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To push a customer and market orientation deep into the organization, many firms have adopted systems by which internal customers evaluate internal suppliers. The internal supplier receives a larger bonus for a higher evaluation. The authors examine two internal customer–internal supplier incentive systems. In one system, the internal customer provides the evaluation implicitly by selecting the percentage of its bonus that is based on market outcomes (e.g., a combination of net sales and customer satisfaction if these measures can be tied to incremental profits). The internal supplier's reward is based on the percentage that the internal customer chooses. In the second system, the internal customer selects target market outcomes, and the internal supplier is rewarded on the basis of the target. In each incentive system, some risk is transferred from the firm to the employees, and the firm must pay for this; but in return, the firm need not observe either the internal supplier's or the internal customer's actions. The incentive systems are robust even if the firm guesses wrongly about what employees perceive as costly and about how employee actions affect profit. The authors discuss how these systems relate to internal customer satisfaction systems and profit centers.

Internal Customers and Internal Suppliers

> In order to drive customer satisfaction with our customers, IBM employees need to be satisfied with the organization and strive to exceed their own internal customer expectations.
>
> —Brooks Carder and James D. Clark, "The Theory and Practice of Employee Recognition"

> [Metropolitan Life Insurance Company of New York] developed a comprehensive program of measuring the expectation of all its customers, including both external and internal [employee] customers.... only 25% [of the employees] are servicing the outside customer.
>
> —Valarie A. Zeithaml, A. Parasuraman, and Leonard L. Berry, *Delivering Quality Service*

> [At Weyerhaeuser] staff support departments such as human resources, accounting, and quality control have used "customer requirements analysis deployment" with line departments, such as sales, marketing, and branch production.... [internal] customers are then asked to rate the suppliers ... in meeting each of their requirements.
>
> —Donald L. McLaurin and Shareen Bell, "Making Customer Service More Than Just a Slogan

DEVELOPING A CUSTOMER ORIENTATION THROUGHOUT THE FIRM

In the 1990s, many firms believe that they will be more profitable if they can push a marketing orientation deep into the organization, particularly in new product development and research and development (R&D). In fact, these goals are the top-listed and top-ranked research priorities of the Marketing Science Institute (1992–1994). Implementing a marketing orientation (including employees and suppliers) remains one of Marketing Science Institute's three "capital" topics for 1994–1996. One aspect of this market orientation is to focus internal suppliers on serving their internal customer who, in turn, serves the external customers. To many firms, such internal suppliers are the next challenge in implementing a marketing orientation. The epigraphs refer to IBM, Met Life, and Weyerhaeuser, respectively; other examples include 3M, ABB, Battelle, Berlex, Cable & Wireless, Chevron, Corning, Hoechst Celanese, Kodak, Honda, and Xerox.[1] Marketing departments are often the internal customers of product development or R&D, though

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[1]Examples (in order) are based on studies by Mitsch (1990), Harari (1993), Freundlich and Schroeder (1991), Azzolini and Shillaber (1993); personal communication with Cable & Wireless, Chevron, Corning, Hoechst Celanese, and Kodak; and studies by Henke, Krachenberg, Lyons (1993) and Menezes (1991).

in some cases, the marketing department is the internal supplier that provides information on customer needs and requirements (Kern 1993). In most cases, marketing professionals are called on to help the firm develop a customer orientation for its internal suppliers.

In many of these firms, the internal customers evaluate the internal suppliers. For example, at an imaging firm, the internal customers evaluate their internal suppliers on both short-term and long-term profit indicators. At an automobile parts firm, the evaluations include measures that can be linked to the internal customer's ability to maximize the firm's profits. In some cases, the internal supplier's compensation is tied directly to the evaluations; in other cases it is tied indirectly with the more qualitative job performance evaluations. Whether the compensation is explicit or implicit, most internal suppliers recognize that, all else being equal, they are more likely to be rewarded if they are evaluated well by the internal customers.

There are at least two motivations for the internal customer–internal supplier evaluation systems. First, the goals of the internal suppliers may conflict with those of the firm. In addition to the usual problem that effort is costly to employees, internal suppliers may have different objectives than those of the firm. For example, one extensive study suggests that many R&D scientists and engineers focus on publication and discovery of knowledge rather than on facilitating the ability of the firm (through the internal customers) to maximize profit (Allen and Katz 1992). In another example, Richardson (1985) suggests that the R&D department works on the technologies it prefers rather than on the technologies needed by the business areas. Furthermore, these conflicting objectives are not limited to R&D groups (Finkelman and Goland 1990). Without incentives to the contrary, the research suggests that internal suppliers underprioritize their customer's (and the firm's) concerns.

Second, the internal customer often can evaluate the effects of the internal supplier's decisions, whereas management may not have the skill, information, or time to do so as effectively. For example, Henke, Krachenberg, and Lyons (1993) give an example of how an internal customer, the *interior trim team,* had better knowledge of how to solve a problem than did the overseeing product management team. This is especially true in R&D, where the decisions often require specialized scientific or engineering knowledge not possessed by top managers. (In some cases, top managers come from R&D, but this is the exception rather than the rule.) Thus, top management direction or involvement is difficult at best. On the other hand, internal customers, such as marketing groups that are affected by R&D's decisions about where to direct its actions and efforts, can often evaluate R&D better than top management.

Another factor, true in many but not all cases, is the significant time lags between the decisions made by the internal supplier and the market outcomes. For example, McDonough and Leifer (1986) suggest that planning and monitoring techniques rarely work for R&D teams, because commercial success is often not known for five to ten years. In these cases, it may be better to reward the internal supplier on the basis of an internal customer's evaluation than on the basis of market outcomes. Although the time lag for the internal customer may be less than that for the internal supplier, it could still be significant. In this case, the internal customer might, in turn, be rewarded on the basis of an evaluation by its downstream customer. Alternatively the firm might choose to use other indicators that measure whether the internal customer is making the decisions that are best for the firm (for one example, see Hauser, Simester, and Wernerfelt 1994).

We formulate the problem in terms of a marketing group as the internal customer and an R&D group as the internal supplier. For example, R&D might supply the technology that the marketing (or product development) group uses to develop a new product, or R&D might supply a more developed product that the marketing group must then sell to the external customer.

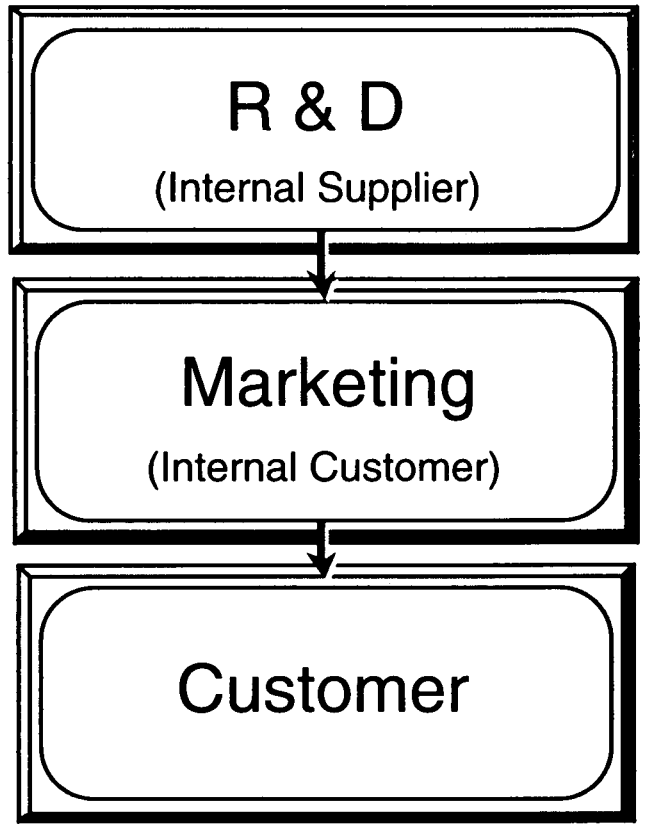
Although internal customer evaluation systems are popular, they are not always easy to implement. One issue is that internal customers may have a tendency to report favorably on their colleagues. In fact, internal suppliers might reward such behavior with various perks to the internal customer. Starcher (1992) gives an example in which the internal supplier faced an aggressive goal to reduce the number of defects found by the internal customer. The internal customer found fewer faults, but only because it allowed more defects to be passed on to the final assembly group. This was costly to the firm because it required more rework (for many other examples, see Zettelmeyer and Hauser 1995).

The temptation for increasing an evaluation is greater if there is no cost to the internal customer for providing a higher evaluation. For example, Zettelmeyer and Hauser (1995) report many examples in which internal customers give uniformly high evaluations if the internal customer provides an evaluation on a one-to-five scale, if the internal supplier is told the evaluation it receives (by whom), and if management never questions any of the internal customer's evaluations. This temptation to provide high evaluations might be counteracted if there is some cost to the internal customer for providing a higher evaluation. This might be as simple as management questioning a history of "all fives"; it might take the form of management holding the internal customer to higher standards if the internal customer reports that it gets uniformly good input from its suppliers (i.e., gives all fives); or it might be formalized.

We examine two reward systems that use internal customer evaluations. The essential idea underlying both of the incentive schemes is that the internal customer need not evaluate the internal supplier by providing a written evaluation. It can reveal its evaluation of the internal customers by selecting the parameters of its own reward function.[2] Both systems provide incentives to both marketing and R&D groups such that, acting in their own best interests, each chooses the actions that the firm would choose to maximize firm profits if it had the information and ability to do so directly and had to reimburse employees only for their costly actions (as if the employees bear no risk). These systems share the properties of using simple-to-specify reward functions and being relatively robust to errors that the firm might make in selecting the parameters of the reward functions. We are interested in simple systems because they are more

[2]Systems in which an agent selects parameters of its incentive system have been used in sales force compensation (Basu et al. 1984; Lal and Srinivasan 1993; Mantrala and Raman 1990).

Figure 1
CONCEPTUAL REPRESENTATION



likely to be implemented than more complicated systems and/or systems that are more sensitive to the parameters of the reward functions.[3] Although the two systems share many properties, they have distinct interpretations and thus provide two alternatives that firms can choose.

A FORMAL MODEL

We consider two employee groups and one group of external customers. This suffices to illustrate the basic points. For simplicity we call the internal supplier "Research and Development," label it as R, and refer to it as the upstream employee group. We call the internal customer "Marketing," label it as M, and refer to it as the downstream group (see Figure 1).

Research and Development (R) expends effort, r. This r refers to the time and energy R expends to identify, discover, or improve technology that M, in turn, uses to develop products for customers. Effort (r) also refers to decisions that R might make, which R views as costly because the decisions conflict with R's personal objectives. This effort (r) is incremental above and beyond the effort R must allocate in the absence of an internal customer–internal supplier incentive system. It is important to think of r as costly effort. Research and Development (R) may work long hours, but if part of the time is on-the-job consumption that conflicts with the needs of the firm, then r may be less than the long hours would suggest. For example, Allen and Katz's (1992) and Richardson's (1985) studies (as well as our own experience) suggest that R prefers those technologies that are new, interesting, and lead to peer recognition and patents. These technologies may conflict with the needs of the internal customer. Research and Development's (R) efforts, r, might include the time and energy necessary to understand M's needs beyond that which R would otherwise allocate. We represent the perceived costs to R as $c_R(r)$, where c_R is thrice differentiable, increasing, and convex. Because the costs are incremental, we normalize $c_R(0) = 0$. Formally, we assume that after R chooses and expends r, M can observe r, but top management (the firm) cannot. For example, consider a situation drawn from our experience with the R and M divisions at a major oil company: R was working on the problem of getting more information to M from remote oil fields. In this situation, M (but not top management) might be able to evaluate whether R's new data compression algorithm allows enough information to be transferred so that M can meet its customer's needs.

Marketing (M) uses the technology that R develops and expends its own incremental effort, m, to serve the customers. We define m to represent incremental and costly efforts, actions, and decisions. (Henceforth, we simply call m, *efforts*.) We represent the perceived costs to M as $c_M(m)$, where c_M is thrice differentiable, increasing, and convex. We normalize $c_M(0) = 0$. If R expends more effort, r, then M finds that its own efforts, are more effective. For example, a better data compression algorithm might enable M to provide better service to its customers. However, M must also expend costly effort to provide that better service. The firm does not observe m directly.

We assume that the firm observes an indicator of the profits that it obtains from the actions of R and M. It uses this profit measure as a (noisy) indicator of r and m. In our example, the firm might observe the increase in profits (more oil recovered, reduced costs) due to the new data transfer system. That is, the firm might compare the profits it now obtains with those it would have obtained using the old data transfer system. (Here we assume the firm can account for other effects on the profitability of the remote oil field.)

In practice, this profit indicator can take many forms. Zettelmeyer and Hauser (1995) report that one firm uses measures of quality, cost-effectiveness, timeliness, communications, and satisfaction from the (external) customer as an indicator of profits from r and m. They also report that another firm uses downstream production cost, labor cost, quality cost, and production investments as indicators of the effect of r and m on short- and long-term profit. If we are to use these measures as proxies for incremental profit, we must assume that the r and m that maximize these indicators (net of cost) are the same values of the r and m that maximize incremental profit.

[3]In the language of agency theory, we seek *first-best* actions. However, because we allow noise in outcomes (and implied noise in the agents' rewards) and agents to be risk averse, agency theory recognizes that the firm may need to reimburse agents for any additional risk that the incentive system imposes on them. The actions that minimize the net of profits minus this extra compensation are called the *second-best* actions. First-best actions may not be optimal in a second best world. However, the definition of *second best* does not consider the administrative costs of extremely complex systems. The definition also assumes that the parameters of the reward systems, no matter how complex, can be set exactly. Thus, we sacrifice some additional compensation costs to obtain systems that are simple, easy to implement, and robust with respect to errors the firm might make in selecting parameters.

Hauser, Simester, and Wernerfelt (1994) provide another example. They demonstrate that if the internal customer maximizes a weighted sum of (external) customer satisfaction and sales (net of costs) then the internal customer chooses the efforts that maximize the firm's long-term profits. In their case, we would use a weighted sum of satisfaction and sales (net of costs) as a proxy for the incremental profits due to r and m (see also Anderson, Fornell, and Lehmann 1994). For our purposes here, we only need the firm to be able to observe some measure that indicates the incremental impact of r and m on the firm's profits. For simplicity, we call this outcome measure *profits,* or $\breve{\pi}(r,m)$. We assume that the firm can scale the measure (or combination of measures) in the units of currency so that it represents the incremental contribution to profits from R and M.

Because no measure is perfect, we model the error it introduces. We write the measure as equal to its mean, $\pi(r,m)$, plus zero-mean and normally distributed noise,[4] e. That is,

$$\breve{\pi}(r,m) = \pi(r,m) + e, \tag{1}$$

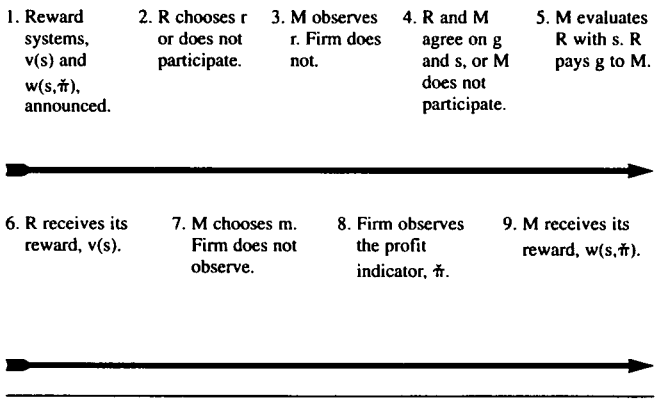
where $e \sim N(0, \sigma^2)$; π is thrice differentiable, increasing, and concave in both arguments; and $\sigma^2 > 0$. We model the risk-neutral firm as using the expected value of $\breve{\pi}$ in the profit-maximization equation that relates to R and M. (The expected value is π.)

After observing r, M chooses an evaluation, s, that indicates to the firm how it values r. (We subsequently use s_1 and s_2 to distinguish between the two reward systems we analyze.) We use s as a mnemonic device because we think of this evaluation as an indicator of how well the internal supplier *satisfies* the internal customer. However, s may not be measured on a typical satisfaction scale. In both of our reward systems, we allow the interpretation that the firm infers s from M's choice of reward functions.

Marketing (M) chooses s before selecting m, but M anticipates how it will set m. That is, M evaluates R and does so anticipating how it will use R's output to serve M's customers. For example, M might choose its bonus plan, and hence evaluate R, after observing a demonstration of the data compression algorithm. Marketing (M) would do so, anticipating how it would use that algorithm to serve its customers and knowing that s affects its own rewards. (Technically, we also could have stated the sequence as M choosing s simultaneously with m, because no one except M observes m directly. Subsequently, we modify this sequence of events to enable R and M to cooperate on the selection of s; see Figure 2.)

After observing s, the firm gives a reward, v, to R that depends on s. We write this function as v(s). At a later time, the firm observes the profit measure, $\breve{\pi}$, and provides a reward, w, to M that depends on this measure and M's choice of s. We write this function as $w(s,\breve{\pi})$. We restrict our attention to incentive systems with integrable and thrice differentiable[5] v and w, which are concave in s. In keeping with the managerial statement of the problem, we consider rewards to R that are larger for higher implicit evaluations (increasing in s). We also want s to be an indicator of r's effect on π; thus, we restrict our attention to w such that $\partial w^2/\partial r \partial s > 0$.

Figure 2
ORDER OF ACTIONS IN FORMAL REPRESENTATION
(COOPERATION ALLOWED)



It is convenient to think of v and w as monetary rewards; however, they need not be. Any set of rewards that R and M value and for which the firm must pay would be appropriate, including new equipment, training, recognition, and awards (Feldman 1992; Mitsch 1990). For simplicity, we assume that the amount that the firm pays is equal to the value that the employee group receives.

We assume that the firm is risk-neutral and profit maximizing and that both R and M act in their own best interests to maximize their expected utilities. We assume that both R and M are risk averse and that perceived costs to R and M are measured on the same scale as are rewards.[6] The utilities, U_R and U_M, are

$$U_R(s,r) = U_R[v(s) - c_R(r)] \tag{2a}$$

and

$$U_M(s,\breve{\pi},m) = U_M[w(s,\breve{\pi}) - c_M(m)], \tag{2b}$$

where U_R and U_M are integrable, thrice differentiable, increasing, and concave.

We assume that the net utilities, $\underline{U}_R$ and $\underline{U}_M$, required by R and M to participate are set by the market—that is, by the other options that R and M have available. (If there are any switching costs favoring the firm, then these are included in the definition of $\underline{U}_R$ and $\underline{U}_M$.) Thus, the total expected utility of R's and M's rewards minus their costs for allocating r and m and reporting s must exceed $\underline{U}_R$ and $\underline{U}_M$. We normalize the utility functions such that they imply that (riskless) market options for R and M are equal to zero. (If the market options have risk, then they must be such that R and M consider them equivalent to a riskless option that is scaled to zero.) In its maximization of expected profits, a risk-neutral firm attempts to set the expected utility to each employee

[4]We here assume normally distributed error because that enables us to derive analytical expressions for linear and quadratic reward systems. Our propositions also apply to the special case of no error. We expect that the qualitative concepts apply, at least approximately, for more general error distributions. See example approximations in Wernerfelt, Simester, and Hauser's (1996) study.

[5]These functions are integrable and thrice differentiable, except at boundaries imposed by any external constraints imposed on s.

[6]The choice of a scaling constant is a nontrivial practical problem. We subsequently address the sensitivity of outcomes to the choice of parameters of v and w.

group just above $\bar{U}_R$ or $\bar{U}_M$ if, by doing so, it can earn nonnegative profits. For example, the oil firm would select v and w such that R and M are willing to develop and use a new data compression algorithm rather than continue to serve the customer with the old system. Recall that the practical problem requires that the oil firm do this without knowing the technical details of compression algorithms.

We summarize the sequence of moves described so far:

1. The firm announces an internal customer–internal supplier incentive system, v(s) and w(s,π).
2. R chooses its actions, r, or does not participate.
3. M observes R's actions, but the firm does not.
4. M chooses s or does not participate.
5. R is rewarded based on v(s).
6. M chooses its actions, m, but the firm can not observe these actions.
7. The profit indicator, $\breve{\pi}$, is observed and the firm pays w(s,$\breve{\pi}$).

This sequence of moves is a well-defined contracting problem, and we could, in principle, evaluate the performance of alternative v's and w's. In this contracting problem, with noise and risk aversion, simple contracts do not do well. The firm can do better by tying pay to performance than by just paying a fixed salary.

In the formal contracting problem, we focus on one set of actions, r and m. In practice, the firm would not reset v and w for every decision that R and M must make. The firm might set v and w such that they apply to repeated interactions between R and M. We do not solve this problem formally. However, we show that our incentive schemes are robust with respect to the specifics of π, c_M, and c_R; hence, it is likely that the key parameters of v and w do not need to be set for every interaction. We formalize this robustness issue subsequently.

RESEARCH AND DEVELOPMENT MIGHT REWARD MARKETING TO CHANGE ITS EVALUATION

Internal customers might have more opportunities to interact with internal suppliers than do outside customers.[7] Hence, they might cooperate in setting s. We illustrate the concept of *cooperation*[8] with an example between a salesperson and the external customer. A colleague recently purchased an automobile. As part of the delivery transaction, our colleague was asked to complete a customer-satisfaction survey. He did so to the best of his ability. After looking at the customer's ratings, the salesperson said that the ratings were unacceptable and that he would be fired if the ratings were not increased. Our colleague agreed to increase the ratings, but in return for a year of routine maintenance paid for by the salesperson. The salesperson agreed, and the ratings were increased. We spoke to an executive vice-president of the consulting firm that designed the ratings-based bonus system that gave the salesperson a monetary bonus for a high rating. The executive vice-president said that the automobile company was aware that instances such as the one with our colleague might happen. The automobile company wanted satisfied customers (in the delivery transaction) and was willing to pay for them. In the long run, the company hoped that the salesperson would find other methods of satisfying the customer—methods that the salesperson would find less onerous than sharing his or her bonus with the customer. If the salesperson became more efficient in satisfying the customer, this would create surplus that, depending on a future reward system, might be shared among the customer, the salesperson, the dealership, and the automobile company.

More recently, one of us purchased a new car. Not only did the sales manager instruct the customer on how to complete the customer-satisfaction questionnaire and imply that his access to supply depends on the ratings, but he sent the customer an expensive gift the day prior to the completion of the satisfaction questionnaire. (We were told that the manufacturer allocated a supply of this popular car to dealerships on the basis of the ratings. Presumably the dealership found it more efficient to increase customer satisfaction with this gift than with other forms of service. Certainly, the customer was satisfied.) We presume that, similar to the salesperson example, the automobile company hopes that, in the long run, the dealership will find other, more efficient ways to satisfy the customer.

Managers and reward systems consultants have indicated to us that they believe that modest sharing of rewards is common in internal customer–internal supplier systems. For two documented cases see Gouldner's (1965) account of a small gypsum mine and Sidrys and Jakštaitė's (1994) account of the Lithuanian university system. See also a *Boston Globe* (1994) editorial applauding frequent flyer programs.

We now analyze cooperation with the formal model. To simplify the analysis, we follow Tirole (1986) and assume that R and M find a way to make a binding agreement exchanging goods or services that are valued at g in return for a higher evaluation. The enforceability of the agreement could come from expected future interactions between R and M or from social norms (e.g., in Sidrys and Jakštaitė's [1994] data, agreements occur more often with local instructors than with foreign instructors). In the agreement, we note that the assumption is that R and M can cooperate on s but not on r. (The effort, r, has already been set.) The payment, g, cannot be contingent on $\breve{\pi}$. In situations in which R and M can cooperate directly on r as well as on s, this assumption restricts the domain of our analysis. However, we believe that this assumption is an important starting point and applies to most of the situations we have observed. We find that it is much harder to monitor agreements about average effort over a month (including detailed technology decisions) than it is to monitor agreements about a single performance evaluation. We leave cooperation on r to further research. Thus, formally, we augment the sequence of events such that R and M can make a binding agreement,

[7]The ability of R and M to cooperate on s depends on there being a small number of evaluators for any given evaluatee. If the number of evaluators is large, for example, hundreds, then it is likely to be too costly for the evaluatee to seek out every evaluator, and the cost imposed on the evaluator for providing a higher evaluation would be small. Such systems look more like traditional (external) customer satisfaction systems. For a discussion of the mechanisms by which R and M groups communicate and cooperate, see Griffin and Hauser (1992, 1996).

[8]For the remainder of the article, we use the more positive term *cooperation* rather than the negative term *collusion*. Although the latter term is more common in the economic literature, it has implicit connotations that go beyond those we wish to discuss here. Indeed, if the firm can anticipate how R and M might cooperate in setting s, they might factor this into the reward system. In any case, we define precisely what we mean by cooperation and derive what cooperation implies for how R and M interact. We return to this issue in the final section.

(g,s), after M has observed r but before M has selected s (see Figure 2).

The gains (if any) from the agreement can be split in many ways between R and M. To simplify the exposition we model the split as a take-it-or-leave-it offer of (g,s) from R to M. This means that M receives only as much as is necessary to induce M to report the agreed-upon s. This assumption does not affect the qualitative interpretations. We could derive similar results for other sharing mechanisms.

We define $\hat{m}$ and $\hat{s}$ as the efforts and evaluation that M selects to maximize U_M for a given r with no cooperation. For concave $U_M(\cdot)$, this maximization of expected utility by M defines three continuously differentiable functions, $\hat{m}(r)$, $\hat{s}(r)$, and $\hat{\pi}(r)$. That is, after R selects r, these functions tell us the efforts, $\hat{m}$, and evaluation, $\hat{s}$, that M would select if cooperation were precluded. Now suppose that for a given r, R wants to influence M to choose another $\tilde{s}$ that is more favorable to R. This $\tilde{s}$ implies an $\tilde{m}(r,\tilde{s})$ that maximizes M's expected utility, given r and $\tilde{s}$. It also implies a $\tilde{\pi}(r, \tilde{m})$. (Note that $\tilde{m}$ may differ from $\hat{m}$, and $\tilde{\pi}$ may differ from $\hat{\pi}$ if $\tilde{s}$ differs from $\hat{s}$.) To influence M to select $\tilde{s}$, R must give M an amount, g, that at least compensates for M's loss. This means that M's expected utility with an agreement, $(g,\tilde{s})$, must at least equal the expected utility that M could obtain without accepting g. Thus, the minimum g that M will accept is defined by Equation 3.

$$(3)\quad EU_M[w(\tilde{s}, \tilde{\pi}) - c_M(\tilde{m}) + g] = EU_M[w(\hat{s}, \hat{\pi}) - c_M(\hat{m})]$$

Research and Development (R) has no incentive to give more than this g in return for $\tilde{s}$, thus R will attempt to get g down to that defined in Equation 3, and M will try to get g up to that defined in Equation 3. Thus, Equation 3 defines a critical value of g for every r. We write this critical value as g(r). Research and Development (R) wants to maximize its own well-being. That is, R will select $\tilde{r}$ and $\tilde{s}$ to maximize its own expected utility:

$$(4)\quad EU_R[\tilde{s}, \tilde{r}] = EU_R[v(\tilde{s}) - c_R(\tilde{r}) - g(\tilde{r})],$$

where g is implied by Equation 3 and $\tilde{m}$, $\hat{m}$, and $\hat{s}$ are implicit in M's maximization problems.

In summary, R maximizes the expression in Equation 4 subject to the constraints imposed by the two maximization problems that define Equation 3. The right-hand side of Equation 3 describes what M would do if there were no cooperation, and the left-hand side of Equation 3 describes what M would do if cooperation were allowed. Naturally, both sides of Equation 3 must be at least as large as that which M could obtain by not participating. Equation 4 must be at least as large as that which R could obtain by not participating (R must consider M's participation because it cannot get $\tilde{s}$ if M does not participate). The firm is interested in maximizing its profits, so it will attempt to select v and w such that it gets the efforts it wants and does not pay R and M more than is necessary. Once the firm specifies v and w, these constraints and maximization problems are sufficient to solve for $\tilde{r}$, $\tilde{m}$, $\tilde{s}$, $\hat{m}$, $\hat{s}$, and the implied $\tilde{g}$ and $\tilde{\pi}$.

We now use this structure to examine two different reward systems. We study these reward functions because they are simple and relatively robust with respect to errors the firm might make in selecting the reward functions. We anticipate that the firm would choose the system that best matches its culture.

TWO PRACTICAL INTERNAL CUSTOMER–INTERNAL SUPPLIER INCENTIVE SYSTEMS

Our analysis of these reward systems is driven by the managerial problem faced by R and M—selecting the "right" technology. For example, Zettelmeyer and Hauser (1995) report that chief executive officers and chief technical officers are more concerned that R and M select the right technology than they are about minimizing the extra incentives for which they must pay R and M for any risk that the incentive system imposes on R and M. (Chief executive officers and chief technical officers are concerned about incentive system costs and would like to keep them small, but this appears to be a less critical problem than providing the incentives for the right technology.) Thus, in our analyses, we focus on reward systems that provide R and M with the incentives to select those actions, r^* and m^*, that maximize the (risk-neutral) firm's expected profits if it had the power and knowledge to dictate actions, observe actions, and reimburse employees only for their costly actions (as if the employees bear no risk). That is,

$$(5)\quad r^* \text{ and } m^* \text{ maximize } \pi(r, m) - c_M(m) - c_R(r).$$

For each of the two reward systems that we study, we seek those particular v's and w's that cause R and M to select r^* and m^*. In the language of agency theory, r^* and m^* are called the *first-best actions.*

Although we concentrate on r^* and m^*, we cannot neglect the costs that risk in the incentive system imposes on R and M. Because the internal customer–internal supplier systems force risk-averse employees to accept risk, the firm must reimburse those employees for accepting that risk. The amount that the firm must pay is called a *risk penalty.* We compute the implied risk penalty and show how the parameters of the reward functions affect that risk penalty. The firm can then select the reward system and parameters (from the two systems we analyze) to minimize risk costs. Alternatively, it can weigh these costs against the ease of implementing the reward system.

The analysis of the problem of choosing incentive systems for risk-averse agents whose actions are unobservable is a topic in agency theory (Holmstrom 1979). One benchmark in agency theory, called the *second best,* is to seek optimal incentive systems that maximize the net of profits minus the risk penalty. According to this benchmark, it may not be optimal to have agents choose r^* and m^*. Thus, our systems might not lead to optimal profits as defined by agency theory.[9] On the other hand, optimal solutions are often extremely complicated and sensitive to model specification (Hart and Holmstrom 1987). However, the definition of *optimal* does not take into account that complex systems might impose administrative costs or that complex systems might be confusing for real employees and hence lead to nonrational actions that neither maximize employee utility nor firm profits. Our systems are less likely to impose such costs because they are simple and robust.

[9]For the case of no noise in profits and/or risk-neutral employees, our systems are optimal. For the case of low risk (as implied by noise and risk aversion), our systems are close to optimal.

To simplify exposition, we conduct our analyses in the context of employee groups with constant (absolute) risk-averse utility functions (Keeney and Raiffa 1976). That is,

$$U_R = 1 - e^{-\rho(v - c_R - g)}. \quad (6a)$$

$$U_M = 1 - e^{-\mu(w - c_M + g)}. \quad (6b)$$

Variable Outcome-Based Compensation Systems

We begin with one of the simplest specifications of v and w—linear functions of s. Linear functions provide a valuable starting point (and a useful benchmark) and, in single-agent problems, have proven to be robust (Holmstrom and Milgrom 1987; Lilien, Kotler, and Moorthy 1992). We begin by stating the general form (Equation 7) and then derive a set of parameter values that provide incentives to R and M such that they select r^* and m^*. Formally, the variable outcome-based compensation system is given by the following functions, where y_o, y_1, z_o, z_1, and z_3 are constants chosen by the firm.

$$\text{(7a)}\quad R: \quad v(s_1) = y_o + y_1 s_1;$$

$$\text{(7b)}\quad M: \quad w(s_1, \pi) = z_o + z_1(1 - s_1) + z_3 s_1 \tilde{\pi}, \quad s_1 \in [0, 1]$$

That is, after observing r and anticipating m, M is asked to evaluate R on a scale from 0 to 1. This evaluation determines the portion of its compensation that is determined by incremental profits. The remaining portion of M's bonus is fixed. (In an alternative interpretation, M is simply asked to select the percentage of its compensation plan that is based on incremental profits, and the firm interprets M's selection as an implicit evaluation of R.) We call this system the *variable outcome-based compensation system* because the implicit evaluation, s, determines how much of M's bonus depends on the (variable) incremental profit.

In other words, if $s_1 = 1$, then M receives its fixed bonus, z_o, plus a bonus proportional to the profit indicator, $z_3\tilde{\pi}$. On the other hand, if $s_1 = 0$, then M receives only a fixed bonus, $z_o + z_1$. For intermediate s_1, the portion is determined by s_1. (We could also specify s_1 as a percentage.) Intuitively we link this implicit evaluation, s_1, to R because if R does its job well, then M will prefer to be rewarded on the profit indicator; and if R does its job poorly, then M will prefer the guaranteed bonus. The firm attempts to select the parameters of the functions so that R and M choose r^* and m^*. (To participate, R and M are compensated for their efforts and any risk they must bear.)

The variable outcome-based compensation system is a formalization of the linear reward systems—popular in marketing and Total Quality Management—that we have seen in practice. If that evaluation is an internal customer satisfaction rating, if there is some cost to M in providing that rating, and if R's and M's bonuses are linear in M's rating, then the following proposition gives us formal tools with which to interpret and improve internal customer satisfaction systems:

> P_1 (variable outcome-based compensation): For z_1 and y_1 above critical values and for $z_3 = 1$, the variable outcome-based compensation system gives incentives to R and M such that, acting in their own best interests, they select r^* and m^*.

The proof and the critical values are in the Appendix.[10] The basic idea is that if z_1 is above a critical value, then M, in the absence of cooperation, will set $\hat{s}_1 = 0$. If y_1 is above its critical value, R has sufficient incentive to provide g to M in order to obtain $\tilde{s}_1 = 1$. Research and Development (R) wants to keep g as small as possible, and keeping g small coincides with selecting r^* and m^*.

For P_1, we can compute g. In addition, because M and R bear risk, we can compute the risk penalty that the firm must pay. To compute this penalty we recognize that, in the solution to Equation 5, the firm would only need to pay R and M for their effort costs, $c_R(r^*)$ and $c_M(m^*)$. The risk penalty is the amount by which v + w exceeds the sum of these costs. Thus, with algebra we obtain

$$g = z_1 - \pi^* + c_M^* + \mu\sigma^2/2, \quad (8a)$$

$$\tilde{s}_1 = 1, \quad (8b)$$

and

$$\text{Risk Penalty} = \mu\sigma^2/2. \quad (8c)$$

The firm can make the g small by selecting a z_1 close to its critical value, but the risk penalty is not affected by z_1 and y_1. The risk penalty implied by this system is equal to that which the firm would incur by transferring all risk to M. (We subsequently investigate a system with a smaller risk penalty.)

With the parameters of P_1, the optimization implies the extreme value solution, $z_3\tilde{s}_1 = 1$. That is, M's compensation becomes a constant plus $\tilde{\pi}$. Thus, in equilibrium, the firm offers M the opportunity to accept responsibility for the incremental outcome, $\tilde{\pi}$, and M accepts this responsibility by choosing $\tilde{s}_1 = 1$. Research and Development (R) is rewarded whenever M gives an evaluation that indicates that M accepts this responsibility. This system gives R the incentives to provide r and g so that M will accept the responsibility.

Transferring responsibility to M is similar in some ways to a mechanism that the agency-theory literature (e.g., Milgrom and Roberts 1992, pp. 236–39) calls "selling the firm to the agent." However, in our case, M becomes the residual claimant only for the *incremental* outcomes of r and m and only for this interaction. The firm retains responsibility for those outcomes (other than the measurement error) that do not depend on r and m. Although the actions and outcomes are the same as making M the residual claimant for the incremental outcomes of r and m, we have found that many managers find a linear evaluation system more reasonable than "selling the firm." The latter, perhaps unintentionally and inadvertently, implies transferring assets, future responsibility, and future rights for global rather than incremental actions. Interpreted with this perspective, the system

[10]The parameters in P_1 cause M to report $\tilde{s}_1 = 1$. Under some special conditions, the firm can choose an alternative parameterization such that the reported s_1 is at an intermediate value. The conditions (for $r = r^*$) require that the risk, $\mu\sigma^2/2$, be so large that $\pi - c_M - \mu\sigma^2/2$ is smaller at m^* than $\pi - c_M$ is at $m = 0$, that is, when M's function is primarily that of a supervisor for R. This alternative parameterization retains the profit-center and residual claimant interpretations but is not as robust as that in P_1. Also, in the special case of a *constrained* linear w with no noise, it is possible to choose a set of parameters such that the firm maximizes profits without collusion. Proofs of both results are available from the authors.

in Equation 7 is a practical means to implement a profit center–like approach.

The profit center relationship may be a new perspective. For example, Harari (1993) argues that internal customer satisfaction systems should be abandoned and replaced with profit center systems. We have spoken to many managers who are strong advocates of internal customer–internal supplier systems. None have described such systems as a means to implement a profit center. Finally, and we discuss this subsequently, the variable-compensation system is surprisingly robust.

Target-Value Compensation Systems

We now introduce nonlinearity into the system by making M's rewards a nonlinear function of s. Specifically, we select a quadratic function of $s - \breve{\pi}$. The linear and quadratic functions are not the only functional forms for w that will yield r^* and m^*, however they suffice to illustrate many of the principles of internal customer–internal supplier incentive systems. Each has a different, but practical, interpretation. Our experience suggests that firms are more willing to use simple than complex functional forms in compensation systems (see also Lilien, Kotler, and Moorthy 1992).

Formally, the target-value system is given by the following functions:

$$\text{(9a)} \qquad R: \qquad v(s_2) = v_0 + v_1 s_2,$$

and

$$\text{(9b)} \qquad M: \qquad w(s_2, \pi) = w_0 - w_2 (s_2 - \breve{\pi})^2,$$

where v_0, v_1, w_0, and w_2 are constants chosen by the firm. That is, after observing r and anticipating m, M selects a target value, s_2, for the profit indicator, $\breve{\pi}$. Marketing (M) receives its maximum bonus if the realized profit indicator, $\breve{\pi}$, equals the target and is penalized for deviations from the target. Note that the target-value function penalizes targets that are set too high *and* too low. We have discussed this concept with managers at commercial banks, computer manufacturers, imaging firms, chemical companies, oil companies, and automotive companies. In each instance, they found the idea of a target-value system appealing and believed that the benefit of an accurate target could outweigh concerns about penalizing an employee group for exceeding its target. The target-value concept is similar to Gonik's reward functions (Gonik 1978; Mantrala and Raman 1990) used in sales force compensation. (Gonik reward functions encourage salespeople to make accurate forecasts by penalizing them for selling more or less than the targets they set.[11])

P_2 (target value): For $v_1 = 1$ and $0 < w_2 < 1/(2\mu\sigma^2)$, the target-value compensation system gives incentives to R and M such that, acting in their own best interests, they select r^* and m^*.

[11]Gonik reward functions use absolute deviations rather than quadratic deviations and apply to a single agent rather than to an internal customer–internal supplier dyad. By comparing the linear and quadratic systems, we see that quadratic functions can provide lower risk penalties. Gonik absolute-value functions share the "make-or-break" properties of the linear system. For the riskless case, it is possible to prove P_2 for any concave function of $(s_2 - \breve{\pi})$ with a finite maximum.

The proof in the Appendix is constructive. We first compute rewards for R and M that are implied by Equation 9. We use Equation 3 to compute the implied g. We use this g in Equation 4 to compute R's net rewards. After these substitutions, we maximize Equation 4 subject to the constraints imposed by Equation 3. This yields the equations for the goals of R and M. We show that these goals yield the same solution as Equation 5—the firm's goals. Finally, we set v_0 and w_0 so that both R and M get sufficient rewards so that they prefer participating to not participating.

To get an intuitive feel for how the target-value function works, notice that, in the absence of cooperation, M would want to minimize the expected deviation of s_2 from $\breve{\pi}$ and, hence, set s_2 equal to π. Because $v_1 = 1$, R's rewards are then proportional to π. With a positive g, R can get M to increase s_2 slightly. This makes R's rewards sensitive to M's costs. When w_2 is set in the given range, R's incentives are maximized at r^* and m^*.

It should not be surprising that we can find a family of nonlinear reward functions, v and w, that yield r^* and m^*. There are a limited number of first-order equations implied by the firm's optimization. Many functional families have enough parameters so that these equations can be solved; however, some simple functional families, like constant rewards, do not. P_2 shows that a quadratic system, which has an intuitive interpretation in terms of targets, has sufficient parameters. General families may not be as simple or robust. (We analyze the robustness of P_2 in the subsequent section.)

Using the parameters of P_2 as a basis, we compute g, the implied evaluation, and the risk penalty.

$$\text{(10a)} \qquad g = c_M(m^*) + 1/(4 w_2) - \mu \sigma^2/2$$

$$\text{(10b)} \qquad \tilde{s}_2 - \pi^* = 1/(2 w_2) - \mu \sigma^2$$

$$\text{(10c)} \qquad \text{Risk Penalty} = -(2\mu)^{-1} \log(1 - 2\mu \sigma^2 w_2) + (\mu \sigma^2/2)(1 - 2\mu \sigma^2 w_2)$$

First, note that when there is no noise ($\sigma^2 = 0$), there is no risk penalty; but g is still positive, and the reported target exceeds the amount that M will achieve. (The condition on w_2 is required for other reasons, but it also assures that g exceeds M's costs and the evaluation exceeds the target profit.)

Second, note that both g and the risk penalty depend on the firm's choice of w_2. If the firm chooses w_2 close to its upper bound, then it can make g smaller, but its risk penalty increases. Thus, for the target-value system, there is an inherent tension between g and the risk penalty. Suppose that we make M's penalty for misforecasting small ($w_2 \to 0$). Then, g becomes large, the distortion in the evaluation (s_2 versus π) becomes large, and the risk penalty approaches what the firm would have incurred had it transferred all risk to M. (If M bore all the risk, its risk premium would be $\mu\sigma^2/2$.) In other words, in systems in which there is only mild social pressure for M to get the forecast right (w_2 is small), selected targets are much larger than achievable targets, g is large, and the firm incurs a larger risk penalty.

For $\mu\sigma > 1$, the risk penalty can be minimized for a w_2 between the extremes, and this minimum is less than

$\mu\sigma^2/2$.[12] In repeated situations, the firm might get to that minimum by trial and error, but in the formal game, it needs to know M's risk aversion coefficient and the noise in the profit measure. For $\mu\sigma \leq 1$, the firm can still get r^* and m^*, but the risk penalty exceeds $\mu\sigma^2/2$.

SENSITIVITY

Both of the incentive systems that we have examined share the property that if the firm sets the constants, v_o and w_o or y_o and z_o, too low, either M or R (or both) will choose not to participate (if they are well informed). If the firm sets these constants too high, either M or R (or both) will be overpaid. This property is not unique to the systems we study here.

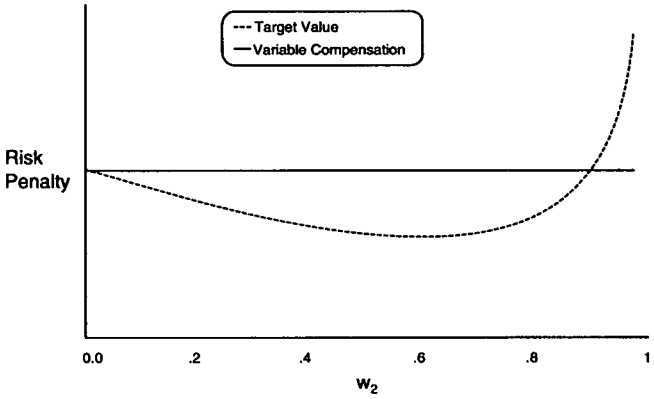
In the formal game, the firm must know such values as π^*, $c_M{}^*$, $c_R{}^*$, μ, σ^2, and $\pi(r^*,0)$ to set the fixed components of compensation, v_o and w_o or y_o and z_o. This conceptual problem is shared with all incentive systems.

However, to implement the variable outcome-based compensation system or the target-value system, the firm must do more than select the fixed components of compensation. It also must select the coefficients that determine how compensation varies as a function of the actions and evaluations. In the linear system, the firm must select the relative coefficient, z_1/z_3, that sets the trade-offs that M must make between compensation that depends on outcomes and compensation that is guaranteed. The firm also must set the coefficient, y_1, that determines how R is rewarded on the basis of s. In the quadratic system the firm must select the coefficient, w_2, that penalizes M for deviations from its target. (Recall $v_1 = 1$.) We now examine the sensitivity of the compensation systems to these variable parameters.

We have already shown that the variable compensation system is not sensitive to z_1 and y_1 as long as they are above their critical values and that the target-value system is not sensitive to w_2 as long as it is within a reasonable range. We state these facts as corollaries for emphasis. (The proofs are obvious by recognizing the conditions of P_1 and P_2, but for completeness are given in the Appendix.) In Corollary 1, $y_1{}^o$ and $z_1{}^o$ refer to parameters just above the critical values in P_1. In Corollary 2, $w_2{}^*$ refers to the w_2 that minimizes the risk penalty.[13] The firm may have a hard time setting $w_2{}^*$ because it needs to know μ and σ^2 to select this value.

Corollary 1 (variable outcome-based compensation sensitivity): If the firm makes an error and selects a value, z_1', that is different than $z_1{}^o$, or a value, y_1', that is different than $y_1{}^o$, then the system still yields r^* and m^* as long as $z_1' \geq z_1{}^o$ and $y_1' \geq y_1{}^o$. The risk penalty is unaffected.

Figure 3
RISK PENALTY



Corollary 2 (target-value sensitivity): If the firm makes an error and selects a value, w_2', that is different than the optimal value, $w_2{}^*$, then the target-value compensation system still yields r^* and m^* as long as $0 < w_2' < 1/(2\mu\sigma^2)$. The risk penalty increases, but it can be less than the risk penalty for the variable outcome-based compensation system when $\mu\sigma > 1$.

COMMENTARY

Both internal customer–internal supplier systems have intuitive interpretations and provide incentives to R and M to select r^* and m^*. However, the target-value system can be superior to the variable compensation system on the criterion of the risk penalty. (Figure 3 is an example plot of the risk penalty as a function of w_2. We also plot the [constant] risk penalty for the linear system. In this plot, $\mu = 5$ and $\mu\sigma^2/2 = .25$.)

We state the variable compensation system as if M chose a percentage and state the target-value system as if M chose an incremental profit target. P_1 and P_2 are not limited to these situations. The firm could choose to implement either system by defining a rating scale such as the five-, seven-, or nine-point Likert or semantic-anchor scale. To implement the variable compensation system, the firm would need to transform the rating scale into a percentage and announce this to both R and M. To implement the target-value system, the firm would need to transform the rating scale into a target. Naturally, the firm would need to scale the parameters of the reward functions to assure consistent units in the relevant equations, either Equation 7 or Equation 9. To implement the variable compensation system, the upper bound of the scale, for example, a 5 on a five-point scale, would correspond to 100%. To implement the target-value system, the firm would need to select the upper bound (if there were any) such that the constraint is not binding on the implied optimization problems in equations 3 and 4.

P_1 implies an evaluation at its upper bound, and P_2 implies evaluations, s_2, that are greater than π. We have spoken to many managers who feel that internal customer satisfaction evaluations are inflated. In fact, it is not uncommon to see evaluations clustered toward the top of the scale.

[12]For $\mu\sigma > 1$, the w_2 that produces the minimum risk penalty is $(2\mu\sigma^2)^{-1}[1 - (\mu\sigma)^{-2}]$. For $\mu\sigma \leq 1$, the minimum occurs as $w_2 \to 0$. An interior minimum occurs because the quadratic target value function introduces both a linear error term, $(1 - 2\mu\sigma^2 w_2)e$, and a quadratic error term, $-w_2e^2$, into M's reward function. For small w_2, the linear term dominates, and the error term behaves as if it were e. For large w_2, the quadratic term dominates. For intermediate w_2, the linear term is less than e, but the quadratic term is not yet so large. The certainty equivalent of the sum of the two errors is at a minimum. Note that the quadratic error, e^2, is proportional to a chi-square variate and hence is uncorrelated with e.

[13]For simplicity of exposition, we use the word "can" in Corollary 1. More specifically, the risk penalty for the target-value system remains below that for the variable outcome-based compensation system if $\mu\sigma > 1$ and $w_2 \in (0, w_2'']$ for a $w_2'' \in (w_2{}^*, (2\mu\sigma^2)^{-1}]$. See the Appendix for details.

Menezes (1991) provides a published example in which Xerox has chosen a target (external) satisfaction that implies that every customer believes the company is at the top of the scale. We have seen many other examples in practice. Indeed, if there is no cost to M of providing a higher evaluation for R, then cooperation should be easier and the evaluations should be more inflated.

Many of the internal customer satisfaction systems that we observe have properties similar to the formal models. The linear system is a logical first cut, and the quadratic system provides an evolution to which managers can move. In many observed systems, management begins by giving the evaluating group (M) little or no penalty, w_2, for misreporting s_2. We predict that these firms could improve their systems by making the evaluator's (M's) compensation depend more steeply on the evaluation.

RELATIONSHIP TO OTHER INCENTIVE SYSTEMS

A profit center system also attempts to use the superior local knowledge. In a profit center system M signals its purchase of R's technology with the acceptance of a transfer price, and its performance becomes more dependent on the quality of the inputs. For example, at Chevron, the operating divisions can "purchase" projects from the R division (or from outside the firm). In both the internal customer–internal supplier systems and profit center systems, M signals its use of an R project with its choice of s; and once M chooses s, its variable compensation depends on the quality of R's performance.

Another common practice, often used in combination with other systems, is management by objectives (MBO). In a typical MBO system, top management consults with M to develop a set of objectives for use in subsequent evaluations. For example, M might select a sales target of $5 million and a customer satisfaction target of 90% extremely satisfied. In the target-value system, M selects a goal, s_2. However, s_2 itself can be comprised of indicators such as net sales and satisfaction. Compared to an MBO, the target-value system specifies a specific reward function, and the target, s_2, is used to reward R.

Finally, many firms have adopted integrating mechanisms that enable M and R to communicate on both customer needs and technological solutions. These systems are complementary to internal customer–internal supplier systems not substitutes.

SUMMARY AND SUGGESTED RESEARCH

There is considerable pressure to push a marketing orientation deep into the organization. In many cases, this means that internal suppliers, such as R&D, see downstream groups, such as Marketing, as their internal customers. In a variety of firms, the internal customer is asked to evaluate the internal supplier, and the internal supplier is rewarded based on that evaluation. We have proposed two systems that can yield r^* and m^*. These are certainly not the only systems possible, but they are among the simplest. The target-value system, in particular, should be relatively easy to implement and, in many cases, will yield a reasonable risk penalty. Judging by our field experience, the linear system seems to be the first system that management adopts. Its simplicity is appealing.

There is certainly room for further research. We use our theory to illustrate the properties that s and $\breve{\pi}$ should have. There are important empirical challenges in developing such measures.

Our systems may not minimize the risk costs that the employees must bear (and for which the firm must pay), but they are simple and perform fairly well for a fairly general set of functions, π, c_M, and c_R. In other words, our systems may not be optimal from the standpoint of minimizing the risk costs. However, if second-best systems are much more complex or less robust, then they might impose yet-to-be-identified implementation costs that overwhelm any savings in risk costs. Implementation costs pose an empirical question that can only be answered with further research.

An alternative research strategy is to establish that some simple v and w minimize the risk cost for some reasonable profit and cost functions. Researchers can also study more general v and w, which yield r^* and m^*. For example, we can replace the quadratic function with more-general, asymmetric, concave functions of $s - \breve{\pi}$, or we can attempt to reduce the risk penalty with higher-order polynomials in s and $\breve{\pi}$. Another direction of research is to extend the analyses to other error distributions besides normal and other utility functions besides constantly risk averse. Each of our systems allow for cooperation. Researchers also might investigate the conditions under which cooperation is an inherent property of internal customer–internal supplier systems and whether this is costly to firms.[14]

Our systems assume that the internal customer and the internal supplier can cooperate on the (implicit) rating, but find it more difficult to cooperate on the effort of the internal supplier. Examining and/or relaxing this assumption is an interesting area for further research.

Other areas of research include extensions to longer chains of employee groups, multiple actions by R&D and Marketing, multiple evaluating groups, multiple groups being evaluated, multiple evaluations, and cases in which r affects c_M or σ^2 directly. Additional research also might extend the analyses to other dyadic relationships besides those of the internal customer and internal supplier. Empirical research might investigate the practical implications of the systems we analyze and/or the implications of such systems as a means to coordinate Marketing and other functions. Finally, it might elaborate on the formal model to include those implementation issues that explain why many firms choose an internal customer–internal supplier system as a means to implement a profit center–like approach.

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[14]Hauser, Simester, and Wernerfelt (1996) show that under fairly general conditions g is positive whenever s is not constrained. They also show that if the firm can choose v and w to implement a set of actions, r^o and m^o while precluding collusion, then it can choose a different v and w to implement the same actions while allowing collusion. It does this by paying M more and R less such that, under collusion, they get just enough to participate. Because the new v and w introduce no new risk costs, the firm earns the same profits under the new system as under the old. Wernerfelt, Simester, and Hauser (1996) demonstrate similar results for nonproductive supervisors and analyze a related case in which collusion is avoided by expanding Equation 7 to a discrete menu of linear functions.

APPENDIX

Proofs To Propositions and Corollaries

P_1 (variable outcome-based compensation): For z_1 and y_1 above critical values and for $z_3 = 1$, the variable outcome-based compensation system will give incentives to R and M such that, acting in their own best interests, they select r^* and m^*. The critical conditions are $z_1 > \max\{\pi(r^*,0), \pi^* - \mu\sigma^2/2 - c_M^*\}$ and $y_1 > z_1 - (\pi^* - c_M^* - c_R^*) + \mu\sigma^2$.

Proof. Define $\hat{\pi} = \pi(r,0)$. Let Ω_m be M's certainty equivalent (left-hand side of Equation 3) and let Ω_R be R's certainty equivalent (Equation 4). That is,

$$\text{(A1a)} \quad R: \quad \Omega_R = y_0 + y_1 s_1 - g - c_R,$$

$$\text{(A1b)} \quad M: \quad \Omega_M = z_0 + z_1(1 - s_1) + z_3 s_1 \pi - z_3^2 s_1^2 \mu\sigma^2/2 - c_M + g,$$

and

$$\text{(A1c)} \quad g = z_1 \tilde{s}_1 - z_3 \tilde{s}_1 \tilde{\pi} + z_3^2 \tilde{s}_1 \mu\sigma^2/2 + \tilde{c}_M - z_1 \hat{s}_1 + z_3 \hat{s}_1 \hat{\pi} - z_3^2 \hat{s}_1^2 \mu\sigma^2/2 - \hat{c}_M.$$

The condition for $\hat{s}_1 = 0$ is that $\partial\Omega_M/\partial s_1 < 0$ when $g \equiv 0$. ($\hat{s}_1 = 0$ implies $\hat{m} = 0$ by Equation A1.) The condition for $\hat{s}_1 = 1$ is that $\partial\Omega_M/\partial s < 0$ when g (defined in Equation A1) is allowed to vary. For $z_3 = 1$ we differentiate to get

$$\text{condition 1 } (\hat{s}_1 = 0): \quad -z_1 + \hat{\pi} - \hat{s}_1 \mu\sigma^2 < 0,$$

and

$$\text{condition 2 } (\tilde{s}_1 = 1): \quad y_1 - z_1 + \tilde{\pi} - \tilde{s}_1 \mu\sigma^2 > 0.$$

First, note that both conditions hold in the neighborhood of r^*, m^*. Condition 1 holds because $z_1 > \hat{\pi}$ by the statement of the proposition. Condition 2 holds because $y_1 > z_1 - \pi^* + \tilde{s}_1\mu\sigma^2$ for all $\tilde{s}_1 \in [0,1]$ by the statement of the proposition. If conditions 1 and 2 hold, then $\tilde{s}_1 = 1$ and $\hat{s}_1 = 0$, and we get

$$\text{(A2a)} \quad \Omega_R = y_0 + y_1 - z_1 - \frac{1}{2}\mu\sigma^2 + [\pi(\tilde{r},\tilde{m}) - c_M(\tilde{m}) - c_R(\tilde{r})],$$

and

$$\text{(A2b)} \quad g = z_1 - [\pi(\tilde{r},\tilde{m}) - c_M(\tilde{m}) - \frac{1}{2}\mu\sigma^2]$$

At $\tilde{r} = r^*$, $\tilde{m} = m^*$, we have $z_1 > \pi(\tilde{r},\tilde{m}) - c_M(\tilde{r}) - \mu\sigma^2/2$ according to the statement of the proposition. Thus, $g > 0$ and the maximization of Ω_R yields r^*, m^*. This means that if conditions 1 and 2 hold, which they do for r^* and m^*, then R and M choose r^* and m^*. Furthermore, we can choose y_0 such that R participates, and we can choose z_0 such that M participates. We need only establish that R never chooses r, and the implied m, for conditions 1 and 2 to be violated.

Suppose condition 1 is false, but condition 2 is true. Then, $\hat{s}_1 = 1$, $\tilde{s}_1 = 1$, and $g = 0$. This implies that $\Omega_R = y_0 + y_1 - c_R(r)$. But condition 1 being false implies that $-z_1 + \pi(r,0) - \mu\sigma^2 > 0$. Adding this positive number to Ω_R yields $\Omega_R < y_0 + y_1 - c_R(r) - z_1 + \pi(r,0) - \mu\sigma^2 = y_0 + y_1 - z_1 - \mu\sigma^2/2 + [\pi(r,0) - c_R(r) - c_M(0)] - \mu\sigma^2/2 < y_0 + y_1 - z_1 - \mu\sigma^2/2 + [\pi(r^*,m^*) - c_R(r^*) - c_M(m^*)]$, which is what R can get with r^* and m^*. The last inequality is by the definition of the optimal. Recall $c_M(0) = 0$. Thus, R can do better if it chooses an r such that condition 1 is true than it can such that condition 1 is false.

Suppose condition 2 is false. (Condition 1 can be true or false.) Then, $\tilde{s}_1 = 0$, $g = 0$, and $\Omega_R = y_0$. This is less than R can get at r^*, m^* (see Equation A6, in which $\Omega_R > y_0$ according to the definitions of y_1 and z_1 in the statement of the proposition). Thus, R can do better if condition 2 is true than if condition 2 is false.

To summarize, R can choose and prefers to choose r such that conditions 1 and 2 are true. When these conditions are true, $r = r^*$, $m = m^*$, and $\tilde{s}_1 = 1$.

P_2 (target value): For $v_1 = 1$ and $0 < w_2 < 1/(2\mu\sigma^2)$, the target-value compensation system will give incentives to R and M such that, acting in their own best interests, they select r^* and m^*.

Proof. We demonstrate[15] that for constantly risk-averse utility and for normally distributed noise, the certainty equivalent, or c.e., of EU_M ($w - c_M + g$) is given by the following ($w_2 < [2\mu\sigma^2]^{-1}$ assures that the logarithm is defined):

$$\text{c.e.} = [w_0 + (1/[2\mu])\log(1 - 2\mu\sigma^2 w_2)] - w_2(s_2 - \pi)^2 - 2\mu\sigma^2 w_2^2 (1 - 2\mu\sigma^2 w_2)^{-1}(s_2 - \pi)^2 - c_M + g$$

$$\equiv w_0' - w_2'(s_2 - \pi)^2 - c_M + g$$

Because EU_R and EU_M are increasing transformations of the certainly equivalents, we evaluate equations 3 and 4 in terms of certainly equivalents. Rewriting Equation 3 yields

$$\text{(A3)} \quad w_0' - w_2'[\tilde{s}_2 - \pi(r,\tilde{m})]^2 - c_M(\tilde{m}) + g = w_0' - w_2'[\hat{s}_2 - \pi(r,\hat{m})]^2 - c_M(\hat{m}).$$

Because $\hat{s}_2$ maximizes the right-hand side of Equation A5, it is easy to see that $\hat{s}_2 = \pi(r,\hat{m})$ when $w_2 > 0$. Similarly, we show $\hat{m} = 0$. Thus,

$$g = w_2'[\tilde{s}_2 - \pi(r,\tilde{m})]^2 + c_M(\tilde{m}).$$

Because R receives its reward on the basis of $\tilde{s}_2$, which is reported prior to market outcomes, $\tilde{\pi}$, there is no risk adjustment for R. Hence, we incorporate M's maximization problems, Equation A3, into R's maximization problem, Equation 4, by substituting for g. Thus, the maximization problem in Equation 4 becomes

$$\text{maximize } \{v_0 + v_1\tilde{s}_2 - c_R(\tilde{r}) - w_2'[\tilde{s}_2 - \pi(\tilde{r},\tilde{m})]^2 - c_M(\tilde{m})\}$$

The first-order conditions for $\tilde{m}$, $\tilde{r}$, and $\tilde{s}_2$ are given, respectively, by equations A4, A5, and A6, ($\tilde{\pi}$, $\tilde{c}_M$, and $\tilde{c}_R$ are shorthand for $\pi[\tilde{r},\tilde{m}]$, $c_M[\tilde{m}]$, and $c_R[\tilde{r}]$, respectively.)

$$\text{(A4)} \quad 2w_2'(\tilde{s}_2 - \tilde{\pi})\frac{\partial\tilde{\pi}}{\partial m} - \frac{\partial\tilde{c}_M}{\partial m} = 0$$

$$\text{(A5)} \quad 2w_2'(\tilde{s}_2 - \tilde{\pi})\frac{\partial\tilde{\pi}}{\partial r} - \frac{\partial\tilde{c}_R}{\partial r} = 0$$

$$\text{(A6)} \quad v_1 - 2w_2'(\tilde{s}_2 - \tilde{\pi}) = 0$$

[15]This proof is available from the authors.

By setting $v_1 = 1$, Equation A6 becomes $2w_2'[\tilde{s} - \pi(\tilde{r},\tilde{m})] = 1$. By substituting this relationship in equations A4 and A5, we get the first-order conditions for r^* and m^*. Finally, we select the constants, v_0 and w_0, such that M's c.e. and R's maximum are preferred to nonparticipation. The firm participates if the profit in Equation 5 exceeds the risk penalty implied by M's c.e. Note that different v_1's implement different actions.

Corollary 1 (variable outcome-based compensation sensitivity): If the firm makes an error and selects a value, z_1', that is different than z_1^o, or a value, y_1', that is different than y_1^o, then the system still yields r^* and m^* as long as $z_1' \leq z_1^o$ and $y_1' \leq y_1^o$. The risk penalty is unaffected.

Proof. Notice that P_1 only requires that z_1 and y_1 be above their critical values. Adjusting the coefficients, z_o and y_o assures participation. The risk penalty in Equation 8 does not depend on z_1 and y_1.

Corollary 2 (target value sensitivity): If the firm makes an error and selects a value, w_2', that is different than the optimal value, w_2^*, then the target-value compensation system still yields r^* and m^* as long as $0 < w_2' < 1/(2\mu\sigma^2)$. The risk penalty increases, but it can be less than the risk penalty for the variable outcome-based compensation system when $\mu\sigma > 1$.

Proof. Notice that P_2 only requires $0 < w_2' < (2\mu\sigma^2)^{-1}$. Adjusting the coefficients, w_0 and v_0, that depend on w_2 assures participation. w_2^* is defined as the w_2 yielding the minimum risk penalty in Equation 10; thus, by definition, the risk penalty weakly increases. Straightforward calculus applied to Equation 10 implies that the second derivative is positive; thus, the increase is strict. Straightforward calculus also implies that the risk penalty approaches $\mu\sigma^2/2$ as $w_2 \rightarrow 0$, the risk penalty approaches ∞ as $w_2 \rightarrow (2\mu\sigma^2)^{-1}$, and $w_2^* > 0$ for $\mu\sigma > 1$. (The equation for w_2^* is given in footnote 10.) Thus, the risk penalty is less than $\mu\sigma^2/2$ over some range, $w_2 \varepsilon (0, w_2'']$, where $w_2^* < w_2'' < (2\mu\sigma^2)^{-1}$. This implies that the risk penalty *can* stay less than $\mu\sigma^2/2$ over this range and that the range includes w_2^*.

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