

Can We All Get Along?
Incentive Contracts to Bridge the Marketing and Operations Divide

Kinshuk Jerath*
Serguei Netessine
Z. John Zhang

The Wharton School
University of Pennsylvania
Jon M. Huntsman Hall
3730 Walnut Street
Philadelphia, PA 19104-6340

November 2007

*Kinshuk Jerath is a doctoral candidate at the Wharton School of the University of Pennsylvania. Serguei Netessine is Associate Professor of Operations Management at the Wharton School of the University of Pennsylvania. Z. John Zhang is Professor of Marketing at the Wharton School of the University of Pennsylvania. E-mail correspondence: kinshuk@wharton.upenn.edu.

Can We All Get Along?

Incentive Contracts to Bridge the Marketing and Operations Divide

Abstract

The marketing and operations management arms in a firm must work in coordination – marketing efforts to create demand go to waste if supply is suboptimal, and vice versa. However, achieving this coordination has remained a long-standing problem, because in most firms these units are managed in a decentralized manner. A major source of conflict is that marketing compensation is usually heavily weighted towards sales whereas operations compensation is usually heavily weighted towards expense reduction. In this paper, we invoke agency theory to determine compensation plans for sales and operations managers to coordinate their activities in the best interests of the firm.

We first show in a single product scenario that, by rewarding the sales manager for increasing sales and the operations manager for reducing total cost, a firm cannot coordinate the two functions. Furthermore, a simple profit-sharing contract does not work, either, because of the free-rider problem. However, we show that each of the following two contract schemes can *always* achieve coordination: (1) rewarding the operations manager separately for increasing sales and reducing costs, and (2) rewarding him separately for reducing missed sales and leftover supply. We thus show that choosing the right performance metrics (before choosing the contract parameters) can mean the difference between being able to align the interests of the salesforce with those of the firm and not being able to do so. We identify coordination between demand and supply as a new driver of compensation structure and find, for instance, that the sales commission for the sales manager, even in the presence of risk aversion, can increase with uncertainty in demand, a conclusion that runs contrary to results from classic agency theory.

In a multiproduct scenario, when one manager manages several products, the coordinating contracts are fairly complicated. However, we show that choosing the right form of workforce allocation – either a *sales-focused organization* (a separate sales manager for every product, one operations manager for all products) or an *operations-focused organization* (a separate operations manager for every product, one sales manager for all products) – can help a firm to achieve near-perfect coordination. This is in line with the observation that most firms have either a “sales image” or a “cost image,” and sheds some light on how the underlying objective of aligning marketing and operations, while keeping the size of the salesforce small and compensation contracts simple, can influence the organization of a firm.

Keywords: marketing-operations interface, salesforce compensation, agency theory.

1 Introduction

The aim of marketing is to create demand, and the aim of operations management (or logistics) is to match supply with demand. Clearly, for every firm, these two functions are closely connected – actual sales increase with higher demand only if supply is also up to the mark – and researchers and practitioners widely agree that harmony between these two arms of the firm will improve profits (Hausman, Montgomery and Roth 2002). Synchronizing these two functions, however, is easier said than done. The two departments are often managed in a decentralized manner by self-interested managers who often have clashing objectives – marketing personnel claim that logistics personnel are “often willing to forsake the customer to save on costs” while logistics personnel are “frustrated by the relative indifference towards the logistics function of their marketing colleagues” (Ellinger, Keller and Hansen 2006).¹

This discord has remained a classic issue for researchers working on the marketing/operations management interface, leading to the well-known article in *Harvard Business Review* titled “Can marketing and manufacturing coexist?” (Shapiro 1977) and to special issues of leading journals like *Management Science* devoted to attempts at solving the problem (Ho and Tang 2004). Shapiro (1977) lays out some broad areas of “necessary cooperation but potential conflict,” which include capacity planning for uncertain sales, quality assurance, breadth of product line, the introduction of new products, and coordinating supply decisions with marketing decisions. The various attempts to bridge this gap usually focus on a specific source of discord and a solution to it. In this paper, we will focus on the last issue pointed out above, i.e., coordinating demand-enhancing efforts on the marketing side and product availability on the operations side.

We have in mind a situation in which a firm employs a sales manager whose job is to increase the level of demand for a product by exerting sales effort, and employs an operations manager who makes the decision on how much of the product to supply. Such situations are common in practice and described, for example, in the teaching cases on demand and supply coordination at LL Bean (Schleifer, Jr. 1992), Hewlett Packard (Kopczak and Lee 1994), Sport Obermeyer (Hammond and Raman 1994) and Le Club Français du Vin (Terwiesch and Gouze 2006). Demand is random, i.e., the returns to sales effort are uncertain, and the product is delivered after a considerable lead time so that the sales is limited by both the demand and supply.²

Most firms manage their operations arms as cost centers, separately from the sales arms, which are managed as revenue centers (Harps 2002, Ellinger et al. 2006). Such a setup with random demand is subject to the discord between marketing and operations discussed above – the sales

¹This issue would not have existed if it was not for the following practical considerations: actions of individuals are often non-observable, non-contractible or costly to monitor, managers tend to behave in a self-interested manner, it is quite impractical to have a single manager in control of both functions, and writing complex contracts that stipulate every contingency is usually too time-consuming.

²In general, the job of the operations manager is to have the product available when demand is realized. This encompasses various scenarios – in a manufacturing setting it implies deciding the quantity of the product to be produced, in a business-to-business or retail setting it implies deciding the quantity to be ordered and supplied as inventory, etc. For simplicity, we will refer to his job as “supplying product” all through the paper. Certainly, there are organizations in which operations managers are not endowed with supply decisions, and such scenarios are outside of the scope of our paper.

manager complains that her effort is going to waste because of too little being supplied so that she loses on sales, while the operations manager complains that the sales promised by the sales manager frequently do not materialize, which drives up the costs (Ellinger et al. 2006). The misalignment often occurs because of the problem in the incentive structure of the managers. Shapiro (1977) identifies this as the *prime reason* for the gap and states:

“On the one hand, the marketing people are judged on the basis of profitable growth of the company in terms of sales. . . . Unfortunately, the marketers are sometimes more sales-oriented than profit-oriented. On the other hand, the manufacturing people are often evaluated on running a smooth operation at minimum cost. Similarly unfortunately, they are sometimes more cost-oriented than profit-oriented. . . . Because the marketers and manufacturers both want to be evaluated positively and rewarded well, each function responds as the system asks it to in order to protect its self-interest.”

Recent evidence from the Internet forum RetailWire points out that this problem of clashing compensation plans remains a doggedly persistent problem thirty years later (RetailWire 2007). Ellinger et al. (2006) and Narayanan and Raman (2004) provide several other examples of coordination failures between marketing and operations due to misaligned incentives, most notably that of Cisco, when in 2001 its much-vaunted supply chain snapped, leading to an estimated loss of \$2.5 billion and a 6% fall in share price on the day of the announcement. There is also evidence that several firms tie the performance evaluation of their operations units to service measures like sales achieved and fill rate³, rather than tying the compensation directly to costs (Cohen, Agrawal and Agrawal 2006). However, there is a lack of research that would explain whether different performance metrics for managers result in different outcomes.

In this paper, we explore whether incentive contracts can be written so that both sales and operations managers, while individually maximizing their utilities based on the trade-off between compensation provided and effort exerted, make their respective choices in such a way that the best interests of the firm are served. We find that the answer to this question is in the affirmative, and has several interesting aspects to it. Broadly speaking, the firm can write simple contracts to coordinate marketing and operations, but needs to carefully choose not just the contract parameters, but also the *performance metrics* that should be contracted upon. We find that if the sales manager is compensated based on sales and the operations manager is compensated based on cost (which is the norm in most firms, as discussed above), then their actions can be coordinated only under certain restrictive conditions on cost. Under random demand, increasing supply increases the expected cost from unsold goods, and reduces the expected cost from missed sales. Since the first component of cost typically dominates the second, the operations manager does not have sufficient incentives to supply the optimal quantity. As the uncertainty in demand increases, the undersupply problem only worsens. Further, a simple profit-sharing contract does not work, either, because of

³defined as $1 - \frac{\text{backorders}}{\text{mean demand}}$

the free-rider problem.

We show that the firm can incentivize the operations manager to supply the optimal quantity by extending his contract in one of two ways: (1) by penalizing him on total cost but rewarding him for sales (which we call an *interdependent contract* because the operations manager is being compensated in part based on metrics borrowed from the sales arm of the firm), and (2) by compensating him separately on the different components of the inventory cost, i.e., penalizing him separately on unsold inventory and backorders (which we call an *information-based contract* because implementing the contract requires the firm to use detailed cost information). The simplest interdependent contract involves compensating the operations manager only on sales (with the total cost muted out of the contract specification), and the simplest information-based contract involves compensating the operations manager only on backorders (with the other components of inventory cost muted out of the contract specification). Both these schemes can *always* achieve coordination since they provide him the incentives to increase supply, and utilize his effort disutility costs (which increase with quantity supplied) to limit it at the optimum quantity. This explains the observation that some firms compensate operations managers based on sales and fill rate (which is a measure derived from backorders alone). We thus show that simply choosing the right performance metrics can mean the difference between aligning the interests of the salesforce with that of the firm and not being able to do so, while still keeping the contracts very simple.

We also consider how the reward structure for the coordinating contracts varies across different industries with product and demand characteristics. We find that as the variance in demand increases, the sales manager's commission rate for sales can increase. In our model, we identify coordination between marketing and operations as a driver of incentive structure in firms and obtain this result complementary to the prediction from classic agency theory (that an increase in demand uncertainty will lead to a reduction of sales incentives provided to a risk-averse sales agent). We assume agents to be risk neutral, and our study is in the spirit of recent literature in economics on incentives in firms which extends incentive theory beyond the risk-insurance trade-off. Assuming agents to be risk averse does not change the insights from the basic model, as we show in an extension.

In a multiproduct scenario, when one manager manages several products, the coordinating contracts (after correcting for the distortion discussed above) are fairly complicated, involving multiple variable parts in the compensation contract for each manager and/or constructing complex performance metrics. In the real world, the contracts offered to managers who manage multiple products are fairly simple – they usually involve one variable component, which is determined by a simple aggregate performance measure like total dollar sales, total inventory costs or total fill rate across all products. This introduces a different kind of distortion in the incentives – that of suboptimal allocation of effort across products because the marginal return on effort for the manager differs from the marginal profit for the firm for the different products – and the firm cannot achieve the coordinated outcome. However, we show that choosing the right form of workforce allocation – either a *sales-focused organization* (a separate sales manager for every product, one operations

manager for all products) or an *operations-focused organization* (a separate operations manager for every product, one sales manager for all products) – can help a firm to achieve near-perfect coordination. This is in line with the observation that most firms have either a “sales image” or a “cost image,” and sheds some light on how the underlying objective of aligning marketing and operations, while keeping the size of the workforce small and compensation contracts simple, can influence the organization of a firm.

The rest of the paper is organized as follows. In Section 2, we review the relevant literature on the marketing/operations management interface and on applications of agency theory in marketing. In Section 3, we consider the case of one product, show the distortion in incentives when rudimentary performance metrics are used, and propose metrics (and associated contracts) to correct the distortion. In Section 4 we consider several extensions (sequential actions of managers in Section 4.1, operational-cost-reduction effort of the operations manager in Section 4.2, risk-averse agents in Section 4.3 and multiple products in Section 4.4) and show that the insights from the basic model are robust to these variations. We conclude in Section 5. All proofs are provided in the appendix at the end of the paper. The extensions with risk-averse agents and two products are analyzed in detail in a supplement accompanying this document.

2 Literature Review

In this section, we first review the literature that lies at the interface of marketing and operations management, and then review the applications of agency theory to salesforce compensation in marketing. Finally, we review some recent developments in agency theory in economics that have not yet seen applications in marketing, but are relevant to our paper.

The literature at the marketing-operations management interface can be broadly classified into two streams: (1) intra-firm coordination between marketing and operations to increase firm profit and competitiveness (our paper falls in this category), and (2) inter-firm coordination where typically supply-chain partners like manufacturers and retailers want to harmonize channel performance. In the intra-firm coordination category, the existing research focuses primarily on centralized coordination. De Groote (1994), Netessine and Taylor (2007), Souza, Bayus and Wagner (2004) and Balasubramanian and Bhardwaj (2004) study the simultaneous choice of marketing and operations variables for a central planner in a firm and show that considering the two together can lead to insights that differ greatly from those generated when they are considered in isolation.

The focus in this paper is on decentralized coordination. A paper related to ours is Porteus and Whang (1991). They consider a firm with a manufacturing manager whose job is to enhance the total capacity for production to be allocated among different products. The firm has one product manager for every product who makes the sales effort and production quantity decisions for her product. The interdependence between decentralized product managers is through the common capacity constraint. Our work differs in fundamental ways. First, we assume that the firm delegates the supply decision (analogous to the production quantity decision made by the sales manager in their model) to the operations manager. Hence, the interdependence between the sales manager

and the operations manager is through their complementary decisions of demand enhancing effort and supply, respectively. In this setting, we show that a firm can achieve coordination based on commonly used performance measures only under a certain condition. We then propose the performance metrics the firm must use and the contracts it should offer to the sales and operations managers to always achieve coordination. We also show how the coordinating contracts vary by product and demand characteristics. Second, in the extension of our basic model to multiple products, we endogenize the decision of the structure of the organization, something that they treat as exogenous.

In the inter-firm coordination category, the typical scenario is that of an upstream supplier or manufacturer supplying to a downstream distributor or retailer. The contracts here are between these two entities (as opposed to the intra-firm coordination case, where the firm contracts with marketing and operations managers, and there is no direct exchange between the managers) and the goal is to coordinate activities like product delivery and information transfer, typically by leveraging instruments like wholesale price, revenue sharing agreements and return policies. There is a huge literature on inter-firm coordination in marketing (Jeuland and Shugan 1983, Moorthy 1987, Desai, Koenigsberg and Purohit 2004, and references therein), operations management (Cachon 2003, and references therein) and at the interface of the two streams (Eliashberg and Steinberg (1987) and Netessine and Rudi (2004)). Since the focus of this paper is on intra-firm coordination, we refer the reader to Netessine and Rudi (2004) for a comprehensive literature review on inter-firm coordination.

Basu, Lal, Srinivasan and Staelin (1985) were the first to apply the agency paradigm from economics to the problem of salesforce compensation in marketing and discuss the impact of uncertainty, risk aversion, sales response effectiveness and other factors on compensation plans. The framework in Basu et al. (1985) has been extended to include a menu of contracts (Lal and Staelin 1986 and Rao 1990), quota-based plans (Raju and Srinivasan 1996), price delegation to the salesforce under competition (Bhardwaj 2001), monitoring of the salesforce (Joseph and Thevarajan 1998), including customer satisfaction measures in the performance measures of the salesperson (Hauser, Simester and Wernerfelt 1994) and assuming a risk-averse firm (Misra, Coughlan and Narasimhan 2005). Another stream of literature focuses on designing compensation plans to extract accurate demand forecasts from sales personnel to compensate them appropriately (Gonik 1978, Rao 1990, Celikbas, Shanthikumar and Swaminathan 1999, Chen 2000, Chen 2005), which can also help in planning operations better.

Almost all papers on salesforce compensation in marketing assume the agent to be risk-averse and rely on the trade-off between incentives and insurance for their main results. In parallel with the development of theoretical models, several studies in marketing have attempted to empirically and experimentally validate the theoretical findings, with mixed results (Coughlan and Narasimhan 1992, Lal, Outland and Staelin 1994, Joseph and Kalwani 1998, Ghosh and John 2000, Misra et al. 2005). Prendergast (1999) cites several examples from economics literature where empirical studies have failed to confirm theoretical predictions. Prendergast (2000) argues that while the

logic behind the risk-aversion assumption is strong, only weak empirical support has been found for the results it predicts and points out several reasons for which one can observe deviations in reality. Similarly, Gibbons (2005) calls for broadening the focus of incentive theory beyond this trade-off and summarizes some recent advances in economics literature, like career concerns and investment in capabilities, that help to explain observed incentive schemes that are unexplained by the risk-incentive trade-off. He points to a very important aspect of incentive contracts observed in the real world – the use of distorted or inappropriate performance measures. Kerr (1975) calls this “the folly of rewarding A, while hoping for B.” In a multitasking framework, where an agent has to allocate effort among a number of different tasks (Holmstrom and Milgrom 1991), Baker (2000) shows that, even in the absence of risk aversion, the variable component of the incentive contract will depend on the degree of alignment between what the firm wants the agent to do and what the performance measure of the agent actually measures. He also provides several examples where distorted performance measures can induce unintended consequences in organizations.

In our analysis in the sections to follow, we show how, in our marketing/operations setting where the firm has to coordinate the decisions of two independent agents, contracting on certain measures like total inventory cost can have the problem of “rewarding A, while hoping for B.” To the best of our knowledge, this misalignment of incentives in such an interdependent setting has not been studied yet. (Holmstrom (1982) considers a team setting in which only the final profit is observable. In this paper, we consider compensation plans based on other observable output metrics like sales, inventory costs and backorders that are pertinent to the marketing/operations setting and used in the industry.) Furthermore, we show that simply choosing appropriate performance metrics can coordinate the decentralized marketing and operations units of the firm. Thus, we also add to the growing literature on the marketing/operations management interface.

Finally, there is extensive literature in economics and management on organization design, which looks primarily at issues like delegation of decision rights in organizations. We do not review this literature here, since our results on organization design focus on a very different aspect (whether the firm should allocate more of its workforce to the sales side or the operations side) and are rooted in trade-offs involved in distorting incentives on either the sales or the operations side.

3 Model

3.1 Model Description and Notation

We model a firm selling one product. The firm (denoted by the subscript f ; referred to as “it”) employs two managers – a sales manager (denoted by the subscript m ; referred to as “she”) whose job is to provide demand enhancing effort for the product, and an operations manager (denoted by the subscript o ; referred to as “he”) whose job is to decide the quantity of product supplied and ensure its availability at the time when demand is realized. To employ the managers, the firm has to compensate them for their efforts. We assume that the compensation for each manager consists of a fixed part, called salary, and a variable part, called commission. The commission for a manager

is determined using a performance metric for that manager and a per-unit commission rate. The performance metrics for the managers can only be observed quantities.

Sales Manager

The sales manager’s task is to exert sales effort to increase the possibility that demand turns out to be high. Formally, the demand for the product is denoted by the random variable $D(A)$ defined as

$$D(A) = A + \varepsilon$$

whereby A is the sales effort and determines the mean demand as A , and uncertainty in demand is incorporated by using an additive random error term ε . Before the selling season begins, only the distribution of demand is known. The sales manager is effort averse and her disutility of effort is given by the function $V_m(A) = \frac{1}{2}A^2$ which is convex in A . (For every extra unit of effort exerted by the sales manager, she has progressively higher disutility.) Denoting the salary, the per-unit commission rate and the performance metric for the sales manager by w_m, α_m and P_m respectively, we denote her total compensation by the random variable $S_m = w_m + \alpha_m P_m$.

Operations Manager

The operations manager’s task is to decide the quantity Q to be supplied, and ensure that this quantity supplied is available when demand is realized.⁴ The operations manager is effort averse and there are two components to his effort. First, supplying a quantity Q leads to a disutility of effort $\frac{1}{2}Q^2$, which is convex in Q .⁵ Second, in accordance with the inventory inaccuracy literature (Liu, So and Zhang 2006), we assume that a random fraction ζ of the total supply becomes “unavailable” but the operations manager needs to exert effort χ per unit unavailable to ensure that it is available *before* demand is realized (in this sense, uncertainty on the operations side is “remediable” uncertainty).⁶ Hence, the total effort required due to supply uncertainty is given by the random variable $\Omega = \chi\zeta Q$. The disutility associated with this effort is given by the random variable $\frac{1}{2}\Omega^2 = \frac{1}{2}\chi^2\zeta^2 Q^2$. Further, we assume that this effort is unobservable due to the random nature of the fraction ζ .

Hence, the total disutility of effort by the operations manager is given by the random variable $V_o(Q) = \frac{1}{2}(1 + \chi^2\zeta^2)Q^2$. To simplify the notation in the analysis that follows, we assume that $k_o = 1 + \omega$, where $\omega = \chi^2 E[\zeta^2]$ and represents the uncertainty in supply since it can be used as a proxy for the variance in the fraction ζ (specifically, $\omega = \chi^2(Var[\zeta] + E[\zeta]^2) > 0$).

⁴This is in accordance with the motivating examples provided in the introduction, where an operations manager decides the quantity of a product to be supplied. In Section 4.2, we extend the work profile of the operations manager to also include operational-cost-reduction effort.

⁵This stems from deterministic effort required to train and oversee personnel who work in the warehouse, schedule delivery in and out of the warehouse, conduct periodic audits, etc. This effort increases as the quantity supplied increases and disutility is assumed convex in Q .

⁶This stems from effort required to prevent theft of inventory (also known as *shrinkage*), finding and replacing misplaced or misaccounted-for units, etc. See Ton and Raman (2004) for more details and evidence.

Denoting the salary, the per-unit commission rate and the performance metric for the operations manager by w_o , α_o and P_o respectively, we denote the total compensation of the operations manager by the random variable $S_o = w_o + \alpha_o P_o$.

Firm-level outcome

The sales realized (denoted by the random variable $Y = \min\{Q, D(A)\}$) depend on the realized demand and the available Q . If the quantity available is higher than demand the firm is left with unsold inventory (denoted by the random variable $U = \max\{Q - D(A), 0\}$), and incurs a penalty c_u per unsold unit. On the other hand, if the quantity available is lower than demand then there are missed sales, leading to backorders (denoted by the random variable $B = \max\{D(A) - Q, 0\}$), and the firm incurs a penalty c_b per backorder. This can be thought of as a penalty due to customer dissatisfaction at not being able to obtain the product after it was advertised by the sales manager. The total “mismatch-in-inventory” cost borne by the firm is denoted by the random variable $C = c_u U + c_b B$. For every unit sold the firm obtains revenue r . The firm’s objective is to maximize $\Pi_f = rY - C - S_m - S_o$, which is also a random variable. We have summarized the notation in Table 1.

We also assume that each manager has an outside option, i.e., if he or she chooses not to work with the firm each has a fall-back option that gives him or her a certain level of utility. We normalize this to zero without any loss of generality.

In our model, we treat the retail price, r , as exogenous. This is a conventional assumption in the salesforce compensation literature and is motivated by the fact that prices are usually sticky over time and are also decided at a “higher,” more strategic, level. Furthermore, firms decide prices based on the characteristics of the market and the consumer base, and do not use them as an instrument to motivate the workforce.

We assume that both the agents and the firm are all risk neutral. The focus of this model is to highlight the fact that achieving coordination between the different units of the firm, given the decentralized nature of decision-making, has interesting implications for the contracts that must be offered to the two managers. Since the risk aversion of agents has been a key assumption of principal-agent models in marketing, we consider the impact of incorporating this assumption in an extension in Section 4.3.

Order of events

The order of events in the game is as follows. In the first stage, the firm decides the performance measures for the two managers and offers S_m and S_o as take-it-or-leave-it contracts to the sales manager and the operations manager respectively. In the second stage, contingent upon their accepting the contracts, the two managers simultaneously make their decisions on sales effort A and quantity Q .⁷ Then demand is realized, profits appropriated by the firm and compensation paid

⁷It is costly to monitor the sales effort exerted by the sales manager, so the firm prefers an “outcome-based contract” for her. The aim of contracting with the operations manager using performance measures is to incentivize

<i>Symbol</i>	<i>Quantity</i>
r	retail price
c_u	unsold inventory cost
c_b	backorder cost
A	sales effort
Q	quantity supplied
$D(A)$	demand when sales effort is A
ε	random error in demand
ζ	proportion of inventory requiring availability effort
ω	proxy for uncertainty in supply
$Y = \min\{Q, D(A)\}$	realized sales
$U = (Q - D(A))^+$	unsold inventory
$B = (D(A) - Q)^+$	backorders
$C = c_u U + c_b B$	inventory mismatch cost
subscripts f, m, o	denote “firm”, “sales manager” and “operations manager”
S_m	total salary of sales manager
S_o	total salary of operations manager
$V_m(A)$	effort disutility function for sales manager
$V_o(Q)$	effort disutility function for operations manager

Table 1: Notation for the model with a firm selling one product

to the managers. We assume that both managers know each other’s contracts and choose their actions simultaneously. We solve for the subgame-perfect outcome of this game, as follows.

Given their contracts, the sales manager and the operations manager simultaneously solve for A^* and Q^* :

$$A^* = \arg \max_A E[\Pi_m | Q^*, A] = E[S_m | Q^*, A] - V_m(A) \quad (1)$$

$$Q^* = \arg \max_Q E[\Pi_o | Q, A^*] = E[S_o | Q, A^*] - EV_o(Q) \quad (2)$$

Anticipating these values of A^* and Q^* in terms of the contract parameters, the firm solves for

optimal supply. The quantity supplied is seemingly observable, so that it should be possible to write a “behavior-based contract” (or a “forcing contract”) to make the operations manager stock this level of inventory. However, there is sufficient evidence from the industry that operations managers are offered outcome-based contracts using cost-based performance measures. This is also due to difficulties in implementing the highly nonlinear forcing contracts. There is also literature that shows that excessive monitoring of employees leads to suboptimal performance (Stanton (2000) and references therein). Furthermore, we will show that the firm can delegate the supply decision and construct contracts to achieve the first-best solution. We therefore use outcome-based contracts for the rest of the paper for both managers. (For a discussion on behavior-based contracts and outcome-based contracts in agency theory, see Anderson and Oliver (1987).) Furthermore, as discussed earlier, part of the operations manager’s effort is unobservable “availability effort.” As we will discuss at the appropriate point, this aspect makes incentive contracts necessary when sales are observable but realized demand is not.

optimal contracts S_m and S_o to maximize its own profits:

$$\begin{aligned} & \max_{\{S_m, S_o\}} E[\Pi_f|Q^*, A^*] = rE[Y|Q^*, A^*] - E[C|Q^*, A^*] - E[S_m|Q^*, A^*] - E[S_o|Q^*, A^*] \\ \text{such that: } & \max_A E[S_m|Q^*, A] - V_m(A) \geq 0 \\ & \max_Q E[S_o|Q, A^*] - EV_o(Q) \geq 0 \end{aligned} \quad (3)$$

where $E[X|\Omega_1, \dots, \Omega_k]$ denotes the expected value of the random variable X given the values $\Omega_1, \dots, \Omega_k$.⁸ The last two constraints are to ensure that the managers choose to work for the firm when offered the contracts rather than to fall back on their outside options.

3.2 First-Best Outcome

Consider the case when the firm can dictate to the sales manager the sales effort and to the operations manager the quantity to be supplied and perfectly monitor their actions. The firm will dictate to them the optimal decisions and accordingly compensate them for their efforts. This is the best the firm can do – we call it the “first-best” solution and use it as the benchmark, i.e., in the cases when the firm cannot dictate actions to the managers it will strive to design their contracts so that their actions achieve the first-best profit for the firm. In this section, we characterize the unique first-best solution in Proposition 1 with the aid of the lemma below.

Lemma 1 *Under the assumptions on demand and effort disutility functions in Section 3.1, the first-best solution to the firm’s problem, given by the pair (Q^{FB}, A^{FB}) , is unique for any arbitrary distribution of ε .*

Proof Refer to Appendix I. ■

To move forward and characterize the first-best solution, we assume for tractability that the error component in demand is distributed as $\varepsilon \sim \text{Uniform}[-\sigma, \sigma]$.

Proposition 1 *Under the assumptions above, the first-best solution is given by the unique pair (Q^{FB}, A^{FB}) , where*

$$\begin{aligned} Q^{FB} &= \frac{r(r + c_u + c_b) + (r - c_u + c_b)\sigma}{(r + c_u + c_b)(1 + k_o) + 2\sigma k_o}, \\ \text{and } A^{FB} &= \frac{r(r + c_u + c_b) + (r + c_u - c_b)\sigma k_o}{(r + c_u + c_b)(1 + k_o) + 2\sigma k_o}. \end{aligned}$$

Proof Refer to Appendix II. ■

⁸To simplify the notation, we will denote $E[X|\Omega_1, \dots, \Omega_k]$ by EX from now on. The values $\Omega_1, \dots, \Omega_k$ based on which this expected value is determined will be clear by context. Where confusion can arise, we will revert to the full notation.

We can verify for the above solution that $A^{FB} + \mu - \sigma \leq Q^{FB} \leq A^{FB} + \mu + \sigma$, i.e., the stocking level is between the maximum and minimum demand that can be realized. Some comparative statics for the above solution will be provided in Section 3.4.

3.3 Incentive Contracts

We now assume that the firm offers incentive contracts to the two managers. Based on these contracts, the managers make their decisions to maximize their own net utilities. The aim of the firm is to construct the contracts in such a way that the actions of the two managers, chosen independently and simultaneously, maximize the firm's profits. The construction of the compensation contracts has two elements requiring a decision:

1. Which performance measure should be contracted on for each manager?
2. Given these performance measures, what should be the parameters of the optimal contract for each manager?

In this part of the paper, we show how choosing the right performance measure can mean the difference between being able to incentivize the managers to achieve the first-best solution, and not being able to do so.

3.3.1 Contracts using rudimentary metrics

The sales manager is responsible for exerting effort to increase demand. The operations manager is responsible for supplying inventory to match supply and demand. A natural metric to measure the performance of the sales manager is the number of units sold (or dollar value of the units sold), while a natural metric to measure the performance of the operations manager is the realized mismatch cost (comprising of cost due to unsold inventory and cost due to backorders). Several well-known firms use these metrics to determine the compensation of sales and operations managers, as pointed out in the introductory section (Shapiro 1977, Ellinger et al. 2006). In this section, we use these metrics for the compensation contracts. We determine the optimal linear contracts and show that the firm will not be able to align the interests of the managers with its own interests because the chosen metrics create a distortion in the incentives of the managers.

Formally, $P_m = Y$ so that $S_m = w_m + \alpha_m Y$, and $P_o = -C$ so that $S_o = w_o - \alpha_o C$, where $C = c_u U + c_b B$. In other words, the compensation structure of the sales manager includes a fixed salary and a linear piece-rate reward for sales achieved, and the compensation structure of the operations manager includes a fixed salary and a linear piece-rate penalty for total cost of mismatch between supply and demand. Effectively, the sales manager will aim to increase sales and the operations manager will aim to reduce total mismatch cost. The following proposition shows that, using contracts of the above form, the firm will be able to achieve the first-best outcome only if the penalty from a backorder is large compared to the penalty from an unsold unit.

Proposition 2 *If the contracts of the sales and operations managers are of the form $S_m = w_m + \alpha_m Y$ and $S_o = w_o - \alpha_o C$ respectively, the firm can achieve the first-best outcome only if $c_b > \left(\frac{r+k_o\sigma}{k_o(r+\sigma)}\right) c_u$.*

Proof Refer to Appendix III. ■

The self-interested actions of the managers will achieve the first-best solution for the firm only if their expected utility functions, under the contracts offered, are concave in their respective actions. If the contracts are of the above form, the condition for concavity of the sales manager's expected utility function always holds, but that for the operations manager's expected utility function holds only under the above condition. (See the proof in Appendix III for details.) Hence, when the above constraint is not satisfied, the incentives of the operations manager will be misaligned and he will go for a solution at the extreme, i.e., supplying zero units of the product, since his utility function is convex rather than concave. Moreover, since the first-best solution is unique, no other solution under this contract can achieve the first-best outcome.

This result is supported by observations reported by Gruen, Corsten and Bharadwaj (2002), who conduct a worldwide study on retail out-of-stocks and find that the rate of stockouts is much higher for items being advertised as compared to items not being advertised. This problem of undersupply is a widespread one – the cost structure of firms is typically such that the condition in the proposition above is not satisfied and this is further exacerbated by the fact that the cost of a backorder is typically an opportunity cost and does not always enter the cost statement of the firm, while the cost due to an unsold unit is a tangible cost that enters the cost statement. Since opportunity costs are underweighted relative to tangible costs (Thaler 1985), the focus is more on the downside due to unsold inventory compared to the downside due to lost demand. Anderson, Fitzsimons and Simester (2006) find that, for the retail catalog they study, the actual stockout rate is twice that of the theoretically optimal stockout rate. (Note that the theoretically optimal stockout rate decreases with increasing cost of backorders, which implies that in the above case the “percieved” cost of a backorder is lesser than the actual cost of a backorder.)

The above analysis implies that the misalignment occurs on the side of the operations manager and not on the side of sales manager, for the following reason. The two decision variables, sales effort and quantity supplied, are complements. To achieve the first-best outcome, the firm wants both these variables to simultaneously reach the first-best levels. The firm rewards the sales manager in such a way that her sales effort reaches the first-best level – since she is being paid for sales realized, she will keep putting in effort to increase the expected level of sales, up to the point where her disutility from effort becomes very high. Now, the firm ideally wants the operations manager to stock according to the demand created by the sales manager's effort.

A closer look at the nature of the metric on which he is being penalized (total cost) makes it clear that he does not have sufficient incentive to do so. For every extra unit that he stocks, the total expected cost from unsold inventory increases (because the expected unsold inventory increases, all else being equal) and the total expected cost due to unmet demand decreases (because the expected

unmet demand decreases, all else being equal). He will raise the level supplied only if the total expected cost decreases, which will happen only if the cost of missing a sale is so high that it can offset the cost of supplying extra units, on some of which he might be levied a penalty if the actual demand turns out to be low. If the condition in the proposition is violated, the penalty from lost sales is not high enough and the operations manager will not stock the optimal amount even though the sales manager might be promoting the product. These insights fall very well in line with the impression conveyed in the introductory section that the method of evaluation for the operations side is overly cost focused, and reflects the classic discord between marketing and operations.

Note that if c_u and c_b are held constant, the miscoordination condition is still influenced by the multiplier $\kappa = \frac{r+k_o\sigma}{k_o(r+\sigma)}$. As the variance in demand σ increases, a higher value of c_b is needed for coordination (in other words, the miscoordination problem worsens). As the retail price r increases, a lower value of c_b is needed for coordination. A higher retail price implies that the firm would want to increase sales, and hence gears incentives to alleviate the undersupply problem. As the variance in supply ω increases, a lower value of c_b is needed for coordination. Higher variance in supply implies more supply effort from the operations manager which implies a lower first-best quantity for the firm, so that the undersupply problem is lesser.⁹

In the following sections, we propose performance measures and the corresponding linear contracts that work under *any* configuration of costs and other parameters.

3.3.2 Interdependent contracts

In the previous section, we showed how contracting with the operations manager on total cost will create a distortion in his incentives and prevent the firm from achieving the first-best profit. The distortion in these cases was that the operations manager had a disincentive to stock a sufficient quantities when rewarded for reducing the total mismatch cost. We now show that if this contract is extended to reward him on the sales achieved, while still keeping the contract linear, the firm can overcome this problem and always structure the compensation scheme to achieve the first-best outcome. Since the firm is using metrics from its sales arm in the compensation contract of the operations arm, we call this an *interdependent contract*. Formally, the contract of the operations manager is $S_o = w_o - \alpha_o C + \beta_o Y$, i.e., he is still being penalized for costs at the rate α_o , but is also being rewarded for sales at the rate β_o . The contract for the sales manager is the same, i.e., $S_m = w_m + \alpha_m Y$. The following proposition gives the optimal contracts.

Proposition 3 *If the contracts of the sales and operations managers are of the form $S_m = w_m + \alpha_m Y$ and $S_o = w_o - \alpha_o C + \beta_o Y$ respectively, the optimal contracts (that achieve the first-best outcome) are characterized by the set of parameters $\{w_m^*, \alpha_m^*, w_o^*, \alpha_o^*, \beta_o^*\}$, where*

$$\alpha_m^* = \frac{r(r + c_u + c_b) + (r + c_u - c_b)\sigma k_o}{r + c_b(1 + k_o) + \sigma k_o},$$

$$w_m^* = -\alpha_m^* E[Y|Q^{FB}, A^{FB}] + V_m(A^{FB}),$$

⁹Note that $\frac{d\kappa}{d\sigma} = \frac{r\omega}{k_o(r+\sigma)^2} > 0$, $\frac{d\kappa}{dr} = \frac{-\sigma\omega}{k_o(r+\sigma)^2} < 0$ and $\frac{d\kappa}{d\omega} = \frac{d\kappa}{dk_o} \cdot \frac{dk_o}{d\omega} = \frac{-r}{k_o^2(r+\sigma)} < 0$.

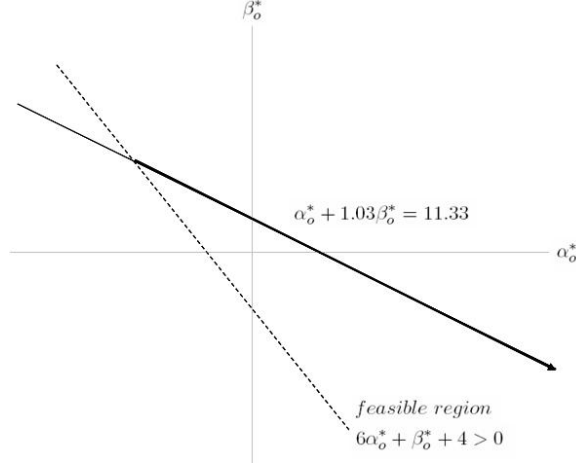


Figure 1: The dark black portion of the straight line represents the set of coordinating interdependent contracts for the operations manager for the case $r = 10, c_u = 3, c_b = 3, \sigma = 1, k_o = 2$.

the pair (α_o^*, β_o^*) satisfies

$$\alpha_o^* + \left(\frac{rk_o + c_u(1 + k_o) + \sigma k_o}{-rc_u + (rc_b + (c_b - c_u)\sigma)k_o} \right) \beta_o^* = \frac{(r(r + c_u + c_b) + (r + c_b - c_u)\sigma)k_o}{-rc_u + (rc_b + (c_b - c_u)\sigma)k_o},$$

and $w_o^* = \alpha_o^* E[C|Q^{FB}, A^{FB}] - \beta_o^* E[Y|Q^{FB}, A^{FB}] + EV_o(Q^{FB})$,

subject to the conditions $\alpha_m^* + 2\sigma > 0$ and $\alpha_o^*(c_u + c_b) + \beta_o^* + 2\sigma k_o > 0$. The firm can always find such a contract.

Proof Refer to Appendix IV.a. ■

Note that the firm can *always* find a contract of the above form to motivate the managers to achieve the first-best outcome. As already shown in the proof of Proposition 2, the condition $\alpha_m^* + 2\sigma > 0$ is always satisfied. Furthermore, a pair (α_o^*, β_o^*) satisfying the conditions in Proposition 3 can always be found. In fact, there is an infinite set of such contracts because any point on the (α_o^*, β_o^*) plane that is on the straight line specified above, and satisfies the constraint $\alpha_o^*(c_u + c_b) + \beta_o^* + 2\sigma k_o > 0$, gives a feasible contract. (See Figure 1 for an example.) Note that this contract works even when the contract with cost penalty alone does not, because his expected reward from higher realized sales offsets the disincentive from supplying a high quantity, and this motivates him to supply more. This reward should be high enough to overcome the cost penalty (and the disutility of effort), which is what the constraint $\alpha_o^*(c_u + c_b) + \beta_o^* + 2\sigma k_o > 0$ ensures. Furthermore, the operations manager does not stock an excessive amount because the disutility of effort from supplying a higher quantity increases in a convex manner.

While the contracts above achieve coordination, they have two variable parts (penalty for cost and reward for sales), which can make them somewhat difficult to implement. From the infinite set of contracts, the firm may want to choose the simplest contract that can coordinate for any values

of the other parameters, possibly a contract with only one variable component. The following corollary characterizes such a contract.

Corollary 3.1 *The simplest interdependent contract for the operations manager that achieves the first-best outcome is given by the parameters*

$$\alpha_{o,s}^* = 0$$

$$\text{and } \beta_{o,s}^* = \frac{(r(r + c_u + c_b) + (r + c_b - c_u)\sigma)k_o}{rk_o + c_u(1 + k_o) + \sigma k_o}.$$

The firm can always find such a contract.

Proof Refer to Appendix IV.b. ■

Thus, the search for the simplest coordinating contract simply leads to the contract $S_m = w_m^* + \alpha_m^* Y$ for the sales manager and the contract $S_o = w_{o,s}^* + \beta_{o,s}^* Y$ for the operations manager. In other words, by compensating both managers on sales alone and appropriately setting the piece-rate rewards the firm can always align their interests with its own.¹⁰

In effect, the firm corrects the situation in the Section 3.3.1 by changing the performance metric of the operations manager and providing him with an incentive to stock larger quantities. However, to ensure that he stocks no more than the optimal quantity, it sets the reward rate such that, at the first-best stocking level, his marginal reward and the marginal disutility of effort from stocking one more unit are equal. The interesting implication from this analysis is that once an appropriate performance metric has been chosen, not only can the firm achieve the optimum, but the contract that achieves it can have a simple structure.

If the sales are observable but the actual demand realized is not, then incentive-based contracting is necessary here for the operations manager. This is because the effort to ensure availability is unobservable by the firm, and to induce this effort the firm has to motivate the operations manager to exert this effort by providing him the incentive to increase availability. In the absence of incentives, the operations manager can shirk away from expending this effort and can make the excuse that sales are low because of the realized demand being low.

We note here that this contract is different from a profit-sharing contract. Under a profit-sharing contract, the firm gives a share of the total profit to every agent to align his or her interests with those of the firm. In our setting, however, such a contract does not achieve the first-best solution

¹⁰The operations manager can try to “game” this contract by ordering an amount larger than the first-best amount, allowing some of it to remain unavailable by shirking on the “availability ensuring effort” and still achieving the same utility. The firm can alleviate this problem by implementing an upper bound constraint on what the operations manager can order, i.e., $Q \leq Q^{FB}$. For instance, the firm can achieve this by setting a budget constraint for the operations manager and thus enforcing a total-cost-of-goods-ordered constraint, or by limiting the capacity of the warehouse where goods are supplied. We also assume that costs from unsold units are high enough such that it is more profitable for the firm to have the operations manager order the first-best amount and exert the required availability effort, rather than have him order more than the first-best, have part of it unavailable, and still achieve first-best availability.

because the agents will not have the incentive to exert an optimal level of effort, since for every extra unit of effort an agent exerts to increase output, he or she only gets a fraction of this increased output, while the other agent gets the rest of it. The incentive, in fact, is to “free ride” on the other agent’s effort and the agents prefer to “shirk” rather than “work.” This problem has been identified in the literature on group incentive schemes as the “free riding” problem (Nalbantian and Schotter 1997).

3.3.3 Information-based contracts

In the previous section, we demonstrated how extending the contract of the operations manager to include sales metrics along with cost metrics can help to coordinate the managers’ actions. In this section, we note that the job of the operations manager is to match supply and demand. Taking a cue from this, we discuss another way of achieving coordination – penalizing him separately for the different components of the mismatch between realized demand and quantity supplied, i.e., imposing one penalty rate if there is unsold inventory and a different penalty rate if there are backorders. Of course, *ex post* only one of the penalties will come into play, but *ex ante* both components of the contract need to be specified. Since the implementation of this contract uses detailed information about the components of total cost, we call this an *information-based contract*. Formally, the contract of the operations manager is $S_o = w_o - \alpha_u U - \alpha_b B$. Here, α_u denotes a penalty per unsold unit of inventory (if demand is lower than quantity supplied) and α_b denotes a penalty per backorder (if demand is higher than quantity supplied). The contract for the sales manager is the same, i.e., $S_m = w_m + \alpha_m Y$. The following proposition gives the optimal contracts.

Proposition 4 *If the contracts of the sales and operations managers are of the form $S_m = w_m + \alpha_m Y$ and $S_o = w_o - \alpha_u U - \alpha_b B$ respectively, the optimal contracts (that achieve the first-best outcome) are characterized by the set of parameters $\{w_m^*, \alpha_m^*, w_o^*, \alpha_u^*, \alpha_b^*\}$, where*

$$\alpha_m^* = \frac{r(r + c_u + c_b) + ((r + c_u - c_b)\sigma)k_o}{r + c_b(1 + k_o) + \sigma k_o},$$

$$w_m^* = -\alpha_m^* E[Y|Q^{FB}, A^{FB}] + V_m(A^{FB}),$$

the pair (α_u^*, α_b^*) satisfies

$$\alpha_u^* - \left(\frac{rk_o + c_u(1 + k_o) + \sigma k_o}{r + c_b(1 + k_o) + \sigma k_o} \right) \alpha_b^* + \frac{(r(r + c_u + c_b) + (r + c_b - c_u)\sigma)k_o}{r + c_b(1 + k_o) + \sigma k_o} = 0,$$

and $w_o^* = \alpha_u^* E[U|Q^{FB}, A^{FB}] + \alpha_b^* E[B|Q^{FB}, A^{FB}] + EV_o(Q^{FB})$,

subject to the conditions $\alpha_m^* + 2\sigma > 0$ and $\alpha_u^* + \alpha_b^* + 2\sigma k_o > 0$.

The firm can always find such a contract.

Proof Refer to Appendix V.a. ■

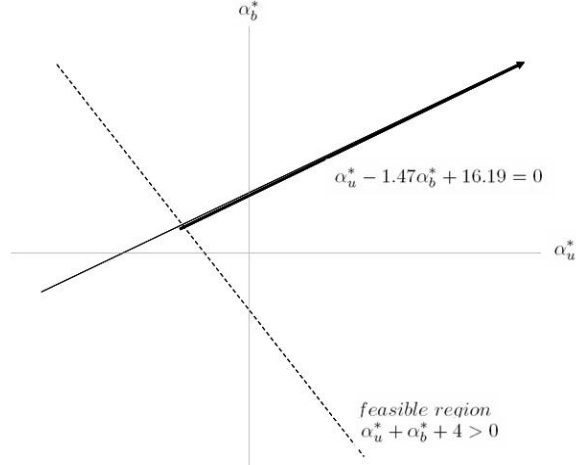


Figure 2: The dark black portion of the straight line represents the set of coordinating information-based contracts for the operations manager for the case $r = 10, c_u = 3, c_b = 3, \sigma = 1, k_o = 2$.

The firm can *always* find an information-based contract to motivate the managers to achieve the first-best outcome, because a pair (α_u^*, α_b^*) satisfying the conditions in Proposition 4 can always be found. (As before, the condition $\alpha_m^* + 2\sigma > 0$ is always satisfied.) In fact, by the same argument as before, there is an infinite set of such contracts. (See Figure 2 for an example.) To see why this contract can incentivize the operations manager to achieve the first-best outcome even when the contract based on total cost cannot, we note that as the operations manager supplies more the expected unsold inventory increases and the expected backorders decrease, all else being equal. If the penalty per backorder is large enough to overcome the penalty per unsold unit (and the disutility of effort), the operations manager has an incentive to increase the amount supplied. This is what the constraint $\alpha_u^* + \alpha_b^* + 2\sigma k_o > 0$ ensures. Furthermore, the operations manager does not stock an excessive amount because the disutility of effort from supplying a higher quantity increases in a convex manner.

Once again, from this infinite set of contracts, the firm may prefer to choose the simplest contract that can coordinate for any values of the exogenous parameters. The following corollary characterizes such a contract.

Corollary 4.1 *The simplest information-based contract for the operations manager that achieves the first-best outcome is given by the parameters*

$$\alpha_{u,s}^* = 0$$

$$\text{and } \alpha_{b,s}^* = \frac{(r(r + c_u + c_b) + (r + c_b - c_u)\sigma)k_o}{r\omega^2 + c_u(1 + k_o) + \sigma k_o}.$$

The firm can always find such a contract.

Proof Refer to Appendix V.b. ■

Thus, the search for the simplest coordinating contract simply leads to the contract $S_m = w_m^* + \alpha_m^* Y$ for the sales manager and the contract $S_o = w_o^* - \alpha_{b,s}^* B$ for the operations manager. In other words, by compensating the sales manager on sales alone and the operations manager on backorders alone and appropriately setting the piece-rates, the firm can always align their interests with its own. This is a very surprising result because the firm needs to set the penalty appropriately only on *one component* of cost to achieve coordination, when actually it has two components (unsold inventory cost and backorder cost). In fact, as we saw earlier, if the operations manager is compensated on the total cost, the firm cannot always achieve coordination. By not having variable compensation depend on components of total cost that increase with quantity supplied, the firm removes the disincentive due to cost associated with a large stocking quantity. Having removed this distortion in the performance metric, it can set the piece-rate on backorders in such a way that, for the operations manager, the trade-off between the reward for reducing lost sales and extra effort leads to the optimal quantity being supplied.¹¹ Validation is lent to this result by the fact that in reality many firms compensate their operations managers on backorders-based measures like fill rate (which is defined as $\text{fill rate} = 1 - \frac{\text{backorders}}{\text{mean demand}}$, and is derived only from backorders, ignoring the other components of cost), as discussed in Cohen et al. (2006).

The literature on compensation of teams identifies that when agents with different skill sets work cooperatively, they prefer that their monetary compensations depend upon performance metrics that are closely related to their work profile so that they do not suffer due to free riding by others (Shaw and Schneier 1995, Sarin and Mahajan 2001). In this light, and recognizing the fact that sales managers and operations managers have very different skill sets (Shapiro 1977), a firm could prefer information-based contracts for coordination, since they compensate the sales manager based on sales and the operations manager based on backorders.

Note that in all the contracts that we consider, the contract for the sales manager is of the form $S_m = w_m + \alpha_m Y$, and does not lead to any coordination problems (unlike the contract for the operations manager). This indicates that sales commission is a robust way to incentivize the sales arm and offers an explanation for the widespread prevalence of this scheme of compensation. Note, however, that the key to using a sales commission scheme properly is to ensure that, at the optimum selling effort, the marginal expected gain for the sales manager from increasing sales is exactly offset by the marginal disutility of sales effort.

3.4 Comparative Statics

We now study how the optimal contracts vary with the exogenous parameters of the model, e.g., retail price, marginal cost, unsold inventory cost, backorder cost, variance in demand and variance in supply. We choose the simplest optimal contracts, i.e., from interdependent contracts we choose the contract that rewards both managers on sales, and from information-based contracts we choose

¹¹As in the case of interdependent contracts, the firm can prevent the operations manager from over-ordering by implementing an upper bound constraint on what he can order, i.e., $Q \leq Q^{FB}$.

	Piece-rates		Expected total compensations		Coordinated decision variables	
	α_m^*	β_o^*, α_b^*	S_m	S_o	A^{FB}	Q^{FB}
r	+	+	+	+	+	+
c_u	+	-	+	-	+	-
c_b	-	+	-	+	-	+
σ	+/-	-/+	+/-	-/+	+/-	-/+
ω	-	+	-	-	-	-

Table 2: Comparative statics for the optimal piece-rates, expected total compensation for the marketing and operations managers, optimal sales effort and optimal supply, with respect to retail price, penalty from unsold inventory, penalty from backorders, variance in demand and variance in supply.

the contract that rewards the sales manager on sales and penalizes the operations manager on backorders alone.

Table 2 summarizes the comparative statics for the piece-rates/penalties and other quantities of interest, e.g., total compensation paid to the marketing and operations managers, and the first-best levels of sales effort and quantity supplied (which the coordinating contracts also achieve).

Variation with r : As the retail price increases, the firm wants to sell more, which means that the optimal sales effort increases. The optimal quantity supplied also increases in tandem with it. Since the salaries for the managers compensate for their respective efforts, the salaries also increase with r . For every unit sold, α_m^* is the reward for the sales manager, so to increase his effort level (when r increases), this reward must go up, as Table 2 shows. Finally, β_o^* is the reward per-unit sold (under interdependent contracts) and α_b^* is the penalty per backorder or penalty per lost sale (under information-based contracts) for the operations manager, both of which increase if the firm wants to induce higher sales.

Variation with c_u and c_b : First note that under the first-best outcome, the quantity supplied is between the minimum and maximum levels of demand given the sales effort. As the penalty from unsold inventory (c_u) increases, the firm wants to reduce the expected level of unsold inventory by increasing the mean demand so that A^{FB} increases (treating supply as constant) and decreasing the amount supplied so that Q^{FB} decreases (treating sales effort as constant). The sales manager exerts sales effort, so the firm must increase the reward for sales to her, and thus α_m^* increases with c_u . As she exerts more effort, her total compensation also increases. The operations manager decides the quantity supplied, so the firm must decrease the reward for sales (or decrease the penalty from lost sales) for him, and thus β_o^* and α_b^* decrease with c_u . As he exerts less effort, his total compensation also decreases.

The variation with backorder cost c_b is simply in the opposite direction for every case, since as c_b increases the firm wants to reduce the level of lost sales, which happens if A^{FB} is reduced (treating supply as constant) and Q^{FB} is increased (treating sales effort as constant).

Variation with σ : An increase in the uncertainty in demand (σ) (holding all else constant) has different effects based on whether the expression $-(r + c_b) + c_u + k_o(r + c_u - c_b)$ is positive or negative. First, to focus on how retail price and costs affect the variation with σ , assume $\omega = 1$ (where $k_o = 1 + \omega$). The above expression then becomes $r + 3(c_u - c_b)$. This expression will be negative only if the penalty from backorders is extremely high. Assuming that this is not the case, we have that $r + 3(c_u - c_b) > 0$, and as the uncertainty in demand increases, the firm wants to minimize the chance of having leftover inventory. Consequently, the optimal sales effort increases and the optimal supply decreases. The results for total compensation follow as before. The piece-rate for sales for the sales manager increases (to incentivize more sales effort) and the piece-rate for the operations manager decreases (to incentivize a lower supply). In the other case, when the penalty from backorders is very high, we have $r + 3(c_u - c_b) < 0$. The firm then wants to minimize the chance of losing a potential sale and all the above effects are reversed.

The results above on piece-rates are in stark contrast to, but complementary to, the results from the classic risk-incentive model, in which an increase in uncertainty in demand always implies a decrease in the piece-rate for the sales agent. We identify the issue of coordination between marketing and operations as a new factor influencing compensation schemes and find that it can drive incentives in a direction opposite to that from conventional salesforce compensation theory.

If we do not assume that $\omega = 1$, the insights remain very similar. The sales commission of the sales manager decreases with σ if $\omega < \frac{-2(c_u - c_b)}{r + c_u - c_b}$, otherwise it increases with σ . Since $\omega > 0$, the above condition can hold only if $c_b > c_u$. All the results and insights above follow. We state the above formally in the following proposition.

Proposition 5 *If $-(r + c_b) + c_u + k_o(r + c_u - c_b) > 0$, then as the uncertainty in demand increases*

- (a) *the piece-rate reward for sales for the sales manager increases, and*
- (b) *the piece-rate reward for sales (under interdependent contracts) and the penalty for backorders (under information-based contracts) for the operations manager decrease.*

If $-(r + c_b) + c_u + k_o(r + c_u - c_b) < 0$, then as the uncertainty in demand increases the effects on piece-rates are reversed.

Variation with ω : As ω increases, the variance in the random effort required for every unit of inventory supplied increases, which in turn increases the disutility of effort on the part of the operations manager. In other words, as ω increases, it becomes less and less desirable for the operations manager to supply more (and, therefore, for the firm as well) and the optimal quantity supplied decreases. Sales effort and stocking quantity being complements, the optimal sales effort also decreases. In line with this, the sales manager's reward for increasing sales decreases, and so does her compensation. The direction of change for the operations manager's compensation is more subtle. The optimal quantity supplied decreases, but the effort per unit supplied is higher (due to higher supply uncertainty). Hence, his reward for sales (under interdependent contracts) and the penalty for missed sales (under information-based contracts) has to be increased even to motivate him to supply this lower level of quantity.

4 Extensions

In this section, we extend the basic model in various ways to confirm that the insights generated are robust to these variations. First, we consider the scenario in which, rather than the two managers acting simultaneously, the operations manager acts first and makes the supply decision and the sales manager then has the task of selling it. Second, we extend the work profile of the operations manager beyond deciding supply to also include effort exerted to reduce the overall operational costs of the firm. Third, we consider risk-averse agents. Finally, we extend the analysis to a firm selling more than one product. We show that the results from the basic model continue to hold in all of these cases. The first two extensions are analysed in detail in this section. The last two extensions are summarized here and the detailed analyses are provided in the accompanying supplement due to space considerations.

4.1 Sequential Actions of Managers

In this section, we show that the implications from the basic model remain unchanged if the operations manager acts first and decides the supply and the sales manager then has the task of selling it.¹²

The first-best outcome remains unchanged, but the game with actions delegated to the agents is played in three stages. In the first stage, the firm offers take-it-or-leave-it contracts to the two managers; in the second stage, the operations manager decides the supply; and in the third stage, the sales manager decides her sales effort. As before, we solve for the subgame-perfect equilibrium.

In the third stage, the sales manager, given her contract and the quantity supplied, solves the following problem:

$$A^*(Q) = \arg \max_A E[S_m|Q, A] - V_m(A) \quad (4)$$

In the second stage, the operations manager, given his contract, solves the following problem:

$$Q^* = \arg \max_Q E[S_o|Q, A^*(Q)] - EV_o(Q) \quad (5)$$

Anticipating these values of A^* and Q^* in terms of the contract parameters, the firm solves for optimal contracts S_m and S_o to maximize its own profits:

$$\max_{\{S_m, S_o\}} E[\Pi_f|Q^*, A^*] = rE[Y|Q^*, A^*] - E[C|Q^*, A^*] - E[S_m|Q^*, A^*] - E[S_o|Q^*, A^*]$$

$$\text{such that: } \max_A E[S_m|Q, A] - V_m(A) \geq 0$$

$$\max_Q E[S_o|Q, A^*(Q)] - EV_o(Q) \geq 0$$

¹²If the sales manager acts first and the operations manager acts second but before demand is realized, the results from the simultaneous-action model again remain qualitatively unchanged.

Contracts Using Rudimentary Metrics: Consider the case when the sales manager is rewarded based on the sales achieved (i.e., $S_m = w_m + \alpha_m Y$) and the operations manager is rewarded based on the total mismatch cost (i.e., $S_o = w_o - \alpha_o C$). In this case, as shown in Appendix VI.a, the firm can achieve the first-best outcome only if $c_b > \left(\frac{r+k_o\sigma}{k_o(r+\sigma)}\right) c_u$ and $c_b > \left(\frac{Q^{FB}+\sigma-A^{FB}}{Q^{FB}+\sigma+A^{FB}}\right) c_u$. Note that the first condition is exactly the same as in Proposition 2. The second condition is an implicit condition between c_b and c_u and it holds whenever the first condition holds, so that effectively it is only the first condition that operates. Hence, the conditions under which the cost-based contract for the operations manager does not work are the same for simultaneous and sequential actions of the managers.

Sales-Based Contract for the Operations Manager: We now consider the case when the operations manager is rewarded based on sales achieved.¹³ Hence, the contract for the sales manager is $S_m = w_m + \alpha_m Y$ and the contract for the operations manager is $S_o = w_o + \beta_o Y$. In this case, as shown in Appendix VI.b, the contracts that can *always* achieve the first-best outcome are characterized by the set of parameters $\{w_m^*, \alpha_m^*, w_o^*, \beta_o^*\}$, where

$$\begin{aligned}\alpha_m^* &= \frac{r(r + c_u + c_b) + (r + c_u - c_b)\sigma k_o}{r + c_b(1 + k_o) + \sigma k_o}, \\ w_m^* &= -\alpha_m^* E[Y|Q^{FB}, A^{FB}] + V_m(A^{FB}), \\ \beta_o^* &= \frac{2Q^{FB}(Q^{FB} + \sigma)\sigma k_o}{A^{FB}(Q^{FB} - (A^{FB} - \sigma)) + (A^{FB} + \sigma - Q^{FB})(Q^{FB} + \sigma)}, \\ \text{and } w_o^* &= -\beta_o^* E[Y|Q^{FB}, A^{FB}] + EV_o(Q^{FB}).\end{aligned}$$

In a similar manner, it can also be shown that a backorders-based contract for the operations manager will always work.¹⁴

Hence, as in the simultaneous-action model, the firm can only achieve the first-best for a specific cost configuration if it uses a cost-based contract for the operations manager, but it can achieve the first-best for any cost configuration if it uses a sales-based or backorders-based contract for him. A sales-based contract always works for the sales manager.

4.2 Cost-Reduction Effort of Operations Manager

In the analysis until now, we assume that the work profile of the operations manager comprises of deciding supply and ensuring availability of the product, and this determines the costs through either unsold inventory or backorders. Operations managers typically also have another task – that of reducing the overall operational costs for the firm, e.g., by taking measures to increase the efficiency of the firm’s operations. In this section, we show that extending the work profile of the operations manager to include this consideration does not impact the results from the basic model.

¹³This is a special case of interdependent contracts – hence showing that this always works is sufficient to show that the more general interdependent contracts also always work.

¹⁴This is a special case of information-based contracts – hence showing that this always works is sufficient to show that the more general information-based contracts also always work.

We introduce unobservable and costly effort that reduces operational costs but does not change c_u and c_b . Specifically, we assume that operational costs are $K + \psi$, where ψ is a random variable with mean zero. If the cost-reduction effort is z , then the operational costs are $C_z = K - z + \psi$ and the disutility of the operations manager from this effort is $V_z(k) = \frac{1}{2}k_z z^2$.¹⁵ Hence the total cost for the firm is the sum of the mismatch cost and the operational cost, given by $C + C_z = (c_u U + c_b B) + (K - z + \psi)$, and the disutility of effort for the operations manager is $\frac{1}{2}k_o Q^2 + \frac{1}{2}k_z z^2$.

The contract for the sales manager is of the form $S_m = w_m + \alpha_m Y$. Since costs from an inventory mismatch can be distinguished from other costs, we assume that the operations manager is rewarded separately for these components of cost. Hence, his contract is either $S_o = w_o - \alpha_o C - \alpha_z C_z$ (based on total inventory mismatch cost) or $S_o = w_o + \beta_o Y - \alpha_z C_z$ (based on sales). The details of the analysis that follows are in Appendix VII.

First consider the first-best solution for the firm, which is obtained in the same manner as before, and is characterized by:

$$Q^{FB} = \frac{r(r + c_u + c_b) + (r - c_u + c_b)\sigma}{(r + c_u + c_b)(1 + k_o) + 2\sigma k_o},$$

$$A^{FB} = \frac{r(r + c_u + c_b) + (r + c_u - c_b)\sigma k_o}{(r + c_u + c_b)(1 + k_o) + 2\sigma k_o},$$

and $z^{FB} = \frac{1}{k_z}$.

Note that the first-best levels of Q^{FB} and A^{FB} are unchanged compared to those in Proposition 1.

Now, consider the cases when actions are delegated to the two managers using incentive contracts. First, consider the case when the contract of the sales manager is of the form $S_m = w_m + \alpha_m Y$ and the contract of the operations manager is of the form $S_o = w_o - \alpha_o C - \alpha_z C_z$. As shown in the appendix, this contract cannot always achieve the first-best outcome, and the condition under which it can achieve the first-best outcome is $c_b > \left(\frac{r+k_o\sigma}{k_o(r+\sigma)}\right) c_u$. Next, consider the case when the contract of the sales manager is of the form $S_m = w_m + \alpha_m Y$ and the contract of the operations manager is of the form $S_o = w_o - \beta_o Y - \alpha_z C_z$. In this case, the firm can always achieve the first-best outcome, and the parameters w_m, α_m, w_o and β_o are exactly as in Proposition 3 and in Corollary 3.1. Furthermore, in all of these cases, the value of the parameter α_z is the same.

The main insight here is that the effort of the operations manager to reduce operational costs does not influence the supply decision as it is independent of the supply effort. Hence, as long as the penalties from unsold inventory and backorders are unaffected by the effort to reduce operational costs, the results of the basic model are unchanged.

4.3 Risk-Averse Agents

A risk-averse agent does not like uncertainty in the outcome, but under a commission-based compensation plan she is exposed to this uncertainty. Hence, in the classical principal-agent literature,

¹⁵This is a standard approach for modeling operational-cost-reduction effort; see, for instance, Scherer (1964) and Kim et al. (2007).

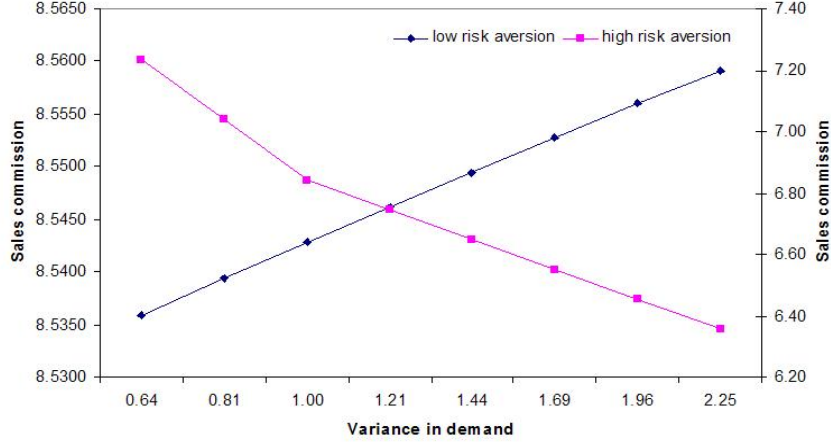


Figure 3: The figure shows how the sales commission for the sales manager varies with variance in demand for different risk aversion tendencies of the sales manager. The above plots are for the parameter values $r = 10, c_u = c_b = 3, k_o = 2$. The low-risk-aversion graph (left vertical axis) is for $\eta = 0.001$ and the high-risk-aversion graph (right vertical axis) is for $\eta = 0.1$.

as the variance in demand increases the optimal commission rate for a risk-averse agent decreases. In our model with risk-neutral agents, coordination between sales and operations leads to the result that as the variance in demand increases the optimal commission rate increases. If agents are risk averse, both forces (risk-aversion and coordination issues) will be at play simultaneously, and the observed direction of change will be determined by the one that dominates.¹⁶ Figure 3 shows an example of exactly this effect. The extent of risk aversion of agents is measured by the parameter η , which is higher for more risk-averse agents. When the agents are only slightly risk-averse ($\eta = 0.001$) the commission rate increases with increasing variance in demand because the coordination effect is stronger, while when the agents are more risk-averse ($\eta = 0.1$) the commission rate decreases with increasing variance in demand because the risk-aversion effect is stronger. The detailed model is developed in Section S.2 of the supplement.

4.4 Two Products

The major difference from the one-product case lies in the demand system, and we assume that effort exerted to promote one product has an adverse effect on the demand for the other product.

All coordination results from the one-product model extend to the two-product case – contracting with the operations manager on total mismatch cost leads to the undersupply problem, and the firm can always achieve coordination by using either interdependent contracts or information-based contracts – but only under the restrictive condition that one manager performs one task for one

¹⁶Note that with risk-averse agents, the firm cannot achieve the first-best outcome under delegation. The issue then is not whether coordination is achieved, but which contract gets closer to the first-best outcome. We find that, consistent with the results of the basic model, interdependent contracts and information-based contracts get closer to the first-best outcome as compared to traditional cost-based contracts.

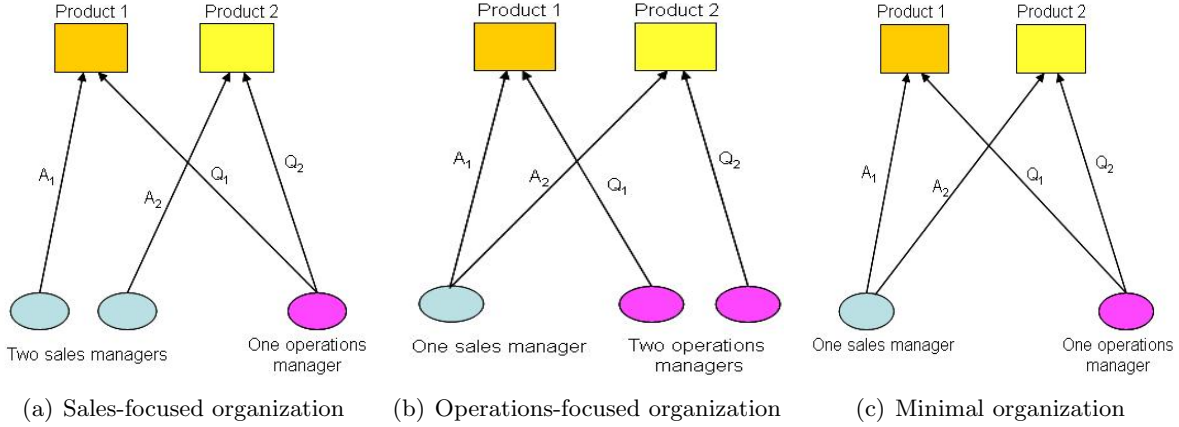


Figure 4: Schematic representation of the sales-focused, operations-focused and minimal organizations.

product.

In reality, one manager often manages several products, i.e., one sales manager is responsible for selling several products, and one operations manager is responsible for supplying several products. Furthermore, managers are typically rewarded based on a simple aggregate metric across all products, e.g., total dollar sales or total backorders for all products. Under the simple contract offered, the marginal return from effort for the manager differs from the marginal profit for the firm for the two products. Therefore, the incentives of the managers are usually misaligned – the effort allocation between the two products that best pays each manager does not create optimal profit for the firm.

What should the firm do to alleviate this problem? Should it always go with one manager for every job? Clearly, we do not always see that in practice. What we do see, however, is that firms usually have either a “sales image,” i.e., they focus on the sales side and have more employees working as sales managers than employees managing operations, or they have a “cost image,” i.e., they focus on the costs side and have more employees managing operations. To explain these observations, we propose that the firm can opt for one of the following three forms of workforce allocation:

1. *Sales-focused organization:* Under this organization scheme, the firm opts for more flexibility on the sales side and has two sales managers (one for each product) and one operations manager. Figure 4(a) shows a schematic representation of this design.
2. *Operations-focused organization:* Under this organization scheme, the firm opts for more flexibility on the operations side and has two operations managers (one for each product) and one sales manager. Figure 4(b) shows a schematic representation of this design.
3. *Minimal organization:* Under this organization scheme, the firm has one sales manager and one operations manager. Figure 4(c) shows a schematic representation of this design.

The firm’s choice is between finely controlling one side but settling for a distortion on the other to limit the size of the organization. Under a sales-focused allocation, the sales managers decide the sales efforts for their respective products while the operations manager jointly decides the quantity supplied for each product. The sales levels are close to first-best, but both stocking quantities are distorted away from first-best – one product is supplied above the optimal level and the other is supplied below the optimal level. Under an operations-focused allocation, sales are similarly skewed, but the stocking levels are close to optimal. Based on the product and demand characteristics for the two products, distortions in the sales arm and the operations arm will harm the firm differently, so it will prefer the workforce allocation scheme that minimizes that harm.

The purpose of our analysis is to illustrate that a firm can have a strong preference for sales-focused or operations-focused allocation due to effects rooted in distortions of the incentive structure because of multitasking; characterizing exactly the conditions for preference of one design over another requires a more detailed study, which we propose as a direction for future research.

Result 1: The most important result from our analysis is that the choice of workforce allocation can greatly influence the profits of the firm. Hence, it is important for a firm to correctly decide its “organization focus.” There are several scenarios that we identify where, between a sales-focused and an operations-focused allocation, the better choice can lead to a profit that is very close to the first-best profit (99% of first-best), but the wrong allocation choice can lead to greatly lower profits (over 50% lower than first-best).

Result 2: For the parameter values considered in the analysis, the firm can on average get very close to the first-best outcome when it has the choice of sales-focused or operations-focused allocation. Always choosing a minimal organization can take the firm very far from the first-best profit (mean deviation 22.0%). Always choosing a sales-focused or always choosing an operations-focused allocation can lead to a substantial difference from the first-best outcome (overall mean deviation 4.5%). However, choosing the better of sales-focused or operations-focused allocation for each scenario gives a mean deviation of only 0.8%. This suggests that most firms will opt for either a sales-focused or operations-focused allocation and supports the observation pointed out earlier that almost all firms have either a “sales image” or a “cost image.” Broadly speaking, when retail prices are low the firm prefers an operations-focused allocation, because the firm needs to “get it right” on the costs side. If the allocation is operations-focused, the firm settles for suboptimal sales but can motivate the stocking quantities such that overall costs are lower. If the allocation is sales-focused, the firm takes a hit on costs. Since retail prices are low, a little is lost in revenue, while the benefit from cost reduction is more significant.

5 Conclusions and Future Work

The results in this paper are two-faceted: we provide a simple and practical solution to the classic marketing and operations coordination problem, and at the same time add to the growing literature on agency theory in economics.

The marketing and operations arms of a firm are interdependent and must work in a coordinated

manner, but the discord between them has remained a long-standing problem. A prime reason for this discord is that these units operate in a decentralized manner, and marketing compensation is typically overly focused on increasing demand whereas operations compensation is typically overly focused on reducing costs. We draw upon agency theory to structure salesforce compensation contracts such that the self-maximizing actions of marketing and operations managers achieve the coordinated outcome.

We start by showing that rewarding the operations manager for reducing the total cost leads to suboptimal supply. Under random demand, increasing supply increases the expected cost from unsold goods, and reduces the expected cost from missed sales. However, the first component of cost typically dominates the second, and the operations manager therefore does not have sufficient incentive to supply the optimal quantity. This case is therefore another example of “the folly of rewarding A, while hoping for B” (Kerr 1975) – a very natural measure of performance for the operations manager (the total cost) is not the right measure from the firm’s point of view. Consequently, the two managers, who are simultaneously deciding on two variables that are complements, do not move towards the optimal solution together.

This “folly” can be corrected simply by changing the performance measure of the operations manager – by rewarding him for sales (as in the simplest interdependent contract) or penalizing him for backorders (as in the simplest information-based contract). Both these schemes can always achieve coordination since they provide him with the incentives to increase supply, and utilize his effort disutility costs to limit the supply at the optimum level. This result adds to the recent literature in economics on how the alignment between the agent’s performance metric and the actual objective of the principal influences the contracts offered (Baker 2000, Gibbons 2005). Moreover, the optimal contracts are still very simple (linear) and easy to implement. The appropriate performance metrics are also simple, but not always *a priori* very obvious (or even intuitive). For instance, the firm can always achieve the coordinated outcome by penalizing the operations manager only on backorders, while total costs are dependent on (and his supply decision influences) not only backorders but also the number of units potentially left unsold.

Furthermore, the contracts might need to be restructured in a specific way. In our case, the distortion was on the side of the operations manager, so the fix was obtained by changing his performance metric. Changing the performance measure of the sales manager alone (e.g., penalizing her on inventory cost while rewarding her for sales) cannot align the incentives in our model.

The comparative statics for the optimal contract parameters provide several interesting and new results on how commission rates and compensations for the sales and operations managers vary with product characteristics (prices and costs), uncertainty in demand and uncertainty in supply. One of our results is that for many configurations of prices and costs, the commission on sales for the sales manager increases with a higher demand uncertainty (even if the agents are risk averse), a result that is contrary to the conventional result from incentive theory. We identify coordination between marketing and operations as a driver of incentive structure, and show that it has implications independent of other drivers identified earlier in the literature (specifically, risk

aversion of agents). This can be an explanation for why several studies have found only lukewarm empirical support for the results predicted by the risk-insurance trade-off (Prendergast 1999). Our results, therefore, also add to the recent stream of literature in economics on incentive theory that aims to explain why variable compensation is often seen to *increase* with uncertainty in demand (Prendergast 2000).

Our analysis for the multiproduct case focuses on distortions in incentives due to multitasking. Our analysis provides insights into how the underlying objective of aligning marketing and operations, while keeping the size of the salesforce small and compensation contracts simple, can induce a clear preference between a sales-focused and an operations-focused workforce allocation for different firms.

We generate a number of hypotheses that can be tested using industry data. Our model predicts that firms that manage their operations units using cost-based measures will experience more frequent marketing/operations coordination failures than firms that use service measures like sales achieved or fill rate. The comparative statics in Section 3.4 provide several hypotheses regarding how the optimal commission rates and total compensation for sales and operations managers vary with product and demand characteristics. (Due to space considerations, we refrain from repeating them here.) We have already provided anecdotal evidence supporting several of the above hypotheses; as suitable data become available they can be tested formally.

Finally, our work is not without its shortcomings. We have assumed that the firm and the agents all have the same information set. It is possible that there are scenarios where the sales manager has more information about the market than the firm and the operations manager, and the operations manager has more information about supply dynamics than the firm and the sales manager. A “menu of contracts” framework can be explored to overcome this information asymmetry problem. Our model also assumes that the operations manager can supply any quantity seamlessly. In reality, production or ordering is done in batches using specialized models for inventory control (like the Economic Order Quantity (EOQ) model, or the (Q, r) model). Once again, the insight that compensation based on reducing total cost will lead to suboptimal supply will be robust to this variation. In the current model, the problem lies only on the operations side. There can be scenarios, however, when the sales manager’s being overly demand-focused can cause distortions away from the first-best outcome. For example, it is possible that when supply occurs in batches, the sales manager generates excess demand, but it is not in the firm’s interests to order an extra batch of goods to meet this excess demand.

Notwithstanding these limitations, our work provides significant insights into the causes of the discord between marketing and operations and the importance of optimally structuring salesforce compensation schemes to bring the two arms into alignment.

References

- Anderson, Eric T., Gavan J. Fitzsimons and Duncan Simester (2006), “Measuring and Mitigating the Costs of Stockouts,” *Management Science*, 52 (11), November 2006, 1751–1763.

- Anderson, Erin and Richard L. Oliver (1987), "Perspectives on Behavior-Based versus Outcome-Based Salesforce Control Systems," *Journal of Marketing*, 51 (4), October 1987, 76–88.
- Baker, George (2000), "The Use of Performance Measures in Incentive Contracting," *The American Economic Review*, 90 (2), May 2000, 415–420.
- Balasubramanian, Sridhar and Pradeep Bhardwaj (2004), "When Not All Conflict Is Bad: Manufacturing-Marketing Conflict and Strategic Incentive Design," *Management Science*, 50 (4), April 2004, 489–502.
- Basu, Amiya K., Rajiv Lal, V. Srinivasan and Richard Staelin (1985), "Salesforce Compensation Plans: An Agency Theoretic Perspective," *Marketing Science*, 4 (4), Fall 1985, 267–291.
- Bhardwaj, Pradeep (2001), "Delegating Pricing Decisions," *Marketing Science*, 20 (2), March 2001, 143–169.
- Cachon, Gerard (2003), "Supply chain coordination with contracts," *Handbooks in Operations Research and Management Science: Supply Chain Management*, Steve Graves and Ton de Kok, Eds., North Holland.
- Celikbas, Muruvvet, J. G. Shanthikumar and J. M. Swaminathan (1999), "Coordinating production quantities and demand forecasts through penalty schemes," *IEEE Transactions*, 31 (3), 851–864.
- Chen, Fangruo (2000), "Sales-Force Incentives and Inventory Management," *Manufacturing & Service Operations Management*, 2 (2), Spring 2000, 186–202.
- Chen, Fangruo (2005), "Sales-Force Incentives, Market Information, and Production/Inventory Planning," *Management Science*, 51 (1), January 2005, 60–75.
- Cohen, Morris A., Narendra Agrawal and Vipul Agrawal (2006), "Winning in the Aftermarket," *Harvard Business Review*, 84 (5), May 2006, 129–138.
- Coughlan, Anne T. and Chakravarthi Narasimhan (1992), "An Empirical Analysis of Salesforce Compensation Plans," *Journal of Business*, 65 (1), Jan 1992, 93–121.
- De Groote, Xavier (1994), "Flexibility and Marketing/Manufacturing Coordination," *International Journal of Production Economics*, 36, 153–167.
- Desai, Preyas, Oded Koenigsberg and Devavrat Purohit (2004), "Strategic Decentralization and Channel Coordination," *Quantitative Marketing and Economics*, 2(1), 2004, 5–22.
- Eliashberg, Jehoshua and Richard Steinberg (1987), "Marketing-Production Decisions in an Industrial Channel of Distribution," *Management Science*, 33 (8), August 1987, 981–1000.

- Ellinger, Alexander E., Scott B. Keller and John D. Hansen (2006), "Bridging the Divide between Logistics and Marketing: Facilitating Collaborative Behavior," *Journal of Business Logistics*, 27 (2), 2006, 1–27.
- Ghosh, Mrinal and George John (2000), "Experimental Evidence for Agency Models of Salesforce Compensation," *Marketing Science*, 19 (4), Fall 2000, 348-365.
- Gibbons, Robert (2005), "Incentives Between Firms (and Within)," *Management Science*, 51 (1), January 2005, 2–17.
- Gonik, Jacob, "Tie salesmen's bonuses to their forecasts," *Harvard Business Review*, 56 (3), May/June 1978, 116–123.
- Gruen, Thomas W., Daniel S. Corsten and Sundar Bharadwaj, "2002 Retail Out of Stocks Study," <http://gbspapers.library.emory.edu/archive/00000035/01/GBS-MKT-2002-001.pdf>.
- Hammond, Janice H. and Ananth Raman (1994), "Sport Obermeyer Ltd.," *Harvard Business School Cases*, 695022, October 13, 1994.
- Harps, Leslie Hansen (2002), "Making Dollars & Sense Out of Logistics," http://www.inboundlogistics.com/articles/features/0302_feature02.shtml.
- Hauser, John, Duncan Simester and Birger Wernerfelt (1994), "Customer Satisfaction Incentives," *Marketing Science*, 13 (4), Fall 1994, 327–350.
- Hausman, Warren H., David B. Montgomery and Aleda V. Roth (2002), "Why should marketing and manufacturing work together? Some exploratory empirical results," *Journal of Operations Management*, 20 (3), 2002, 241–257.
- Ho, Teck H. and Christopher S. Tang (2004), "Introduction to the Special Issue on Marketing and Operations Management Interfaces and Coordination," *Management Science*, 50 (4), April 2004, 429–430.
- Holmstrom, Bengt (1982), "Moral Hazard in Teams," *The Bell Journal of Economics*, 13 (2), Autumn 1982, 324–340.
- Holmstrom, Bengt and Paul Milgrom (1991), "Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design," *Journal of Law, Economics, & Organization*, 7, 1991 (Special Issue), 24–52.
- Jeuland, Abel P. and Steven M. Shugan (1983), "Managing Channel Profits," *Marketing Science*, 2(3), Summer 1983, 239–272.
- Joseph, Kissan and Manohar U. Kalwani (1998), "The role of bonus pay in salesforce compensation plans," *Industrial Marketing Management*, 27 (2), March 1998, 147–159.

- Joseph, Kissan and Alex Thevarajan (1998), “Monitoring and Incentives in Sales Organizations: An Agency-Theoretic Perspective,” *Marketing Science*, 17 (2), Feb 1998, 107–123.
- Kerr, Steven (1975), “On the Folly of Rewarding for A while Hoping for B,” *Academy of Management Journal*, 18 (4), December 1975, 769–783.
- Kim, Sang-Hyun, Morris A. Cohen and Serguei Netessine (2007), “Performance Contracting in After-Sales Service Supply Chains,” *Management Science*, forthcoming.
- Kopczak, Laura and Hau L. Lee (2001), “Hewlett-Packard DeskJet Printer Supply Chain (A),” *Stanford Business School Cases*, GS3A, 2001.
- Lal, Rajiv, Donald Outland and Richard Staelin (1994), “Salesforce Compensation Plans: An Individual Level Analysis,” *Marketing Letters*, 5 (2), April 1994, 117–130.
- Lal, Rajiv and V. Srinivasan (1993), “Compensation Plans for Single- and Multi-Product Salesforces: An Application of the Holmstrom-Milgrom Model,” *Management Science*, 39 (7), July 1993, 777–793.
- Lal, Rajiv and Richard Staelin (1986), “Salesforce Compensation Plans in Environments with Asymmetric Information,” *Marketing Science*, 5 (3), Summer 1986, 179–198.
- Liu, Shaoxuan, Kut C. So and Fuqiang Zhang (2006), “Effects of Inventory Inaccuracy in Joint Marketing and Inventory Decisions,” working paper, University of California, Irvine.
- Misra, Sanjog, Anne T. Coughlan and Chakravarthi Narasimhan (2005), “Salesforce Compensation: An Analytical and Empirical Examination of the Agency Theoretic Approach,” *Quantitative Marketing and Economics*, 3 (1), March 2005, 5–39.
- Moorthy, K. Sridhar (1987), “Managing Channel Profits: Comment,” *Marketing Science*, 6(4), Autumn 1987, 375–379.
- Nalbantian, Haig R. and Andrew Schotter (1997), “Productivity Under Group Incentives: An Experimental Study,” *The American Economic Review*, 87 (3), June 1997, 314–341.
- Narayanan, V.G. and Ananth Raman (2004), “Aligning Incentives in Supply Chains,” *Harvard Business Review*, 82 (11), Nov 2004, 94–102.
- Netessine, Serguei and Nils Rudi (2004), “Supply chain structures on the Internet and the role of marketing-operations interaction,” *Handbook of quantitative supply chain analysis: modeling in the ebusiness era*, D. Simchi-Levi, S. D. Wu and M. Shen, Eds., Kluwer.
- Netessine, Serguei and Terry A. Taylor (2007), “Product line design and production technology,” *Marketing Science*, 26 (1), Jan/Feb 2007, 101–117.
- Porteus, Evan L. and Seungjin Whang (1991), “On Manufacturing/Marketing Incentives,” *Management Science*, 37 (9), Sep 1991, 1166–1181.

- Prendergast, Canice (1999), "The Provision of Incentives in Firms," *Journal of Economic Literature*, 37, March 1999, 7–63.
- Prendergast, Canice (2000), "What Trade-Off of Risk and Incentives?," *The American Economic Review*, 90 (2), May 200, 421–425.
- Raju, Jagmohan S. and V. Srinivasan (1996), "Quota-Based Compensation Plans for Multiterritory Heterogeneous Salesforces," *Management Science*, 42 (10), Oct 1996, 1454–1462.
- Rao, Ram C. (1990), "Compensating Heterogeneous Salesforces: Some Explicit Solutions," *Marketing Science*, 9 (4), Fall 1990, 319–341.
- RetailWire (2007), "Crossing the Marketing and Logistics Divide," http://retailwire.com/Discussions/Sngl_Discussion.cfm/11948.
- Sarin, Shikhar and Vijay Mahajan (2001), "The effect of reward structures on the performance of cross-functional product development teams," *Journal of Marketing*, 65 (2), April 2001, 35–53.
- Scherer, F. M. (1964), "The Theory of Contractual Incentives for Cost Reduction," *The Quarterly Journal of Economics*, 78 (2), May 1964, 257–280.
- Schleifer, Jr., Arthur (1992), "L.L. Bean, Inc.: Item Forecasting and Inventory Management," *Harvard Business School Cases*, 893003, October 27, 1992.
- Shapiro, Benson P. (1977), "Can marketing and manufacturing coexist?" *Harvard Business Review*, 55 (5), Sep-Oct 1977, 104–114.
- Shaw, Douglas G. and Craig Eric Schneier (1995), "Team measurement and rewards: How some companies are getting it right," *Human Resource Planning*, 18 (3), 1995, 34–49.
- Souza, Gilvan C., Barry L. Bayus and Harvey M. Wagner (2004), "New-Product Strategy and Industry Clockspeed," *Management Science*, 50 (4), April 2004, 537–549.
- Stanton, Jeffrey M. (2000), "Reactions to Employee Performance Monitoring: Framework, Review, and Research Directions," *Human Performance*, 13 (1), 2000, 85–113.
- Terwiesch, Christian and Antoine Gouze (2006), "Forecasting and Procurement at Le Club Français du Vin," Case Study, The Wharton School.
- Thaler, Richard (1985), "Mental Accounting and Consumer Choice," *Marketing Science*, 4 (3), Summer 1985, 199–214.
- Ton, Zeynep and Ananth Raman (2004), "The Effect of Product Variety and Inventory Levels on Retail Store Sales: A Longitudinal Study," working paper, Harvard Business School.

Appendix

I Proof of Lemma 1

The firm has to ensure that the expected utilities of the two managers are just equal to their utilities from their outside options. In other words, the constraints in (3) are binding. Hence, the firm sets the salary components of the compensations as $w_m = -\alpha_m P_m + V_m(A)$ and $w_o = -\alpha_o P_o + EV_o(Q)$. Folding this into the expression for profit, the firm solves

$$\max_{\{A, Q\}} E\Pi_f^{FB} = rEY(Q, A) - EC(Q, A) - V_m(A) - EV_o(Q)$$

which, using the substitutions $U = Q - Y$, $B = D(A) - Y$ and $Y = \min\{Q, D(A)\}$, can be written as

$$\max_{\{A, Q\}} E\Pi_f^{FB} = (r + c_u + c_b)E \min\{Q, D(A)\} - (c_o + c_u)Q - c_b ED(A) - V_m(A) - EV_o(Q) \quad (A1)$$

Note that the above is independent of the contract parameters α_m and α_o .

For uniqueness, we need to ensure that the function $E\Pi_f^{FB}$ is concave, which is true iff the Hessian matrix is negative semidefinite. The first derivatives are given by

$$\begin{aligned} \frac{\partial E\Pi_f^{FB}}{\partial Q} &= (r + c_u + c_b) \Pr\{D(A) > Q\} - c_u - \frac{dEV_o(Q)}{dQ} \\ \frac{\partial E\Pi_f^{FB}}{\partial A} &= (r + c_u + c_b) \Pr\{D(A) < Q\} - c_b - \frac{dV_m(A)}{dA} \end{aligned}$$

The second derivatives are given by

$$\begin{aligned} \frac{\partial^2 E\Pi_f^{FB}}{\partial Q^2} &= -(r + c_u + c_b) \Pr\{D(A) = Q\} - \frac{d^2 EV_o(Q)}{dQ^2} \\ \frac{\partial^2 E\Pi_f^{FB}}{\partial A^2} &= -(r + c_u + c_b) \Pr\{D(A) = Q\} - \frac{d^2 V_m(A)}{dA^2} \\ \frac{\partial^2 E\Pi_f^{FB}}{\partial A \partial Q} &= \frac{\partial^2 E\Pi_f^{FB}}{\partial Q \partial A} = (r + c_u + c_b) \Pr\{D(A) = Q\} \end{aligned}$$

Since $V_o(\cdot)$ and $V_m(\cdot)$ are convex, $\frac{d^2 EV_o(Q)}{dQ^2} > 0$ and $\frac{d^2 V_m(A)}{dA^2} > 0$, which clearly implies that $\frac{\partial^2 E\Pi_f^{FB}}{\partial Q^2} < 0$ and $\frac{\partial^2 E\Pi_f^{FB}}{\partial A^2} < 0$ (i.e., both diagonal elements of the Hessian are negative). The positivity of the determinant is equal to the following condition:

$$\frac{\partial^2 E\Pi_f^{FB}}{\partial Q^2} \frac{\partial^2 E\Pi_f^{FB}}{\partial A^2} - \frac{\partial^2 E\Pi_f^{FB}}{\partial A \partial Q} \frac{\partial^2 E\Pi_f^{FB}}{\partial Q \partial A} > 0.$$

The left-hand side can be expanded and written as

$$(r + c_u + c_b) \Pr\{D(A) = Q\} \left(\frac{d^2 EV_o(Q)}{dQ^2} + \frac{d^2 V_m(A)}{dA^2} \right) + \frac{d^2 EV_o(Q)}{dQ^2} \frac{d^2 V_m(A)}{dA^2}$$

which is clearly positive. Hence, the first-best solution is unique. ■

II Proof of Proposition 1

Under the assumptions above, the demand distribution takes the form $D(A) \sim \text{Uniform}[A - \sigma, A + \sigma]$ and the expected effort disutilities are given by $EV_m(A) = \frac{1}{2}A^2$ and $EV_o(Q) = \frac{1}{2}k_o Q^2$. Substituting in the first-order conditions $\left. \frac{\partial E\Pi_f^{FB}}{\partial Q} \right|_{Q^{FB}} = 0$ and $\left. \frac{\partial E\Pi_f^{FB}}{\partial A} \right|_{A^{FB}} = 0$ and solving simultaneously results in the pair (Q^{FB}, A^{FB}) as in the proposition. By Lemma 1, the solution is unique. ■

III Proof of Proposition 2

According to (1) and (2), in the second stage of the game, given her contract $S_m = w_m + \alpha_m Y$, the sales manager solves the problem

$$\begin{aligned} \max_A E\Pi_m &= w_m + \alpha_m EY - V_m(A) \\ \text{or, } \max_A E\Pi_m &= w_m + \alpha_m E \min\{Q, D(A)\} - V_m(A) \end{aligned}$$

and given his contract $S_o = w_o - \alpha_o C$, where $C = c_u U + c_b B$, the operations manager simultaneously solves the problem

$$\begin{aligned} \max_Q E\Pi_o &= w_o - \alpha_o EC - EV_o(Q) \\ \text{or, } \max_Q w_o + \alpha_o(c_u + c_b)E \min\{Q, D(A)\} &- \alpha_o c_u Q - \alpha_o c_b ED(A) - EV_o(Q) \end{aligned}$$

The first derivatives are given by

$$\begin{aligned} \frac{dE\Pi_m}{dA} &= \alpha_m \Pr\{D(A) < Q\} - A \\ \text{and } \frac{dE\Pi_o}{dQ} &= \alpha_o(c_u + c_b) \Pr\{D(A) > Q\} - \alpha_o c_u - k_o Q. \end{aligned}$$

The second derivatives are given by

$$\begin{aligned}\frac{d^2 E\Pi_m}{dA^2} &= -\left(\alpha_m \frac{1}{2\sigma} + 1\right) \\ \text{and } \frac{d^2 E\Pi_o}{dQ^2} &= -\left(\alpha_o(c_u + c_b) \frac{1}{2\sigma} + k_o\right).\end{aligned}$$

To obtain unique utility maximizing solutions for both managers, both the second derivatives above should be positive, resulting in the conditions

$$\begin{aligned}\alpha_m + 2\sigma &> 0 \\ \text{and, } \alpha_o(c_u + c_b) + 2\sigma k_o &> 0.\end{aligned}\tag{A2}$$

When these conditions hold, the first-order conditions give the unique solution pair (Q^*, A^*) in terms of the contract parameters α_m and α_o

$$\begin{aligned}Q^* &= \frac{\alpha_o(c_b(\alpha_m + \sigma) - c_u\sigma)}{\alpha_o(c_b + c_u) + (\alpha_m + 2\sigma)k_o} \\ A^* &= \frac{\alpha_m(\alpha_o c_b + \sigma k_o)}{\alpha_o(c_b + c_u) + (\alpha_m + 2\sigma)k_o}.\end{aligned}\tag{A3}$$

As in formulation (3), given these values of A^* and Q^* , the firm solves for optimal values of w_m, α_m, w_o and α_o to maximize its own profits. First note that the firm simply needs to make the participation constraints in (3) binding. Hence, it sets $w_m = -\alpha_m E[Y|Q^*, A^*] + V_m(A^*)$ and $w_o = \alpha_o E[C|Q^*, A^*] + EV_o(Q^*)$. The optimization problem of the firm then becomes (after a little bit of algebra)

$$\max_{\{\alpha_m, \alpha_o\}} E\Pi_f = (r + c_u + c_b)E \min\{Q^*, D(A^*)\} - c_u Q^* - c_b ED(A^*) - V_m(A^*) - EV_o(Q^*) \tag{A4}$$

To find the optimal values of α_m and α_o , we can take the first-order conditions w.r.t. both these parameters and solve for them. This, however, gets very unwieldy, so we use a different method to arrive at the optimal values of these parameters. Notice that the expressions for firm profit in (A4) above and in (A1) have the same structure, and will be exactly identical if the firm can achieve $Q^* \equiv Q^{FB}$ and $A^* \equiv A^{FB}$. Moreover, the first-best solution is unique, which means that if in this case the firm can set contract parameters such that the first-best solution is achieved, A^* must be identical to A^{FB} and Q^* must be identical to Q^{FB} . Therefore, to obtain the optimal contract parameters, we solve for α_m^* and α_o^* by equating the solution provided in Proposition 1 and (A3). This gives us the complete characterization of the contracts as the set of parameters

$\{w_m^*, \alpha_m^*, w_o^*, \alpha_o^*\}$, where

$$\begin{aligned}\alpha_m^* &= \frac{r(r + c_u + c_b) + (r + c_u - c_b)\sigma k_o}{r + c_b(1 + k_o) + \sigma k_o}, \\ w_m^* &= -\alpha_m^* E[Y|Q^{FB}, A^{FB}] + V_m(A^{FB}), \\ \alpha_o^* &= \frac{(r(r + c_u + c_b) + (r + c_b - c_u)\sigma)k_o}{-rc_u + (rc_b + \sigma(c_b - c_u))k_o} \\ \text{and } w_o^* &= \alpha_o^* E[C|Q^{FB}, A^{FB}] + EV_o(Q^{FB}),\end{aligned}$$

subject to the conditions $\alpha_m^* + 2\sigma > 0$ and $\alpha_o^*(c_u + c_b) + 2\sigma k_o > 0$.

Using the optimal value for α_m^* , we can write $\alpha_m^* = \frac{2\sigma A^{FB}}{Q^{FB} - (A^{FB} - \sigma)}$, which is positive, because $A^{FB} - \sigma \leq Q^{FB} \leq A^{FB} + \sigma$. Hence, the first condition (for the sales manager) is always satisfied.

The second condition (for the operations manager; using the optimal value for α_o^*), however, is satisfied only if $c_b > \left(\frac{r + \sigma k_o}{k_o(r + \sigma)}\right) c_u$. Hence, the firm can achieve the first-best outcome using contracts of the above form only if the condition in the proposition holds. ■

IV Proofs for Interdependent Contracts

IV.a Proof of Proposition 3

Given these contracts, the sales manager solves the same problem as before, and the operations manager solves

$$\begin{aligned}\max_Q E\Pi_o &= w_o - \alpha_o EC + \beta_o EY - EV_o(Q) \\ \text{or, } \max_Q w_o + (\alpha_o(c_u + c_b) + \beta_o)E \min\{Q, D(A)\} &- \alpha_o c_u Q - \alpha_o c_b ED(A) - EV_o(Q).\end{aligned}$$

The first derivative is given by

$$\frac{dE\Pi_o}{dQ} = (\alpha_o(c_u + c_b) + \beta_o) \Pr\{D(A) > Q\} - \alpha_o c_u - k_o Q.$$

The second derivative is given by

$$\frac{d^2 E\Pi_o}{dQ^2} = -\left((\alpha_o(c_u + c_b) + \beta_o)\frac{1}{2\sigma} + k_o\right).$$

Proceeding exactly as earlier (i.e., solving the first-order conditions for Q^* and A^* and equating them to Q^{FB} and A^{FB}) we obtain the coordinating contracts as in the statement of the proposition.

The conditions $\alpha_m^* + 2\sigma > 0$ and $\alpha_o^*(c_u + c_b) + \beta_o^* + 2\sigma k_o > 0$ ensure that the first-order conditions maximize the net utilities of the two managers. ■

IV.b Proof of Corollary 3.1

We need $\beta_{o,s}^* + 2\sigma k_o > 0$. We can write $\beta_{o,s}^* = \frac{2\sigma k_o Q^{FB}}{(A^{FB} + \sigma) - Q^{FB}}$, which is positive, because $A^{FB} - \sigma \leq Q^{FB} \leq A^{FB} + \sigma$. Hence, $\beta_{o,s}^* + 2\sigma k_o > 0$ holds. ■

V Proofs for Information-Based Contracts

V.a Proof of Proposition 4

Given these contracts, the sales manager solves the same problem as before, and the operations manager solves

$$\begin{aligned} \max_Q E\Pi_o &= w_o - \alpha_u EU - \alpha_b EB - EV_o(Q) \\ \text{or, } \max_Q w_o + (\alpha_u + \alpha_b)E \min\{Q, D(A)\} - \alpha_u Q - \alpha_b ED(A) - EV_o(Q). \end{aligned}$$

The first derivative is given by

$$\frac{dE\Pi_o}{dQ} = (\alpha_u + \alpha_b) \Pr\{D(A) > Q\} - \alpha_u - k_o Q.$$

The second derivative is given by

$$\frac{d^2 E\Pi_o}{dQ^2} = - \left((\alpha_u + \alpha_b) \frac{1}{2\sigma} + k_o \right).$$

Proceeding exactly as we did earlier (i.e., solving the first-order conditions for Q^* and A^* and equating them to Q^{FB} and A^{FB}) we obtain the coordinating contracts as in the statement of the proposition. The conditions $\alpha_m^* + 2\sigma > 0$ and $\alpha_u^* + \alpha_b^* + 2\sigma k_o > 0$ ensure that the first-order conditions maximize the net utilities of the two managers. ■

V.b Proof of Corollary 4.1

We need $\alpha_{b,s}^* + 2\sigma k_o > 0$. We can write $\alpha_{b,s}^* = \frac{2\sigma k_o Q^{FB}}{(A^{FB} + \sigma) - Q^{FB}}$, which is positive, because $A^{FB} - \sigma \leq Q^{FB} \leq A^{FB} + \sigma$. Hence, $\alpha_{b,s}^* + 2\sigma k_o > 0$ holds. ■

VI Proofs for Model with Sequential Action

VI.a Contracts Using Rudimentary Metrics

In the third stage of the game, given her contract $S_m = w_m + \alpha_m Y$, the sales manager solves the problem

$$\max_A E\Pi_m = w_m + \alpha_m EY - V_m(A)$$

The first-order condition for the above is:

$$\frac{dE\Pi_m}{dA} = \alpha_m \Pr\{D(A) < Q\} - A$$

and the second order condition is

$$\frac{d^2 E\Pi_m}{dA^2} = -\alpha_m f_{D(A)}(Q) - 1$$

The solution to the FOC above is given by $A^* = \frac{\alpha_m(Q+\sigma)}{\alpha_m+2\sigma}$ and the condition for this to be a maximum is $\frac{\alpha_m}{2\sigma} + k_m > 0$.

In the second stage of the game, the operations manager, given his contract $S_o = w_o - \alpha_o C$, where $C = c_u U + c_b B$, solves the problem

$$\max_Q E\Pi_o = w_o - \alpha_o EC - EV_o(Q)$$

The first-order condition for the above is:

$$\frac{dE\Pi_o}{dQ} = \frac{\partial E\Pi_o}{\partial Q} + \frac{\partial E\Pi_o}{\partial A} \frac{dA^*(Q)}{dQ}$$

Solving this condition, we obtain:

$$Q^* = \frac{2\alpha_o\sigma(c_b(\alpha_m + \sigma) - \sigma c_u)}{2(c_u + c_b)\alpha_o\sigma + k_o(\alpha_m + 2\sigma)^2}$$

$$A^* = \frac{\alpha_m(2c_b\alpha_o\sigma + k_o\sigma(\alpha_m + 2\sigma))}{2(c_u + c_b)\alpha_o\sigma + k_o(\alpha_m + 2\sigma)^2}$$

Solving for α_m and α_o in the same manner as in Appendix III, we obtain

$$\alpha_m = \frac{2A^{FB}\sigma}{Q^{FB} - (A^{FB} - \sigma)}$$

$$\alpha_o = \frac{2Q^{FB}k_o\sigma(Q^{FB} + \sigma)}{(Q^{FB} - (A^{FB} - \sigma))(-c_u(Q^{FB} - (A^{FB} - \sigma)) + c_b(A^{FB} + \sigma - Q^{FB}))}$$

Imposing the conditions for these to be utility-maximizing solutions for the two managers, we

obtain

$$\begin{aligned} \frac{d^2 E\Pi_m}{dA^2} &= -\alpha_m f_{D(A)}(Q) - k_m = -\left(\frac{\alpha_m}{2\sigma} + 1\right) < 0 \\ \text{and } \frac{d^2 E\Pi_o}{dQ^2} &= -\left(\frac{2(c_u + c_b)\alpha_o\sigma + (\alpha_m + 2\sigma)^2}{(\alpha_m + 2\sigma)^2}\right) \\ &= -\left(\frac{k_o(c_b(A^{FB} + Q^{FB} + \sigma) - c_u(Q^{FB} - (A^{FB} - \sigma)))}{(Q^{FB} + \sigma)(-c_u(A^{FB} + Q^{FB} + \sigma) + c_b(A^{FB} + \sigma - Q^{FB}))}\right) < 0 \end{aligned}$$

We need that $c_b > \left(\frac{r+k_o\sigma}{k_o(r+\sigma)}\right) c_u$ and $c_b > \left(\frac{Q^{FB} - (A^{FB} - \sigma)}{A^{FB} + Q^{FB} + \sigma}\right) c_u$.

VI.b Sales-Based Contract for Operations Manager

In the third stage of the game, given her contract $S_m = w_m + \alpha_m Y$, the sales manager solves the problem

$$\max_A E\Pi_m = w_m + \alpha_m EY - V_m(A)$$

The solution to the FOC above is given by $A^* = \frac{\alpha_m(Q+\sigma)}{\alpha_m+2\sigma}$ and the condition for this to be a maximum is $\frac{\alpha_m}{2\sigma} + k_m > 0$.

In the second stage of the game, the operations manager, given his contract $S_o = w_o + \beta_o Y$, solves the problem

$$\max_Q E\Pi_o = w_o + \beta_o EY - EV_o(Q)$$

The first-order condition for the above is:

$$\frac{dE\Pi_o}{dQ} = \frac{\partial E\Pi_o}{\partial Q} + \frac{\partial E\Pi_o}{\partial A} \frac{dA^*(Q)}{dQ}$$

Solving this condition to obtain Q^* and A^* , and then solving for α_m and α_o in the same manner as in Appendix III, we obtain

$$\begin{aligned} \alpha_m &= \frac{2A^{FB}\sigma}{Q^{FB} - (A^{FB} - \sigma)} \\ \beta_o &= \frac{2Q^{FB}k_o\sigma(Q^{FB} + \sigma)}{A^{FB}(Q^{FB} - (A^{FB} - \sigma)) + (A^{FB} + \sigma - Q^{FB})(Q^{FB} + \sigma)} \end{aligned}$$

It can be checked that the second-order conditions for these solutions to be utility-maximizing solutions for both the managers always hold.

VII Proofs for Model with Operational-Cost-Reduction Effort

First-Best Solution

The problem that the firm solves to obtain the first-best solution is

$$\max_{\{A, Q, z\}} rEY - EC - EC_z - \frac{1}{2}A^2 - \frac{1}{2}k_oQ^2 - \frac{1}{2}k_zz^2$$

As in Appendix II, we take the first-order conditions $\left. \frac{\partial E\Pi_f^{FB}}{\partial Q} \right|_{Q^{FB}, z^{FB}} = 0$, $\left. \frac{\partial E\Pi_f^{FB}}{\partial A} \right|_{A^{FB}, z^{FB}} = 0$ and $\left. \frac{\partial E\Pi_f^{FB}}{\partial z} \right|_{A^{FB}, Q^{FB}} = 0$ we obtain the values in Section 4.2.

Solution Under Incentives

First consider the case when the sales manager has the contract $S_m = w_m + \alpha_m Y$ and the operations manager has the contract $S_o = w_o - \alpha_o C - \alpha_z C_z$. In the second stage of the game, the sales manager solves the problem

$$\max_A E\Pi_m = w_m + \alpha_m EY - \frac{1}{2}A^2$$

and the operations manager solves the problem

$$\max_{Q, z} E\Pi_o = w_o - \alpha_o EC - \alpha_z C_z - \frac{1}{2}k_oQ^2 - \frac{1}{2}k_zz^2$$

Solving as in Appendix III, we obtain

$$Q^* = \frac{\alpha_o(c_b(\alpha_m + \sigma) - c_u\sigma)}{\alpha_o(c_b + c_u) + (\alpha_m + 2\sigma)k_o},$$

$$A^* = \frac{\alpha_m(\alpha_o c_b + \sigma k_o)}{\alpha_o(c_b + c_u) + (\alpha_m + 2\sigma)k_o}$$

and $z^* = \frac{\alpha_z}{k_z}$.

Once again, solving by imposing $Q^* \equiv Q^{FB}$, $A^* \equiv A^{FB}$ and $z^* \equiv z^{FB}$, we obtain

$$\alpha_m^* = \frac{r(r + c_u + c_b) + (r + c_u - c_b)\sigma k_o}{r + c_b(1 + k_o) + \sigma k_o},$$

$$\alpha_o^* = \frac{(r(r + c_u + c_b) + (r + c_b - c_u)\sigma)k_o}{-rc_u + (rc_b + \sigma(c_b - c_u))k_o}$$

and $\alpha_z^* = 1$.

Note that the quantities related to the sales effort and supply decisions remain unaffected in the presence of operational-cost-reduction effort by the operations manager. Hence, the conditions

under which the cost-based contract cannot coordinate remains the same as in Proposition 2.

In the same manner, in the case when the sales manager has the contract $S_m = w_m + \alpha_m Y$ and the operations manager has the contract $S_o = w_o + \beta_o Y - \alpha_z C_z$, the firm can always achieve the first-best solution.