Managing Competition:
Promotions that Reduce Pricing Pressure

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Abstract
When firms have more capacity than their full price customers will consume in the short term, and have access to a pool of very price elastic customers, they can use deep promotions to clear the excess inventory without cannibalizing their high margin demand and so avoid directly competing for high value customers. Examples include airlines’ release of limited blocks of seats for discount fare classes, and “Black Friday” offerings of limited quantities of toys, electronics and other consumer durables at the beginning of the Christmas selling season. By pricing a limited quantity at below market clearing rates, these “rationed promotions” allow firms to recruit enough excess demand to clear excess inventory while effectively excluding high value customers from purchasing at the discount price.

We show that competition weakly increases prices above the optimal monopoly level, but lowers revenues because the higher prices fail to achieve optimal segmentation of heterogeneous consumers. Nonetheless, by clearing excess inventory, yield managing firms avoid direct competition for their most profitable customers and retain most of the revenues available to the monopolist. This has important consequences for capacity choice in these markets. Since rationed promotions dramatically improve profitability in low demand states, firms using them elect significantly higher capacities when facing variable or uncertain demand. This leads to substantial social welfare gains in these markets. While in the monopoly case most of this gain goes to consumers, under duopoly competition firms gain all the benefits. We extend these results to situations of asymmetric competition and horizontally differentiated products and find that in these contexts competition can lead to either higher or lower prices depending on the degree and nature of preference heterogeneity.
1. Introduction

Sellers must often set capacity far in advance of actual sales. When demand falls short of expectations, this can leave the seller having to clear the excess inventory, especially when the goods are perishable or have a limited saleable life. Familiar examples include airlines that choose routes and allocate planes months in advance, fashion retailers facing lead times of six to nine months for products with a shelf life as short as 9 weeks, and toy sellers that do 2/3 of their annual business in the weeks before Christmas. Discounting to expand demand may solve this problem only at the expense of cannibalizing high margin sales and so actually decrease revenues and profits; and, in the case of competing firms, may trigger a price war with even more undesirable consequences.

Marketers have developed many strategies for balancing these goals. For example, when customers are unsure what value they will place on a product at consumption, firms can increase sales and revenues through advance selling at a discounted price (Xie and Shugan 2001). More generally, when total demand is uncertain, firms should adjust price to the remaining inventory levels to ensure that products are allocated to the highest value consumers and that profitable sales are not left on the table (Lazear 1986, Gallego and van Ryzin 1994). The various strategies for dynamically managing prices generally go under the rubric of Yield Management or Revenue Management and have found applications across many industries since they were first used in the airline business in the late 1970s. Often such strategies require limiting the number of units initially offered at low price points so as to preserve capacity for future sales with higher margins. A familiar example is airlines’ release of limited blocks of seats for discount fare classes. A less obvious one is of “Black Friday” offerings of limited quantities of toys, electronics
and other consumer durables at the beginning of the Christmas selling season. When a small quantity of product is made available at far below the market clearing price the excess demand often results in a scramble of customers to claim the discounted units. It is not immediately obvious why sellers should leave so much revenue on the table when they could obviously sell out at much higher prices; however, when the distribution of consumer willingness to pay is such that demand is inelastic at high prices but elastic at low prices, this proves to be the revenue maximizing pricing policy. We refer to pricing strategies in which a firm offers to sell a limited quantity of its product at a price below the market clearing value as rationed promotions.

We study the interplay of competition and rationed promotions. We analyze a model of competition and characterize the equilibrium prices under duopoly in a market with consumer segments of differing price sensitivities. The results under competitive interaction are particularly striking. We find that prices are (weakly) higher under competition than under monopoly pricing. This suggests that some famous examples of price wars may be misinterpreted. Under our model, deeper promotions are a symptom of cooperative behavior between firms. Furthermore, equilibrium is in dominant strategies and so is robust against the state dependence that often makes competitive analysis of yield managing firms intractable. Since there exists an isomorphism between our mechanism and the standard model of revenue management (intertemporal price dispersion in response to stochastic demand, eg. Gallego and van Ryzin 1994), our findings represent a substantial contribution to understanding competition in the context of yield management. Moreover, our work suggests that yield management and related dynamic pricing strategies may have substantially broader application in competitive
environments than previously thought. This is because under Yield Management the monopolist uses rationed promotions to fully allocate capacity only to the extent that marginal sales to low value customers add to total revenue; the existence of unused capacity does not impede his ability to extract surplus from high value consumers. Under competition a further challenge arises; while a monopolist might find it optimal to not sell his entire inventory, competing firms generally cannot resist the temptation to make additional sales at the expense of their rivals. Therefore, competing firms must allocate unused capacity, lest the existence of unused capacity leads firms to compete away surplus from high value customers. This need to manage inventories in order to reduce competitive pressures means that rationed promotions have a utility for competing firms which is distinct from their value to monopolists simply trying to extract maximum revenue from finite capacity.

Prior work analyzing the impact of competition on yield management is limited. This reflects both theoretical and practical considerations. Incorporating competition adds complexity to an already complex problem. The paucity of theoretical models also reflects a serious analytical challenge: optimal pricing policies typically reflect the relationship between current inventory and expected demand, and so are state dependent on the changing realization of those variables; furthermore, competing firms (and potentially consumers) can react to the state dependent strategies of their competitors in ways that generate intractably complex game structures. We characterize a representative environment that supports a dominant strategy equilibrium in prices, independent of remaining capacity allocation for duopoly competitors using rationed promotions. In this way we offer robust conclusions about the impact of competition on rationed promotions.
It is important to note that the results are also significant for many firms that do not engage in traditional yield management practices, as the Black Friday example shows. The main takeaway is that when competing firms have more capacity than their full price customers can consume in the short term, and have access to a pool of very price elastic customers, they can use deep promotions to clear the excess inventory without cannibalizing their high margin demand and so avoid directly competing for high value customers. With access to this tool for managing excess inventories, both monopoly and competitive firms can commit to larger capacities, increasing both welfare and profits.

**Review of Literature**

Past research has focused on the problem of pricing over time in order to clear inventory or allocate capacity to higher willingness to pay customers under uncertain demand; an exhaustive review is Talluri and van Ryzin (2004). Generally these models balance the expected revenues from ex ante uncertain marginal sales with the cost of additional capacity to service them, adjusting the price trajectory in response to the observed realization of the underlying stochastic process. Typically such models do not exploit heterogeneity in consumer reservation values, except as required to support higher spot prices for additional sales in high demand states. Indeed, for tractability reasons, such models typically assume demand is such that expected revenue is maximized using a single price strategy (McAfee and te Velde, 2008). Under such assumptions price changes are observed only in response to deviations from expected demand.

Another area of past research has focused on how firms might offer multiple prices in order to price discriminate among consumers when willingness to pay is correlated with observable characteristics (3rd degree price discrimination) or with preferences over non
price product attributes (2nd degree price discrimination) (Anderson and Dana 2009, Gallego 2010). Wilson (1988) showed that even in the absence of demand uncertainty a monopolist might want to vary prices over time in order to discriminate among consumers who differ only in willingness to pay by rationing the discounted product to allow some lower priced sales while excluding higher willingness to pay customers through proportional allocation.

It is useful to relate Wilson’s results to other promotional strategies. Wilson’s mechanism assumes that all prices are available and consumers purchase the lowest priced units first. As such it is a model of “introductory offer pricing” in which a low initial price is offered on a limited quantity of the product and when that quantity is exhausted, the price reverts to a higher, full price which exploits higher willingness to pay consumers. Ferguson (1994) compares introductory offer pricing with clearance pricing (where the price is initially high, and later decreases) and shows that with complete information and forward looking and rational consumers the two practices are revenue equivalent. Denicolo and Garella (1999) show that introductory offers solve a problem of commitment that arises in the case of clearance sales. In order to implement the optimal separating equilibrium sellers must typically set the clearance price below the market clearing price, which is no longer rational if high value customers have already bought.

While Wilson assumes that any demand uncertainty can be ignored by appeal to a law of large numbers, related work has generally focused on the impact of demand uncertainty. Harris and Raviv (1981) show that rationed quantity discounts are optimal under their “priority pricing” mechanism in which consumers reveal their willingness to pay in order to get priority in allocation in event of stock-out (similar to mechanisms used in electrical
energy pricing). Lazear (1986) uses declining prices as a means of demand discovery, with applications to seasonal goods and real estate. Dana (2001) finds that, with demand uncertainty, introductory offer pricing may dominate uniform pricing even when firms can increase capacity at constant marginal cost (Wilson had showed that uniform pricing is superior if demand is certain). More recently Nocke and Peitz (2007) find that clearance sales dominate both intro offer and uniform pricing in their special case when demand is uncertain and firms can commit to clearance pricing. Liu and Van Ryzin (2008) suggest that limiting inventories can improve segmentation by creating rationing risk. Aviv and Pazgal (2008) find empirical evidence to support a strategy of pre-commitment to fixed-discount clearance sales under strategic consumer behavior.

Compared with this vast past research focused largely on monopoly, there has been relatively little work analyzing yield management in competition. In extending Wilson’s model to duopolistic competition, we add to the growing attempts to understand yield management in a competitive context that find results differing substantially from outcomes when either is considered alone. Borrenstine and Rose (1994) find empirical evidence from the airline industry that supports models of price discrimination in monopolistically competitive markets. Belobaba and Wilson (1997) conduct a simulation using airline industry yield management software to examine the impact of yield management on duopoly competitors. They find that if only one firm adopts yield management they gain substantially by pushing low-fare customers onto their competitor while reserving capacity for late booking high-fare customers. When both firms employ yield management, they still increase revenue by about 17% compared to the competitive outcome without yield management by pricing closer to customers’ willingness to pay.

The rest of the paper is organized as follows: We briefly review the general results of Wilson (1988) and apply them to a generalized linear demand model to derive closed form solutions for optimal pricing policy. We then extend this model to duopoly competition and find a dominant strategy equilibrium solution to the two player game. We analyze capacity choices for monopoly and competitive firms using these pricing strategies in markets with variable or uncertain demand. Finally, various extensions explore the consequences of product differentiation and relationship between rationed promotions and other price discrimination mechanisms.

2. Model

To motivate our approach, consider an airline selling tickets for a plane which seats 100 passengers. The airline knows before it sells any seats that there are 60 business customers who are willing to spend up to $1000 each on the flight. Additional demand comes from leisure travelers and in aggregate is price elastic, specifically linear according to D = 600 - P. The best single price strategy is to price at $1000 and leave the plane nearly half empty. Alternatively the monopolist can sell 56 seats at $450. At that price 150 leisure travelers wish to purchase, along with all 60 business travelers. By
proportional allocation only $56*60/210=16$ seats are purchased by business travelers, so the remaining 44 seats can be sold to the business travelers who were not able to purchase at the discount for their full reservation price $1000$, generating total revenue of $69,200$.

The rationed promotion works to segment the market based on willingness to pay because by pricing substantially below the market clearing price for the elastic leisure traveler segment the seller can exclude most of the smaller number of high value customers from purchasing at the discounted price. The optimal pricing strategy is achieved by trading off lower revenues from low discount pricing with better segmentation which limits the “leakage” of revenue from high value business customers buying at the discounted prices.

2.1 Optimal Pricing Policy of a Monopolist

Consider a monopolist wishing to sell $q$ units of a homogeneous good.¹ A large number of consumers with unit demand and heterogeneous reserve prices arrive in random order and purchase the lowest priced available unit if the price is below their reserve price. The distribution of willingness to pay is characterized by the demand function $D(p)$ where:

$$D(p) = \begin{cases} \alpha & \text{for } r \leq p \leq 1 \\ \alpha + \beta (r - p) & \text{for } 0 \leq p \leq r \end{cases}$$  \hspace{1cm} (1)$$

This corresponds to a two segment demand in which there are $\alpha$ “high” types with reservation price 1 and linear “low” type demand at prices below $r < 1$ (prices are normalized to the high reserve value for notational convenience). This functional form has the property that the single price revenue function is not concave, and the linear

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¹ The section on monopoly closely follows Wilson (1988) and is best seen as a generalization of his model.
formulation allows it to roughly approximate a range of such non-concave functions while remaining mathematically tractable. This sort of demand curve, which is inelastic at high prices and elastic at low prices, has considerable support both in the stories we commonly tell about market demand and in the empirical literature. For example Oum, Waters and Young’s (1990) survey of price elasticity in transportation finds price elasticity of 1.1-2.7 for airline vacation travelers and 0.4-1.2 for non-vacation travelers. Soysal (2012) empirically tests a structural model of clearance pricing in the retail coat market, and finds that the demand is composed of two segments of consumers who differ substantially in price elasticity such that clearance sales improve profits.

We want to explore the pricing strategy of a monopolist facing the demand function (1). We assume that the monopolist’s marginal cost is zero. The optimal pricing solution is then as described in proposition 1.

Proposition 1: Given demand as in (1), a single product monopolist with zero marginal cost and fixed capacity q, \( a < q \leq a + \sqrt{\alpha \beta (1-r)} \), maximizes revenues by a) offering a rationed discount of \( q_0 = (q - \alpha)(1 + \sqrt{\alpha / \beta (1-r)}) \) units at \( p_i = r - \sqrt{\frac{\alpha (1-r)}{\beta}} \) and b) selling the remaining units at the high reserve price, 1.

Proof: Wilson (1988) shows that the maximum revenue can be achieved by offering units at no more than two prices \( \{p_l, q_l\}, \{p_h, q_h\} \) for any left-continuous non-increasing demand function \( D(p) \). Now \( p_h = 1 \) by construction, and the two price solution always
clears capacity, $q_l + q_h = q$. So the problem reduces to choosing $p_l$ and $q_l$ to maximize revenue.

For simplicity in exposition we will write $D(p_i)$ as $D_i$ and $Q(p_i)$ as $q_i$.

Since customers arrive in random order and select the lowest priced unit available, the demand at any price above the lowest will be reduced by the fraction of consumers who previously purchased at a lower price. Assuming random arrival and appealing to the Law of Large Numbers to impose the expected value on the distribution of reserve prices in any sample, the fraction of customers with reserve price greater than or equal to $p_l$ who successfully purchase at $p_l$ is just $p_l/D_l$. Moreover the proportion of these customers with reserve price greater than or equal to any higher price $p_i > p_0$ will be $D_h/D_l$. Therefore the excess demand $E_h$ at price $p_h$ after sales at $p_l$ is:

$$E_h = D_h - q_l \left( \frac{D_h}{D_l} \right) = D_h \left( 1 - \frac{q_l}{D_l} \right)$$

Setting $q_h$ equal to residual demand and substituting we find that:

$$q_l = \left( \frac{q - D_h}{D_l - D_h} \right) \left( \frac{D_l}{D_i} \right) = \frac{(q - \alpha) \left[ 1 + \frac{\alpha}{\beta(r - p_l)} \right]}{$$}

We can now write an expression for firm Revenues $R(p)$ solely in $p$

$$R(p_i) = q - (1 - p_i)(q - \alpha) \left[ 1 + \frac{\alpha}{\beta(r - p_i)} \right]$$

Taking the partial with respect to $p$ we obtain the first order condition for the optimal price

$$\frac{\partial R}{\partial p_i} = -(q - \alpha) \left[ \frac{\alpha (1 - r)}{\beta (r - p_i)^2} \right] - 1 = 0$$

And solving for the optimal $p$ we find
\[ p_i = r - \frac{\alpha(1-r)}{\sqrt{\beta}} \]  

(6)

Substituting into (4) yields \( q_i = (q - \alpha)(1 + \sqrt{\alpha / \beta(1-r)}) \).

Figure 1 shows the single price revenue curve (bold line) as a function of \( q \). We can see that the optimal discount price \( q^* \) is the point where the chord from the high price revenue maximum is tangent to the revenue curve. By offering a limited number of discount tickets the monopolist can increase revenue at any point below this chord to the convex combination of the single price revenue results, and so achieve the optimum revenue (given by the chord).

![Figure 1. Single Price Revenue Function – Quasi-linear Demand](image)

2.2 Continuous Time Stochastic Demand

How is our model related to a model of stochastic demand that is explored in yield management? Consider a dynamic situation and suppose that customer arrival follows a
Poisson process with rate $\lambda = (\alpha + \beta r)/q$. Further let willingness to pay for each customer be drawn from the following distribution:

- $1$ with probability $\alpha/(\alpha + \beta r)$
- Uniform $(0, r)$ with probability $\beta r / (\alpha + \beta r)$

If we impose the large sample result that the process realizes its expectation and that consumers are myopic (a new arrival purchases if and only if the current price is less than his reservation value), then offering the optimum discount price

$$\bar{p} = r - \sqrt{\frac{\alpha(1-r)}{\beta}}$$

for a fraction of the remaining time $q_l = (1-\alpha)(1 + \alpha / \beta (r-p))$ implements the rationed promotion optimum. Alternatively, we can offer each customer the discount price with probability $q_l$. In this sense the two approaches are isomorphic, and the results hold both in the monopoly and competitive cases, again relying on the assumption that the sample proportion of customer willingness to pay and sample arrival rate match their expected values. Finally we can achieve maximum expected profits in response to the stochastically realized demand if we adjust the probability of discount for each arrival to

$$q' = \left(1 - \frac{\tau}{\xi} \frac{\alpha}{1-\alpha}\right)$$

where $\tau$ is the fraction of capacity remaining and $\xi$ is the fraction of time remaining. The primary distinction between this result and the normal yield management in response to stochastically realized demand papers is that we are assuming a non concave revenue function which gives rise to multiple local revenue optima, while models in the mold of
Gallego and van Ryzin (1994) assume concave revenue (typically exponential demand) in order to ensure a single price solution at each point in the realized sales trajectory.

3. Competition:

Suppose instead of a single firm, capacity is divided equally between two competing firms. We assume that each firm can choose a promotional price in the first period and will sell to any remaining customers at the high reserve price in the second period. Residual demand is divided evenly between the firms if they have sufficient remaining capacity. As a result the tradeoff between maximizing revenues from promotional units and full price units is slightly different. In the monopoly case, a high type customer excluded from purchasing by the additional demand generated by lowering the promotional price purchases from the firm at the full price; now that additional full price demand is shared equally between the firms. As a consequence, in equilibrium the firms will set a higher discount price relative to the monopolist and will have to sell more discount tickets in order to clear their excess inventory.

We define a strategy for firm $i$ as a discount price $p_i$ and quantity $q_i$ for $i=1,2$.

Proposition 2: The duopoly two stage pricing game in which symmetric firms with fixed capacity $q_i$, $\frac{\alpha}{2} < q_i < $ $\frac{\alpha}{2} + \sqrt{\frac{\alpha \beta (1-r)}{2} - \frac{\alpha^2}{4}}$, compete has the unique Nash Equilibrium:

\[
p_1 = p_2 = r - \frac{\alpha}{2} \sqrt{\frac{2 \beta (1-r)}{\alpha} - 1} - 1 \quad \text{and} \quad q_1 = q_2 = \frac{(q - \alpha)}{2} \left(1 + \frac{\alpha}{\beta (r-p)}\right)
\]
Proof: Let \( \{(p_1,q_1),(p_2,q_2)\} \) be a Nash equilibrium for the pricing game, with \( p_1 \leq p_2 \). We first consider the best response \( (p_2,q_2) \) of player two to an arbitrary price and quantity combination \( (p_1,q_1) \).

The residual demand at any price above \( p_1 \) is:

\[
E_2 = D(p_2)(1 - \frac{q_1}{D_1}) = \gamma(\alpha + \beta(r - p_2))
\]

and the residual demand at the high reserve price (1):

\[
E_h = D_h(1 - \frac{q_2}{D_2} - \frac{q_1}{D_1}) = \alpha(\gamma - \frac{q_2}{\beta(r - p_2)})
\]

where \( \gamma = (1 - \frac{q_1}{D_1}) \) is the proportion of buyers who fail to get tickets from the first firm.

Since high residual demand is divided the inventory clearing condition is now:

\[
\frac{E_h}{2} + q_2 = \frac{\alpha}{2}(\gamma - \frac{q_2}{\beta(r - p_2)}) + q_2 = \frac{q}{2}
\]

Solving for \( q_2 \):

\[
q_2 = \frac{(1 - \gamma\alpha)(\alpha + \beta(r - p_2))}{(\alpha + 2\beta(r - p_2))}
\]

So revenue as a function of \( p_2 \):

\[
R(p_2) = \frac{q}{2} - (1 - p_2)q_2
\]

\[
\frac{\partial R}{\partial p_2} = q - (1 - p_2) \frac{\partial q_2}{\partial p_2} = \left[ \frac{(1 - \gamma\alpha)(\alpha + \beta(r - p))}{(\alpha + 2\beta(r - p))} - \frac{(1 - p)\alpha\beta(1 - \gamma\alpha)}{(\alpha + 2\beta(r - p))^2} \right] = 0
\]

which simplifies to

\[
\frac{(1 - \gamma\alpha)((\alpha + \beta(r - p))(\alpha + 2\beta(r - p)) - (1 - p)\alpha\beta)}{(\alpha + 2\beta(r - p))^2} = 0
\]
which requires:

\[(2\beta^2 (r - p)^2 + 2\alpha \beta (r - p) + \alpha^2 - \alpha \beta (1 - r)) = 0 \quad (13)\]

This is just a quadratic equation in \(r-p\); the solution is:

\[p_2^* = r - \frac{\alpha}{2\beta} \left( \frac{2\beta (1-r)}{\alpha} - 1 \right) \quad (14)\]

It remains to show that \((p_1,q_1)\) is a best response to \((p_2,q_2)\).

As before:

\[E_h = D_h (1 - \frac{q_2}{D_2} - \frac{q_1}{D_1})\]

But \(q_2\) is a function of \(p_1\) and \(q_1\) through \(\gamma\).

\[q_2 = \frac{(1-\gamma\alpha)(\alpha + \beta (r - p_2))}{(\alpha + 2\beta (r - p_2))}\]

Note that the proportion of consumers who successfully purchase \((q_1/D_1)\) decreases as \(p_1\) becomes smaller, so \(\gamma\) increases and \(q_2\) shrinks. Therefore:

\[E_h = D_h (1 - \frac{q_2}{D_2} - \frac{q_1}{D_1}) \leq D_h (1 - \frac{q_2^*}{D_2} - \frac{q_1}{D_1})\]

where \(q_2^*\) is the equilibrium value, with equality holding only when \(p_1=p_2^*\).

Inventory clearing requires:

\[\frac{q_2}{2} - q_1 = \frac{\alpha}{2} (1 - \frac{q_2}{D_2} - \frac{q_1}{D_1}) \leq \frac{\alpha}{2} (1 - \frac{q_2^*}{D_2} - \frac{q_1}{D_1}) \quad (15)\]

Which in turn implies that:
\[
q_i \geq \frac{\left( q - \alpha + \frac{q^*_2}{D_2} \right) (\alpha + \beta (r - p_i))}{(\alpha + 2\beta (r - p_i))}
\]

So the revenue function is bounded from above by:

\[
R(p_1) = \frac{q}{2} - (1 - p_1)q_i \leq \frac{q}{2} - \frac{\left( q - \alpha + \frac{q^*_2}{D_2} \right) (\alpha + \beta (r - p_i))}{(\alpha + 2\beta (r - p_i))}
\]

The expression on the RHS has the same FOC as in (12) so attains its maximum at

\[
p_1 = p^*_2 = r - \frac{\alpha}{2\beta} \sqrt{\frac{2\beta (1-r)}{\alpha} - 1 - 1}
\]

Since the expression holds with equality when \(p_1 = p^*_2\) and the left hand side is strictly lower for values of \(p_1 < p^*_2\), our result is proved.

QED

There are several interesting features of the equilibrium strategy. First, the equilibrium price is independent of the firms’ capacity provided it is in the appropriate range. This is the same as in the case of monopoly. However, if we look at prices, we find that compared to the monopolist solution (when it exists), competing firms set a higher discount price; in other words, the promotion is not as deep. Turning to the number of units offered for sale at the discounted price, we find that the duopolists offer a higher quantity than the monopolist. They are willing to lose more by way of leakage to higher value customers but in return they realize a higher margin on sales during the promotion.

Why do they do that? Recall that while the monopolist can choose not to sell all his capacity, competing firms with fixed capacity will not do so in equilibrium. In other words, the monopolist values selling to the high value consumer relative to exhausting
inventory but the duopolists place a relatively higher value on exhausting the inventory so as not to leave any low value consumers unserved that could result in competing away total profits. As a result, while competing firms segment the market slightly less efficiently than monopolists, they benefit from rationed promotions under circumstances where the monopolist would not choose to discount.

Our ideas become clearer if we return to the original airplane example. Now with capacity shared between identical firms, we find that the equilibrium price increases from $450 to $525. With less stringent segmentation more seats (72) must be sold to clear demand, but the competing firms still realize joint revenues of $65,800, more than the single price monopolist and 17.5% more than they would generate at the Bertrand competition price of $560.

4. Capacity Choice

In the foregoing analysis we took firm capacity as given and calculated the optimal one and two price strategies for monopoly and duopoly firms. In this section we will develop optimal strategies for firms choosing capacity anticipating the pricing problem in the previous sections.

In particular we will consider the capacity choice problem for monopoly and duopoly firms when the demand is perfectly known a priori (under both single and two price strategies) assuming that firms can invest in capacity at a constant marginal cost $c$. Then we will consider a two stage game in which firms that share a common prior choose their capacities simultaneously, then demand is revealed to all players (firms and customers) and then firms choose prices.
4.1 Known Demand.

A monopolist using the optimal single price strategy simply prices at the high reserve and sells \( \alpha \) units leaving remaining capacity unused. Obviously with \( D_h \) known to be \( \alpha \), the optimal capacity is \( \alpha \) as well for any \( c \) greater than the marginal revenue (which is negative and large for the first unit beyond \( \alpha \)). For competitive firms using a single price strategy, we first need a solution to the duopoly pricing game. For total capacity near \( \alpha \), firms have a max min strategy of pricing at 1 (the high reserve) and selling whatever remains of demand after the other firm exhausts its inventory at a lower price. This results in a Varian (1980) like equilibrium in which firms randomize price over a continuum to competitively dissipate any revenue from additional capacity. As a result competitive firms choose capacity \( \alpha/2 \) in equilibrium and reach the collusive outcome.

With rationed promotions and known demand we can exploit the fact that marginal revenue is constant at quantities greater than \( \alpha \). If \( c \) is greater than this marginal revenue, the firm sets capacity at \( \alpha \). If \( c \) is less than marginal revenue the firm increases capacity to at least \( q^* \).

For the monopoly firm marginal revenue is the discount price times the additional discount tickets to sell one additional unit less the expected leakage from high priced customers:

\[
MR_m = (r - \sqrt{\frac{\alpha(1 - r)}{\beta}})(1 + \sqrt{\frac{\alpha}{\beta(1 - r)}}) - \sqrt{\frac{\alpha}{\beta(1 - r)}}
\]

Solving yields:

\[
MR_m = r - \frac{\alpha}{\beta} - 2(1 - r)\sqrt{\frac{\alpha}{\beta(1 - r)}}
\]

The competitive firm adding a unit of capacity sees half the leakage.
Recall that the optimal discount price for competing firms is:

\[ p = r - \frac{\alpha}{2\beta} \left( \sqrt{\frac{2\beta(1-r)}{\alpha}} - 1 - 1 \right) \]

We simplify notation by letting

\[ \delta = \frac{\alpha}{2\beta} \left( \sqrt{\frac{2\beta(1-r)}{\alpha}} - 1 - 1 \right) \]

So \( p = r - \delta \). Then Marginal Revenue for a competing firm is:

\[ MR_r = (r - \delta) \left( 1 + \frac{\alpha}{2\beta\delta} \right) - \frac{\alpha}{2\beta\delta} \]

which reduces to

\[ r - \frac{\alpha}{2\beta} - \delta - \frac{\alpha}{2\beta\delta} \]

Substituting for \( \delta \)

\[ r - \frac{\alpha}{2\beta} - \frac{\alpha}{2\beta} \left( \sqrt{\frac{2\beta(1-r)}{\alpha}} - 1 - 1 \right) - \frac{\alpha}{2\beta} \left( \frac{\alpha}{2\beta} \left( \sqrt{\frac{2\beta(1-r)}{\alpha}} - 1 - 1 \right) \right) \]

which simplifies to:

\[ r - \frac{\alpha}{2\beta} \sqrt{\frac{2\beta(1-r)}{\alpha}} - 1 - \frac{1}{2\beta(1-r) - 1 - 1} \]

Since both monopoly and competitive firms face constant marginal revenue in the range of sales where rationed discounts are potentially profitable, when the demand is known before firms choose capacity they will choose either to serve only the high value
customers or they will choose a capacity greater than the critical value. Either way a single price policy is optimal and rationed promotions would not be observed.

4.2 Stochastic Demand

Finally we consider the case when demand is uncertain when the capacity choice is determined. In particular we let demand from both classes of customers vary according to a multiplicative shock $\theta$ so that in state $\theta$ high type demand is $\theta \alpha$ and low type demand is $\theta \beta (r-p)$ with $\theta \alpha$ distributed according to cumulative distribution $F(\theta \alpha)$. While we present the analysis for a seller facing uncertain demand in a single period, this case also covers the situation when a seller must fix a capacity across many selling periods with varying demand that follows the distribution $F$.

As the single price monopolist sells only to high value customers he chooses capacity, as in a newsboy problem, such that the probability of realizing a marginal sale just equals the cost of the marginal inventory (remember price is normalized to 1):

$$[1 - F(q)] = c \quad \text{or}$$

$$q = F^{-1}(1 - c)$$

Once again the competitive firms dissipate any profits from excess capacity so the potential gains from adding an additional unit are identical to the monopolist and competitive firms each choose to stock half the monopoly inventory.

For the monopolist using optimal two part pricing (note that optimal pricing will not depend on $\theta$ since $\alpha$ and $\beta$ always enter as a ratio):

$$\left[1 - F(q)\right] + MR_m F(q) = c$$

which implies that
\[ q = F^{-1}((1-c)/(1-MR_m)) \]

For competing firms the same applies substituting \( MR_c \).

We can illustrate the foregoing by returning to our airline example. Let high end demand be Uniform on 55-115 and cost $500. We then obtain the following results: both monopoly and competitive firms set capacity = 85 when using a single price. The monopolist earns $35000 in expectation; competing firms share $27,500. Using rationed promotions allows both to extract more revenue when demand falls short of capacity and so encourages higher capacity choices. For the monopolist marginal revenue for inventory in excess of high demand is $230, which though less than cost allows a profitable increase in capacity to 95 units which generates expected profits of $37,500. Competitive firms see higher marginal revenue. Adding a unit of capacity requires selling more than one additional unit at the discount price because of leakage, but this cost is shared with the competitor in the duopoly case so the focal firm sees marginal revenue of $335, higher than the monopolist, although the total marginal increase in revenues for both firms is only $145. This leads to competitive firms setting an even higher capacity, 100 units, which they segment less efficiently, generating joint profits of $35571.

<table>
<thead>
<tr>
<th>High Price</th>
<th>Single Price Monopolist</th>
<th>Single Price Duopoly</th>
<th>Two Price Monopolist</th>
<th>Two Price Duopoly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>Min ((\theta a, 85))</td>
<td>Min ((\theta a-42.5, 42.5))</td>
<td>Max(1.4(\theta a-36,95))</td>
<td>Max(1.4(\theta a-36,95))</td>
</tr>
<tr>
<td>Discount Price</td>
<td>1000((\theta a-85)/85)</td>
<td>445</td>
<td>525</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>42.5</td>
<td>Min(1.4(95- (\theta a),0))</td>
<td>Min(1.8(100- (\theta a),0))</td>
<td></td>
</tr>
<tr>
<td>Marginal Revenue</td>
<td>0</td>
<td>0</td>
<td>230</td>
<td>335</td>
</tr>
<tr>
<td>Revenues</td>
<td>1000*Min ((\theta a, 85))</td>
<td>1000*Min ((\theta a-42.5, 42.5))</td>
<td>21850 + 770 * (\theta a)</td>
<td>12325 + 855 * (\theta a)</td>
</tr>
<tr>
<td>Consumer Surplus</td>
<td>0</td>
<td>Min(1000(42.5- (\theta a/2),0))</td>
<td>Min(300(95- (\theta a),0))</td>
<td>Min(418(100- (\theta a),0))</td>
</tr>
<tr>
<td>Capacity (q)</td>
<td>85</td>
<td>85</td>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>Expected Revenues</td>
<td>77500</td>
<td>70000</td>
<td>84733</td>
<td>85571</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Expected Profits</td>
<td>35000</td>
<td>27500</td>
<td>37233</td>
<td>35571</td>
</tr>
<tr>
<td>Expected Consumer Surplus</td>
<td>0</td>
<td>7500</td>
<td>4000</td>
<td>7054</td>
</tr>
<tr>
<td>Total Surplus</td>
<td>35000</td>
<td>35000</td>
<td>41233</td>
<td>42625</td>
</tr>
</tbody>
</table>

As is clear from the table above, the inability of either monopoly or competitive firms relying on a single price strategy to profit from sales to low type customers leads both make conservative capacity choices. We do not see the normal Cournot result that competitive firms provide more capacity in aggregate because excess capacity leads them to compete away some of their profits so they individually see the same marginal revenue as the monopolist. Using rationed promotions allows firms to profit from their excess capacity and so encourages higher capacity which in expectation substantially increases total surplus. The distribution of the welfare gains is different for the monopoly and competitive cases. While the monopolist’s expected profits increase slightly, most of the gains go to consumers. In contrast while expected total welfare increases even more when competitors use rationed promotions, consumer surplus actually decreases; all of the benefits accrue to the sellers.

5. **Heterogeneity in Product Preferences**

In the analysis thus far, proportional allocation of rationed discount units ensured that our result is robust against various interpretations of the model. In this section we will consider heterogeneous demand structures that do not necessarily give rise to proportional allocation. Thus it will be necessary to add additional structure on the arrival process, and see how the pricing strategy depends critically on this structure.
For example, it is often assumed that high value customers will pay a considerable premium for their preferred product (departure and arrival times in the case of airline customers) while low value customers are indifferent between offerings (more willing to adjust their schedules to take advantage of discounts). We model this by making high types loyal to a specific product so that they will not attempt to purchase the competing product even at substantial discount. If we adopt the Wilson structure in which the monopolist prices all units in advance and customers arrive randomly according to their relative frequency, this model is identical to the original monopoly model analyzed in section 2. However, if the firms can alternate promotions so that only one type is available at a time, each subgroup of the high type customers is in competition with the entire cohort of low type customers. Not surprisingly, this allows the monopolist to charge a higher discount price with less leakage and achieve higher profits.

In particular the revenue maximizing price schedule is to discount to:

$$p = r - \frac{(q - \alpha) + \sqrt{(8\alpha \beta(1-r)-2\alpha)}}{2\beta}$$

a quantity of each type:

$$q_i = \frac{q-\alpha}{2}(1+\alpha/2(\beta(r-p)-(1-3\alpha)/4))$$

Here the discount is less deep than the original monopoly case and the number of units sold at discount much lower.

In our airline example the optimal promotional price is $484 and number of tickets 51. (11 high types get discount tickets). Profits are $73,684. Compared to the case of homogeneous product preferences, the discount price is higher, leakage is less and profits are higher.
5.1 Competition between differentiated firms

Adding product differentiation to the case of competing firms changes the nature of their competition significantly. When firms compete for both high and low types, competitive pressure leads them to increase their discount prices in order to “steal” high end customers from the competitor. Since that is not possible in this case, the competitive pressure will work to lower discount prices. The firm which sets the lower discount price will see demand from all of the low types, the higher priced seller only has the residual demand, and consequently higher leakage and lower profits.

Consider the response of firm 1 to a price of $p_2$ offered by firm 2.

Effective low type demand is:

$$D_l = \beta (r - p) \quad p_1 \leq p_2 < r \quad (17)$$

$$D_h = \beta (r - p) - \frac{q - \alpha}{2} \quad p_2 \leq p_1 < r \quad (18)$$

The effective demand facing the higher priced firm is reduced by the number of low type customers that get the lower discount price at the competitor.

As before we calculate leakage and the inventory clearing number of discount tickets for each case:

$$q_l = \frac{(q - \alpha)}{2} (1 + \alpha / 2 (\beta (r - p))) \quad p_1 \leq p_2 < r \quad (19)$$

$$q_h = \frac{(q - \alpha)}{2} (1 + \alpha / 2 (\beta (r - p) - \frac{(q - \alpha)}{2}) \quad p_2 \leq p_1 < r \quad (20)$$

Profit is $\frac{1}{2} - (1-p)q$ so $q_l < q_h$ implies that profit is discontinuous at $p_2$ (profit is strictly higher when $p_1$ is below $p_2$). We can calculate profit as a function of price for both cases:

$$R_l = \frac{1}{2} - (1-p)(q - \alpha)\frac{1}{2} + \frac{\alpha}{4\beta(r-p)} \quad p_1 \leq p_2 < r \quad (21)$$
\[ R_h = \frac{1}{2} - (1 - p) \frac{(q - \alpha)}{2} (q + \alpha / 2(\beta (r-p)) - \frac{(q - \alpha)}{2}) \quad p_2 \leq p_1 < r \] (22)

And the profit maximizing price

\[ \bar{p}_i = r - \sqrt{\frac{\alpha (1-r)}{\beta}} \quad p_1 \leq p_2 < r \] (23)
\[ \bar{p}_h = r - \frac{(q - \alpha) + \sqrt{2\alpha \beta(1-r) + \alpha(q - \alpha)}}{2\beta} \quad p_2 \leq p_1 < r \] (24)

We can now determine the best response correspondence:

\[ p_1 = \bar{p}_i = r - \sqrt{\frac{\alpha (1-r)}{\beta}} \quad p_1 \leq p_2 < r \] (25)

Note that neither firm would ever price above \( \bar{p}_1 \).

\[ p_1 = p_2 - \epsilon \quad \epsilon < p_2 \leq \bar{p}_1 \] (26)

Firm 1 would like to undercut the price of firm 2 and get the lower leakage associated with having the low discount price. However as \( p_2 \) decreases eventually the profit will be lower than simply pricing at the optimal higher price \( \bar{p}_h \).

So:

\[ p_1 = \bar{p}_h = r - \frac{(q - \alpha) + \sqrt{2\alpha \beta(1-r) + \alpha(q - \alpha)}}{2\beta} \quad p_2 \leq \bar{p} \] (27)

where \( \bar{p} \) is the price such that \( \pi_1(\bar{p}) = \pi_h(\bar{p}_h) \).

We can now characterize the equilibrium.

If firms announce prices sequentially, there is a second mover advantage. The firm which chooses its price first can choose either \( \bar{p} \) in which case the other will respond with \( \bar{p}_h \) the optimal high price and both will earn equal profits, or the first firm can choose \( \bar{p}_h \) and allow the second to achieve higher profits by pricing at \( \bar{p}_h - \epsilon \) to get profits \( \pi_1(\bar{p}_h) \). The
latter action, \( (\bar{p}_l) \), weakly dominates \( p \) as it achieves higher profits when the other firm prices above \( \bar{p}_h \) or below \( p \) (though neither is a best response).

If firms announce prices simultaneously and then choose quantities, they will randomize their discount prices over the interval \([p, \bar{p}_l]\) with the distribution function satisfying

\[
\pi_h(p)F(p) + \pi_l(p)(1 - F(p)) = \pi_h(\bar{p}_h)
\]

Returning to the airline example, \( \bar{p}_h = 468 \), and the high priced firm must sell 51 tickets at this price generating profit of $73,000. In order to achieve equal profits the lower priced firm charges $425 and must sell 47 tickets to clear its inventory. In a sequential move equilibrium one firm either announces a promotional price of $425 and the other responds with $468, both earning $73,000 profits or the first announces $468 and the second $467 with respective profits $73,000 and 73,900. In simultaneous moves they randomize within the range $425–468, again generating expected profits of $73,000.

5.2 Entry of Low Cost Competitors – the case of People Express

The extensive use of yield management techniques began with major American airlines shortly after they were deregulated in the mid-seventies. Under regulation they had largely been restricted to single price strategies, and they continued to price at market clearing rates. The entry of low cost competitors like People Express made this untenable. The first response was to yield the low cost leisure market to the newcomers, which led to substantial profits for the entering firms. However in 1985, American instituted their new “Ultimate Super Saver” fare classes which substantially undercut People. Within a few months, People Express was bankrupt and out of business. We can use our model to demonstrate how effectively yield managing firms using rationed promotions can compete with entrants that target only low type consumers.
Consider the airline example, with capacity 100 initially serving 60 high type customers (R=1000) and 40 low types at the market clearing price of $560. Another carrier enters with its own capacity of 100 and prices at $500. If the original carrier competes on price, it reduces the price to the market clearing value $460 cutting the original firm’s revenues by 18%. Unwilling to incur this loss, the established firm retreats to its high end and discovers that demand from high types is sufficient to actually increase revenues. Both firms make modest profits. Eventually the original firm adopts yield management to segment the market and finds a way to compete to fill its vacant capacity. Pricing at the optimal rationed promotional price of $450, it can price lower than what its competitor is willing to price at (the entrant exhausts capacity at $460) and the low cost competitor has no impact on the yield managing firm’s demand. Revenues increase to 69,200 (more than 15%) even though the firm is now pricing discount seats lower than the previously unprofitable price war level. Once again we see that rationed promotions dramatically change the competitive relationship, here between asymmetric competitors, by focusing competition on low valuation customers. Because the firm using rationed promotions gains from improved segmentation as it lowers discount prices it can increase profits while its single price competitor must lose money in order to remain competitive.

6. **Relation to Price Discrimination**

In motivating the paper we ruled out traditional forms of price discrimination by assuming that consumers differed only on their willingness to pay. However in many situations where yield management is practiced there are opportunities to practice traditional 2\textsuperscript{nd} and 3\textsuperscript{rd} degree price discrimination. It is reasonable to ask whether rationed promotions have any use in such situations. We modify the model to allow two
representative types of price discrimination often used in the context of yield management and find the optimal combination of pricing strategies for each. Obviously a monopolist who can practice 1st degree price discrimination by charging each individual his willingness to pay has no need of our mechanism. Similarly a monopolist that can distinguish our high and low types can charge high types their reserve price and low types the market clearing price to maximize revenues. A more interesting example of 3rd degree price discrimination is when observed type is imperfectly correlated with consumer behavior. Airlines take advantage of differences in preferences for time of booking to separate customers; high value business customers typically prefer to book at the last minute, while leisure customers prefer to book early. Offering advance purchase discounts allows the airline to profitably segment the market.

6.1 3rd degree Price Discrimination

We first consider a two period model in which all customers have a strict preference for the time of purchase. Customers will buy only if offered a price below their reserve price in their preferred period. Customer types correspond to the model offered in section 2.1. In each period high type demand is $\alpha_i$ for $p \leq 1$ and low demand given by $\beta_i(r-p)$. The firm must allocate capacity across the two periods and choose a high price and discount price and number of tickets (if any) for each period. Clearly given the allocation of tickets each period corresponds to the two price solution offered in section 2.2. Therefore the problem reduces to simply choosing the allocation of tickets between periods. Depending on the parameters for each period, the optimal pricing solution can be to price at the high reserve, the market clearing price or the two price optimal solution given in 2.2. If a rationed promotion is offered in both periods then the allocation will result in
equal marginal revenue across the two periods. Thus in the case of 3rd degree price discrimination, rationed promotions complement traditional pricing strategy. Note that while we motivated the segmentation as based on time of purchase, there is no explicit dynamic behavior in the model and it applies equally well to any other observable basis for contingent pricing.

6.2 2nd Degree Price Discrimination

Note that 2nd degree price discrimination differs because it is not possible to condition pricing on type, and customers typically self select according to preferences that are less strongly correlated with type. We capture this by adapting the two period model offered above by allowing customers to choose which period in which to purchase based on preferences that incorporate both time of purchase and price. In particular we will assume that preferences are as in section 2.1 save that high type customers place a lower value on tickets purchased in period 1. Their willingness to pay remains 1 in period 2 but is reduced to $\delta$ in period 1. All consumers then purchase in whichever period offers them higher expected utility.

In this case, the traditional 2nd degree price discrimination pricing strategy is to choose the market clearing price in period 1 and reduce the period 2 price to make high type consumers indifferent between the advance purchase discounted price and the full second period price. In particular:

$$P_1 = r - (1 - \alpha)/\beta$$  \hspace{1cm} (29)

and

$$P_2 = P_1/\delta = \left[r - (1 - \alpha)/\beta\right]/\delta$$  \hspace{1cm} (30)
For $\delta \leq r - (1 - \alpha)/\beta$ this allows the seller to implement the optimal 3rd degree solution, since high types are unwilling to purchase in the first period even at the market clearing price. For $\delta$ greater than the market clearing price the seller must reduce the second period price to prevent high types from switching to the discounted first period offering. Alternatively the seller could implement the rationed promotion optimal pricing strategy, which will yield higher profits when $\delta$ is large (close to 1). We show that it is not optimal, given our construction, to implement both strategies. Obviously it will not be optimal to sell to high types in the first period so a strategy that segments the market both using both temporal discrimination (selling to low types at a discount in period 1) and rationed promotion (selling to a mix of types in period 2) must specify $p_1$ (the first period price), $p_2$ (the second period discount price), $p_3$ (the second period full price) and $q_2$ (the number of discount tickets offered in period 2) that satisfy the following constraints:

Proportional rationing: the probability $\varphi$ of any consumer getting a discount ticket is the number of discount tickets divided by total demand:

$$\varphi = \frac{q_2}{(\alpha + \beta(r - p_2))} \quad (31)$$

where $r$ is the threshold reserve price at which low types are indifferent between purchasing in the first period and entering the lottery in the second:

$$(r - p_1) = \varphi(r - p_2) \quad (32)$$

and the market clearing condition:

$$q_2 = \frac{(q - \alpha - \beta(r - r))(\alpha + \beta(r - p_2))}{\beta(r - p_2)} \quad (33)$$

Substituting (33) into (31) yields:
\[
\varphi = \frac{(q - \alpha - \beta (r - r))}{\beta (r - p_2)}
\]  
(34)

In turn, substituting into (32) and reducing gives:

\[
p_1 = r - \frac{q - \alpha}{\beta}
\]  
(35)

But this is just the market clearing price, so there is no excess inventory to clear in the second period. The intuition behind this result is that lowering the discount price in the second period in order to reduce leakage makes the lottery much more attractive to marginal low types (the ones with lower willingness to pay) since they are getting zero surplus when they buy in period 1; as a consequence the threshold price \( r \) (the minimum willingness to pay for customers that choose to purchase in the first period) will be substantially higher than the period one price. Thus used together, 2\textsuperscript{nd} degree price discrimination and rationed promotions work at cross purposes, each less effective than when used alone. In the case of linear supplemental demand considered here, the two strategies are perfect strategic complements: it is never optimal to use both. However, the linear demand case is exactly the boundary that finds this result, and if the low type demand curve were also convex, rationed promotions could again be useful to segment the low type demand.

7. Conclusions

Rationed promotions allow firms that have more capacity than their full price customers will consume in the short term to enlist very price sensitive customers to clear the excess inventory without cannibalizing their high margin demand. Real world examples include airlines’ release of limited blocks of seats for discount fare classes, and “Black Friday”
offerings of limited quantities of toys, electronics and other consumer durables at the beginning of the Christmas selling season. By pricing a limited quantity at well below market clearing rates, firms are able to recruit enough excess demand to clear excess inventory while effectively excluding high value customers from purchasing at the discount price through proportional allocation.

While the monopoly results are interesting in their own right, the primary contribution of the paper is the analysis of competing firms using rationed promotions. We show that competition weakly increases prices above the optimal monopoly level, but lowers revenues because the higher prices fail to achieve optimal segmentation of heterogeneous consumers. Nonetheless, by clearing excess inventory, yield managing firms avoid direct competition for their most profitable customers and retain most of the revenues available to the monopolist. A very nice feature of our equilibrium is that it is in dominant strategies which are independent of remaining capacity allocation. Therefore, we have a robust closed form solution for the competitive pricing game. Typical yield management dynamic pricing strategies adjust to remaining inventory levels. This state dependence often leads to intractably complicated game structures that make it impossible to identify competitive equilibria for yield managing firms. We show an isomorphism between our model and the usual stochastic demand models from yield management which we believe makes our result a substantial contribution to understanding the impact of yield management in competitive markets.

We analyze capacity choice for firms that use rationed promotions and compare to optimal elections when the firms rely on single price strategies. Because rationed promotions dramatically improve profitability in low demand states, firms using them...
elect significantly higher capacities when facing variable or uncertain demand. This leads to substantial social welfare gains in these markets. While in the monopoly case most of this gain goes to consumers, under duopoly competition firms gain all the benefits. We extend these results to situations of asymmetric competition and horizontally differentiated products and find that in these contexts competition can lead to either higher or lower prices depending on the degree and nature of preference heterogeneity. Finally, we consider the relationship between rationed promotions and other price discrimination tools. We find that rationed promotions complement traditional third degree price discrimination when segment demand has the non concave revenue function property. We also show that rationed promotions substitute for 2nd degree price discrimination when consumer preferences over non-price attributes are weakly correlated with willingness to pay.

We believe that the results from this analysis apply to a wide range of markets characterized by short term fixed capacity and heterogeneity in consumer willingness to pay and offer new and important insights into the interaction between yield management and competition.
References:


