1. Introduction

In many firms, manufacturing is evaluated as a cost center that seeks lower costs and operational efficiency, while marketing is evaluated as a revenue center with control over price and other marketing elements. Otley (2002) discusses how dividing a firm into independent units for measuring performance on accounting terms would lead to misaligned incentives and suboptimal system performance. Malhotra and Sharma (2002) emphasize the need for the alignment of manufacturing and marketing incentives with the firm’s goals and objectives. The two prominent aspects of customer service, price and leadtime, involve the decisions and actions of both departments. In this paper, we address the following research questions:

1. What are the inefficiencies that result from the decentralization of price and leadtime decisions as quoted by marketing and production, respectively?

2. How can we design a coordination scheme that will align the incentives of marketing and production with the firm’s overall objectives?

3. What is the impact of different market characteristics on the optimal decisions and contract design?

The most relevant papers to our work within the due date management literature are those that model steady-state systems, price and leadtime sensitive demand and uniform delivery time guarantees (Palaka et al. 1998, So and Song 1998, Boyaci and Ray 2003, Ray 2004). However, all these papers assume a centralized decision maker. For an extensive review on due-date management policies, the reader is referred to Keskinocak and Tayur (2004).
Eliashberg and Steinberg (1987), Kumar et al. (2000) and Li and Atkins (2002) consider marketing/operations interface for coordination of pricing and inventory replenishment decisions; Balasubramanian and Bhardwaj (2004) for price versus quality; Teck and Zheng (2004) and Chatterjee et al. (2002) for only leadtime quotations. To the best of our knowledge, our paper is the first to study price and leadtime decisions within the marketing/operations interface (Pekgun et al. 2005).

2. The Model

We model firm operations as an M/M/1 queue with mean production rate (capacity), $\mu$, and mean arrival (demand) rate, $\lambda = (a - bp - cL)$, which decreases linearly in quoted price, $p$, and leadtime, $L$. In this demand function, $a$ is the market potential, $b$ is the price sensitivity and $c$ is the leadtime sensitivity of customers. Capacity is assumed to be constant, while price and leadtime are decision variables. We impose a service level constraint, which specifies the minimum probability of meeting the quoted leadtime, $s$. For computational simplicity, we define $k = \ln(1/(1-s))$. We assume that there is positive demand for the firm to provide its services when the smallest reasonable price, i.e., the unit production cost, $m$, and the shortest leadtime that satisfies the service level constraint, $(k/\mu)$, are chosen. We use subscripts $C$ and $D$ to denote centralized and decentralized settings, respectively.

2.1 The Centralized Setting

In the centralized setting, marketing and production decisions are considered simultaneously. The objective is to maximize revenues less variable production costs.

$$\max_{(\lambda_C, p_C, L_C) \geq 0} \pi_C = \lambda_C (p_C - m)$$

s.t. \hspace{1cm} \hspace{1cm} 1 - e^{-(\mu - \lambda_C)L_C} \geq s

We choose to eliminate price, $p_C$, from this formulation since $p_C = (a - \lambda_C - cL_C)/b$, and we can rewrite the service level constraint as $(\mu - \lambda_C)L_C \geq k$. The service constraint is binding at optimality as in Palaka et al. (1998) and So and Song (1998). The optimal decisions are given as follows:

$$(a - 2\lambda^*_C - mb)(\mu - \lambda^*_C)^2 = ck\mu \hspace{1cm} \text{and} \hspace{1cm} L^*_C = \frac{k}{\mu - \lambda^*_C}$$

This result is a special case of that found in Palaka et al. (1998) for the fixed capacity case, when there are no holding or lateness costs.
2.2 The Decentralized Setting

In the decentralized setting, production and marketing make their decisions based on individual incentives. We model the sequence of decisions as a Stackelberg game, where production is the leader and marketing is the follower. We employ backwards induction starting with marketing’s problem. The profit of marketing is given by the revenue of the firm.

\[
\max_{p_D \geq 0} \pi^M_D = p_D(a - bp_D - cL_D)
\]

We find the optimal price and demand as follows:

\[
p^*_D(L_D) = \left[\frac{a - cL_D}{2b}\right]^+ \quad \text{and} \quad \lambda^*_D(L_D) = \left[\frac{a - cL_D}{2}\right]^+
\]

Note that there should be an incentive given by the firm to production for generating positive demand. A reasonable incentive is chosen as \(p^*_D(L_D)\), which turns production’s problem into the firm’s overall problem in the decentralized setting.

\[
\max_{0 \leq L_D \leq \frac{a}{c}} \pi^P_D = \pi^P_D = (p^*_D(L_D) - m)\lambda^*_D(L_D)
\]

\[\text{s.t.} \quad (\mu - \lambda^*_D(L_D)) L_D \geq k\]  \hspace{1cm} (1)

**Proposition 1** The decentralized problem has a nontrivial optimal solution with positive profit if and only if \(\mu > bm + \frac{ck}{a - 2mb}\) and \(a > 2mb\). In this case, the optimal leadtime is given by \(L^*_D = y_D\), where \(y_D\) is the positive root of (1) when it is binding.

Long leadtimes under restricted capacity motivate marketing to quote low prices in order to maximize its profits. When the price to be quoted by marketing is not sufficient for production to cover its costs, production drives demand to zero. Thus, the minimum capacity requirement in Proposition 1 corresponds to a minimum price constraint for marketing such that the price quoted by marketing should be at least \(m\).

2.3 Comparison of the Decentralized and Centralized Settings

When we compare the two settings, we observe the following:

- In the decentralized case, total demand generated is larger, leadtimes are longer, quoted prices are lower, and the firm profits are lower as compared to the centralized case.

- Even when there are no capacity and service level constraints, the decentralized setting performs worse than the centralized setting in firm profits: \(\pi_C - \pi_D = m^2b/4 > 0\).
• Under coordination, marketing generates more revenues, while production achieves lower costs as compared to the decentralized setting.

Sensitivity of the optimal decisions $\lambda^*_c$, $L^*_c$, and $p^*_c$, to the problem parameters for both the centralized and decentralized settings are given in Table 1. The change in optimal price with respect to $\mu$, $c$ and $s$ is not theoretically obvious under the centralized setting. However, a numerical analysis shows that:

• The firm charges a higher price to quote lower leadtimes within a tight capacity interval. After a threshold, price decreases approaching the unconstrained solution.

• At high or low capacities, the optimal price decreases in $c$ and $s$. At medium capacities, quoted price increases in $c$ and $s$ up to a threshold and then decreases. Up to a critical $c$ and a critical $s$, $\mu$ is sufficient for charging higher for better service. Beyond this point, the quoted leadtime can only be decreased slightly in $c$, and has to be increased sharply in $s$, given $\mu$. Thus, the quoted price decreases to attract more customers. Low, medium, and high capacities are defined with respect to $a$, $m$ and $b$ (See Figure 1).

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<th>Table 1: Sensitivity analysis on optimal decisions</th>
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3. Transfer price contract with bonus payments

Under this proposed contract for achieving coordination between marketing and production, marketing pays $w$ to production for each unit produced, and both departments receive a bonus payment as the fraction of the total revenues generated. Let $\alpha_1$ denote the share for marketing and $\alpha_2$ the share for production. We assume that the fraction of revenues received by the two departments do not necessarily add to 1, i.e., $0 \leq \alpha_1 \leq 1$ and $0 \leq \alpha_2 \leq (1 - \alpha_1)$. 
Figure 1: Price vs. Leadtime Sensitivity \((a = 50, b = 4, m = 5, s = 0.95)\)

**Proposition 2** The Transfer Price Contract with Bonus Payments has a nontrivial optimal solution with positive profit if and only if, for every \(\alpha_1; \alpha_2\) and \(w\) are chosen such that production’s profit margin is positive: \(\alpha_2 p^*_D + w - m \geq 0\).

If the contract parameters are chosen according to Proposition 2, the service level constraint is tight at optimality. Thus, in order to achieve coordination, we can choose the transfer price that will equate the demand generated in the decentralized setting to that in the centralized setting. We find that there exists a unique transfer price that achieves coordination: \(w^* = \alpha_1 [a - 2\lambda^*_C - ck/(\mu - \lambda^*_C)] / b\). Analysis of some special cases of this contract shows that under a revenue sharing contract \((\alpha_1 + \alpha_2 = 1)\) or a transfer price-only contract \((\alpha_1 = 1, \alpha_2 = 0)\), coordination can be achieved with a unique transfer price. However, coordination cannot be achieved with a revenue sharing contract with no transfer price \((w = 0)\).

4. Conclusions

We studied a firm which serves customer demand that is sensitive to price and leadtime decisions, which are made by marketing and production, respectively. We analyzed the inefficiencies that result from decentralization of these two functions. In order to achieve coordination, we proposed a transfer price contract with bonus payments, and showed the existence of a unique coordinating transfer price as long as production receives a satisfactory incentive. As a future extension of this research, it would be interesting to change the sequence of decisions, where marketing becomes the leader and production the follower. Extensions to operational settings, such as a multi-period model, would also be of interest, as the steady-state results may not always hold in day-to-day operations of a firm.
Acknowledgments

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References


