A Note on Modeling Service Capacity Allocation under Varying Intensities of Competition

Hongkai Zhang
East Central University

James Rauch
East Central University

Based on a linear deterministic price response function, sales revenue is analytically determined for five alternative policies for allocating service capacity over a two-period planning horizon for a service provider in a competitive environment, in which the intensity of competition varies over time. A numerical study is conducted to compare the performances of the considered policies and examine the impacts of competition and price sensitivity.

INTRODUCTION

Advance selling occurs when sellers allow buyers to make purchases at a time preceding consumption (Xie and Shugan, 2001). The practice of advance selling is a rapidly growing phenomenon in service industries. Recent technological advances such as electronic tickets, smart cards and online prepayment have made it a suitable marketing tool to nearly all service providers (Shugan and Xie, 2004) and as a direct result, they now can conveniently advance sell their services prior to consumption. For example, major airlines and hotel chains nowadays advance sell their service capacities extensively through online websites (e.g., www.travelocity.com and www.hotels.com). Movie theaters, amusement parks and providers of other services are also increasingly practicing advance selling to increase sales.

In spite of the growing practice of advance selling by various service industries, the literature on advance selling (and related capacity allocation and pricing) so far has been rather limited. In a notable article, Xie and Shugan (2001) propose several pricing strategies for advance selling under certain conditions of service capacity. In a more recent study based on a two-period model, Shugan and Xie (2005) explore the impact of competition on advance selling driven by consumer uncertainty about future consumption states and conclude that advance selling can be a very effective marketing tool in a competitive setting. Also using a two-period model, Png (1989) argues that a service reservation provides insurance for risk-averse buyers against the uncertainty in service valuation and unavailability of service capacity. Png (1991) further suggests that service providers should practice advance selling to maximize profits through premium advance prices and a discount price for the remaining capacity as the time of consumption approaches. Lee and Ng (2001), incorporating price sensitivity in their modeling framework, analytically determine the optimal allocation of service capacity over a two-period planning horizon and corresponding pricing strategies in a monopoly setting. In addition to the above studies that are of general orientation, some related studies focus on certain service industries. Ladany (1996), using a dynamic programming approach, presents a market segmentation strategy that optimizes the number of market segments, the corresponding prices, and the number of hotel rooms allocated to each segment. Ladany and Arbel (1991) determine for a cruise liner the optimal segmentation of total and unused capacities for certain cases. The studies cited above shed interesting lights on the issue of service capacity allocation and pricing.

In the marketing literature, a particularly important question still stands only partially answered, which is regarding the best way of allocating a service capacity over time for spot and advance selling so that a certain performance measure is optimized. Unlike the study of Shugan and Xie (2005) that uses a modeling approach at the individual level, this study employs a modeling approach at the aggregate level. In this research, we attempt to address the above question over a two-period planning horizon while taking varying intensities of competition into account.

In the next section, we first develop the models for the prices of service capacity over the advance and spot periods, respectively, and then the sales revenues of five alternative policies for service capacity allocation policies are analytically determined.

The third section presents a numerical example to compare the performances of the five allocation policies and examine the impacts of price sensitivity and competition intensity. Finally, the paper concludes with a summary of its findings and managerial implications in the fourth section.

MODEL DEVELOPMENT

Consider a service provider (designated as the focal firm) in a competitive environment, which has a service capacity of K identical units available for allocation over a planning horizon of two consecutive time periods. The firm's sales revenue generated over the planning horizon is chosen to measure the performance of an allocation policy. The problem we intend to solve can be specifically stated as follows: *What is the best scheme in a competitive environment to completely allocate a service capacity of K identical units over a two-period planning horizon for spot and advance selling so that the service provider's sales revenue will be maximized?* We make the following basic assumptions while formulating this optimization problem:

(1) The price charged for a unit of service capacity is constant in a period but may vary across the two-period planning horizon.

(2) The capacity is produced and consumed in the second period.

(3) The timing of competitive entry and its captured market share are known for certainty.

Beginning from the starting point of the planning horizon, the two periods are successively denoted as Period i (i = 1, 2). Period 1 is referred to the advance period in which advance selling could occur, while Period 2 is called the spot period in which both spot selling and the consumption of service take place. In practice, the length of the planning horizon is industry-specific. For example, in the hotel and airline industries service providers may sell their capacities more than a year in advance, while in the advertising industry television networks usually sell their advertising spaces approximately six months in advance (Lee and Ng, 2001).

As a service provider in general operates with a high fixed cost, C, which is much higher than the variable costs of capacity, we only consider the case in which C is a constant exogenously determined and variable costs are sufficiently small to be ignored, as in the study of Lee and Ng (2001). Examples of such a case can be found in the airline and hotel industries (Desiraju and Shugan, 1999). Several terms used to formulate the optimization problem stated above are defined below:

P_i the price of a unit of capacity in Period i;

x_i the amount of the focal firm's capacity allocated to Period i;

R_i the firm's sales revenue in Period i;

R the firm's total sales revenue over the two-period planning horizon;

π the firm's profit over the two-period planning horizon;

K the firm's total capacity available for consumption;

$1/(\lambda+1)$ the fraction of the sales capacity taken by the competition upon entry ($\lambda > 0$).

A linear form of a price response function is extensively employed in both theoretical and empirical studies (see Lee & Ng, 2001 for a review). Linear formulations are more appealing because of the relative ease of parameter estimation through classical statistical methods (Zufryden, 1975). We assume that price is a linear decreasing function of total capacity projected for utilization at any point of time as in the price response function employed in the work of Lee and Ng (2001). Following Mesak (1990), we here introduce the parameters λ_i (i = 1, 2) to reflect the intensity of competition between the focal firm and its rival(s) in period i. It is assumed that if competition is present in Period i, a fraction of capacity, $(1/(\lambda_i+1))x_i$, is taken away from the focal firm in this period. Therefore, the fraction of capacity that can be sold by the focal firm in Period i is $(\lambda_i/(\lambda_i+1))x_i$. To improve exposition, let $w_i = \lambda_i/(\lambda_i+1)$ for i = 1, 2. Apparently, w_i is a value in the interval (0, 1). A larger value of λ_i means a smaller market share taken away by the competition and thus a larger market share (a larger value of w_i) achieved by the focal firm in period i. If λ_i approaches infinity, then w approaches one, indicating that the focal firm is completely in control of the market. The value of λ_i (and hence w_i) depends largely on the relative marketing mix between the focal firm and the competitor(s) (Mesak, 1990).

Based on the above discussion, if competition is present in the advance and spot periods (i.e., Periods 1 and 2), the prices over the two-period planning horizon are given by Equations (1-1) and (1-2):

$$P_1 = \alpha - \beta_1(w_1 x_1 + w_2 x_2)\,, \tag{1}$$

$$P_2 = \alpha - \beta_2 w_2 x_2\,. \tag{2}$$

In the expressions shown above, $\alpha > 0$, $\beta_i > 0$, i = 1, 2.

In these expressions, the coefficient β_i represents the price sensitivity for Period i, which measures the change in the price of service for Period i due to a unit change in the amount of service capacity available in that period. Time, in reality, is a significant factor affecting the stability of price sensitivity. Price sensitivity is most likely to be constant over a single period which length is sufficiently short. Because of the dynamic nature of supply and demand, on the other hand, price sensitivity may vary across different periods with longer durations. In this regard, it is assumed in our present study that price sensitivity is constant over a single period but may vary across Periods 1 and 2.

The total sales revenue R of the focal firm generated by advance and spot selling over the entire two-period planning horizon is stated as

$$R = P_1 w_1 x_1 + P_2 w_2 x_2 = \alpha w_1 x_1 - \beta_1(w_1^2 x_1^2 + w_1 w_2 x_1 x_2) + a w_2 x_2 - \beta_2 w_2^2 x_2^2\,. \tag{3}$$

Several main alternative types of policies for allocating service capacity are examined in this study. They are defined below:

(1) *Pure Advance Selling Policy (PASP)*: Under this policy, the focal firm allocates its entire service capacity in the advance period (i.e., Period 1).

(2) *Pure Spot Selling Policy (PSSP)*: Under this policy, the focal firm allocates its entire service capacity in the spot period (i.e., Period 2).

(3) *Uniform Policy* (*UP*): This is a policy in which the focal firm allocates an equal amount of its service capacity to each period of the two-period planning horizon.

(4) *Pulsing Allocation Policy (PAP)*. According to this policy, the focal firm alternates between high and low levels of service capacity allocation. If the firm allocates a higher level of capacity in the advance period, the related policy is designated as PMP-I; otherwise it is designated as PAP-II. For illustrative purposes, we only consider in this study the special case for both PMP-I and PMP-II in which the high level of capacity allocated is twice the low level.

Given the allocation scheme of each policy discussed above and the service capacity K, the yielded sales revenue is analytically determined by model (3). Table 1 summarizes the allocation schemes and sales revenues.

It is shown in Table 1 that the density of competition in the advance period, w_1, does not affect the sales revenue yielded by pure spot selling (PSSP). In contrast, the density of competition in the spot period, w_2, does not affect the sales revenue yielded by pure advance selling (PASP). It is also found that the densities of advance and spot periods interactively affect the sales revenues yielded under the other three allocation policies, UP, PAP-I and PAP-II.

TABLE 1
ALLOCATION SCHEMES AND SALES REVENUES OF THE CONSIDERED POLICIES

Policy	Allocation scheme	Sales revenue (R)
PASP	$x_1 = K,\ \ x_2 = 0$	$\alpha w_1 K - \beta_1 w_1^2 K^2$
PSSP	$x_1 = 0,\ \ x_2 = K$	$\alpha w_2 K - \beta_2 w_2^2 K^2$
UP	$x_1 = K/2,\ \ x_2 = K/2$	$\frac{1}{2}\alpha(w_1 + w_2)K - \frac{1}{4}\beta_1(w_1^2 + w_1 w_2)K^2 - \frac{1}{4}\beta_2 w_2^2 K^2$
PAP-I	$x_1 = 2K/3,\ \ x_2 = K/3$	$\frac{1}{3}\alpha(w_1 + 2w_2)K - \frac{1}{9}\beta_1(w_1^2 + 2w_1 w_2)K^2 - \frac{4}{9}\beta_2 w_2^2 K^2$
PAP-II	$x_1 = K/3,\ \ x_2 = 2K/3$	$\frac{1}{3}\alpha(2w_1 + w_2)K - \frac{2}{9}\beta_1(2w_1^2 + w_1 w_2)K^2 - \frac{1}{9}\beta_2 w_2^2 K^2$

A NUMERICAL EXAMPLE

For illustrative purposes, we present in this section a numerical example to compare the performances of the five policies for service capacity allocation. Such a numerical approach is commonly used in the marketing literature for conducting sensitivity analysis.

Suppose that the service capacity available for consumption in the spot period is K = 3000 units. Four pairs of (w_1, w_2) are chosen to examine the impact of competitive intensity on the performances of the five allocation policies: (0.2, 0.8), (0.8, 0.2), (0.2, 0.2) and (0.8, 0.8). The first two pairs of (w_1, w_2) indicate weaker and stronger competition in the advance period (Period 1), respectively. The last two pairs of (w_1, w_2) each indicate a lower and higher constant level of competitive intensity over the two-period planning horizon. We assume α = \$1000. Four pairs of the price sensitivities (β_1, β_2) are considered to study the impact of price sensitivities on the optimal scheme of capacity allocation: (0.3, 0.4), (0.4, 0.3), (0.3, 0.3) and (0.4, 0.4). The first two pairs of (β_1, β_2) show a higher and lower price sensitivity in the spot period (Period 2), respectively. The last two pairs of (β_1, β_2) each indicate a constant distribution of price sensitivity over the planning horizon. Lower price sensitivity in the spot period could be due to imminent perishability of the service (Lee and Ng, 2001). For example, a consumer who has not made advance booking for a hotel room or a flight seat is likely to be less price-sensitive when he/she requires a room or a seat at the time of consumption than one who has made an advanced booking well ahead of the time of consumption. For the case of higher price sensitivity in the spot period, Xie and Shugan (2001) assert that buyers may pay a premium in the advance period over the spot price, because advance buying has a higher expected buyer surplus than waiting towards the consumption (spot) period as in most bakery services and high-fashion clothing. For the case of constant price sensitivity, customers are assumed to value the service equally over time. Examples of related services include catering, lawn care and repair services.

Table 2 reports the sales revenues of all the five alternative policies of capacity allocation in sixteen cases, together with the optimal policy identified for each case. For example, when the price sensitivities $\beta_1 = 0.3$ and $\beta_2 = 0.4$ and the competitive intensity parameters $w_1 = 0.2$ and $w_2 = 0.8$, the sales revenues generated by the Pure Advance Selling Policy (PASP) and the Pure Spot Selling Policy (PSSP) are $49,200 and $9600, respectively.

It is noted in Table 2 that if price sensitivity and competition intensity both remain constant over the two-period planning horizon, the optimal allocation policy appears to be UP, which generates the highest sale revenue, while both pure advance selling and pure spot selling produce the lowest sales revenue. This result is consistent with the analytical findings of Lee ang Ng (2001) and Zhang and Mesak (2008). When price sensitivity increases or decreases over the planning horizon, on the other hand, the pulsing allocation policies (PAP-I or PAP-II), may be superior to the uniform policy (UP) in yielding sales revenue.

TABLE 2
SALES REVENUE GENERATED BY THE ALTERNATIVE ALLOCATION POLICIES (IN $10,000)

(β_1, β_2)	(w_1, w_2)	*PASP*	*PSSP*	*UP*	*PAP-I*	*PAP-II*	*Optimal policy*
(0.3, 0.4)	(0.2, 0.8)	4.92	0.96	7.89	6.68	8.00	PAP-II
(0.3, 0.4)	(0.8, 0.2)	6.72	4.56	9.24	8.48	9.20	UP
(0.3, 0.4)	(0.2, 0.2)	4.92	4.56	5.10	5.00	5.12	PAP-II
(0.3, 0.4)	(0.8, 0.8)	6.72	0.96	9.60	8.00	9.92	PAP-II
(0.4, 0.3)	(0.2, 0.8)	4.56	6.72	8.88	8.88	8.16	UP, PAP-I
(0.4, 0.3)	(0.8, 0.2)	0.96	4.92	7.53	7.68	6.36	PAP-I
(0.4, 0.3)	(0.2, 0.2)	4.56	4.92	5.01	5.04	4.92	PAP-I
(0.4, 0.3)	(0.8, 0.8)	0.96	6.72	8.16	8.64	6.72	PAP-I
(0.3, 0.3)	(0.2, 0.8)	4.92	6.72	9.33	9.24	8.64	UP
(0.3, 0.3)	(0.8, 0.2)	6.72	4.92	9.33	8.64	9.24	UP
(0.3, 0.3)	(0.2, 0.2)	4.92	4.92	5.19	5.16	5.16	UP
(0.3, 0.3)	(0.8, 0.8)	6.72	6.72	11.0	10.6	10.6	UP
(0.4, 0.4)	(0.2, 0.8)	4.56	0.96	7.44	6.32	7.52	PAP-II
(0.4, 0.4)	(0.8, 0.2)	0.96	4.56	7.44	7.52	6.32	PAP-I
(0.4, 0.4)	(0.2, 0.2)	4.56	4.56	4.92	4.88	4.88	UP
(0.4, 0.4)	(0.8, 0.8)	0.96	0.96	6.72	6.08	6.08	UP

Table 2 shows that if price sensitivity increases over the planning horizon ($\beta_1 < \beta_2$), all the allocation policies produce higher sales revenue under the increasing competitive intensities ($w_1 > w_2$) than the decreasing ones ($w_1 < w_2$). In contrast, if price sensitivity decreases over time ($\beta_1 > \beta_2$), the above conclusion is reversed. It is also found that for all the four pairs of price sensitivity considered, a lower constant competitive intensity over the two-period planning horizon will allow UP, PAP-I and PAP-II to yield higher sales revenue than a higher constant one. In addition, price sensitivity appears to have an impact on the performances of the allocation policies. As shown in Table 2, all the polices produce higher sales revenue under a low constant level of price sensitivity than a higher one.

SUMMARY AND CONCLUSIONS

In this study, a linear price response function is employed to describe the relationship between the price and the capacity projected for utilization in a competitive setting with varying competitive intensity over a two-period planning horizon. Sales revenue is analytically determined for five alternative policies of service capacity allocation, respectively. A numerical example is presented to compare the performances of the policies and shed light on the interactive effects of price sensitivity and competition intensity. Managerial implications based on our main findings are summarized below:

(1) The focal firm should not allocate all its capacity in the advance or spot period only. A combination of advance and spot selling characterized by UP or PAP would yield higher sales revenue.

(2) The focal firm should consider the marketing mix variables to reduce consumers' price sensitivity.

(3) Reducing the intensity of competition will improve the firm's profitability.

The modeling effort developed in this paper is exploratory, revealing several possibilities for future research. First, the price response function employed in our models has a linear and deterministic structure. A probabilistic price response function with a nonlinear may be considered for model development. Second, the sales revenues of the alternative policies are determined based on a two-period model. Such an analytical approach could be extended to a general *n*-period planning horizon. Third, the findings of our numerical study are valid for the chosen model parameters. A wider range of the parameter values should be used to obtain more general conclusions.

REFERENCES

Desiraju, R. & Shugan, S. M. (1999). Strategic Service Pricing and Yield Management. *Journal of Marketing*, 63, 44-56.

Ladany, S. P. (1996). Optimal Market Segmentation of Hotel Rooms – The Nonlinear Case. *Omega,* (1), 29-36.

Ladany, S. P. & Arbel, A. (1991). Optimal Cruiser-Liner Passenger Cabin Pricing Policy. *European Journal of Operational Research*, 55, 136-147.

Lee, K. S. & Ng, I. C. L. (2001). Advance Sale of Service Capacities: Theoretical Analysis of the Impact of Price Sensitivity on Pricing and Capacity Allocations. *Journal of Business Research*, 54, 219-225.

Mesak, H. I. (1990). Impact of Anticipated Competitive Entry and Cost Experience on Optimal Strategic Pricing of Technological Innovations. *Computers and Operations Research*, *17* (1), 27 – 37.

Ng, I. C. L, Wirtz, J. & Lee, K. S. (1999). The Strategic Role of Unused Service Capacity. *International Journal of Service Industry Management*, 10 (2), 211-238.

Png, I. P. L. (1989). Reservations: Customer Insurance in the Marketing of Capacity. *Marketing Science*, 8 (3), 248-264.

Png, I. P. L. (1991). Most-Favored-Customer Protection versus Price Discrimination over Time. *Journal of Political Economy*, 99 (5), 1010-1028.

Shugan, S. M. & Xie, J. (2004). Advance Selling for Services. *California Management Review*, 46 (3), 37-54.

Shugan, S. M. & Xie, J. (2005). Advance-Selling as a Competitive Marketing Tool. *International Journal of Marketing*, 22 (3), 351-373.

Xie, J. & Shugan, S. M. (2001). Electronic Tickets, Smart Cards, and Online Prepayments: When and How to Advance Sell. *Marketing Science*, 20 (3), 219-243.

Zhang, H. & Mesak, H. (2008). Allocating and Pricing Service Capacity over Time in a Competitive Environment. *Proceedings of the 2008 Decisions Sciences Institute Annual Meeting*, 1051 – 1056, Baltimore, November 2008.

Zufryden, F. S. (1975). Optimal Multi-Period Advertising Budget Allocation within a Competitive Environment. *Operational Research Quarterly*, 26 (4), 743-754.