Salesforce and Sales Support

Our interest in side payments stems from working with the sales manager for a 2 billion dollar organization that served both consumer and industrial markets.[1] The chief executive officer had begun a program to increase customer satisfaction fivefold and the sales manager felt that his salespeople needed support to achieve this effort. He was preparing to introduce a system in which salespeople rated the support people on how well sales were supported. The sales manager had many years of experience and was quite savvy. He was concerned that the salespeople would demand a side payment from sales support in return for a higher rating.

We will call the sales support organization the upstream agent (U). This upstream agent provides goods and services to a downstream agent (D), the salesforce. Both agents work for the same firm. The downstream agent is asked to evaluate the upstream agent and the upstream agent receives a reward based on that rating. The reward to sales support might be a monetary bonus, say $1,000 times the rating, or the reward might simply be recognition and an increased chance of promotion. The reward must have effective monetary value to U. Formally, we assume the rating is a numerical rating, say a 7-point scale going from "unsatisfactory" to "excellent." However, the theory extends to any combination of measures or observations that can be transformed into a numerical rating. We denote this rating with r and we denote the upstream agent's reward (chosen by the firm) with $v(r)$.

If the reward system is to be effective, the actions and efforts of the upstream and downstream agents must add value to the firm. In our formalization, we call the actions that the upstream agent takes, u, and the actions that the downstream agent takes, d. For example, u might be the time, effort, and materials needed to produce advertising, brochures, and other sales materials, while d might be sales efforts such as travel to clients, meetings with clients, and written proposals. If U and D do their jobs well, then the firm makes some incremental profit, which we denote with $\pi(u, d)$. For example, the firm might make incremental profit on the sales that result from the actions of U and D brought about by the incentive system. We include in $\pi(u, d)$ any costs that U and D cause the firm to incur (printing and mailing the brochures, production costs, etc.), but we do not include the incremental salaries and bonuses paid to U and D.

Accounting systems are rarely exact; incremental profits are hard for the firm to measure. Thus, we make the realistic assumption that the firm can only estimate incremental profits. For example, the firm might measure incremental sales revenue (net of costs) to capture today's profit and might measure customer satisfaction to capture tomorrow's profit. (In our case, part of the firm's initiative was to translate customer satisfaction measures into estimates of future profit. Incentives on customer satisfaction measures are now an important aspect of executive compensation at the firm. Other measures might apply to other firms.) The firm's estimate, $\tilde{\pi}$, is equal to true incremental profits modified by zero-mean noise, e.

The sales manager wanted to achieve the CEO's goals and, to do this, he wanted the agents to take actions that were above and beyond the actions they were taking under the status quo. Most likely, these actions would be perceived by the agents to be more onerous than the status quo. For example, the salesperson (D) might prefer chatting with his or her colleagues at the office rather than making a difficult cold call on a new client. We denote these perceived incremental costs by $c_u(u)$ for the upstream agent and by $c_d(d)$ for the downstream agent. (Both c_u and c_d are defined in monetary equivalents.) Finally, we make some reasonable technical assumptions for the formal proofs.[2]

The reward to the upstream agent, $v(r)$, compensates that agent for the perceived costs of its incremental actions. To compensate the downstream agent for the perceived costs of its incremental actions, the sales manager modified D's reward structure as follows. To motivate the salesforce to exert efforts, the firm chose

[1]Our interest in this topic is scientific. Nothing in this paper should be interpreted as advocating side payments.

[2]Formally, we assume that profit is concave in both arguments and thrice differentiable and that the cost functions are increasing, convex, and thrice differentiable. All functions and variables are real valued and all actions are nonnegative.

to compensate the salesforce based on the firm's measure(s) of incremental profit, $\tilde{\pi}$. Thus, D's reward function can depend upon $\tilde{\pi}$. In addition, given the potential for side payments, the firm might want to make the salesforce accountable for its ratings of sales support's performance. It can do this by choosing a reward function that depends on r. Based on these properties, we denote D's reward with $w(r, \tilde{\pi})$. We revisit this issue in a later section when we discuss whether the firm would want to choose a w that depends on r.

For example, salesforce rewards often depend upon salesforce targets (e.g., Gonik 1978). In our case, the sales manager might set higher targets for sales teams with higher rated sales support. Such targets might mean that a sales team achieving $1 million in net sales with "unsatisfactory" sales support would achieve its target and receive a large bonus. However, a sales team achieving $1 million in net sales with "excellent" sales support might miss its target and receive a smaller bonus. In this case, $w(r, \tilde{\pi})$ would be downward sloping in r. We argue later that it often makes sense for the firm to penalize the downstream agent for a rating that is too high. (For completeness we also address other cases, say where the sales team's reward is a concave function that is maximized for some optimal r. Gonik (1978) reward functions are practical examples of such functions.) Technically, we restrict our analyses to v and w that are concave in their arguments.[3]

The reward functions, v and w, are notable for what they do not assume. The upstream agent is paid only on the rating and the downstream agent is paid only on a measure of incremental profits (and perhaps the rating). To pay the bonuses based on v and w, the firm does not have to observe U's actions, u, or D's actions, d, nor does it have to observe the perceived costs, $c_u(u)$ and $c_d(d)$.

We cannot totally ignore the actions and perceived costs, however. Those readers familiar with agency theory will recognize that the firm must also set base salaries for U and D and that these base salaries are likely to depend on $\pi(u, d)$, $c_u(u)$, $c_d(d)$, and their derivatives. However, such knowledge is a formal requirement for almost any reward system. If the firm wants to maximize its own profits, then it needs to know the marginal productivity of its employees. If it pays them too much, then it has lost the opportunity for profits; if it pays them too little, then they will leave the firm. The key managerial question is whether the ratings-based system makes it more or less practical to select a reward system. In our case, the sales manager already had a system for paying the salesforce and sales support. Presumably, the firm was able to determine enough about the marginal productivity and perceived costs of its employees and was able to set their salaries accordingly. Thus, for this paper, we focus on the impact of v and w rather than the practical problems of setting base salaries.

The Issues We Address

We begin with the sales manager's perspective. He wanted to improve the status quo by introducing a rating system to coordinate U and D. He needed to know whether side payments would undermine any potential gain in profit from the rating system. He also wanted to know whether he should invest in costly monitoring and punishment procedures to preclude side payments. Alternatively, he wanted to know whether he could design a rating system under which there would be no incentives for side payments. Our analyses seek to address his questions:

- Can the firm design a ratings system under which there are no incentives for side payments?
- Do side payments decrease profits? Can the firm do as well under a system that allows side payments as it could do under a system that precludes side payments?

Our first result is focused on his first question; our second result on his second question.

Hauser, Simester, and Wernerfelt (1996), hereafter HSW, have already demonstrated that practical methods can be designed for ratings-based reward systems such as those that the sales manager sought to implement. In their paper, they analyzed two specific examples for v and w. In the first example, both v and w are linear functions of r. In the second example, v remains a linear function of r, but w becomes a quadratic

[3] A higher rating indicates more effort, thus $v(r)$ is increasing in r. We also want r to be an indicator of u's effect on π, thus we examine w's such that $\partial w^2/\partial u \partial r > 0$. For the formal proof we make a technical assumption that $\partial^2 w/\partial u \partial r$ has no lower bound.

function of ($r - \tilde{\pi}$). However, the authors address neither of the manager's qualitative questions.

The authors allow side payments but never demonstrate whether side payments are necessary or avoidable. HSW do not tell us whether a practical reward system exists such that there is no incentive for U to provide D with a side payment. More important, HSW do not investigate whether the side payments are costly to the firm (more costly than a system without side payments). Our students and colleagues (and many managers) hypothesize that the side payments are costly to the firm and that, if only we could come up with a system without side payments, then the firm could do better. Certainly common intuition holds that side payments are detrimental in many circumstances. A situation in which side payments are not costly to the firm would surprise many.

HSW demonstrate that their systems yield "first-best" actions, but impose a (quantified) risk penalty. (First-best actions are those actions that would 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.) However, the profits from first-best actions are not necessarily the highest profits obtainable. See related discussion in Basu et. al. (1984). To direct future research on systems to improve profits, we would like to know: (1) Should we examine systems that allow side payments and attempt to improve profits with more complex v and w functions? Or, (2) should we search for systems under which there are no incentives for side payments? We would like to know whether the reduction in profits is due to the presence of side payments or due only to the risk that the system imposes on D and/or U.[4]

In contrast to HSW, we deal with more general v and w and go deeper into the structure of the problem. We demonstrate that (1) side payments are, in most cases, unavoidable, and (2) the firm can often anticipate cooperation between U and D and costlessly factor out the effects of side payments. (Our proof demonstrates one way to do this.) We answer both of the manager's qualitative questions and we focus research attention on improved v and w rather than on systems to avoid side payments.

[4]D's risk is due to the facts that (1) there is uncertainty in $\tilde{\pi}$ and (2) w depends on $\tilde{\pi}$. There will be a risk penalty for D when D is risk averse. A general reward system might transfer risk to U, but that is not the case in the HSW systems.

Formal Structure

To address the sale manager's questions, we adopt the formal structure that was used by HSW. We summarize here only the basic structure. For further motivation and technical discussion we refer the reader to their paper or to the appendix.

The Formal Game

HSW formalize the order of actions as follows: (1) The firm acts first and announces a reward system, v and w. Based on this reward system, (2) the upstream agent acts next to select its actions, u, if by doing so it can do better than not acting. (3) The downstream agent observes these actions, but the firm does not. (4) Next, U and D are free to agree on an enforceable contract for a side payment, s, and a rating, r. Both do so anticipating what this will imply for D's actions, d, and the resulting expected profit, π. If they can not agree on a contract, D takes the actions (possibly no actions) that D would take without a contract. (5) D announces the rating, r. (6) The upstream agent receives its reward, $v(r)$, based on this rating. (7) The downstream agent, D, acts in its own best interests to choose its actions, d. (8) The firm observes a noisy measure of profit, $\tilde{\pi}$, and (9) pays D its reward, $w(r, \tilde{\pi})$.

Naturally, we assume that the firm will announce a reward system only if it can do better with the actions and profits implied by the reward system than it could do in the absence of a reward system. (Our normalization implies that, without a reward system, the agents set u and d to zero.)

Firm's Goals, Agents' Goals

We assume that the firm is risk neutral and profit maximizing. Thus, the firm will seek to maximize the expected value of profits minus wages:

$$\text{Expected Net Profit} = E[\tilde{\pi}(u, d) - v(r) - w(r, \tilde{\pi})]. \quad (1)$$

We assume that both the upstream and downstream agents are risk averse and will act in their own best interests to maximize their expected utilities, EU_u and EU_d.[5] (Please note: Our mnemonic notation for the upstream agent, U, is distinguished from the notation for expected utility, EU, by the use of subscripts.) In the absence of a side payment, each agent acts in his or her own best interests to maximize the expected utility of wages minus perceived costs. Even in the absence of a side payment, the rating, r, might be positive if w is increasing in r over some range. For example, the expected value of the quadratic "target-value" reward system analyzed by HSW is maximized for $r = \pi(u, d)$.

$$\text{Upstream Agent Maximizes } EU_u[v(r) - c_u(u)],$$

$$\text{Downstream Agent Maximizes } EU_d[w(r, \tilde{\pi}) - c_d(d)]. \quad (2)$$

The upstream agent acts first by choosing an action, u, that the downstream agent (but not the firm) can observe. In the absence of a side payment, the downstream agent will take u as given and act to maximize the second expression in Equation (2). Thus, for every u, chosen by U, Equation (2) implies corresponding values for the rating, D's actions, and incremental profit. We denote these values by a hat (^) to imply optimization over the second expression in Equation (2). Our technical assumptions assure that the rating ($\hat{r}$), D's actions ($\hat{d}$), and the incremental profits ($\hat{\pi}$), under the no-side-payment condition, are continuously differentiable functions.

Now consider a situation where U offers a side payment, s, to D in return for a higher rating. We use a tilde (˜) to denote ratings, actions, or incremental profits when side payments are allowed. For example, the rating that U offers is denoted by $\tilde{r}$. This side payment need not be monetary but it must be valued by D and be costly for U to provide. It might be extranormal service that is valued by D but does not affect π directly. Such services might include fancy brochures with D's picture on the cover, sales "training" for D in Aruba, or "warm-up" jackets with the company's logo that can be given to friends and relatives.

HSW model this offer as a take it or leave it offer, but we could obtain similar results for other assumptions on how U and D share surplus, if any, from the $(s, \tilde{r})$ contract. It will be in D's interest to accept this contract if D can do at least as well with the contract as without. That is, D's expected utility from the contract must be at least as large as that which D can obtain in the absence of a side payment. On the other hand, U must be equal or better off with the contract than without. Thus, U's expected utility (for a given v and w) must be at least as large with the contract as its expected utility without the contract. (Recall that the contract implies that the side payment is subtracted from U's monetary rewards and added to D's monetary returns.) Finally, when side payments are allowed, both U and D must be able to achieve at least as much expected utility as they could without taking any incremental actions. We call these minimum expected utilities, $E\bar{U}_u$ and $E\bar{U}_d$.

HSW derive formal equations to calculate, for every v and w, the actions, rating, incremental profit, and side payment, $\tilde{u}$, $\tilde{d}$, $\tilde{r}$, $\tilde{\pi}$, and s, that result when U, D, and the firm each act in their own best interests (assuming side payments are allowed). (The equations are summarized in the appendix.) We now address the sales manager's first question.

Side Payments Almost Always Occur

The upstream/downstream structure almost always guarantees side payments. By this we mean that there are economic incentives for side payments. To preclude side payments, the sales manager would likely have to impose an exogenous system such as a reprimand (or worse) for any perceived impropriety. Such a monitoring and policing system could be costly to the firm.

Interior Solutions

There will be incentives for side payments if the structure of the reward functions, v and w, are such that one agent, say U, is better off with a side payment while the other agent, say D, is no worse off. In this case, there will be "gains to trade" and a contract of side-payment-for-increased-rating will be feasible. The formal proof is in the appendix, but the following two equations provide the intuition.

[5]Technically, the utility functions are integrable, thrice differentiable, increasing, and concave. We assume the error is specified such that the expected utility functions are well-behaved.

We begin with the case where v and w imply interior solutions for r, that is, an r between the highest and lowest possible rating (if the rating is constrained). In this case, in the absence of a side payment, D will maximize the first expression in Equation (2) by setting the derivative to zero.

$$\frac{\partial EU_d[w(\hat{r}, \hat{\pi}) - c_d(\hat{d})]}{\partial \hat{r}} = 0. \tag{3}$$

Thus, the marginal loss to D of a very small increase in r is zero. On the other hand, because U's utility is increasing in v and v is increasing in r, U gains by having D increase r. We see this by differentiating the second expression in Equation (2).

$$\frac{\partial EU_u[v(\hat{r}) - c_u(u)]}{\partial \hat{r}} > 0. \tag{4}$$

Thus, intuitively there appear to be gains to trade at the rating which D would have provided in the absence of a side payment. Thus, for a small increase in the rating, U gains more than D loses.

The actual proof is more complex because we have to account for the integration implied by the expected utility operators, but the basic intuition does not change. For any v and w chosen by the firm such that (1) the firm makes positive profits, (2) U and D find it better to take some actions than to take no actions, and (3) the v and w imply interior solutions, then there are economic incentives to use side payments. (Technically, $\tilde{r} > \hat{r}$ and $s > 0$.)

Notice that if D is not penalized for a higher rating, then $\partial w / \partial r \equiv 0$ and Equation (3) will hold for all r. There will always be gains to trade. In this case, even a minimal side payment from U will persuade D to rate U as high as is feasible. When w does not depend on r, U need not put in any effort beyond this minimal side payment. Thus, if the firm wants to use a rating system to entice U to put forth sufficient effort, w must be a function of r.

Constrained Ratings

The sales manager may ask D to rate U on a continuous 7-point scale. For example, the highest rating possible might be "excellent." For some v and w, this constraint may mean that the optimal solution for r, in the absence of a side payment, might not be an interior solution. In general, if r is constrained to be less than some upper bound, $\bar{r}$, and this upper bound is less than that which D would otherwise choose, then D might find it to be in its best interest (even without a side payment) to set $r = \bar{r}$. Formally, such a constraint might replace the equality in Equation (3) with an inequality and there may be no gains to trade.

Constraints on r do not rule out side payments, however. For example, HSW demonstrate a linear system in which the firm's choice of v and w causes U to provide D with a side payment in return for reporting $r = \bar{r}$. The side payment is necessary in that system because D can not achieve $E\bar{U}_d$ without the side payment, but can achieve $E\bar{U}_d$ with a side payment.

No Room to Trade

There is a final situation we must consider. Suppose v increases at a slower rate than w decreases. If this happens over the entire range, there will never be any r where there are gains to trade. However, such a situation will not occur for a rational firm. If v increases at a slower rate than w decreases, then the optimal response for D is to set $r = 0$. However, this means that U will set $u = 0$ because any actions incur perceived costs without rewards. This will, in turn, cause D to set $d = 0$ and the firm will earn only as much with the reward system in place as it did without the reward system in place. This violates one of our assumptions.

This covers all the cases for continuous v and w. In the appendix we prove formally that:

RESULT 1. *For incentive systems in which the rewards to the upstream agent are increasing in the downstream agent's rating, the upstream agent will provide a positive side payment to the downstream agent unless the firm sets a binding upper bound on the rating (or otherwise precludes side payments). Even with a binding upper bound, there may be side payments.*

Side Payments Need Not Hurt the Firm's Profits

Because most ratings-based reward systems encourage side payments and because it might be expensive to use monitoring and punishment to preclude side payments, we now address the sales manager's second question. Do the side payments necessarily decrease the firm's profits? We want to compare the profits from a system that precludes side payments to the profits from a system that allows side payments. We first address whether a ratings-based system with side payments exists that does not decrease profits. We then discuss whether it is practical.

Let's consider the sales manager's firm. That firm has a long history with salesforce compensation. It appears to have been practical for this large firm to set base salaries and to adjust variable rewards (e.g., sales commissions) by trial and error. We expect that the existing system was reasonably profitable for the firm within the class of reward systems that it was using.

Now let's assume the firm introduces a rating system that encourages side payments. If the previous system was inefficient, the new system might induce higher u and d and the firm will have to reimburse the agents for their increased perceived costs. But how about the side payment? The upstream agent will have to pay s and the downstream agent will receive s. The firm may be aware of these side payments, but it would be impractical to set up an accounting system to measure the side payments and adjust salaries accordingly.

Our sales manager would like to use v and w to adjust the compensation to U and D. In particular, he must change v so that U gets enough additional compensation to pay s (otherwise U will quit) and he must change w so that D's compensation is reduced by s (otherwise he is paying D more than the market wage). In adjusting v and w, however, the sales manager wants to be able to achieve the desired u and d, that is, he wants at least as much profit from the new system as he earned with the old. Finally, the new system (with side payments) cannot impose any addition risk on either of the agents. Otherwise, the manager would have to pay them more in order to reimburse them for any increased risk. (If they are not paid more, they will quit.) All of this must happen with the agents acting in their own best interests. The following result says simply that the sales manager can choose the appropriate v and w. The result is reasonably general. It holds for fairly general concave profit, cost, and reward functions. The non-side-payment reward systems can be profit maximizing, but they need not be. Result 2 is proven in the appendix.

RESULT 2. *Suppose the firm can preclude side payments and choose a reward system, v^0 and w^0, such that the upstream and downstream agents, acting in their own best interests, choose actions u^0 and d^0. Then there exists a reward system that allows side payments in return for higher ratings, such that (1) there is no loss of profits to the firm and (2) the upstream and downstream agents, still acting in their own best interests, choose u^0 and d^0.*

The basic proof follows the intuition of the salesforce example. The modified reward system changes the slopes of v and w with respect to r to achieve the new equilibrium implied by side payments. The change in the slope of v offsets the cost of the side payment to U and the change in the slope of w reduces D's rewards accordingly. Together these changes do not affect the first-order conditions for $\tilde{u}$ and $\tilde{d}$, nor do they add any risk. (Recall that the rating is given before the noisy outcome, $\tilde{\pi}$, is observed. Thus, the change in the rating imposes no new risks on either U or D.)

Practical Internal Ratings Systems (which allow side payments)

Result 2 answers the sales manager's second question—a ratings-based reward system can be found that does not reduce profits even though side payments are allowed. However, Result 2 does not guarantee that the rating system is practical.

Ratings systems do exist (e.g., Zeithaml et al. 1990, Chester 1994, Shapira and Globerson 1983, and our own experience), so some must be practical. They have survived the market test, so they must provide reasonable profits. More formally, the two example reward systems discussed by HSW are practical because, in both systems, the firm's profits are robust with respect to the slopes of v and w. The slopes can be set by judgment or by trial and error with little loss of profit (versus optimal slopes). Thus, for those two reward systems, the practical (empirical) challenge of setting the slopes of v and w seems to be no more difficult than the challenge of setting base salaries and sales commissions.

As discussed above, however, the simple rating systems may not handle risk optimally. Result 2 gives the sales manager confidence to begin with easy-to-implement systems and then tinker with more complex systems in the pursuit of higher overall profits.

For example, he might add a cubic term to w or explore successively higher order terms in Taylor's series approximations to more general functions of $(r - \bar{\pi})$. He knows that the side payments introduced by more complex systems need not decrease profits. Result 2 suggests that future research can focus on improving profit while allowing side payments rather than searching for a system that eliminates side payments.[6]

Summary and Future Directions

Side payments are common in marketing. Our analysis suggests that this should not be surprising because (1) the structure of intrafirm upstream-downstream ratings systems often guarantees that there are economic incentives for side payments and (2) if the firm can control the reward functions it can *always* factor the side payments into the compensation system with no loss of profits. Side payments may not occur if the rating is constrained appropriately (Result 1) or if the firm or society uses peer pressure, cultural norms, or punishment to prevent side payments.

There are many areas for future research. We suggest five. First, we feel that our results can be extended to the case where r is an implicit rating. That is, the firm might observe how D behaves and infer from D's actions how D would have rated U. For example, the firm might offer D a menu of reward functions and infer the rating from D's choice from the menu. Second, there might be cases where side payments are efficient. That is, the value of the side payment to D might be higher than the perceived cost to U. This may be true if the extranormal goods and services provided by U have low marginal cost to U and if D would have to pay more on the open market. Third, we might be able extend our analyses across firm boundaries (U might work for another firm). In this case, the firm would not control $v(r)$ directly, but may have some control, say if it is a monosony. (Result 2 still says that v and w exist, but a single firm no longer controls both.) An interesting interfirm case is frequent flyer miles, which can be viewed as a side payment from the airline to the traveler. Fourth, there are many interesting instances of side payments in marketing beyond the salesforce/sales-support example that motivated our paper. We have heard of side payments (some across firm boundaries) in customer-satisfaction systems, internal-customer rating systems, buyer-seller relations, channels of distribution, and supervisor ratings. Finally, the challenge remains to design more practical and more profitable ratings-based reward systems.[7]

[6]There might be ethical reasons, beyond the scope of this paper, to search for systems that preclude side payments.

Appendix: Proofs

Following the text we use a hat (^) to indicate the rating ($\hat{r}$), D's actions ($\hat{d}$), and the incremental profits ($\hat{\pi}$) that result when D optimizes its expected utility in the absence of a side payment (second expression in Equation (2)). This means that the downstream agent's reaction to u implies three continuously differentiable functions, $\hat{r}(u)$, $\hat{d}(u)$, and $\hat{\pi}(u)$, which tell us how D would react to U's choice of actions and how expected profit would be affected if there were no side payment. We use a tilde (~) to indicate the rating ($\tilde{r}$), D's actions ($\tilde{d}$), and incremental profits ($\tilde{\pi}$) that result when side payments are allowed under a take-it-or-leave-it offer from U to D on a side-payment-for-rating contract, $(s, \tilde{r})$.

If D can do at least as well with the contract as without, then this implies Constraint (C1):

$$EU_d[w(\tilde{r}, \tilde{\pi}) - c_d(\tilde{d}) + s(u, \tilde{r})] = EU_d[w(\hat{r}, \hat{\pi}) - c_d(\hat{d})]. \quad \text{(C1)}$$

For a given v and w, the upstream agent will select u and $\tilde{r}$ to maximize its expected utility according to Constraint (C2):

$$EU_u[\tilde{r}, u] = EU_u[v(\tilde{r}) - c_u(u) - s(u, \tilde{r})]. \quad \text{(C2)}$$

To earn non-zero profits, the firm must retain its employees. Let $\bar{U}_u$ and $\bar{U}_d$ be the minimum expected utilities that U and D require to participate. Thus, to induce U and D to participate, the firm must set v and w such that:

$$EU_u[v(\tilde{r}) - c_u(u) - s(u, \tilde{r})] \geq \bar{U}_u, \quad \text{(C3)}$$

$$EU_d[w(\tilde{r}, \tilde{\pi}) - c_d(\tilde{d}) + s(u, \tilde{r})] \geq \bar{U}_d. \quad \text{(C4)}$$

Because the firm is maximizing expected profits, it will try to keep wages as low as is feasible. Formally this means that the firm will attempt to select v and w such that the constraints are binding.

[7]This research was funded by the International Center for Research on the Management of Technology (ICRMOT). It has benefitted from presentations before the member companies and, in particular, from a two-day ICRMOT special interest conference on the "Marketing/R&D Interface" that was held at 3M. This paper has benefitted from seminars at the Marketing Science Conference at the University of Arizona, Duke University, the University of Florida, the University of Minnesota, the Massachusetts Institute of Technology, the University of Pennsylvania, and the U.S. Army Soldier Systems Laboratory. We thank Subrata Sen for many interesting suggestions and we thank a number of anonymous colleagues and students who have spoken to us frankly about side payments in marketing situations and in non-US cultures.

RESULT 1 *For incentive systems in which the rewards to the upstream agent are increasing in the downstream agent's rating, the upstream agent will provide a positive side payment to the downstream agent unless the firm sets a binding upper bound on the rating (or otherwise precludes side payments). Even with a binding upper bound, there may be side payments.*

PROOF. Consider a given u. Let $F(e)$ be the distribution function for e. Consider first the case where there is no upper bound on r or it is not binding. U will seek to maximize the expression in (C2) subject to the conditions imposed by D's maximization problems in (C1). Let $x = v - c_u - s$. Differentiating (C2) we obtain:

$$\int \frac{\partial U_u}{\partial x} \frac{\partial[v(\tilde{r}) - c_u(u) - s(u, \tilde{r})]}{\partial \tilde{r}} dF = 0.$$

By assumption, $\partial U_u/\partial x > 0$. The error, e, appears in w, but it does not appear in v, c_u, or s. Thus, this integral can be zero if and only if $\partial[v - c_u - s]/\partial \tilde{r} = 0$. Thus, this first-order condition holds if and only if:

$$\frac{\partial v(\tilde{r})}{\partial(\tilde{r})} - \frac{\partial s(u, \tilde{r})}{\partial(\tilde{r})} = 0. \tag{A1}$$

Let $y = w - c_d + s$. We now use implicit differentiation on (C1) recognizing that the right-hand side (RHS) does not depend on $\tilde{r}$.

$$\int \frac{\partial U_d}{\partial y} \left[\frac{\partial y}{\partial w} \frac{\partial w(\tilde{r}, \pi)}{\partial \tilde{r}} + \frac{\partial y}{\partial s} \frac{\partial s(u, \tilde{r})}{\partial \tilde{r}}\right] dF = 0. \tag{A2}$$

By assumption $\partial U_d/\partial y$, which depends on e, is positive. Furthermore, $s(u, \tilde{r})$ does not depend upon e, and $\partial y/\partial w = \partial y/\partial s = 1$. Hence, Equation (A2) becomes:

$$\int \frac{\partial U_d}{\partial_y} \frac{\partial w(\tilde{r}, \pi)}{\partial \tilde{r}} dF = -\frac{\partial s(u, \tilde{r})}{\partial \tilde{r}} \int \frac{\partial U_d}{\partial y} dF. \tag{A3}$$

From (A1), we have $\partial s(\tilde{r}, u)/\partial r = \partial v(\tilde{r})/\partial r$. But $\partial v(\tilde{r})/\partial r > 1$ by assumption. Thus, the RHS of (A3) is negative:

$$\int \frac{\partial U_d}{\partial y} \frac{\partial w(\tilde{r}, \pi)}{\partial \tilde{r}} dF < 0. \tag{A4}$$

By similar arguments we use implicit differentiation on (C1) to obtain:

$$\int \frac{\partial U_d}{\partial y} \frac{\partial w(\hat{s}, \pi)}{\partial \hat{s}} dr < 0. \tag{A5}$$

Finally, we differentiate the left-hand side (LHS) of (A4) or (A5) to demonstrate that the second derivative with respect to r is negative (concave) because $\partial U_d/\partial y > 0$ and $\partial^2 w/\partial r^2 < 0$. Thus, we have shown that the first derivative of a concave function is negative at $\tilde{r}$ and zero at $\hat{r}$. Hence, $\tilde{r} > \hat{r}$. The side payment is positive by (C1). In the case where r is constrained, we add a Langrange multiplier, $-\lambda(r - \bar{r})$, to U's optimization problem. This might allow a solution of the form $\partial v/\partial \tilde{r} = \lambda$ and $\partial s/\partial \tilde{r} = 0$. If u were limited to a finite set, we obtain a result similar to that for Lagrange multipliers by using a series of piecewise functions for w such that each piece corresponds to a different action by U. Finally, the reader can verify side payments for $v = v_0 + v_1 r$ and $w = w_0 + w_1(1 - r) + w_3 r\tilde{\pi}$ for $s \in [0, 1]$ and sufficiently large v_1 and w_1. □

RESULT 2. *If the firm can preclude side payments and choose a reward system, v and w, such that the upstream and downstream agents, acting in their own best interests, choose actions u^0 and d^0, then there exists a reward system such that (1) there is no loss of profits to the firm and (2) the upstream and downstream agents, still acting in their own best interests, choose u^0 and d^0 even though they are free to make side payments in return for higher ratings.*

PROOF. Let us first denote the game in which the firm precludes side payments by G^0 and the game in which side payments are allowed as G^1. Formally, we show that if (v^0, w^0) implement (u^0, d^0, r^0) in G^0, and the participation constraints bind, then there exist real numbers ϕ, θ_u, θ_d such that $(v^1, w^1) = (0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$ leads to U and D choosing (u^0, d^0, r^0) in G^1 at the same expected cost to the firm. We will assume that w^0 satisfies the same assumptions as w and that utility is strictly increasing in monetary payments (with the slope bounded away from zero). Finally we also require that $\forall d$, π is increasing in u when $u = u^0$, and that the integrals over $f(e)$ are defined correctly. These are all rather weak (and natural) assumptions.

Note that under the new reward system only D incurs risk and this risk is due to w^0 (as under the old reward system). Hence, the risk premium paid by the firm will be unchanged if we implement (u^0, d^0, r^0) in G^1. Moreover, if we can implement (u^0, d^0, r^0) in G^1, we can adjust θ_u, θ_d until both participation constraints bind. Therefore, we need only show that we can choose γ and ϕ to implement (u^0, d^0, r^0) in G^1 with $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$. To do so, we first show that if we can implement u^0 and d^0 with $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$, then, when the participation constraints are binding, we will also implement r^0. Next, we show that if we can implement u^0 and r^0 with $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$, then, when the participation constraints are binding, we will also implement d^0. Finally we show that we can choose a γ and ϕ so that $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$ implements u^0 given d^0 and r^0.

Note that r^0 is determined by D in G^0 from the following first-order condition:

$$\int \frac{\partial U_d}{\partial y} \frac{\partial w^0}{\partial r} dF = 0. \tag{A6}$$

Under G^1, r is determined by U maximizing $\int U_u(v^1 - c_u(u) - s)dF$, which yields the following first-order condition:

$$\left(\phi - \frac{\partial s}{\partial r}\right) = 0. \tag{A7}$$

Using the implicit function theorem on (C1) we get:

$$\frac{\partial s}{\partial r} = \left(\int \frac{\partial U_d}{\partial y} \gamma dF - \int \frac{\partial U_d}{\partial y} \left[\frac{\partial w^0}{\partial \pi} \frac{\partial \pi}{\partial d} \frac{\partial d}{\partial r} + \frac{\partial w^0}{\partial r}\right] dF\right)\left(\int \frac{\partial U_d}{\partial y} dF\right)^{-1} = 0. \tag{A8}$$

Inserting this into (A7) yields:

$$\left(\phi - \gamma + \int \frac{\partial U_d}{\partial y}\left[\frac{\partial w^0}{\partial \pi}\frac{\partial \pi}{\partial d}\frac{\partial d}{\partial r} + \frac{\partial w^0}{\partial r}\right]dF\left[\int \frac{\partial U_d}{\partial y}\,dF\right]^{-1}\right) = 0. \quad \text{(A9)}$$

We can select $\phi - \gamma$ to make this zero if (A6) holds, since all derivatives are evaluated at their participation constraints. So if we can use $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$ to implement u^0 and d^0 in G^1, we will also implement r^0. Note that this result holds even if there is an upper bound on r that constrains r^0 in G^1. Although (A6) will not hold in those circumstances, because the LHS of (A9) equals the LHS of (A6), we know that the constraint will also be binding in G^1.

We turn now to implementation of d^0, and make the analogous argument that if $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r_0 + \theta_d)$ implement u^0 and r^0 in G^1, we will also implement d^0. Note that d^0 is determined by D in G^0 from the following first-order condition:

$$\int \frac{\partial U_d}{\partial y}\left(\frac{\partial w^0}{\partial \pi}\frac{\partial \pi}{\partial d}\right)dF - \int \frac{\partial U_d}{\partial y}\frac{\partial c_d}{\partial d}\,dF = 0. \quad \text{(A10)}$$

Under G^1, d is determined by D maximizing $\int U_d(w^1 - c_d(d) + s)dF$, which yields the following first-order condition:

$$\int \frac{\partial U_d}{\partial y}\left(\frac{\partial w^0}{\partial \pi}\frac{\partial \pi}{\partial d}\right)dF - \int \frac{\partial U_d}{\partial y}\frac{\partial c_d}{\partial d}\,dF = 0. \quad \text{(A11)}$$

This holds if (A10) holds since all derivatives are again evaluated at their participation constraints. For fixed $\phi - \gamma$ we now need only show that we can find a γ that implements u^0 using $(0.5\phi^2 + \phi r + \theta_u, w^0 - 0.5\gamma^2 - \gamma r + \theta_d)$. Under G^1, u is determined by U maximizing $\int U_u(v^1 - c_u(u) - s)dF$, which (using the envelope theorem) yields the following first order condition:

$$\frac{\partial U_u}{\partial x}\left[\int \frac{\partial U_d}{\partial y}\bigg|_a \frac{\partial w^0}{\partial \pi}\frac{\partial \pi}{\partial u}\,dF - \int \frac{\partial U_d}{\partial y}\bigg|_b \frac{\partial w^0}{\partial \pi}\frac{\partial \pi}{\partial u}\,dF\right]\left[\int \frac{\partial U_d}{\partial y}\bigg|_a dF\right]^{-1} - \frac{\partial U_u}{\partial u}\frac{\partial c_u}{\partial u} = 0 \quad \text{(A12)}$$

where

$$a = (w^1(u^0, d^0, r^0) - s, d^0),$$
$$b = (w^1(u^0, \hat{d}, \hat{r}), \hat{d}).$$

Suppose again that we fix u^0, d^0, and r^0 and use θ_u, θ_d to ensure that the participation constraints remain binding, does there exist a γ such that (A12) holds?

Under these constraints, only the second $(\partial w^0/\partial \pi)(\partial \pi/\partial u)$ term changes as we change γ. On the other hand, (C4) tells us that the change is continuous. Suppose first that $\phi = 0$. In this case, $s = 0$, $\hat{r} = r^0$, and $\hat{d} = d^0$, so the LHS of (A12) reduces to $-(\partial U_u/\partial d)(\partial C_u/\partial u) < 0$. Consider next what happens as $\gamma \to \infty$. Using the implicit function theorem on the first-order condition for $\hat{r}$, we see that $d\hat{r}/d\gamma$ is negative if:

$$\int \frac{\partial^2 U_d}{\partial y^2}\left[\frac{\partial w^0}{\partial r} - \gamma\right](\gamma + \hat{r})dF + \int \frac{\partial U_d}{\partial y}\,dF > 0. \quad \text{(A13)}$$

We would like to show that $\hat{r} \to -\infty$ as $\gamma \to \infty$ (we assume that D's threat point $\hat{r}$ has no lower bound). Let us assume, to derive a contradiction, that this is not the case. This implies that (A13) is not satisfied, and $(\gamma + \hat{r}) > 0$ as $\gamma \to \infty$. Note that because w^0 is concave in r, $\partial w^0/\partial r$ is nonincreasing as γ increases. Hence, for sufficiently large γ, we know that $\partial w^0/\partial r - \gamma < 0$. Thus, we have derived a contradiction because if $\partial w^0/\partial r - \gamma < 0$ and $(\gamma + \hat{r}) > 0$, then both terms in Equation (A13) are positive as $\gamma \to \infty$. Hence, we know that $\hat{r} \to -\infty$ as $\gamma \to \infty$. Since by assumption $\partial w^0/\partial \pi \to -\infty$ as $\hat{r} \to -\infty$, this will eventually make the LHS of (A12) positive. So, by continuity there exists a γ such that (A12) holds and this γ implements u^0. □

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This paper was received March 5, 1996, and has been with the authors 8 months for 2 revisions; processed by Brian T. Ratchford.