shareholders do significantly better in the cascade case than the first two (column 6 versus column 7), and somewhat better in the no-cascade case (column 12 versus column 13). (ii) Punishment components (columns 2, 3, 8, and 10 of Table 5) are uniformly higher when compared to column 2 of Table 2. (iii) The third firm's shareholders do better when order is known and contractible, for both cascade and no-cascade cases (column 6 of Table 5 versus column 7 of Table 2 and column 12 of Table 5 versus column 8 of Table 2, respectively). (iv) The first and second firms' shareholders do worse than when order is not known. (v) The first two managers search more under the no-cascade scenario when order is known and contractible (column 9 of Table 5 versus column 3 or 4 of Table 2).

These five comparisons occur for reasons similar to strategic substitutability, explored in Fershtman and Judd (1987) and others. Since the third firm imposes a competitive externality on the other two, it can affect their behavior by making its own manager search more aggressively through a higher intensity of incentives via higher punishment components for similar weights on profit sharing. The first two firms also become more aggressive as seen from condition (ii) above. However, unlike Fershtman and Judd, aggressiveness does not necessarily lower total expected profits to below those where order is not contractible because of efficiency gains through order-based contracts. Also, the third firm uniformly gains from being in that position, and even more so when order is contractible since it can transfer some of the first two firms' profits to itself by making them search more.

In spite of the richer strategic interaction when order is known and contractible, the major conclusions of the previous sections remain. Higher profit sharing results in less cascading, higher punishment in more. Cascading is not always undesirable, so depending on the extent of externality an industry may or may not exhibit copycat behavior. However, because of higher punishment components when order is known, more contracts are feasible and this reduces the frequency of rational overcompensation.

5. Testable Implications and Empirical Issues

Empirical research on incentives has documented a strong relationship between pay-performance sensitivity of managerial compensation and firm performance, and also between bad performance and managerial dismissals [see Warner, Watts, and Wruck (1988), Weisbach (1988), and others]. While this is reassuring, Jensen and Murphy (1990) claim that even though these relationships are significant, the sensitivity levels of both rewards and punishment are too small to take care of the underlying agency problems. In fact between the 1930s and the 1980s, the sensitivity of pay to performance has dropped eightfold, suggesting an even lesser dependence in recent times on an important motivating factor. What they find more perplexing is the large reported variance in the pay-for-performance sensitivity in contracts across the 250 largest corporations. While one interpretation for these observations is that firms (rightly or wrongly) do not consider incentive contracts useful in motivating managers, another interpretation is that pay for performance and dismissals represent only some of the important considerations that determine an incentive contract.[22] The extent of strategic interaction, potential for cascades, and the cost of specific incentive contracts can at least partially explain the low sensitivities, the observed variance in contracts, and the time-series pattern documented.[23]

Recent articles by Aggarwal and Samwick (1997) and Kedia (1997) investigate incentive contracts in strategic environments.[24] They show when substitutability is higher (i.e., rival firm actions can affect own-firm profitability more), weight on own-firm performance in the incentive contracts is lower. This article reaches the opposite conclusion: that manager's pay-performance sensitivity should increase with substitutability. The difference lies mainly in the nature of the problem being solved. Their reasoning is based on the Fershtman and Judd (1987) argument that when firms want managers to be more aggressive, more weight is put on variables like firm or industry sales. In such models, since managers do not incur any cost, there is no agency problem. Also there is no new investment decision. Thus managerial contracts essentially perform the role of a commitment device. In my model, since there is both costly effort choice and investment selection, managerial contracts serve the different function of solving a multitasking problem. Given risk neutrality, the moral hazard problem is easy to solve. However, contracts with a large punishment component can result in undesirable entry decisions. Since the cost of such entry is increasing in substitutability, avoiding it becomes more important. Higher weight on profits solves both problems but is costly. This tension leads to the following testable implications.

(i) Managers with low pay-profit sensitivity (or higher weight on pun-

[22] There is some evidence of substitutability provided by Hadlock and Lumer (1997), who suggest that there has been an apparent shift toward more punishment. They document that the frequency of dismissals has increased twofold in the 1980s over the 1930s.

[23] As shown in Harris and Holmstrom (1982), Narayanan (1985), Hirshleifer and Thakor (1992), and others, managerial reputation concerns also impact managerial decisions and potentially incentive contracts. While admittedly hard to measure, Jensen and Murphy (1990) use a number of proxies for reputation and find that it does not change their original results.

[24] Articles which look at strategic effects, but without incentive contracts, include Chevalier (1995), which looks at the effect of LBOs on product market competition, Kovenock and Phillips (1995), which studies capital structure effect on plant closing and investment decisions, and Sundaram, John, and John (1996), which examines the strategic effects of R&D spending announcements.

ishment) are more likely to imitate decisions of competing firms even if it leads to overcapacity.[25] They are also less likely to innovate.[26]

(ii) Since managers are collecting correlated signals, shareholders can gain from copycat behavior in industries where competitive externalities are relatively small. Without need to restrict copycat behavior, these industries should display a larger range of contracts with differing pay-profit sensitivity. They should also display more copycat tendencies.

(iii) Industries that have substantial negative externalities from copycat investments will on average put higher weight on profit and lower weight on punishment in contracts to managers.[27]

(iv) When competitive externalities are large, firms may potentially overcompensate their managers to avoid copycat behavior. The overcompensation will come in the form of a larger stake or profit sharing, but not as an increase in cash wage.

(v) For larger projects, managers get a higher portion of their wage through pay for profit. Thus shareholders may need to overcompensate their managers even more, suggesting that managerial compensation will increase with firm size.[28]

(vi) Since cascading may be more expensive to prevent in larger firms, such firms are more likely to exist in industries where overproduction is not very costly and innovation requirements are low.

(vii) Since, in this model, introducing debt into the capital structure is like reducing project size, industries with highly levered firms and LBOs/MBOs should show more innovation and less overcapacity.[29]

Testing these hypotheses requires that industries with different levels of substitutability be identified. Kedia (1997) uses correlations in past profit changes to check whether firms are complements or substitutes, while Aggarwal and Samwick (1997) use the Herfindahl index to measure industry concentration levels. High concentration is a proxy for low substitutabil-

[25] Khanna and Poulsen (1995) report that in the 3 years before filing for Chapter 11, managers of financially distressed firms take actions very similar to firms not in financial distress. Since the value of manager's ownership is likely to be low in the distressed firms, they are likely candidates for copycat behavior. Another example of low ownership is the mutual fund industry. While earlier work by Lakonishok, Shleifer, and Vishny (1992) did not find evidence of cascading by pension fund managers, recent studies by Grinblatt, Titman and Wermers (1995), Khorana (1996), and Kodres and Pritsker (1997) all report evidence of herding by some classes of institutional investors.

[26] Francis and Smith (1995) find evidence in support of this.

[27] Kedia (1997) finds evidence of lower punishment in firms that are strategic substitutes.

[28] While Jensen and Murphy (1990) report smaller managerial holdings in larger firms, they do not control for extent of strategic substitutability and value of innovation. If these are low, their finding is consistent with the results of this article. This hypothesis is also consistent with ability matching, that is, higher ability managers run larger firms since they are more difficult to manage.

[29] This approach provides a natural incentive-based explanation for why MBOs may improve firm performance with the same managers [see Kaplan (1989)]. The higher ownership stake gives the managers a rational reason to not cascade and accept negative NPV projects. This suggests that the conflict of interest argument, though possible, is not the only explanation.

ity and vice versa.[30] While each has merit, Foresi and Mei (1997) caution against using correlations in past performance as indicators of strategic interaction because results may be contaminated by the presence of common factors. After controlling for common factors, one of their results is that past investment of other firms in related business is positively correlated with the firm's new investment. This evidence is consistent with existence of cascading in new investments in the environment modeled here.

Finally, while a model with only three firms is not adequate to rigorously examine the issue of fragility of cascades, it still provides some insights. A public release of information before the third manager decides reduces his dependence on the signals inferred from earlier decisions and thus reduces the possibility of a cascade. However, the potential of a public release affects the $t = 0$ effort choice. Knowing that there could be some more information available later will reduce the quality of information collected. This will result in more bad cascades starting. Whether shareholders like to give contracts to prevent cascades will depend on the cost of cascades and the probability and quality of the expected public information. For a given cost of cascading, when both quality and frequency of public information are high, private signals are less valuable and shareholders would require lower effort from managers. Lower quality signals would start more bad cascades, but because of the nature of public information they will be short lived. Thus such industries should appear more faddish. What happens in other cases though requires a rigorous analysis in a model with more firms.

6. Conclusion

This article models managerial decisions when firms are in competition and managers, facing a common uncertainty, collect correlated signals and learn from each other's actions. It shows that in this environment managers may choose to ignore their own information and copy other managers' decisions even when the resulting overcapacity makes their decision a negative NPV one. Optimal contracts that put more weight on profit can resolve this problem while also providing them the incentive to choose the desired effort level. However, if managers are wealth constrained then such contracts may be infeasible. In such events shareholders may either choose to overcompensate their managers or live with copycat behavior. This problem gets exacerbated as the size of the project becomes larger. A number of empirical implications about interindustry differences in managerial ownership, probability of innovation/overcapacity, and firm size emerge.

This article does not directly model the problem of reputation dynamics

[30] The article found that motor vehicles, cigarettes, and beer were the most concentrated, steel, semiconductors, machine tools were in between, and sawmills, sealants, and book publishing were the least concentrated.

when managers' ability is uncertain, as in Harris and Holmstrom (1982), Scharfstein and Stein (1990), Diamond (1991), Zweibel (1995), and others. However, if reputation is based on decision quality it would be similar to increasing the punishment component of the contract, resulting in either more cascading or more overcompensation. This in turn will impact effort choice and the frequency and fragility of cascades. In a related model, Khanna and Slezak (1997) study information aggregation within organizations. They show that when firm employees can incur effort to get useful but imperfect signals, delegating decisions to lower-level teams may be inferior (because of potential cascades) to centralized reporting and decision making. Again reputation concerns are likely to make the problem harder to solve, suggesting that different businesses may need to be organized in different ways.

This article does not endogenize the order of decision making as in Chamley and Gale (1994) and Zhang (1997). Zhang, in particular, establishes two potential sources of inefficiency when, in a similar multifirm environment, firms can also choose when to invest. One is that investment is delayed and is thus less valuable. The second is that immediately after the manager with the most precision decides to invest, every other manager mimics. It would be interesting to study whether these inefficiencies persist when managers can choose effort levels and shareholders can offer order-based contracts. These and other extensions are left to future research.

Appendix

Proof of Proposition 1. I first show that managers at the first and second positions strictly decrease the probability of being correct ex post, by ignoring their own signal. This is trivially true at the first position. If the first manager gets signal H, then his posterior about the state being H is

$$\Pr(H/\theta_1 = H) = \Pr(\theta_1 = H/H)^* \Pr(H)/\Pr(\theta_1 = H), \tag{1A}$$

by Bayes' theorem. Since,

$$\Pr(\theta_1 = H) = \Pr(\theta_1 = H/H)^* \Pr(H) + \Pr(\theta_1 = H/L)^* \Pr(L),$$
$$\Pr(H/\theta_1 = H) = .5p/(.5p + .5(1-p)) = p.$$

Since $p \geq .5$ by assumption, $(1-p) \leq .5$. Thus probability of being wrong if the first manager follows his signal and invests is $(1-p)$, which is less than p, the probability of being wrong if the first manager ignores his signal and does not invest. The same is true when $\theta_1 = L$ by symmetry.

I now check at the second position. Given the belief system, I show that the second manager's probability of being correct is also higher if he follows his signal. Table 6 will facilitate the calculation of the posterior probabilities. Check the first row. The manager who was randomly selected

Table 6
Decisions and probabilities with two firms

Action and signal of player in 1st position	Signal of player in 2nd position	Probability that the signals come from State $= H$	State $= L$
A/H	H	p^2	$(1-p)^2$
	L	$p(1-p)$	$p(1-p)$
R/L	H	$p(1-p)$	$p(1-p)$
	L	$(1-p)^2$	p^2

A/H implies the manager accepted given signal $\theta_1 = H$, and R/L implies the manager rejected given $\theta_1 = L$.

to go first has signal H and has accepted. The manager selected to go second also has signal $\theta_2 = H$. Thus, if he accepts, by Bayes' rule the probability of being right ex post is $\Pr(H/\theta_1 = H, \theta_2 = H) = \Pr(\theta_1 = H, \theta_2 = H/H)^*\Pr(H)/\Pr(\theta_1 = H, \theta_2 = H) = .5p^2/\Pr(\theta_1 = H, \theta_2 = H)$, and being wrong, $.5(1-p)^2/\Pr(\theta_1 = H, \theta_2 = H)$. Since $p \geq .5$, his probability of being correct is higher if he accepts. For the second and third rows he is indifferent (where I assume he follows his signal) and for the fourth row his probability is higher if he rejects as per his signal. In fact, if the second manager acts according to his signal, the expected probability (at the time of effort choice) of his being wrong is

$$\begin{aligned}
&\Pr(L/\theta_1 = H, \theta_2 = H)^*\Pr(\theta_1 = H, \theta_2 = H)\\
&\qquad + \Pr(H/\theta_1 = H, \theta_2 = L)^*\Pr(\theta_1 = H, \theta_2 = L)\\
&\qquad + \Pr(L/\theta_1 = L, \theta_2 = H)^*\Pr(\theta_1 = L, \theta_2 = H)\\
&\qquad + \Pr(H/\theta_1 = L, \theta_2 = L)^*\Pr(\theta_1 = L, \theta_2 = L)\\
&\quad = .5(2(1-p)_2 + 2p(1-p)) = (1-p),
\end{aligned}$$

which makes intuitive sense since he is ignoring the first manager's action.

Now I perform a similar exercise for the manager who is randomly selected to go third (see Table 7). I will show that if he ignores the information in the previous decisions, his probability of being wrong is again $(1-p)$. However, if he conditions on the information in the actions of previous managers, then he can in certain instances reduce his probability of making an incorrect decision. This occurs at this and any later positions because the signals are correlated and when two managers show agreement by taking the same action, the third manager improves the probability of being correct by copying their decision independent of his own signal. The belief system is that for both positions 1 and 2, an accept implies that the manager has signal H and a reject implies a signal L.

The first two columns of Table 7 are discussed above. The third column lists the possible signals that the manager in the third position can get. The fourth and fifth columns give the probability that the set of signals in each row comes from either the H or L state. The sixth column (no cascading)

Table 7
Decisions and probabilites with three firms

Action and Signal		Signal	Prob. signals come from		3rd position action	
In first position	In second position	3rd position	State = H	State = L	No-cascade	Cascade
A/H	A/H	H	p^3	$(1-p)^3$	A	A
		L	$p^2(1-p)$	$p(1-p)^2$	R	A
	R/L	H	$p^2(1-p)$	$p(1-p)^2$	A	A
		L	$p(1-p)^2$	$p^2(1-p)$	R	R
R/L	A/H	H	$p^2(1-p)$	$p(1-p)^2$	A	A
		L	$p(1-p)^2$	$p^2(1-p)$	R	R
	R/L	H	$p(1-p)^2$	$p^2(1-p)$	A	R
		L	$(1-p)^3$	p^3	R	R

consists of his decision if he ignores previous actions. The seventh column is the set of recommendations when he takes the information contained in previous decisions into account and takes that action which has the highest probability of being right ex post. For instance, in row 2 his probability of being right with action R by Bayes' rule is $.5p(1-p)^2/\Pr(\theta_1 = H, \theta_2 = H, \theta_3 = L)$, which is less than $.5p^2(1-p)/\Pr(\theta_1 = H, \theta_2 = H, \theta_3 = L)$, the probability of being right with action choice A. Thus he chooses to copy. The same is true for row 7. All other actions are the same for both columns, either because the third manager's signal is the same as those implied by previous decisions (rows 1 and 8), or the previous two decisions are not the same and thus do not convey any information (rows 3–6). Using these probabilities and Bayes' rule, the expected probability of being wrong in the third position with no cascading is $.5(2(1-p)^3+2p^2(1-p)+4p(1-p)^2) = 1-p$.

Using the actions in the cascading column, the same probabilities as above (because the 3rd manager's signal is the same whether he cascades or not), and Bayes' rule, the expected probability of being wrong is $.5^*(2(1-p)^3 + 6p(1-p)^2) = (1-p)^2(1+2p) < 1-p$ for all $p > .5$. Thus this manager can reduce the probability of being wrong by taking previous actions into account. ∎

Proof of Proposition 3. Start with the firm in the third position. Table 7 will be used for the required probabilities.

$$
\begin{aligned}
&E(\pi(\text{3rd firm, no-cascades})) \\
&\quad = .5[p^3(1-d) + (1-p)^3(-d) + 2p^2(1-p) \\
&\qquad + 2p(1-p)^2(0) + p(1-p)^2 + p^2(1-p)^*0 \\
&\qquad - \{p^3 + (1-p)^3 + 3p^2(1-p) + 3p(1-p)^2\}^*c]
\end{aligned}
$$

The first term is the probability that the state is H given that all three got H signals, multiplied by both the probability of three H signals and the gross profits of a firm when the state is H and all three firms enter. In symbols, the first term is $\Pr(H/\theta_1 = H, \theta_2 = H, \theta_3 = H)^*\Pr(\theta_1 =$

$H, \theta_2 = H, \theta_3 = H)^*(1-d)$, which by Bayes' rule equals $\Pr(\theta_1 = H, \theta_2 = H, \theta_3 = H/H)^*\Pr(H)^*(1-d)$. The second term is the probability that the state is L given that all three got H signals, multiplied by both the $\Pr(\theta_1 = H, \theta_2 = H, \theta_3 = H)$ and the gross profits of a firm when the state is L and all three firms enter. The third term is the probability that the state is H given that two (including the third manager) got H signal and one got L, multiplied by the probability of such signals and the gross profits of a firm when the state is H and two firms enter, and so on. The above expression reduces to $.5(p - d + 3pd - 3p^2d - c)$. Similarly

$$\begin{aligned}
&E(\pi(\text{3rd firm, cascades}))\\
&\quad= .5[p^3(1-d) + (1-p)^3(-d) + p^2(1-p)(1-d)\\
&\qquad + p(1-p)^2(-d) + p^2(1-p) - \{p^3 + (1-p)^3\\
&\qquad + 3p^2(1-p) + 3p(1-p)^2\}^*c]\\
&\quad= .5[3p^2 - 2p^3 - 2p^2d + 2pd - d - c].
\end{aligned}$$

Next I need to develop expressions for the expected gross profit if the manager is either at the second or first position. Since the managers either do not have or ignore previous decisions, the expected gross profits are the same at either position. However, they still vary with respect to whether the third manager cascades or not since that creates production externalities for all.

$$\begin{aligned}
&E(\pi(\text{2nd firm, no-cascades}))\\
&\quad= \Pr(H/\theta_1 = H, \theta_2 = H, \theta_3 = H)\\
&\qquad \times\ \Pr(\theta_1 = H, \theta_2 = H, \theta_3 = H)^*(1-d)\\
&\qquad +\ \Pr(L/\theta_1 = H, \theta_2 = H, \theta_3 = H)\\
&\qquad \times\ \Pr(\theta_1 = H, \theta_2 = H, \theta_3 = H)^*(-d)\\
&\qquad +\ \Pr(H/\theta_1 = H, \theta_2 = H, \theta_3 = L)^*\Pr(\theta_1 = H, \theta_2 = H, \theta_3 = L)\\
&\qquad +\ \Pr(L/\theta_1 = H, \theta_2 = H, \theta_3 = L)^*\Pr(\theta_1 = H, \theta_2 = H, \theta_3 = L)^*0\\
&\qquad +\ \Pr(H/\theta_1 = L, \theta_2 = H)^*\Pr(\theta_1 = L, \theta_2 = H)\\
&\qquad +\ \Pr(L/\theta_1 = L, \theta_2 = H)^*\Pr(\theta_1 = L, \theta_2 = H)^*0\\
&\qquad -\ \Pr \text{ investment}^*c\\
&\quad= .5[p - d + 3pd - 3p^2d - c],
\end{aligned}$$

which is the same as $E(\pi(\text{3rd firm, no-cascades}))$ since, by assumption, there is no advantage to observing earlier decisions. The same is not true when the manager uses the cascade strategy.

$$\begin{aligned}
&E(\pi(\text{2nd firm, cascades})\\
&\quad= \Pr(H/\theta_1 = H, \theta_2 = H)^*\Pr(\theta_1 = H, \theta_2 = H)^*(1-d)
\end{aligned}$$

$$
\begin{aligned}
&+\ \Pr(\text{state} = L/\theta_1 = H, \theta_2 = H)^* \Pr(\theta_1 = H, \theta_2 = H)^*(-d)\\
&+\ \Pr(\text{state} = H/\theta_1 = L, \theta_2 = H)^* \Pr(\theta_1 = L, \theta_2 = H)\\
&+\ \Pr(L/\theta_1 = L, \theta_2 = H)^* \Pr(\theta_1 = L, \theta_2 = H)^* 0\\
&-\ \Pr \text{ investment}^* c\\
&= .5[p^2(1-d) + (1-p)_2(-d) + p(1-p)\\
&\quad -\ c(p^2 + (1-p)^2 + 2p(1-p))]\\
&= .5[p - d + 2pd - 2p^2 d - c].
\end{aligned}
$$

Now $E(\pi(p, \kappa = \text{no-cascades})) = .5[p - d + 3pd - 3p^2 d - c]$, while

$$
\begin{aligned}
&E(\pi(p, (\kappa = \text{cascades}))\\
&\quad = (1/3)^* .5[3p^2 - 2p^3 - 2p^2 d + 2pd - d - c]\\
&\quad\quad +\ (2/3)^* .5[p - d + 2pd - 2p^2 d - c]\\
&\quad = (1/6)[2p - 3d + 6pd - 6p^2 d + 3p^2 - 2p^3 - 3c]. \qquad \blacksquare
\end{aligned}
$$

Corollary 2. *The second manager will decide A if $\theta_1 = H$ and R if $\theta_1 = L$ if, for $\kappa =$* no-*cascades,*

(i) for $c > .5$, $.5\lambda(p - d + 3pd - 3p^2 d - c) - \gamma(.5 - p) > 0$,

(ii) for $c < .5$, $.5\lambda(p^2 - d + 3pd - 3p^2 d - c + 2p(1-p)c) - \gamma(.5 - p) > 0$,

or for $\kappa =$ cascades*,*

(i) for $c > .5$, $.5\lambda(p - d + 2pd - 2p^2 d - c) - \gamma(.5 - p) > 0$,

(ii) for $c < .5$, $.5\lambda(p^2 - d + 2pd - 2p^2 d - c + 2p(1-p)c) - \gamma(.5 - p) > 0$.

Proof. From Table 6, the second manager's probability of penalty increases whenever he goes against his signal. However, for signal realization $\theta_1 = H$, $\theta_2 = H$, by choosing action R, the second manager can prevent the third manager from cascading and generating negative externality. The gross expected profit, $E\pi$, to the firm from this strategy is

$$
\begin{aligned}
&\Pr(H/\theta_1 = L, \theta_2 = H)\Pr(\theta_1 = L, \theta_2 = H)\\
&\quad + \Pr(L/\theta_1 = L, \theta_2 = H)\Pr(\theta_1 = L, \theta_2 = H)^* 0\\
&\quad - \Pr(\theta_1 = L, \theta_2 = H)^* c,
\end{aligned}
$$

which using Bayes' rule is $.5p(1-p) - .5(p(1-p) + (1-p)p) = p(1-p)(.5 - c)$. This is less than 0, for $c > .5$. Thus the manager will not invest at all and his expected profit is zero. For $c < .5$ he will invest. Thus $E(\pi) = \max(0, p(1-p)(.5-c))$.

Next consider probability of penalty P. If he invests for $(\theta_1 = L, \theta_2 = H)$ and rejects for $\theta_1 = H, \theta_2 = H)$, from the proof of Proposition 1 and Bayes' rule, $P(.) = .5[(1-p)^2 + 2p(1-p) + p^2) = .5$. The same expression holds if he rejects for both. Therefore, for the above strategy, the second manager's expected wealth is $\omega + \lambda\{\max(0, p(1-p)(.5-c))\} - .5\gamma - .5e^2$. He will not follow this strategy if his expected wealth is higher with the strategy in Proposition 3. Thus the manager will A if $(\theta_1 = H, \theta_2 = H)$, if for $\kappa =$ no-cascades (i) for $c > .5$, $\omega + .5\lambda(p - d + 3pd - 3p^2d - c) - \gamma(1 - p) - .5e^2 - \omega + .5\gamma + .5e^2 > 0$, or $.5\lambda(p - d + 3pd - 3p^2d - c) - \gamma(.5 - p) > 0$;

(ii) for $c < .5$, $\omega + .5\lambda(p - d + 3pd - 3p^2d - c) - \gamma(1 - p) - .5e^2 - \omega + \lambda p(1 - p)(.5 - c) + .5\gamma + .5e^2 > 0$, or $.5\lambda(p^2 - d + 3pd - 3p^2d - c + 2p(1 - p)c) - \gamma(.5 - p) > 0$. For $\kappa =$ cascades, the only difference in the proof is that the expression for the gross profit from Proposition 3 is $(p - d + 2pd - 2p^2d - c)$. ■

Proof of Proposition 4. First identify the optimal q^* for the manager given the others choose p. Then find the fixed point by equating this q^* to p. Do so for the cascade strategy and the no-cascade strategy separately. Start with the no-cascade strategy. Take the expressions for $E\pi$(3rd firm, no-cascades) and $E\pi$(2nd firm, no-cascades) developed in Proposition 3 under the assumption that all managers choose effort p, and replace the appropriate p with a q. For instance, the first three terms of $E\pi$(3rd firm, no-cascades) will now be $.5p^2q(1 - d)$, $.5(1 - p)^2(1 - q)(-d)$ and $p(1 - p)q$. Thus,

$$\begin{aligned} E(\pi(\text{no-cascades})) \;=\;& (1/3)^*.5[p^2q(1-d) + (1-p)^2(1-q)(-d) \\ & + 2p(1-p)q + q(1-p)_2 - c] \\ & + (2/3)^*.5[p^2q(1-d) + (1-p)^2(1-q)(-d) \\ & + pq(1-p) + q(1-p) - c] \\ =\;& .5[q(1 + d - 2pd) - d(1 - 2p + p^2) - c]. \end{aligned}$$

Given this expression for gross profit, the manager chooses q to maximize his net rents as in Equation (2). That is, he has $\max_q \omega + \lambda^2.5[q(1 + d - 2pd) - d(1 - 2p + p^2) - c] - \gamma(1 - q) - .5((q - \alpha)/\beta)^2$, which has the solution $q^*_{\text{nc}} = \beta^2[.5\lambda(1 + d - 2pd) + \gamma] + \alpha$. The fixed point thus solves $q^*_{\text{nc}} = \beta^2[.5\lambda(1 + d - 2q^*_{\text{nc}}d) + \gamma] + \alpha$, which gives $q^*_{\text{nc}} = (.5\lambda\beta^2(1 + d) + \beta^2\gamma + \alpha)/(1 + \lambda\beta^2 d)$. Similarly

$$\begin{aligned} E(\pi(\text{cascades})) \;=\;& (1/3)^*.5[p^2q(1-d) + (1-p)^2(1-q)(-d) \\ & + p^2(1-q)(1-d) + q(1-p)^2(-d) \\ & + 2pq(1-p) - c] + (2/3)^*.5[pq(1-d) \\ & + (1-p)(1-q)(-d) + (1-p)q - c] \\ =\;& (1/6)[q(2 + 2d - 4pd + 2p - 2p^2) \\ & + p^2 - d(3 - 4p + 2p^2) - 3c]. \end{aligned}$$

Again, the manager will $\max_q \omega + (\lambda/6)[q(2 + 2d - 4pd + 2p - 2p^2) + p^2 - d(3 - 4p + 2p^2) - 3c] - \gamma(1 - p)(1 + p - 2pq) - .5((q - \alpha)/\beta)^2$, which has the solution $q^*_{\text{c}} = \beta^2[(\lambda/6)(2 + 2d - 4pd + 2p - 2p^2) + 2p(1 - p)\gamma] + \alpha$.

The fixed point is the solution to $q_c^2(-\lambda\beta^2/3 - 2\beta^2\gamma) + q_c(\lambda\beta^2(1-2d)/3 + 2\beta^2\gamma - 1) + \lambda\beta^2(1+d)/3 + \alpha = 0$. ■

Proof of Proposition 7. From the proof of Proposition 4, $E(\pi(\text{no-cascades}))$ will now become $.5m(q(1+d-2pd) - d(1-2p+p^2) - c)$, and $E(\pi(\text{cascades})) = (m/6)[q(2+2d-4pd+2p-2p^2) + p^2 - d(3-4p+2p^2) - 3c]$. Thus, $E(u(\text{no-cascades}))$ of the manager is $\omega + .5\lambda m[q(1+d-2pd) - d(1-2p+p^2) - c] - \gamma(1-p) - .5((q-\alpha)/\beta)^2$. Thus, $q_{\text{nc}}^* = (.5m\lambda\beta^2(1+d) + \beta^2\gamma + \alpha)/(1 + m\lambda\beta^2 d)$. Similarly q_c^* is a solution to $q_c^2(-m\lambda\beta^2/3 - 2\beta^2\gamma) + q_c(m\lambda\beta^2(1-2d)/3 + 2\beta^2\gamma - 1) + m\lambda\beta_2(1+d)/3 + \alpha = 0$. Also, following Proposition 5, the optimal effort choice for the shareholders is $p_{\text{nc}}^* = (.5m(1+3d) + \alpha/\beta^2)/(3md + 1/\beta^2)$. Finally, from Proposition 6, the locus where $q_{\text{nc}}^* = p_{\text{nc}}^*$, is defined by $m + 3md - 6md\alpha = \lambda(2m^2\beta^2 d - 2m\alpha d + md + m) + \gamma(2 + 6m\beta^2 d)$. ■

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