MANAGEMENT SCIENCE
Vol. 56, No. 7, July 2010, pp. 1161–1179
ISSN 0025-1909 | EISSN 1526-5501 | 10 | 5607 | 1161

DOI 10.1287/mnsc.1100.1169

Why Are Bad Products So Hard to Kill?

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It is puzzling that firms often continue to invest in product development projects when they should know that demand will be low. We argue that bad products are hard to kill because firms face an inherent conflict when designing managers' incentives. Rewarding success encourages managers to forge ahead even when demand is low. To avoid investing in low-demand products, the firm must also reward decisions to kill products. However, rewarding managers for killing products effectively undermines the rewards for success. The inability to resolve this tension forces the firm to choose between paying an even larger bonus for success and accepting continued investment in low-demand products. We explore the boundaries of this argument by analyzing how the timing of demand information affects product investment decisions.

Key words: product development; managerial incentives; moral hazard; adverse selection; information acquisition
History: Received January 23, 2009; accepted February 2, 2010, by Preyas Desai, marketing. Published online in *Articles in Advance* May 17, 2010.

> But it isn't simply the monumental failure in the marketplace that makes the SelectaVision story worth remembering. It's that RCA insisted on plowing money into the product....
>
> (Royer 2003, p. 5)

1. Introduction

This RCA example is far from unique. Many company histories include bad products they wished they had killed sooner. The inability to stop product development is among the most costly marketing mistakes that firms make. We argue that one reason for these "mistakes" is that firms face an inherent conflict when designing managers' incentives. The firm rewards success by promising a bonus to the manager if the outcome is successful. This encourages the manager to continue as long as success is still possible. To avoid investing in low-demand products, the firm must also pay a bonus when product development projects are terminated. However, rewarding managers for killing products effectively diminishes the rewards for success.

We motivate our analysis using examples obtained through interviews with participants in the product development process. The examples highlight different ways that product managers respond to unfavorable demand information. To prevent the firm from killing their products, managers may suppress the information. However, information provided by outside research suppliers is often difficult to suppress. Instead, reactions may include distorting the information, discrediting it, or simply not collecting information that might reveal that demand is low. We show that these distortions can all contribute to continued investment in low-demand products.

We also explore the boundaries of the findings by studying how the timing of information affects the outcome. If the manager receives an early signal of demand before choosing effort, then the firm can ensure that the manager uses this information to terminate low-demand products. However, when the firm is uncertain about when demand information is received, the tension between rewarding success and killing bad products is amplified, making investments in bad products more likely. We summarize the key findings in Table 1.

Previous explanations for overinvestment in bad products have focused on the tendency of decision makers to escalate their commitment to failing courses of action (see, for example, Brockner and Rubin 1985, Brockner 1992, Boulding et al. 1997). A leading explanation for this tendency is bias in managers' beliefs about the likelihood that the product will succeed. Biyalagorsky et al. (2006) argue that escalation of commitment can reflect the decision maker's "belief inertial distortion," whereby the manager places too much reliance on initial beliefs and gives too little weight to negative information.[1] Similarly, March and Shapira (1987) argue that "managerial conceit" may contribute to excessive optimism; if managers believe that they can control fate through their own actions,

[1] Boulding et al. (1999) observe the same distortion in consumers whose perceptions of service quality are overly dependent on their prior beliefs.

Table 1 Summary of the Key Findings

Rewarding success makes it difficult to kill low-demand products if the manager can
- suppress or withhold unfavorable demand information
- distort information to make it appear demand is high
- discredit unfavorable demand information
- not collect information that may reveal demand is low

Low-demand products are harder to kill when
- the firm is uncertain when the manager receives information about demand
- the manager has biased expectations about the likelihood of success

Low-demand products are easier to kill when
- the manager learns demand earlier in the process
- the manager can control when to collect demand information
- it is cost-effective for the firm to monitor the manager's effort
- the firm can severely punish the manager if the manager recommends continued investment but the project fails

then they may unreasonably believe that they can prevent failure through hard work. Biases in managers' beliefs can explain why managers make inefficient decisions, including their reluctance to kill bad products. However, they do not explain why firms do not take steps to prevent inefficient decisions by their managers. We will argue that if the firm can anticipate these distortions, it can adjust managers' incentive contracts to accommodate them. The dilemma is why firms do not use appropriate contract design to deter continued investments in unpromising products.

The effects that we study can be compared to other distortions that result from incompatible incentives. Desai and Srinivasan (1995) investigate a franchisor that has private information about the quality of a new product. Charging a high wholesale price and low fixed fee to signal quality undermines the franchisee's incentives to sell the product. Hauser (1998) anticipates a similar tension in his review of R&D metrics: "To avoid false program *choice* the firm would want the weight on market outcomes to be small, but to induce the right research and process *efforts* the firm would want the weight on market outcomes to be large" (p. 1680). He recommends that firms find metrics that are correlated with effort but uncorrelated with outcomes. To the extent that these metrics make effort verifiable, they relax the underlying tension between motivating effort and eliciting truthful reporting of demand. Levitt and Snyder (1997) investigate the trade-off that a principle faces when eliciting early warnings from an agent. They assume that the timing of early warnings is exogenous, and focus on the role of interventions the principle can take to obscure the link between effort and the project outcome. Other related papers include Shin (2008), who investigates a manager's incentives to acquire information about the cost of implementing a project. If the manager is the residual claimant for any unspent budget, then he has an incentive to overstate this cost (see also Guo 2009).

In research on capital allocation, Bernardo et al. (2001) investigate how a manager's private information about the quality of a project may lead firms to underinvest in the project. For low-value projects the cost of providing information rents to the manager may lead the firm to abandon the project altogether. In a more recent paper, Laux (2008) argues that imposing influence costs on an internal project manager may improve capital budgeting. By requiring that the manager spend time and effort developing internal support for a project, the firm can implement a screening mechanism—the manager's willingness to engage in influence activities reveals his private information about the project's prospects. In the context of mergers, Friebel and Raith (2010) find that team-based incentives can encourage division managers to truthfully communicate their local knowledge, but make it more costly to induce managerial effort.

Finally, the findings can also be compared with previous work on risk aversion. It is now well established that risk aversion may act as a barrier to innovation (see, for example, Sung 1995, Bergmann and Friedl 2008). If managers are risk averse, it is more costly to motivate them to work on risky projects. Other researchers have studied how risk aversion affects the profitability of delegating project selection to managers (Lambert 1986, De Paola and Scoppa 2006, Bester and Krähmer 2008), and whether managers are more likely to be innovative if firms adopt long-term incentives that reduce risk by smoothing outcomes over time (Im and Nakata 2008, Maine 2008).

Our paper differs from the previous literature in several important ways. We focus on the firm's trade-off between motivating effort and eliciting information. Although this distinguishes our paper from the earlier work on manager's psychological biases, we can show that these biases complement our findings by making it more difficult to convince managers to terminate low-demand products. Second, we focus on the firm's decision to make additional investments in product development projects. This is a different problem than the delegation of authority to managers. Finally, we do not rely on risk aversion. The manager in our model is risk neutral, and so the findings do not depend upon the efficient allocation of risk between the manager and the firm.

The paper proceeds in §2 with the introduction of a formal model. We begin with several examples that help to motivate the key assumptions. The analysis starts in §3, where we illustrate how the tension between rewarding success and truthful reporting of demand can lead to continued investment in low-demand products. In §4, we investigate the timing of demand information and consider settings in which the timing is either exogenous or chosen by the manager. The paper concludes in §5 with a summary of the findings and a review of future research opportunities.

2. A Principal-Agent Model of Product Development

To motivate our model, we begin with several examples that arose during background interviews for this research. We then present the model assumptions and provide interpretation for them.

2.1. Examples

The first example involves a multinational food products company that is developing a new range of healthy snacks. To head the project, it hired a manager with experience in leading product development projects for other consumer goods companies. The manager's contract pays a very large bonus if three-year revenue goals are met. This has led to at least one positive outcome: the product development team has coalesced into a dedicated group that works long hours, focused on achieving the revenue goal. However, other outcomes are less positive. The manager is unwelcoming of evidence that will slow or impede the launch process. She has argued against conducting market tests, instead favoring a larger-scale launch. The interview subject, who is part of the team, believes that launch is inevitable. Opinions that the product should be killed meet resistance from the manager, even if supported by evidence.

A key feature of this story is the bonus for success. This has proven to be an effective mechanism to motivate the manager and (in turn) the entire product development team. However, the larger the rewards for success, the more likely the manager will favor continued investment in the product even when the likelihood of success is low. The firm can mitigate this tendency by also offering a bonus if the product is killed. However, because killing the product does not require effort, a termination bonus undermines the incentive to succeed. The inability to resolve this tension forces the firm to choose between paying an even larger bonus for success, and accepting that it will continue to invest in some bad products.[2]

While the manager in this example chose not to collect information, our interviews also revealed other types of managerial responses. For example, managers may simply suppress information that indicates demand will be low. This is easier if the research has been collected internally. When the information comes from an outside research provider, managers may resort to other alternatives, such as distorting the information. Our interviews revealed one example of distortion involving a field test for a new cleaning product. Sales in the test market were very high—so high that the independent research firm working on the test was prompted to investigate. It discovered that the project manager had personally visited the test stores and installed end-of-aisle displays and point-of-sale promotions to ensure that the test market yielded a favorable result. Interviews with other independent research managers revealed that it is common for product managers to announce in advance what they want the research to reveal. One interview subject reported that this was so common that his research firm joked internally that their tagline should read: "The number you want, when you want it, just give us a hint." Product managers would repeatedly exaggerate inputs to the forecasting model, such as expected distribution and awareness levels, to ensure that the resulting forecast was high enough to justify product launch. As another interview subject put it, "They'd find a way to convince themselves they could get 80% awareness with an advertising plan that had never achieved anything more than 50%. And all this with an ad that didn't yet exist or, if it did, one that wasn't testing very well."

If none of these approaches yield the desired outcome, the product manager can turn to another solution: discredit the research process. Product managers who are disappointed with the outcome of the research process are apparently quick to argue that their new product is "too different" for the forecasts to be reliable. This is particularly common in markets for new technologies, where the product managers can cite the absence of comparable products.

We begin our analysis by focusing on situations in which managers suppress or withhold unfavorable information. However, we also show how the findings can be extended to describe settings in which information is distorted, discredited, or not collected (§3.5). We motivate these extensions by returning to the examples discussed above.

We next present the basic setup of the model. We then discuss two key assumptions, concerning the observability of the manager's effort and the observability of demand.

2.2. The Model

Our model focuses on a risk-neutral firm (the principal) that hires a risk-neutral manager (the agent) to develop a product. After investing effort in the development process and obtaining a better understanding of market conditions, the manager makes a recommendation about whether product development should continue. The firm's goal is to ensure that the manager works diligently on developing the

[2] The example also highlights the manager's supervisory role. In practice, success generally depends upon the efforts of an entire team, who work jointly on collecting demand information and developing the product. Although we will not explicitly model the supervisory relationship between the manager and the team, we can interpret the manager's efforts in our model as time spent monitoring the activities of team members. Under this interpretation, the contribution of the manager's effort reflects the collective contribution of the entire team.

Table 2 Probability of Product Success

	Effort	No effort
High demand	a	b_D
Low demand	b_E	0

product, and truthfully reveals when market conditions are unfavorable. We will show that these two incentives are inherently inconsistent, and this inconsistency may lead to firms allowing continued investment in products that are likely to fail.

The product development process yields a return of $Y > 0$ upon success, and zero upon failure. Product success depends on two factors: the discretionary effort from the manager, and the intrinsic demand for the product. We model the contribution of effort and demand by allowing the probability of success to depend on each factor (see Table 2).

We assume that effort always increases the probability of success, so that $0 < b_i < a < 1$ for $i = \{D, E\}$.

In practice, product development managers always appear to work hard. However, we note that this is an equilibrium outcome that may change if there are no rewards for success. Although the "no effort" and "zero probability of success" interpretations aid our exposition, the results do not depend upon these modeling conveniences. We observe the same tension when the manager chooses between "high" and "very high" effort (rather than effort and no effort) or when there is always a small probability of success. In §3.4, we will illustrate these alternative assumptions in a more general model, in which effort and demand are continuous.

We adopt the standard principal-agent assumption that the manager's effort level is not observed by the firm. Effort does not guarantee success (or prevent failure), and so even after observing the outcome, the firm cannot be sure whether the manager exerted effort. As a result, the firm must motivate the manager by constructing a contract under which it is in the manager's interests to exert effort. We also assume that the manager has private information about demand (see below). These two assumptions about the observability of the manager's effort and the observability of demand are key aspects of our model. We provide additional justification and interpretation for both assumptions at the end of this section.

Investment in continued product development is costly. We denote this investment as $Z > 0$. The most favorable state is if demand is high and the manager has exerted effort. Products in this state will be successful with probability a (see Table 2). We assume that it is efficient for the firm to continue investing in these products: $Z < aY$. If demand is low or the manager does not exert effort, we will assume that it is not efficient for the firm to make additional investments. It follows that the firm will always want the manager to exert effort, because without effort a product is never worth continuing. However, as we shall see, the firm may not always kill low-demand products. We summarize these assumptions as Condition (1):

$$b_i Y < Z < aY, \quad i = \{D, E\}. \tag{1}$$

Both the firm and the manager know the values of Y, Z, a, b_D, and b_E. Moreover, the firm and the manager share the same prior beliefs that demand is high with probability $0 < s < 1$ and low with probability $1 - s$.

2.3. Timing of the Game

We will consider two alternative timing sequences. We begin by assuming that the manager chooses effort before observing demand. It leads to the following sequence of actions:

Step 1. A manager is hired to lead development of the new product. The firm and manager both know that demand for this new product will be high with probability s.

Step 2. The manager chooses whether to exert effort. The manager's cost of effort is $c > 0$.

Step 3. The manager observes whether demand is high or low.

Step 4. The manager recommends whether to kill the product.

Step 5. If the firm kills the product, the manager receives a fixed "termination bonus" $X \geq 0$; otherwise, the product continues and the firm invests Z.

Step 6. Following investment, the product either succeeds or fails. The manager receives $W \geq 0$ upon success and 0 upon failure.

In §4.1, we will investigate what happens when the manager observes demand before choosing his effort level. This effectively reverses Steps 2 and 3 in the sequence. We further extend the model in §4.3 to allow the manager to determine when he receives demand information.

2.4. The Compensation Scheme

The firm has two parameters to determine: W and X. The success bonus (W) induces effort, whereas the termination bonus (X) encourages the manager to terminate low-demand products. The format of the compensation scheme is not assumed but is supported in equilibrium. If the product is terminated, there is no variable outcome to serve as the basis of a variable compensation scheme. Therefore, the firm can only offer a fixed payment. If the product continues, the firm can in theory offer both the outcome-based bonus and a fixed payment that is independent of the product outcome. However, a fixed payment increases the wage bill without inducing efficient effort or investment, and so the firm will always prefer to reduce the fixed payment to zero.

We assume that the cost of effort (c) is sufficiently small so that it is efficient for the manager to exert effort when demand is high: $aY > Z + c$.[3] We also assume that the manager cannot simply switch projects and his outside opportunity is zero, so that his participation constraint is satisfied if his expected wages are equal to his effort costs (if any). This assumption is analytically convenient because it allows us to focus on incentive compatibility. However, it is not crucial to the analysis; we can establish similar results when the outside option is (strictly) positive or negative.[4]

Finally, we assume that the manager has limited liability to the firm so that the minimum wage of the manager is zero. This implicitly rules out degenerate contracts in which the firm effectively sells itself to the manager. The assumption of limited liability is common in the related literature.[5] In our context, the assumption can be justified by recognizing that the manager always has the option of resigning. We will later investigate how relaxing this assumption affects the results.

Before analyzing the model, it is helpful to discuss two key assumptions: the observability of the manager's effort, and the manager's private information about demand. This discussion will focus both on justifying these assumptions and broadening their interpretation.

2.5. Observability of Effort and Demand

Several factors may limit a firm's ability to observe a project manager's effort. First, the firm may be able to observe whether the manager is exerting effort, but unable to distinguish between "high" and "very high" effort. Even when feasible, this may require a level of monitoring that is costly and interferes with the manager's effectiveness. Second, the manager may be working at full capacity, but faces a multitask problem, in which he has to allocate scarce effort between different activities (Holmström and Milgrom 1987). If the importance of the tasks is not fully observable to the senior managers, it creates an incentive for the product manager to misallocate effort, unless his incentives are aligned through a bonus. An alternative interpretation is that senior managers may be able to observe the level of effort, but not the quality of effort. For example, the manager may be working a lot of hours doing busy work (e.g., writing reports), but not spending time on difficult activities (e.g., managing employees). Third, in small firms the project manager may be the CEO, with the investors or Board of Directors serving the supervisory role. Because the investors and Board are rarely colocated with the CEO, the CEO's efforts may be particularly difficult to observe.[6]

Our second key assumption is that the firm has less information than the product manager about whether the product will succeed. This assumption is common in the related literature.[7] The product manager will almost certainly have had more direct communications with key participants in the process, including suppliers, distributors, customers, market research professionals, and other members of the product development team. It seems reasonable to expect that the depth and frequency of the manager's interactions with these participants place him in a unique position for understanding demand.

Notice that our assumption requires not just that the product manager has more information, but also that the firm cannot contract on whether the manager reveals this information truthfully (see also Demski and Sappington 1987, Baiman and Sivaramakrishnan 1991). There are at least three reasons to believe that contractibility will be imperfect. First, whereas some of the information gained from these interactions can be communicated directly to senior managers (and contracted upon), other information will be more difficult to communicate. For example, although senior managers may be able to require that the product manager supplies the final report produced by a market research firm, they cannot contract on whether the manager correctly reports what he observes during the research process. Second, the manager presumably not only receives private information, but also has private information about how much information he receives. Although the senior managers may

[3] We rely on analogous assumptions to ensure that the firm always earns positive expected profits in equilibrium.

[4] If the manager retains the right to resign at any time, the payment upon failure needs to be greater than or equal to the manager's outside opportunity to be effective. As a result, a positive outside opportunity cannot help the firm eliminate the investment inefficiency problem.

[5] For recent examples of papers that make the same assumption, see Bester and Krähmer (2008), Bergmann and Friedl (2008), and Shin (2008).

[6] These explanations all describe why the firm may need to induce the manager to exert effort. It is also possible that the firm may reward success for other reasons. For example, it would be sufficient that the manager has private information about his effectiveness. In this situation, the reward for success may reflect the firm's efforts to screen managers. Because competent managers are more likely to develop successful products, rewarding success can ensure that the position attracts only competent managers. In terms of our model, managerial effort could be relabeled "managerial competency," and the cost of effort could be reinterpreted as the incremental payoff that capable managers could have earned (over incapable managers) outside the firm. The rest of the model remains unchanged.

[7] Lambert (1986) and Shin (2008) both make similar assumptions.

know whether the product manager purchased market research, they may not know how many conversations he had with suppliers and customers, or the level of certainty that these conversations provide. Third, when demand information is observable to the firm, managers may find other ways to respond. The examples at the start of this section suggest that they may distort the information, discredit it, or simply not collect it.

It is convenient to label the manager's private information as knowledge of demand. However, the information could equivalently describe knowledge about suppliers or other factors that determine product success. Examples might include knowledge about the cost and availability of critical components. It is also plausible that both the firm and the manager share common knowledge about the likelihood of success that is not shared by outside bystanders. This common knowledge is not important to the model, and so we will assume it is already reflected in the probabilities in Table 2.

3. Initial Analysis

We begin by considering two benchmark models. Comparisons between the full model and these benchmark models will help illustrate the tension between rewarding success and inducing the manager to accurately report demand.

3.1. Benchmark Cases

The "First-Best." If the firm and the manager are integrated as one entity, they do not need W or X to motivate effort and kill low-demand products. The joint entity will exert effort and only continue the product if demand is high. The expected joint profit equals $s(aY-Z)-c$, which is the maximum expected profit the firm and manager can achieve.

Verifiable Effort. When effort is observable and verifiable, so that the firm and manager can contract on the manager's effort level, the firm can directly reimburse the manager for his effort costs. To persuade the manager to truthfully reveal whether demand is high, the firm must construct W and X such that $aW \geq X \geq b_E W$. It can do so by making W infinitesimally small, and then offering $X = b_E W$, which is also infinitesimally small. In this way, the firm can kill low-demand products and again approach first-best profits.

These benchmark models confirm that it is only when the firm cannot contract on the manager's effort level that a tension emerges between implementing efficient investment and motivating effort.

We next illustrate this tension by returning to our assumption that effort is unobservable (we will later consider settings in which effort is observable but unverifiable). We begin analysis of the optimal success and termination bonuses (W and X) by recognizing that the firm's key decision is whether to ensure that the manager kills low-demand products. Killing low-demand products is costly because the firm must pay the manager a termination bonus. This means that the manager can always earn a bonus without exerting effort, and so the firm must pay an even larger bonus in order to induce effort. An alternative is to allow low-demand products to continue. This avoids the need for a termination bonus and in turn reduces the bonus required to induce effort.

3.2. Killing Low-Demand Products

The optimal contract that ensures that low-demand products are killed can be found by solving the following optimization problem, where the subscript "K" stands for "kill low-demand products":

$$\max \quad \Pi_K = s(aY-Z) - saW - (1-s)X$$

$$\text{s.t.} \quad aW \geq X \quad (\text{IC}_1\text{: continue high-demand products}),$$

$$X \geq b_E W \quad (\text{IC}_2\text{: kill low-demand products}),$$

$$saW + (1-s)X - c \geq s\max(b_D W, X) + (1-s)X \quad (\text{IC}_3\text{: exert effort}).$$

The firm earns an expected net return of $aY-Z$ from continuing a high-demand product, which occurs with probability s. Meanwhile, the firm must pay the manager an expected salary of $saW+(1-s)X$. The firm chooses a contract (W, X) to maximize its expected net profit. In doing so, the firm must ensure that the manager chooses to work hard before observing the true state of demand (IC_3), continues the product if he subsequently observes that demand is high (IC_1), and terminates the product if demand is low (IC_2).

Because there is a positive probability that even low-demand products will succeed ($b_E > 0$), the firm must offer a strictly positive termination bonus ($X > 0$) to satisfy IC_2 and ensure that low-demand products are killed. However, this makes it harder to satisfy the effort constraint (IC_3). Notice also that if the manager is indifferent between terminating and continuing a low-demand product, he will strictly prefer to continue high-demand products, so that if IC_2 is binding, then IC_1 is slack. We know that IC_2 must be binding in equilibrium; otherwise, the firm can always reduce X and improve profits. Similarly, the effort constraint must be binding too; otherwise, the firm can reduce W and improve profits. Solving these binding constraints, we obtain the equilibrium contract and firm profit:

$$W_K^* = c/\{s[a-\max(b_D, b_E)]\},$$

$$X_K^* = b_E W_K^*,$$

$$\Pi_K^* = s(aY-Z) - [sa+(1-s)b_E]W_K^*.$$

The firm's expected profit is strictly lower than the first-best profit because it must overcompensate the manager by paying him more than his cost of effort. The firm pays the manager an expected wage of $c + ck$, where

$$k = \max\{b_E/s(a - b_E),\ [b_E(1 - s) + sb_D]/s(a - b_D)\} > 0.$$

The premium that the firm pays the manager (ck) is increasing in both b_D and b_E. Any increase in the (small) probability that a low-demand product will succeed makes it more difficult to persuade the manager to kill the product. As a result, the firm has to pay a larger bonus upon termination. This weakens the manager's incentive to work, and so the firm must also pay a larger success bonus to encourage effort. We will return to this point when we discuss the role of biases in managerial beliefs. If these biases increase the perceived probability that low-demand products will succeed, it becomes more costly for the firm to ensure that they are terminated.

When the cost of terminating low-demand products is too high, the firm may allow them to continue, even though the manager has information indicating that demand will be low. We investigate this possibility next.

3.3. Allowing Low-Demand Products to Continue

The most profitable contract under which a manager exerts effort and prefers continued investment in low-demand products can be found by solving the following optimization problem:

$$\begin{aligned} \max\quad & \Pi_{NK} = s(aY - Z) + (1-s)(b_E Y - Z) \\ & \qquad - [sa + (1-s)b_E]W \\ \text{s.t.}\quad & aW \geq X \quad (\text{IC}_1\text{: continue high-demand products}), \\ & b_E W \geq X \quad (\text{IC}_2\text{: continue low-demand products}), \\ & [sa + (1-s)b_E]W - c \geq s\max(b_D W, X) + (1-s)X \\ & \qquad\qquad (\text{IC}_3\text{: exert effort}). \end{aligned}$$

The firm pays an expected wage of $[sa + (1-s)b_E]W$ and expects to earn $aY - Z$ from high-demand products and to lose $Z - b_E Y$ from low-demand products. The manager's contract induces effort, but now the manager will not terminate the product even if he observes that demand is low (IC_2). In fact, no products will be terminated once the manager has exerted effort. Some low-demand products will be a success, albeit with a low probability b_E. Therefore, the firm will observe success with probability $sa + (1-s)b_E$.

It should be clear that X will be zero in equilibrium. Because the firm no longer tries to distinguish between high- and low-demand products, it gains nothing from offering a termination bonus, which only counters the incentive to work. Mathematically, X does not enter the firm's objective function, but enters the constraints, where $X = 0$ imposes the weakest constraint. The equilibrium value of W is derived by solving the binding effort constraint IC_3:

$$W^*_{NK} = c/[s(a - b_D) + (1-s)b_E],$$

$$X^*_{NK} = 0,$$

$$\Pi^*_{NK} = s(aY - Z) + (1-s)(b_E Y - Z) - [sa + (1-s)b_E]W^*_{NK}.$$

By allowing low-demand products to continue, the firm incurs a net loss of $Z - b_E Y$ with probability $(1-s)$. However, the firm no longer pays a termination bonus. Moreover, the elimination of the termination bonus makes it less expensive to motivate the manager to work, so that $W^*_{NK} < W^*_K$.

Whether the firm wants to terminate low-demand products depends on which strategy yields higher equilibrium profits. The firm will prefer to kill low-demand products ($\Pi^*_K > \Pi^*_{NK}$) iff

$$\begin{aligned} &(1-s)(Z - b_E Y) \\ &\quad > [sa + (1-s)b_E](W^*_K - W^*_{NK}) \\ &\quad = [sa + (1-s)b_E]\big(c/\{s[a - \max(b_D, b_E)]\} \\ &\qquad\qquad - c/[s(a - b_D) + (1-s)b_E]\big). \qquad (2) \end{aligned}$$

The condition demonstrates that there exist parameter values under which the firm prefers to allow continued investment in a product, even though the manager knows that demand for the product is low. This is a key finding in the paper, which we summarize in the following proposition:

Proposition 1. *If the firm cannot observe effort or demand, it may be optimal to continue investing in products even after the manager has learned that demand is low.*

Proof. By construction.

The firm trades off efficient investment with payroll reduction. To ensure that only high-demand products continue, the firm must grant the manager a bonus for terminating low-demand products. The firm may find it more profitable to eliminate the termination payment, which lowers the manager's compensation but introduces the risk of inefficient investments in low-demand products.

Recall that the previous literature offers evidence that managers may have biased expectations about the probability a product will succeed. In the appendix, we present two findings that help to illustrate the role of these psychological biases. First, if the firm anticipates the bias, it can design incentive contracts that overcome the resulting distortions.[8]

[8] Designing contracts to accommodate distortions in managers' behavior has a parallel in the literature on performance evaluation.

This suggests that biased expectations are not on their own sufficient to explain why firms allow continued investment in low-demand products. However, this does not imply that these biases play no role. To the contrary, belief distortions and managerial conceit both can make it more costly to kill low-demand products. The firm must pay a higher termination bonus to induce an overly optimistic manager to abandon a product. This greatly amplifies the tension that we study, making it more likely that the firm will continue to invest in low-demand products.

3.4. Continuous Effort and Demand

To aid clarity, we have presented a model with discrete effort and demand levels. However, the underlying tension between motivating effort and truthful reporting of demand is a general phenomenon that survives when we allow effort and demand to be continuous. In particular, assume that the manager chooses effort from a continuous strategy space, where the lowest level of effort is $\underline{e}$. The cost of the effort is given by the function $c(e)$. After choosing effort, the manager privately observes the demand parameter d, which represents a draw from a continuous distribution. The outcome of the product development process also represents a draw from a continuous distribution, where the expected outcome increases with effort and the demand parameter. To ensure that effort cannot be inferred from the outcome, we assume that the support of the outcome distribution is fixed.

We label the first-best effort as e^* and label the threshold demand level at which it is efficient to continue investing in the product as d^*. We focus on the nondegenerate case where $e^* > \underline{e}$, and can show that the firm will only earn the first-best profits if it can verify and contract on effort. We formally prove this result as our second proposition:

Proposition 2. *If effort and demand are continuous, and the firm can verify and contract on effort, then it can achieve first-best profits. If effort is not observable to the firm, then the firm cannot implement efficient product termination without overcompensating the manager.*

Proof. We begin by proving that first-best profits cannot be achieved when effort and demand are unobservable to the firm. When the observed demand is d^*, the manager must be indifferent about continuing or terminating the product; otherwise, for slightly lower or slightly higher demand realizations, the manager will not make the efficient recommendation. Because the outcome distribution has fixed support, we know that after observing d^* the manager earns a positive expected wage if the product continues. Therefore, the termination bonus must be strictly positive; otherwise, the manager will not be indifferent about continuing. Because the manager can earn a positive termination bonus by choosing the lowest level of effort $\underline{e}$, he must earn more than $c(e^*) - c(\underline{e})$ if he chooses e^*.

In contrast, if the firm can verify and contract on effort, it can mandate that the manager choose e^* and pay him $c(e^*)$ when he does so. In addition, because the expected outcome increases with demand, the firm can use an infinitesimal performance-based bonus and termination bonus to ensure that the manager only wants to continue the product when demand exceeds d^*. Q.E.D.

The tension that prevents the firm from achieving first-best profits in the discrete model also arises in this continuous model. When the firm cannot observe demand it must pay a bonus to convince the manager to terminate low-demand products. However, this bonus undermines the incentives to work, and so the firm must increase the manager's expected wage when working. This tension disappears if the firm can verify and contract on effort.

Our analysis has focused on the manager's incentives to suppress demand information. The motivating examples in §2 reveal that this is not the only type of response that we observe from managers. In particular, where the demand information is provided by an outside research provider, it may not be possible for the manager to suppress it. Instead, the examples suggest that managers may respond by distorting the information, discrediting it, or simply not collecting it. We consider these settings next and illustrate how our findings can be extended to accommodate these responses.

3.5. Other Distortions

We cited several examples of product managers distorting information to make demand look more favorable. These included inflating inputs to forecasting models and visiting stores to manipulate test market findings. Our model requires that the manager has private information about demand. This suggests two possibilities; either the distorted information is additional to what the manager receives (such as a market test that supplements information the manager has already acquired), or the manager acquires the information but can distort what the firm sees (such as changing the distribution and advertising assumptions in a forecasting model). Either interpretation is consistent with the current model. The manager acquires private information that the firm does

Hauser et al. (1997) investigate side payments between marketing managers and their employees and show that side payments will almost always occur. However, if firms can anticipate the resulting inflation in the employee evaluations, they can write first-best contracts that adjust for these distortions.

not see, and the manager can distort the information that the firm does observe. This is equivalent in modeling terms to the manager deciding what to tell the firm about demand.

Our interview subjects also reported that it is common for product managers to discredit unfavorable research outcomes by arguing that the findings are unreliable. We can easily extend the model to accommodate this response. Assume that market research yields a demand signal. The manager and the firm observe the signal, but only the manager observes its accuracy. Specifically, informative market research accurately indicates whether demand is high or low. Uninformative market research also signals whether demand is high or low, but this signal is just noise, providing no additional information beyond the prior probabilities. Unless the manager is offered a sufficient termination bonus, he will prefer to discredit negative information by claiming that the negative signal is inaccurate. For the manager to honestly admit that negative information is accurate, the firm must ensure that $X \geq b_E W$. This requires a positive termination bonus X, which undermines the manager's effort incentives and escalates the firm's payroll costs. Alternatively, the firm can accept the manager's claim that negative information is inaccurate. This option parallels the baseline model; not offering a termination bonus means that the firm may invest in all products (including low-demand products). The trade-off between these two options yields a condition analogous to Condition (2) describing parameter values under which the firm continues to invest in the product despite unfavorable demand information (that the manager knows is accurate).

Recall that the product manager in the healthy snack example chose not to conduct a market test, apparently out of concern that an unfavorable result would threaten product launch. Forgoing information is very similar to discrediting information, and introduces the same trade-offs. Assume that after exerting effort the manager can conduct additional research before recommending further investment. The outcome of the research is the same as in the discrediting information example. The only difference is that in this case the manager privately anticipates the accuracy of the research *before* it is collected. If the manager honestly reports that market research yields accurate demand information, then any negative research outcome will lead to product termination. Therefore, unless there is a sufficient termination bonus, the manager will argue that market research is inaccurate and should be skipped. This termination bonus again weakens the effort incentive and escalates the firm's payroll costs. To avoid paying a termination bonus, the firm can accept the manager's claim that the research is inaccurate. In this case, the firm does not condition its investment decisions on the outcome of the research, and instead invests in all products. If it does not use demand information, then there is no need to incur the expense of collecting it, and so the firm will allow the manager to forgo the additional research even when the manager knows that it will be accurate.

We conclude that the tension between rewarding success and terminating low-demand products extends beyond suppressing or withholding information to include a broad range of managerial distortions.

3.6. Additional Robustness Checks

To investigate the robustness of our findings, we explore how relaxing different assumptions in the model affects the results. Formal analysis of each of these robustness checks is available in the technical appendix (provided in the e-companion).[9]

We first consider the possibility that the manager's effort is observable to the firm but not verifiable, so that the firm cannot contract on it. In this case, the firm cannot condition the manager's compensation on effort. However, it can change its investment decisions. In particular, if the firm observes low effort, it can terminate the product even when the manager claims that demand is high. This is equivalent to assuming that b_D equals zero, because the product will never succeed when the manager shirks. For some parameter values, this modification strengthens Condition (2), and for other parameter values it weakens it. The net outcome is that the tension between rewarding success and inducing truthful reporting of demand survives. The firm still has to offer a success bonus to motivate effort and, consequently, still has to pay a termination bonus to elicit truthful reporting of demand.

We also consider the possibility that by investing in monitoring, the firm can collect verifiable information about the manager's effort level that allows it to directly contract on effort.[10] Monitoring can enable the firm to overcome the tension between rewarding success and killing low-demand products. However, if monitoring costs are high, it will be more profitable to allow continued investment in low-demand products. Moreover, we show that the firm cannot improve the profitability of monitoring by implementing it on a random basis (Townsend 1979, Border and Sobel 1987). To be credible, the firm must be indifferent about whether to monitor, and this cannot be as profitable as both never monitoring and always monitoring.

[9] An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

[10] If by monitoring the firm observes but does not verify effort, there again emerges a tension between rewarding success and killing low-demand products (see the previous paragraph).

The firm could also offer the manager a menu of contracts, and it is at least theoretically possible that the manager may be able to delay his choice of those contracts until after he has observed demand. However, we can show that this cannot improve the firm's profits because the manager's recommendation effectively already acts as a choice from a menu of contracts. We can consider W and X as different contracts in a menu, where the manager elects to receive the bonus for success when demand is high, and to receive the bonus for termination when demand is low.

We assume that the manager has limited liability so that he cannot be punished if he recommends investment but the product fails. This assumption is stricter than we require; we just require a limit on how large any negative wage can be (if sufficiently large punishments are possible, the firm would no longer have to reward success). This issue has attracted attention in the popular press recently to explain why bankers can receive large bonuses in profitable years, but are merely fired, and do not have to repay bonuses in unprofitable years. Our findings suggest that tying bonuses to the success of investments may not be sufficient to prevent bankers, or loan officers, from overlooking unfavorable risk information. If limited liability insulates them from the downside risk, they will tend to underweight the risk of failure as long as there remains a positive probability that the investment will succeed.

3.7. Summary

We have investigated how rewards for success may lead firms to continue investing in low-demand products even when a manager knows that demand is low. This tension survives when we generalize the model to continuous effort and demand, and is aggravated when managers are overly optimistic about the probability of success. We have also shown that a similar tension can explain other managerial responses, including distorting information, discrediting information, or forgoing opportunities to collect information.

So far, we have assumed that the manager chooses whether to work before observing demand. In the next section, we investigate how the timing of information affects the outcome.

4. The Timing of Demand Information

We investigate three questions concerning the timing of demand information. First, we consider the possibility that the manager receives information about demand before choosing effort. This reverses Steps 2 and 3 in the sequence of actions. Second, we recognize that firms will often be unsure about the timing of demand information. We investigate whether mere uncertainty about this timing can make it harder to kill low-demand products (compared to when the timing is known with certainty). Finally, we consider settings in which the timing of demand information is endogenous, and allow the manager to determine when to gather demand information.

4.1. Early Information About Demand

In practice, managers may observe demand before choosing whether to work. When this is true the firm will prefer that the manager exerts effort when demand is high and kills the product when demand is low. The key question is as follows: By inducing effort when demand is high, does the firm create an incentive for the manager to also preserve low-demand products? The answer is no. We formally state this as our third proposition:

Proposition 3. *If the manager chooses effort after observing demand, the firm will only invest in high-demand products.*

Proof. See the appendix.

Intuitively, if the manager is indifferent between shirking and working on a high-demand product, he will always prefer shirking to working on a low-demand product. As a result, the firm can always ensure that low-demand products die because the manager prefers to terminate them without wasting effort on them. This outcome is consistent with recommendations that product development take a "gated" or "phased" approach, where each phase generates useful information for subsequent decisions.

When the manager has access to early demand information, the firm can motivate effort with a smaller success bonus because it no longer has to compensate the manager for wasted effort on low-demand products. This smaller success bonus in turn reduces the size of the termination bonus the firm must pay to kill low-demand products. As a result, the manager will prefer that the firm always believes that early demand information is unavailable. We focus on this issue next, and explore whether uncertainty about the timing of demand information affects the likelihood of investing in low-demand products.

4.2. Uncertainty About When the Manager Receives Demand Information

We have previously assumed that the firm knows when the manager receives his demand signal. In practice, this may not always be the case. The firm may be uncertain not just about whether demand is high or low; it may also be uncertain about whether the manager learns demand before choosing effort.

We modify our model by assuming that only the manager knows whether early demand information is available before he chooses whether to work. The firm's prior beliefs are that early demand information is available with probability q, where $0 < q < 1$. Moreover, to establish a basis for comparison, we will also assume that Condition (2) holds. Recall that if managers learn demand *after* choosing effort then Condition (2) determines whether firms invest in low-demand products. If managers learn demand *before* choosing effort, Proposition 3 establishes that firms never invest in low-demand products. Jointly this implies that if Condition (2) holds and the timing of demand information is known, then investment in low-demand products will never be optimal. This allows us to investigate whether *mere* uncertainty about the availability of early demand information increases the range of parameter values for which firms invest in low-demand products.

We prove the following proposition:

Proposition 4. *Uncertainty about whether early demand information is available may make it more profitable to allow continued investment in low-demand products.*

Proof. See the appendix.

Why do things change when the firm is uncertain about the manager's access to demand information? Killing low-demand products is relatively inexpensive when the manager receives early demand information. However, if the demand information arrives after effort is chosen, killing low-demand products becomes more expensive. This presents the firm with a trade-off: It can pay a lower salary in the hope that the manager receives demand information early. In doing so, it risks that it may invest in low-demand products if the information is late. The more likely that demand information will be early (when q is high), the more profitable this option becomes.

We conclude that the tension between motivating effort and implementing efficient product termination does not just depend upon whether the firm can observe demand. It also depends upon whether the firm knows how informed its manager is when choosing effort. Uncertainty about demand and uncertainty about how much the manager knows both make it more expensive to kill low-demand products than to continue them. If these costs are high enough, it is in the firm's interests to continue investing even though the manager may know that demand is low.

We have assumed that the timing of the manager's demand signal is exogenously determined. In practice, the manager may be able to affect this timing through his influence on the product development team's priorities. We investigate this possibility next.

4.3. The Incentives to Acquire Demand Information Early

If it takes no additional cost or effort to collect demand information earlier, then the manager will always do so, because he can avoid wasting effort on products that will be killed. However, if additional effort is required, the manager must trade off the cost of this additional effort with the advantage of knowing when not to work. The timing of the manager's demand information also affects the firm's profits. If the firm knows that early demand information is available, it will lower the manager's compensation. This in turn influences the manager's willingness to reveal whether he has acquired the information early.

To ensure that the findings depend solely on the timing of the information, we will assume that the content of the information is not affected by when it is received. We begin by showing that if there is no cost to getting demand information early, then the manager will always want to do so. Formally, given any contract (W, X), the maximum payoff the manager can earn by choosing effort after observing the demand signal is

$$UA = s\max(aW - c, b_D W, X) + (1-s)\max(b_E W - c, X).$$

On the other hand, the maximum payoff the manager can earn if effort is chosen before receiving the demand signal is

$$UN = \max[saW + (1-s)\max(b_E W, X) - c, \; s\max(b_D W, X) + (1-s)X].$$

Notice that $UA \geq UN$ by construction. Other things being equal, the manager is always (weakly) better off if he can choose effort after learning about demand. We conclude that if there is no cost to getting the information early, then the problem is equivalent to when the manager always receives demand information before choosing effort (§4.1). In these settings the firm only invests in high-demand products (Proposition 3).

If the manager incurs a cost to collect demand information early, he will balance this cost with the value of the information, which is determined by the difference between UA and UN. This difference depends upon his wage contract. Intuitively, the manager will have no incentive to acquire information if the contract allows the firm to extract all of the information rents. Therefore, whether information acquisition emerges in equilibrium is ultimately the firm's decision.

In analyzing the firm's decision, we will focus on the case where the firm can contract on whether the manager acquires information early.[11] We begin by

[11] We show in the appendix that similar results emerge if the firm cannot contract on information acquisition, and instead must use the success and termination bonuses to induce the manager to implement the firm's preferred outcome.

deriving the optimal contract under which the manager acquires information early, and then derive the optimal contract in which he forgoes this option. We compare the resulting profits and establish the conditions under which the firm prefers early information acquisition. Finally, we explore how the option of acquiring information early affects the firm's decision to kill low-demand products.

If the firm can contract on whether the manager acquires demand information early, then it is straightforward to *prevent* information acquisition. The cheapest way to do so is to offer a payment of zero if the manager acquires information. If the manager does not acquire information early, we revert to the situation in §3. The firm offers a contract that either ensures that low-demand products are either killed (W_K^*, X_K^*) or allowed to continue (W_{NK}^*, X_{NK}^*), and the preferred option is determined by Condition (2).

The cheapest way to *implement* information acquisition is to offer a payment of zero if the manager does not acquire information, and a contract (T, W_H^*, X_H^*) otherwise, where $T \geq 0$ represents the bonus for acquiring information, and (W_H^*, X_H^*) is the optimal contract when the firm knows for certain that early demand information is available (§4.1). The bonus T ensures that the manager is compensated for his information acquisition costs, whereas (W_H^*, X_H^*) ensures that the firm makes efficient use of the acquired information.

We denote the cost incurred by the manager to acquire early demand information by $A > 0$. Let P denote the manager's expected payment from acquiring information and accepting the contract (T, W_H^*, X_H^*). The manager will acquire information iff $P - A - sc \geq 0$, where the effort cost term is sc because the manager only exerts effort when demand is high. The firm earns a profit of $s(aY - Z) - P$ if early demand information is available. This profit exceeds the highest profit from not acquiring information iff $P < s(aY - Z) - \max(\Pi_K^*, \Pi_{NK}^*)$. Therefore, information is acquired early in equilibrium iff the information acquisition cost A is small enough:

$$A < s(aY - Z - c) - \max(\Pi_K^*, \Pi_{NK}^*). \qquad (3)$$

This condition also allows us to characterize how the option of acquiring information early affects the likelihood that low-demand products will be killed. In the absence of early demand information, the firm cancels low-demand products when $\Pi_K^* > \Pi_{NK}^*$ (Condition (2)). If we evaluate Condition (3) when Condition (2) is just binding $(\Pi_K^* = \Pi_{NK}^*)$, we can determine whether the option of collecting early demand information makes it more or less likely to kill low-demand products. Substituting $\Pi_K^* = \Pi_{NK}^*$ into Condition (3), we see that the firm no longer allows low-demand products to continue if

$$A < s(aY - Z - c) - \Pi_K^*.$$

The right-hand side of this expression is strictly positive. Therefore, the option of acquiring early demand information increases the range of parameters under which the firm will kill low-demand products. We formally restate this result as Proposition 5.

Proposition 5. *The manager's option of acquiring demand information early reduces the likelihood that the firm will invest in low-demand products. The lower the cost of acquiring information early, the more likely that low-demand products will be killed.*

Proof. By construction.

In summary, if there is *no cost* to acquiring information early, then the manager will always acquire it, and the model reverts to the setting in §4.1, where the manager always has demand information before selecting his effort level. In this case, the firm never allows investments in low-demand products (Proposition 3). Second, if it is very costly to acquire demand information early, then the manager will never acquire it. In this case, the manager only receives demand information after choosing his effort level, and the model reverts to the setting in §3. Finally, if the cost of acquiring demand information early falls within an intermediate range, the decision to acquire information early depends upon how doing so affects the firm's profits. The firm ensures that the manager acquires early information as long as the cost of doing so is low enough. This (weakly) increases the firm's profit from killing low-demand products, which makes it more likely that low-demand products are killed.

5. Discussion and Conclusions

This paper offers an explanation for why firms continue to invest in products even after the product manager has received information indicating that the product is unlikely to succeed. Our explanation focuses on the tension between rewarding success and inducing the manager to truthfully report when demand is low. To ensure that the manager abandons low-demand products, the firm must reward the manager for product termination. However, this termination bonus undermines the rewards for success. We first demonstrate this tension by focusing on the manager's incentives to withhold negative demand information. We then show that a similar tension arises with other managerial responses, including distorting information, discrediting information, and not collecting information. Although in our model the rewards for success serve to motivate the manager to exert effort, the findings are not limited to this setting. In general, whenever the firm rewards success a similar tension arises, increasing the likelihood that the firm will make inefficient investments in low-demand products.

We investigate how the findings differ according to the timing of the manager's demand information. If the manager learns about demand before choosing effort, then the firm can design a contract that kills low-demand products. It is only when demand is revealed to the manager after choosing effort that firms invest in low-demand products. This result highlights the benefits of using a sequence of small market tests rather than a single-phased launch. We also consider the possibility that the firm does not know when demand information is received, and show that mere uncertainty about the timing of demand information can increase the probability of investing in low-demand products. The firm must choose between paying a generous contract to always implement efficient product termination, forgoing some high-demand product opportunities, and allowing low-demand products to continue. When it is likely that the manager has access to early demand information, then the risk of investing in low-demand products is diminished, making the last option more profitable.

The timing of demand information is unlikely to be entirely exogenous. In many cases the product manager will be able to affect this timing through his influence on the product development team's priorities. If there is no cost to acquiring information early, then the manager will always do so, and the firm will never make inefficient investments in low-demand products. Even if acquiring information early is costly, the option of acquiring early demand information may still make it more likely that the firm will kill low-demand products (compared to when demand information is never available early). The lower this cost, the more likely that low-demand products are killed. This is true even if the firm cannot directly contract on the timing of the information.

We can extend the intuition to other marketing decisions. Examples may include the failure to experiment when setting prices or designing product lines. Market experiments may enhance these decisions, but they add cost and introduce delay. By offering incentives to experiment when uncertainty is high, the firm may also encourage unnecessary experiments when uncertainty is low. Similar intuition may explain underinvestment in channel relationships. Lavishing sports tickets or expensive meals on channel partners may be an effective way to build channel relationships, but they may also act as a substitute for employee effort. If investments and effort both contribute to market success, then by rewarding success the firm creates incentives for abuse.

Opportunities for future research include investigation of other mechanisms for resolving this tension. For example, Guedj and Scharfstein (2004) evaluate clinical trial strategies of biopharmaceutical firms and compare "mature" firms with a large number of drugs under development to those of "early stage" firms with fewer drugs in development. Their findings suggest that firms with a larger portfolio of products under development are quicker to abandon less promising products. The uncertainty in their setting is on the supply side about whether the drugs will be effective. However, we might expect the same result to extend to managing demand uncertainty, suggesting that firms with more products under development will be better at killing low-demand products. Although this mechanism may improve firm decisions, we caution that it may be less useful for aligning individual manager's incentives. The depth of involvement required from a product development manager means that it is generally not feasible for individual managers to maintain a portfolio of product development projects. Future research could also explore the agency problem faced by the manager in motivating his team.

6. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mansci.journal.informs.org/.

Acknowledgments

The authors thank Scott Fay, John Hauser, Dmitri Kuksov, Matthew Selove, Catherine Tucker, Glen Urban, J. Miguel Villas-Boas, Joseph Weber, and Birger Wernerfelt for helpful comments. They have also received valuable suggestions from seminar participants at Carnegie-Mellon, MIT, Rensselaer Polytechnic Institute, Tilburg University, University of Pittsburgh; and attendees at the 2009 Marketing Science Conference, 2009 Summer Institute of Competitive Strategy, 2009 MIT Applied Economic Theory Summer Camp, and the 2009 Quantitative Marketing and Economics Conference. The authors also thank the department editor, associate editor, and anonymous reviewers.

Appendix

A.1. Psychological Biases in Beliefs

A.1.1. Psychological Biases Cannot on Their Own Explain Continued Investment in Low-Demand Products. We can model belief inertia distortions by assuming that when the manager receives a negative signal about demand he believes that the probability of success is b', whereas the true probability is b.[12] To confirm that this distortion cannot on its own explain continued investments in low-demand

[12] The negative information is underweighted rather than ignored, and so we assume $a > b'$.

products, we begin by removing the tension that we study in this paper. In particular, assume that the firm can directly compensate the manager for verifiable effort. If the firm offers a success bonus of $W^* = \epsilon$ and a termination bonus of $X^* = b'W^*$, it can kill low-demand products and approach first-best profits (by setting ϵ sufficiently low). In the case of managerial conceit, once the manager has exerted effort, we assume that he perceives the probability of success is a′ when demand is high, and b'_E when demand is low, where $a' > a$, $b'_E > b_E$, and $a' > b'_E$. If the firm can directly compensate the manager for effort, it will offer a success bonus of $W^* = \epsilon$ and a termination bonus of $X^* = b'_E W^*$. This again allows the firm to kill low-demand products and restore first-best profits.

However, psychological biases in beliefs can complement our model by acerbating the tension between effort inducement and information elicitation. If managers are overly confident about the probability of success, then a larger termination bonus is required to kill low-demand products. This in turn increases the required success bonus, resulting in a higher wage bill and lower profits. We formally model this situation below.

A.1.2. Belief Inertia Distortion May Contribute to the Continuation of Low-Demand Products. Biyalagorsky et al. (2006) find that belief distortions may arise even if the manager has not exerted effort. In our model, decision inertia distortion means that by simply thinking that the product is viable in the first place (which is plausible given that the manager has agreed to take charge of product development), the manager will subsequently discount the information that demand is low. He will perceive a low-demand product's chance of success as b'_E, where $b_E < b'_E < a$, and a dead product's chance of success as d, where $0 < d < b'_E$.

Belief inertia distortion hurts the firm in two ways: a higher termination bonus is demanded to kill low-demand products, which in turn makes effort more expensive to motivate. Let the subscript "B" represent belief inertia distortion. To terminate all low-demand products, the firm solves the following optimization problem:

$$\max \quad \Pi_{K-B} = s(aY - Z) - saW - (1-s)X$$

$$\text{s.t.} \quad aW \geq X \quad (\text{IC}_1\text{: continue high-demand products}),$$

$$X \geq b'_E W \quad (\text{IC}_2\text{: kill low-demand products}),$$

$$saW + (1-s)X - c \geq s\max(b_D W, X) + (1-s)\max(dW, X) \quad (\text{IC}_3\text{: exert effort}).$$[13]

The equilibrium contract is

$$W^*_{K-B} = c/\{s[a - \max(b_D, b'_E)]\} \geq W^*_K,$$

$$X^*_{K-B} = b'_E W^*_{K-B} > X^*_K.$$

Naturally, to encourage the manager to abandon low-demand products, the firm must compensate him for what he perceives to be the forgone return from continuation, which is higher than its actual value. The firm can avoid overcompensating the manager by allowing low-demand products to continue. In this case, the firm's optimization problem is

$$\max \quad \Pi_{NK-B} = s(aY - Z) + (1-s)(b_E Y - Z) - [sa + (1-s)b_E]W$$

$$\text{s.t.} \quad aW \geq X \quad (\text{IC}_1\text{: continue high-demand products}),$$

$$b'_E W \geq X \quad (\text{IC}_2\text{: continue low-demand products}),$$

$$[sa + (1-s)b'_E]W - c \geq s\max(b_D W, X) + (1-s)\max(dW, X) \quad (\text{IC}_3\text{: exert effort}).$$

The equilibrium contract is

$$W^*_{NK-B} = c/[s(a - b_D) + (1-s)(b'_E - d)],$$

$$X^*_{NK-B} = 0.$$

The bonus for success may be higher or lower than that without belief inertia distortion (W^*_{NK}), depending on the relative size of b'_E and d.

Belief inertia distortion acerbates the inefficient continuation of low-demand products when $\Pi^*_{K-B} - \Pi^*_K < \Pi^*_{NK-B} - \Pi^*_{NK}$, that is, when $[sa + (1-s)b_E]W^*_K - [sa + (1-s)b'_E]W^*_{K-B} < [sa + (1-s)b_E](W^*_{NK} - W^*_{NK-B})$. It can be shown that this condition holds for some parameter values.

A.1.3. Managerial Conceit May Contribute to the Continuation of Low-Demand Products. Let the subscript "MC" represent managerial conceit. To terminate low-demand products, the firm solves the following optimization problem:

$$\max \quad \Pi_{K-MC} = s(aY - Z) - saW - (1-s)X$$

$$\text{s.t.} \quad a'W \geq X \quad (\text{IC}_1\text{: continue high-demand products}),$$

$$X \geq b'_E W \quad (\text{IC}_2\text{: kill low-demand products}),$$

$$sa'W + (1-s)X - c \geq s\max(b_D W, X) + (1-s)X \quad (\text{IC}_3\text{: exert effort}).$$

The effort constraint reflects the manager's belief that the products he has chosen to work on have a better chance of success than what the objective probabilities would suggest. The equilibrium contract is

$$W^*_{K-MC} = c/\{s[a' - \max(b_D, b'_E)]\},$$

$$X^*_{K-MC} = b'_E W^*_{K-MC}.$$

The bonus for success W^*_{K-MC} may be higher or lower than W^*_{NK}, depending on the relative size of a', b_D, and b'_E. As a result, the total expected wages can be higher or lower than without managerial conceit.

Alternatively, the firm may choose to continue low-demand products and solve the following problem:

$$\max \quad \Pi_{NK-MC} = s(aY - Z) + (1-s)(b_E Y - Z) - [sa + (1-s)b_E]W$$

$$\text{s.t.} \quad a'W \geq X \quad (\text{IC}_1\text{: continue high-demand products}),$$

$$b'_E W \geq X \quad (\text{IC}_2\text{: continue low-demand products}),$$

$$[sa' + (1-s)b'_E]W - c \geq s\max(b_D W, X) + (1-s)X \quad (\text{IC}_3\text{: exert effort}).$$

[13] The effort constraints assume the manager is "boundedly rational yet sophisticated" and anticipates the termination bonus to accommodate his biased beliefs (see O'Donoghue and Rabin 2001).

The equilibrium contract is similarly derived as

$$W^*_{NK-MC} = c/[s(a' - b_D) + (1-s)b'_E],$$

$$X^*_{NK-MC} = 0.$$

Note that $W^*_{NK-MC} < W^*_{NK}$. Managerial conceit makes it more attractive to continue low-demand products by lowering the payroll cost to induce effort without increasing the manger's information rent.

Overall, managerial conceit acerbates the inefficient continuation of low-demand products when $\Pi^*_{K-MC} - \Pi^*_K < \Pi^*_{NK-MC} - \Pi^*_{NK}$, that is, when $[sa + (1-s)b_E]W^*_K - [sa + (1-s)b'_E]W^*_{K-MC} < [sa + (1-s)b_E](W^*_{NK} - W^*_{NK-MC})$. It can be shown that this condition holds for some parameter values.

A.2. Proof of Proposition 3

We begin with the case where the firm encourages effort if and only if demand is high. The firm solves the following optimization problem:

$$\max \quad \Pi_H = s(aY - Z) - saW - (1-s)X$$

$$\text{s.t.} \quad aW - c \geq b_D W \quad (\text{IC}_1\text{: exert effort when demand is high}),$$

$$aW - c \geq X \quad (\text{IC}_2\text{: continue high-demand products}),$$

$$X \geq \max(b_E W - c, 0) \quad (\text{IC}_3\text{: kill low-demand products; prevent wasteful effort}).$$

The constraint IC_3 must be binding in equilibrium; otherwise, the firm can reduce X and improve profits. It follows that IC_2 is redundant: if $X = 0$, IC_1 implies IC_2; if $X = b_E W - c$, IC_2 automatically holds as well. Given that IC_2 is redundant, IC_1 must be binding in equilibrium too; otherwise, the firm can always reduce W and improve profits. It follows that

$$W^*_H = c/(a - b_D),$$

$$X^*_H = \max[c(b_D + b_E - a)/(a - b_D), 0],$$

$$\Pi_H* = s(aY - Z) - c[sa + (1-s)\max(b_D + b_E - a, 0)]/(a - b_D).$$

It remains to check whether the firm has any incentive to also induce effort when demand is low. Suppose the firm does support such an equilibrium; its optimization problem becomes

$$\max \quad \Pi_L = s(aY - Z) + (1-s)(b_E Y - Z) - saW - (1-s)b_E W$$

$$\text{s.t.} \quad aW - c \geq b_D W \quad (\text{IC}_1\text{: exert effort when demand is high}),$$

$$aW - c \geq X \quad (\text{IC}_2\text{: continue high-demand products}),$$

$$b_E W - c \geq 0 \quad (\text{IC}_3\text{: exert effort when demand is low}),$$

$$b_E W - c \geq X \quad (\text{IC}_4\text{: continue low-demand products}),$$

where the subscript "L" stands for "work even when demand is low." The equilibrium is

$$W^*_L = c/\min(b_E, a - b_D),$$

$$X^*_L = 0,$$

$$\Pi^*_L = s(aY - Z) + (1-s)(b_E Y - Z) - c[sa + (1-s)b_E]/\min(b_E, a - b_D).$$

Note that $W^*_H \leq W^*_L$ and that X^*_H equals either 0 or $b_E W^*_H - c < b_E W^*_H \leq b_E W^*_L$. That is, by also inducing effort when demand is low, the firm pays the manager a higher expected compensation, but only to make less-efficient investments ($b_E Y < Z$). Therefore, the firm has no incentive to implement this wasteful outcome. Q.E.D.

A.3. Proof of Proposition 4

We will demonstrate that the firm must choose from four options. The first option is to kill low-demand products, with the manager working unless he knows demand is low. The second option is more conservative. The firm only implements effort when the manager knows in advance that demand is high. We rule out a third option, whereby the firm confronts its uncertainty using a menu of contracts that induces the manager to truthfully report whether he has early information about demand. Finally, the fourth option is to allow continued investment in low-demand products. We explore whether this can yield higher profits, even though the firm would never allow investments in low-demand products if it knew the timing of the demand information (given our assumption about Condition (2)).

Option 1: Killing Low-Demand Products. In Lemma 1 we identify the optimal "single" contract that implements the outcome under which low-demand products are killed and the manager works unless demand is known to be low.

Lemma 1. *If the firm is uncertain whether early demand information is available, then (W^*_K, X^*_K) is the optimal contract that ensures that low-demand products are killed and the manager works unless demand is known to be low.*

Proof. We first show that (W^*_K, X^*_K) both kills low-demand products and implements effort unless the manager knows demand is low. We then show that (W^*_K, X^*_K) is the cheapest contract to achieve this goal.

When early demand information is unavailable, the contract (W^*_K, X^*_K) induces the manager to work and to terminate low-demand products (see §3). When early demand information is available, (W^*_K, X^*_K) satisfies the new IC constraints with slack:

$$aW^*_K - c > b_D W^*_K \quad (\text{IC}_1\text{: exert effort when demand is high}),$$

$$aW^*_K - c > X^*_K \quad (\text{IC}_2\text{: continue high-demand products}),$$

$$X^*_K > b_E W^*_K - c \quad (\text{IC}_3\text{: kill low-demand products; save effort}).$$

The firm maximizes the same profit function $\Pi = s(aY - Z) - saW - (1-s)X$. Because (W^*_K, X^*_K) is the unique optimal solution to this objective function when there are fewer constraints, it must also be the unique optimal solution when there are additional slack constraints. Q.E.D.

It should also be clear that never implementing effort is dominated by (W^*_K, X^*_K). However, we do have to consider the possibility that the firm will only induce effort when demand is known to be high.[14] We consider this possibility next.

[14] It can be shown that there is no single contract that only induces effort if early demand information is unavailable.

Option 2: A More Conservative Approach. The contract (W_K^*, X_K^*) overcompensates the manager when early demand information is available. This is because effort is cheaper to induce if the manager can avoid wasting effort on low-demand products. Therefore, it is possible that the firm could improve profits by forgoing effort and killing all products when early demand information is unavailable. The optimal contract that implements this solution (which we denote by "*C*" for conservative) is determined from

$$\max \quad \Pi_C = q[s(aY-Z) - saW - (1-s)X] + (1-q)(-X)$$

s.t. If early demand information is available:

$$aW - c \geq \max(b_D W, X)$$

(IC$_1$: work on and continue high-demand products),

$$X \geq \max(b_E W - c, 0)$$

(IC$_2$: kill low-demand products; save effort);

If early demand information is unavailable:

$$X \geq s\max(aW, X) + (1-s)\max(b_E W, X) - c$$

(IC$_3$: save effort),

$$X \geq b_D W \quad \text{(IC}_4\text{: kill the product).}$$

The IC$_1$ constraint, which requires that $aW - c \geq X$, must be binding in equilibrium; otherwise, the firm can decrease W and improve profits. It follows that IC$_2$ and IC$_3$ hold with slack, and that the final constraint is binding ($X = b_D W$). Consequently, the equilibrium contract and profit can be derived as

$$W_C^* = c/(a - b_D) < W_K^*,$$
$$X_C^* = cb_D/(a - b_D),$$
$$\Pi_C^* = qs(aY - Z - c) - cb_D/(a - b_D).$$

We can compare the profitability of this contract (W_C^*, X_C^*) with (W_K^*, X_K^*). The outcome depends on the parameters. However, we know that the most profitable contract of the form (W, X) is one of these two contracts.

Option 3: Menus of Contracts. In Lemma 2 we establish that menus of contracts cannot achieve higher profits than (W_K^*, X_K^*) and (W_C^*, X_C^*).

Lemma 2. *When the firm is uncertain whether early demand information is available, a menu of contracts is no more profitable than the optimal single contract.*

Proof. To terminate low-demand products and motivate effort, the firm needs to retain the contractual instruments W and X. In addition, the firm can offer a lump-sum payment $T_j \geq 0$ if the manager reports that the state of early demand information availability is j, where j equals either "*A*" (available) or "*N*" (unavailable). Altogether, the menu of contracts includes (W_A, X_A, T_A) and (W_N, X_N, T_N). Let $U_i(W_j, X_j, T_j)$ be the manager's expected payment minus expected effort cost if he accepts (W_j, X_j, T_j) while the true state is i, where i equals either A or N. For the manager to tell the truth, the menu of contracts must satisfy the following IC constraints:

$$U_A(W_A, X_A, T_A) \geq U_A(W_N, X_N, T_N),$$
$$U_N(W_N, X_N, T_N) \geq U_N(W_A, X_A, T_A),$$

where

$$U_A(W_N, X_N, T_N) = s\max(aW_N - c, b_D W_N, X_N) + (1-s)\max(b_E W_N - c, X_N) + T_N,$$
$$U_N(W_A, X_A, T_A) = \max[saW_A + (1-s)\max(b_E W_A, X_A) - c, s\max(b_D W_A, X_A) + (1-s)X_A] + T_A.$$

Given the assumption about Condition (2), the firm will always kill low-demand products once it finds out whether the manager has early demand information. If by using the menu of contracts, the firm wants the manager to work when demand is either known to be high or uncertain, then its expected profit is

$$\Pi_M = s(aY - Z) - q[saW_A + (1-s)X_A + T_A] - (1-q)[saW_N + (1-s)X_N + T_N].$$

Note, however, that $U_A(W_A, X_A, T_A) = saW_A + (1-s)X_A - sc + T_A$ in this case, and that $U_A(W_N, X_N, T_N) \geq saW_N +$ (1-s) $X_N - sc + T_N$ by definition. Therefore, the IC constraint $U_A(W_A, X_A, T_A) \geq U_A(W_N, X_N, T_N)$ means that $saW_A + (1-s)X_A + T_A \geq saW_N + (1-s)X_N + T_N$. It follows that

$$\Pi_M \leq s(aY - Z) - [saW_N + (1-s)X_N + T_N]$$
$$\leq s(aY - Z) - [saW_N + (1-s)X_N].$$

The right-hand side of this expression is the profit from using a single contract (W_N, X_N) to induce effort without early demand information and to kill low-demand products. However, the optimal single contract to achieve this outcome is (W_K^*, X_K^*). Therefore, Π_M cannot exceed Π_K^*.

It can be similarly shown that the firm cannot improve profits by offering a menu of contracts that induce effort only when demand is known to be high. This menu of contracts is always weakly dominated by (W_C^*, X_C^*). Neither can the firm improve profits by using a menu of contracts that induce effort only when demand is uncertain. Lastly, the firm has no incentive to offer a contract menu that always discourages effort. Q.E.D.

The intuition for this result is that inducing the manager to reveal whether early information is available requires a transfer of surplus to the manager. This transfer of surplus depends upon the foregone rents that the manager enjoys from early information. As a result, the cost of inducing the manager to select the appropriate contract is no less than the rents that the manager enjoys when the firm uses a single contract.

We conclude that the most the firm can earn if it only invests in high-demand products is either Π_K^* (which induces effort when demand is high or uncertain) or Π_C^* (which only induces effort when demand is high). In the final step in our analysis, we demonstrate that it may be possible for the firm to earn more than either Π_K^* or Π_C^* by allowing low-demand products to continue.

Option 4: Allowing Low-Demand Products to Continue. Rather than fully characterizing the optimal contract that allows investments in low-demand products, we instead provide an example of a contract that allows low-demand products to continue and yields higher profits than the three previous options. Because the firm would not allow low-demand products to continue when it knows the timing of demand information (under our assumption that Condition (2) holds), the existence of such a contract is sufficient to show that mere uncertainty about the timing of the demand information can increase the likelihood that the firm invests in low-demand products.

An obvious candidate is the optimal contract that kills low-demand products when the manager has early access to demand information: (W_H^*, X_H^*). If early demand information is unavailable, it can be shown that $aW_H^* > X_H^*$, so that the manager would still recommend high-demand products for continuation once effort is sunk. However, $X_H^* < b_E W_H^*$, which means that the manager would prefer to continue a low-demand product. In addition, $X_H^* < b_D W_H^*$; hence, if no effort is exerted, the manager would prefer to continue a high-demand product than to terminate it. Altogether, the effort constraint becomes $saW_H^* + (1-s)b_E W_H^* - c \geq sb_D W_H^* + (1-s)X_H^*$, which is satisfied if and only if $b_D + b_E \geq a$. Therefore, by offering (W_H^*, X_H^*) while early demand information is unavailable, the firm may allow low-demand products to continue, and earns an expected profit of

$$\Pi_U = s(aY - Z) + (1-s)(b_E Y - Z) - [sa + (1-s)b_E]W_H^* \quad \text{if } b_D + b_E \geq a$$

and

$$\Pi_U = s(b_D Y - Z) - sb_D W_H^* \quad \text{if } b_D + b_E < a.$$

When the firm is uncertain about the availability of early demand information, offering (W_H^*, X_H^*) yields expected profits of

$$\Pi_E = q\Pi_H^* + (1-q)\Pi_U.$$

When q is close to 1, so that early demand information is generally available, the firm earns a profit close to Π_H^*, while still investing in low-demand products in the rare occasions that early demand information is unavailable. Because Π_H^* exceeds the profits under (W_K^*, X_K^*) and (W_C^*, X_C^*), investing in some low-demand products is more profitable than always terminating them. Q.E.D.

A.4. When the Firm Cannot Contract on the Manager's Information Acquisition Activities

The firm must use success and termination bonuses to influence the manager's actions. We first prove that by inducing information acquisition the firm will not continue low-demand products. This result simplifies our subsequent search for optimal contracts that induce information acquisition. We then derive the optimal contracts that prevent information acquisition. We will show that the manager's ability to acquire early demand information increases the firm's profit from killing low-demand products, but weakly lowers the firm's profit from continuing low-demand products. Consequently, the firm is more likely to kill low-demand products than when early demand information is unavailable.

A.4.1. If the Firm Induces Information Acquisition, It Will Kill Low-Demand Products. Suppose the manager acquires early demand information in equilibrium. First note that the firm cannot both induce effort regardless of demand and kill low-demand products; knowing that low-demand products will be killed ($b_E W < X$) would have discouraged the manager from exerting costly effort on low-demand products in the first place ($b_E W - c < X$). Therefore, it remains to check whether the firm would want to induce effort regardless of demand and retain low-demand products. The answer is no, and the reason is as follows. By acquiring information, exerting effort regardless of demand, and retaining low-demand products, the manager earns a net payoff of $-A + [sa + (1-s)b_E]W - c$. However, if the manager deviates by skipping information acquisition, he still at least earns $[sa + (1-s)b_E]W - c$ by exerting effort regardless of demand. Therefore, for any $A > 0$ the firm cannot prevent the manager from skipping information acquisition. Intuitively, wasting effort on low-demand products defeats the purpose of acquiring demand information.[15] Because the manager will not work on low-demand products, these products are dead and will be terminated for certain. Therefore, if the firm induces information acquisition, it will only continue high-demand products.

A.4.2. The Optimal Contract to Induce Information Acquisition. We have shown that to induce information acquisition the firm wants the manager to only work on high-demand products and recommend these products for continuation. The optimal contract to achieve this goal solves the following optimization problem:

$$\max \quad \Pi_A = s(aY - Z) - saW - (1-s)X$$

$$\text{s.t.} \quad aW - c \geq \max(b_D W, X)$$

$$\text{(IC}_1\text{: work and continue high-demand products)},$$

$$X \geq \max(b_E W - c, 0)$$

$$\text{(IC}_2\text{: not work and kill low-demand products)},$$

$$-A + s(aW - c) + (1-s)X \geq \max[saW + (1-s)\max(b_E W, X) - c,\ s\max(b_D W, X) + (1-s)X]$$

$$\text{(IC}_3\text{: acquire demand information)}.$$

We investigate the cases of $X < b_E W$ and $X \geq b_E W$, respectively.

Case 1: $X < b_E W$. When $X < b_E W$, the IC_3 constraint of the firm's optimization problem becomes

$$-A + s(aW - c) + (1-s)X \geq saW + (1-s)b_E W - c,$$

$$-A + s(aW - c) + (1-s)X \geq s\max(b_D W, X) + (1-s)X,$$

which can be rearranged as

$$X \geq A/(1-s) + b_E W - c,$$

$$aW - c \geq \max(b_D W, X) + A/s.$$

[15] It can be similarly verified that by inducing information acquisition, the firm has no incentive to induce effort only upon low demand or to always discourage effort.

Note that the necessary condition for $X \geq A/(1-s)+b_E W - c$ to hold when $X < b_E W$ is that $A < (1-s)c$. All the constraints for the optimization problem can be simplified into two constraints:

$$X \geq \max[A/(1-s)+b_E W - c, 0],$$
$$aW - c \geq \max(b_D W, X) + A/s.$$

These two constraints must bind in equilibrium; otherwise, the firm would be able to decrease X and/or W to improve profits. Therefore, the optimal W must satisfy the following equation:

$$aW - c = \max[b_D W, A/(1-s)+b_E W - c] + A/s.$$

If $b_D W \geq A/(1-s)+b_E W - c$, the optimal W solves $aW - c = b_D W + A/s$, which leads to

$$W_1^* = (A+sc)/s(a-b_D).$$

For $b_D W_1^* \geq A/(1-s)+b_E W_1^* - c$ to hold, we need either $D \leq 0$, or $D > 0$ and $A \leq (1-s)ct$, where $D = s(a-b_E) - b_D + b_E$, and $t = s(a-b_E)/D$.

If $b_D W < A/(1-s)+b_E W - c$, the optimal W solves $aW - c = A/(1-s)+b_E W - c + A/s$, which leads to

$$W_2^* = A/s(1-s)(a-b_E).$$

For $b_D W_2^* < A/(1-s)+b_E W_2^* - c$ to hold, we need $D > 0$ and $A > (1-s)ct$.

Recall that the necessary condition for Case 1 to be relevant is $A < (1-s)c$. Also, when $D > 0$, $t \leq 1$ if and only if $b_D \leq b_E$. Collecting terms, the optimal success bonus in Case 1 can be summarized as

$$W^* = W_1^* \quad \text{if } b_D > b_E \text{ and } A < (1-s)c,$$
$$\text{or} \quad b_D \leq b_E \text{ and } A \leq (1-s)ct$$
$$W^* = W_2^* \quad \text{if } b_D \leq b_E \text{ and } (1-s)ct < A < (1-s)c.$$

The optimal termination bonus is

$$X^* = \max[A/(1-s)+b_E W^* - c, 0].$$

Case 2: $X \geq b_E W$. When $X \geq b_E W$, the IC_3 constraint of the optimization problem can be simplified as

$$A \leq (1-s)c,$$
$$aW - c \geq \max(b_D W, X) + A/s$$

Note that $aW - c \geq \max(b_D W, X) + A/s$ implies that IC_1 must hold, and that $X \geq b_E W$ guarantees that IC_2 must hold as well. Therefore, the optimal W in Case 2 is solved by $aW - c \geq \max(b_D W, X) + A/s$ and $X \geq b_E W$, both of which bind in equilibrium:

$$W^* = (c + A/s)/(a - \max(b_D, b_E)),$$
$$X^* = b_E W^*.$$

It can be easily verified that Case 2 yields higher W^* and X^* than Case 1, although both cases are subject to the same condition of $A < (1-s)c$. Therefore, the solution to the optimization problem (W_A^*, X_A^*) comes from Case 1 and is formally stated as

$$W_A^* = (A+sc)/s(a-b_D) \quad \text{if } b_D > b_E \text{ and } A < (1-s)c,$$
$$\text{or } b_D \leq b_E \text{ and } A \leq (1-s)ct,$$
$$W_A^* = A/s(1-s)(a-b_E) \quad \text{if } b_D \leq b_E \text{ and } (1-s)ct < A < (1-s)c,$$
$$X_A^* = \max[A/(1-s)+b_E W_A^* - c, 0],$$

where $t = s(a-b_E)/[s(a-b_E) - b_D + b_E]$. It is then straightforward to verify that

$$W_H^* < W_A^* < W_K^*.$$

Meanwhile, $X_A^* < b_E W_A^* < b_E W_K^* = X_K^*$. Also, $X_H^* = \max(b_E W_H^* - c, 0) \leq \max(b_E W_A^* - c, 0) \leq \max[A/(1-s) + b_E W_A^* - c, 0] = X_A^*$. That is,

$$X_H^* \leq X_A^* < X_K^*.$$

By inducing information acquisition, the firm earns an equilibrium profit higher than Π_K^* because it kills low-demand products by paying lower wages than (W_K^*, X_K^*). This equilibrium profit decreases with A since the wages increase with A.

A.4.3. The Optimal Contract to Prevent Information Acquisition. We first explore the optimal contract to prevent information acquisition and kill low-demand products. It can be shown that given the contract (W_K^*, X_K^*) the manager has no incentive to deviate and seek demand information iff $A \geq (1-s)c$. Meanwhile, unless $A < (1-s)c$, information acquisition cannot emerge in equilibrium. Therefore, when $A \geq (1-s)c$, the optimal contract to kill low-demand products is (W_K^*, X_K^*), which prevents information acquisition and yields a profit of Π_K^*. When $A < (1-s)c$, if the firm wants to prevent information acquisition and kill low-demand products, it earns no more than Π_K^* because the manager's information acquisition constraint is binding. Recall that the firm earns a higher profit than Π_K^* from inducing information acquisition. Therefore, when $A < (1-s)c$, if the firm wants to kill low-demand products, it will prefer to induce information acquisition.

It remains to derive the optimal contract to prevent information acquisition and continue low-demand products. The optimization problem is the same as the original "*NK*" problem except for the additional IC constraint that prevents the manager from seeking demand information:

$$\max \quad \Pi = s(aY - Z) + (1-s)(b_E Y - Z) - [sa + (1-s)b_E]W$$
$$\text{s.t.} \quad aW \geq X \quad (IC_1),$$
$$b_E W \geq X \quad (IC_2),$$
$$[sa + (1-s)b_E]W - c \geq s\max(b_D W, X) + (1-s)X \quad (IC_3),$$
$$[sa + (1-s)b_E]W - c \geq -A + s\max(aW - c, b_D W, X) + (1-s)\max(b_E W - c, X) \quad (IC_4).$$

Note that X must be zero in equilibrium; otherwise, the firm can lower X and improve profits. It follows that IC_1

and IC_2 hold with slack, and that IC_3 and IC_4 can be rewritten as

$$[sa+(1-s)b_E]W-c \geq sb_D W,$$
$$[sa+(1-s)b_E]W-c \geq -A+s(aW-c)+(1-s)(b_E W-c),$$
$$[sa+(1-s)b_E]W-c \geq -A+s(aW-c),$$
$$[sa+(1-s)b_E]W-c \geq -A+sb_D W+(1-s)(b_E W-c),$$
$$[sa+(1-s)b_E]W-c \geq -A+sb_D W.$$

The second and the fifth constraints are obviously redundant. The optimal success bonus is

$$W^* = \max[W^*_{NK}, [(1-s)c-A]/(1-s)b_E, (sc-A)/s(a-b_D)].$$

Therefore, $W^* \geq W^*_{NK}$, and W^* weakly decreases with A. It follows that by preventing information acquisition and continuing low-demand products, the firm earns an equilibrium profit no better than Π^*_{NK}. This equilibrium profit weakly increases with A.

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