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The Joint Determination of Price, Quality, and Capacity: An Application to Supermarket Operations

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Abstract. This paper focuses on a service provider who, faced with competition, must determine the optimal price and level of service quality to provide in order to maximize profits. Service quality and price are assumed to impact jointly on demand for services. Both demand and service quality impact on the cost of providing service. While a considerable literature exists on the impact of service quality on demand or cost, less work has focused on the explicit impact of service quality jointly on both demand for and the cost of providing services. A service quality constraint is appended to the formulation in order to guarantee that a declared service standard is met. Conditions are developed which characterize optimal solutions, together with comparative statics. Illustrative results are presented based on empirical data obtained from a supermarket study.

Keywords: Decision Making, Optimization, Service Operations, Price, Quality

1. Introduction and Literature Review

The issue of service quality has become prominent in the development of strategies employed by firms seeking competitive advantages (Headley and Choi, 1992). Many of these firms either operate in competitive or oligopolistic markets, although some firms previously imbued with monopoly status have also been forced to contend with entry and competition (Dobbenberg, 1993). For

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example, consider the emergence of competition for services within both the telecommunications and postal service industries during the past 10 years. This paper deals with the important issue of price and quality as it impacts on a firm in competition, whose objective is profit maximization. It is assumed that quality impacts on both demand for and the cost of providing services, and that in addition to price and service quality recommendations, operational decisions, such as capacity allocation, must also be made.

Both quality and price have been noted as important attributes that impact on demand (Berry, Zeithaml, and Parasuraman, 1990), as well as a firm's ability to remain competitive in a market economy (Lewis, 1989). Umesh, Pettit, and Bowman (1989) indicate that quality, measured in terms of service time is significant with regard to consumer behavior in retail establishments. Moreover, Starr (1996) reports that consumers' quality expectations often override price considerations. However, the emphasis in practice on cost reduction and short-term profits, which are more easily measured, sometimes supersedes the emphasis on service quality (Zeithaml, Berry, and Parasuraman, 1988), although recent findings suggest that this trend may be reversing (Rust, Zahorik, and Keiningham, 1995). For example, many firms that have been highly successful in providing quality service, including Delta Airlines and McDonald's, are noted for the establishment of formal goals that relate to service quality. In general, the establishment of such goals has been shown to improve organizational performance (Ivancevich and McMahon, 1982).

The importance of maintaining a balance between quality as discussed in the marketing literature (Berry, Zeithaml, and Parasuraman, 1990) and a more production/manufacturing oriented systems perspective of service quality is discussed in Chase and Bowen (1991), who indicate that the joint consideration of (a) important production oriented concepts such as the effective use of technology, capacity, and materials, together with (b) marketing and management oriented concepts regarding price and quality in the development and implementation of system wide effective delivery services have been neglected to some extent in much of the literature to date. Chase and Bowen (1988, 1991) suggest that the joint consideration of (a) a producer component, considering important production oriented concepts such as the effective use of capacity, together with (b) a consumer component, where marketing and management oriented concepts regarding price and quality be considered jointly in the development and implementation of system wide effective delivery services.

The model presented here attempts to bridge this gap by considering both a consumer component, where demand is influenced by both service quality and price, and an operations component focusing on how quality and demand impact jointly on total costs. A service quality constraint is appended to the basic formulation in order to guarantee that the stated level of service quality is adhered to. The net result of the analysis provides not only optimal price and service quality recommendations, but simultaneously results in operational decisions, such as capacity allocation. This approach has been encouraged in the treatment of service quality issues (Sasser, Olsen, and Wyckoff, 1976).

The model developed here is a slight generalization of the models developed in Stidham (1992) and Rump and Stidham (1998), whose results build upon the work of Dewan and Mendelson (1990), who focus on the determination of optimal price and level of service quality from a microeconomic standpoint, as done here, together with issues of equilibrium. The primary difference between this literature and the model presented here is that we assume that price and level of service quality are ex-ante declared and perfectly observable by consumers, which in turn generates demand, as opposed to assuming that consumers have rational expectations of service quality and continually update this expectation based on particular realizations of service quality encountered within the system.

The model presented here also represents a variant of our previous work on optimal price and service and quality (Boronico, 1998; Crew and Kleindorfer, 1992) where welfare maximization is considered and profit maximization is alluded to but not specifically addressed. The models developed therein have been applied to postal services (Boronico, 1998a) and derive from those initially presented in Boronico, Crew, and Kleindorfer (1992). The application of the model presented here to the food industry builds upon Ittig (1994), extending that analysis through the incorporation of and simultaneous determination of both price and service quality as endogenous choice variables.

Methodological findings here are consistent with those found elsewhere (Boronico, 1998; Dewan & Mendelson, 1990; Crew and Kleindorfer, 1979), in that optimal price should be increased from quality-constrained marginal cost, with the percentage increase inversely related to the price elasticity of demand. The so-called “inverse-elasticity” pricing rules emanates from the seminal work of both Ramsey (1927) and Boiteaux (1956) and has been widely acknowledged and applied to public utilities (Crew and Kleindorfer, 1986). Results here are differentiated from traditional results however, since marginal costs are influenced by service quality, and are derived utilizing the envelope theorem (Silberberg, 1978; Crew and Kleindorfer, 1992; Boronico, 1997). In addition to pricing, the following intuitive prescriptions also apply: (1) service quality should be set so as to equate the benefits of increasing service quality to the costs of doing so, and (2) operational variables are set so as to minimize costs while adhering to the optimal level of service quality.

The remainder of the paper is organized as follows. The theoretical model is developed in Section II, where optimal solutions are characterized. These solutions are then applied to a supermarket study in Section III. Comparative statics and sensitivity analysis are pursued in Section IV, with conclusions and implications for future research presented in Section V.

2. The Quality-Constrained Profit Maximization Model

We assume that the objective of the enterprise is to determine price (*p*), service quality (*w*), and a local operating variable (μ) so as to maximize expected profits ($\prod$). Installed capacity would represent a typical local operating variable μ. Demand for service (*X*), is assumed to be a function of both price and quality of service. The basic formulation includes a service quality constraint (*H*) representing the required relationship between quality (*w*), demand (*X*) and a local operating variable (μ) necessary to achieve the specified service quality level.

The specific form for the service quality constraint may vary across applications. For example, a systems service support helpdesk might require that the mean wait time for service does not exceed a declared service standard (Boronico, Zirkler, and Siegel, 1996). A service repair facility might provide a percentage guarantee that repairs will be effective or alternatively declare a probability for which a given repair's lifespan will exceed an established period of time. Similar types of probabilistic service quality constraints might be found in emergency medical facilities, where both time to service and survival rates are critical. For example, ambulatory allocation problems may focus on meeting a prespecified mean response time with a certain probability (Klafehn, Weinroth, and Boronico, 1996).

The objective for the general optimization problem of interest follows:

$$\textit{Maximize}\ \Pi(X(p,w),p,\mu) = pX(p,w) - C(X(p,w),\mu) \tag{1}$$

$$\textit{subject to:}\ H(X(p,w),\mu) \le 0 \tag{2}$$

where $C(X(p,w),\mu)$ represent the costs required to meet demand at the stated price and service quality. In order to guarantee that the declared service quality level is met, the service quality constraint (2) is appended to the formulation (1). The general problem (1)-(2) may be written as follows:

$$\textit{Maximize}\ \Pi(X(p,w),p,\mu) \mid H(X(p,w),\mu) \le 0 \tag{3}$$

Operating Variable Rule: The local operating variable μ is set so as to minimize expected costs while adhering to the service quality constraint.

More specifically:

Theorem 1: $C(X(p,w),\mu^*) = \underset{\mu}{Min}\{C(X(p,w),\mu) \mid H(X(p,w,\mu),\mu) \le 0\}$ (4)

where μ^* represents the optimal value for the local operating variable μ.

Proof: Available upon request.

It remains to determine the optimal price-service quality vector (p^*, w^*) for the problem given by (3), established in the following theorem:

Theorem 2: Necessary conditions for the price-service quality vector for the problem given by (3) are characterized by the following:

(a) $$\left\{p - \frac{\partial C}{\partial X} - \lambda \frac{\partial H}{\partial X}\right\}\frac{\partial X}{\partial p} = -X \text{ , and} \quad (5)$$

(b) $$p\frac{\partial X}{\partial w} = \left\{\frac{\partial C}{\partial X} + \lambda \frac{\partial H}{\partial X}\right\}\frac{\partial X}{\partial w}. \quad (6)$$

These first-order results may be obtained by associating Lagrange multiplier λ to the constraint (2), and applying the Karush-Kuhn-Tucker conditions. Sufficient conditions concerning the optimality of these necessary conditions for the problem (3) are developed for the specific realization of the model which is discussed in the following section.

Rearrangement of terms and division by p results in the following alternative specification for the price characterization (5):

$$\frac{p - \frac{\partial C}{\partial X} - \lambda\frac{\partial H}{\partial X}}{p} = \frac{1}{\eta} \quad (7)$$

where $\eta = -\left(p/X\right)/\left(\partial p/\partial X\right)$ and represents the price elasticity of demand. Moreover, for the constrained optimization problem given by (3), it is shown elsewhere (Boronico, 1997b) that marginal cost may be derived from the envelope theorem for constrained optimization problems (Silberberg, 1978) and is given by:

$$MC = \frac{\partial C}{\partial X} + \lambda \frac{\partial H}{\partial X} \tag{8}$$

Note that marginal cost here represents the cost of meeting one extra unit of demand. The following is then obtained through direct substitution of (8) into (7):

$$\frac{p - MC}{p} = \frac{1}{\eta} \tag{9}$$

Under the ordinary assumption that demand for service is inversely related to price (Bolton, 1989), (9) results in the following pricing rule:

Pricing Rule: Optimal quality-constrained price is increased from marginal cost, with the resulting percentage deviation of optimal price from marginal cost inversely proportional to the price elasticity of demand.

The intuitive rational for this rule is that in order to maximize profits, prices should be raised for those services with inelastic demand rather than from those which are more sensitive to price. These results owe much to Ramsey (1927), and the more recent synthesis by Lipsey and Lancaster (1956) and Baumol and Bradford (1970), who both consider “second-best” pricing solutions under those conditions where departures from marginal cost pricing are appropriate (e.g. competitive equilibrium is not achieved) . We note, however, that results here differ from traditional pricing results as price is embodied within marginal costs as influenced by service quality, and are derived utilizing the envelope theorem.

With respect to optimal service quality, condition (6) supports the following prescription:

Service Quality Rule: Optimal service quality is set so as to equate the marginal benefit of increasing reliability (the left hand side of equation 6) with the marginal cost of doing so (the right hand side).

The application of these results and the prescription provided in Theorem 2 is pursued in the following section.

3. Illustrative Example

Ittig (1994) performs an empirical supermarket study where optimal service capacity is determined and demand is impacted by mean wait time. Price is assumed to be fixed and is not a managerial decision variable. The illustrative example presented here builds upon these results by determining price, quality of service, and capacity so that profits are maximized utilizing the results of section II, under the assumption that demand is impacted jointly by both price and quality of service, and that costs are influenced by both demand for service and quality.

The local operating variable represents capacity, measured in terms of the overall service rate (μ) necessary to achieve a specified level of service quality, measured by the mean wait time (w) at a checkout counter in the checkout facility. The overall service rate represents the total throughput rate at the checkout facility. The number of checkout lanes required is approximated by dividing this throughput by the empirically measured mean service rate for one checkout clerk; this *M*/*M*/*1* approximation provides an upper bound on profits, since it is well known that one fast server is superior in terms of throughput than multiple servers providing the same overall service rate (Hillier and Lieberman, 1995).

Other assumptions and data from Ittig (1994) are also maintained: the queuing process operates under the assumption of exponential service time and a Poisson arrival process. The consideration of exact solutions for multiple channel queues, an investigation into the relaxation of the assumptions made for *M*/*M*/*C* queues, and the consideration of general service time processes are left as implications for future research. The markup for a typical basket of goods is approximately $5.08, or 9% of revenues. Equivalently, this represents a purchase price to the consumer of approximately $56.44 for a typical basket of goods, with associated cost of $v = \$56.44 - \$5.08 = \$51.36$. The clerk cost at the checkout counter is provided by supermarket management and set at $s = \$.3812/\text{service}$, based on hourly wage and mean service times.

The objective here is to illustrate how the theoretical results of section II may be applied to determine the profit-maximizing (a) price to charge for a typical basket of goods (p), (b) amount of capacity (μ), and (c) level of service quality (w), measured in mean hours spent at the checkout counter. Supermarket management can utilize optimal price in the determination of an overall markup strategy for their products, while service quality and capacity recommendations assist in the determination of staffing requirements and shift scheduling.

Demand is governed by an exponential distribution, as discussed in Ittig (1994). This choice for the demand distribution is further supported in the retail literature (Lee and Cohen, 1985; Lilien and Kotler, 1983), and has been found to characterize increasing returns to scale well, in addition to capturing other effects of price, such as sales approaching zero at high levels of price (Bolton, 1989). Alternative choices for the demand distribution form an important consideration for future research. Although linear demand functions are sometimes employed, linearity in terms of the impact of wait time on demand is questionable. For example, Osuna (1985) and Larson (1987) both indicate that psychological costs associated with wait times escalate nonlinearly.

The particular form utilized for the exponential demand distribution is shown below:

$$X(p,w) = \alpha e^{-\beta w - \gamma p} \tag{10}$$

X represents the mean demand for service at the stated price and mean wait time, and α, β, and γ represent demand constants.

The resulting formulation (1)-(2) for the supermarket optimization problem is shown below:

$$\begin{aligned} \mathit{Maximize}\, \Pi(p,w,\mu) &= pX(p,w) - C(X(p,w),\mu) \\ &= pX(p,w) - \{s\mu + vX(p,w)\} \end{aligned} \tag{11}$$

$$\textit{Subject to: } H(X(p,w),\mu) = \frac{1}{\mu - X(p,w)} - w = 0 \tag{12}$$

The service quality constraint (12) establishes the relationship between mean hourly demand X, service quality w, and the local operating variable μ. The cost function $C(X(p,w),\mu) = \{s\mu + vX(p,w)\}$ represents the capacity cost of providing service ($s\mu$) in addition to the product acquisition cost ($vX(p,w)$).

Theorem 3: The solutions to the problem (11)-(12) under the demand distribution (10) are characterized by the following:

$$p^* = v + s + \frac{1}{\gamma} \tag{13}$$

$$w^2 e^{-\beta w - \gamma p^*} = \frac{s}{\left\{p^* - v - s\right\}\beta\alpha} \tag{14}$$

Proof: Available upon request.

Equation (13) indicates that as the demand sensitivity (γ) increases, optimal price approaches marginal costs (*MC*), given by $MC = v + s$, as shown in Appendix B, and consistent with the inverse elasticity result suggested earlier. The resulting marginal cost result in this example is intuitive; similar marginal cost findings in other contexts have indicated that counterintuitive results often obtain (Boronico, 1998). Moreover, (13) suggests that the monopolist might set price in the area where demand is inelastic, however, this is not unreasonable in light of the fact that the demand curve utilized is nonlinear and exponential in nature, and that the firm simultaneously competes in the domain of service quality as well as price. Substitution of (13) into (14) allows for the determination of the optimal wait time, w^*. The solution to (14) may be obtained through an iterative search in conjunction with the utilization of spreadsheet software.

Data from Ittig (1994) allows for the determination of the following empirical values for demand parameters:

$$\alpha = 13{,}951{,}325\,,\ \beta = .40\,,\ \text{and}\ \ \gamma = .21\,. \tag{15}$$

The numerical solution to the problem (11)-(12) is found by substituting these values into (13)-(14), from which the following are obtained:

$$p^* = \$56.50,\ w^* = .0455\ \text{hours} \tag{16}$$

Substitution of these values into (10), together with the values from (15), leads to the following mean demand, at optimum: $X(56.50,.0455) = 96.27$ purchases per hour. The solution for the operating variable μ^* is found through substitution of respective values into the service quality constraint (12), from which $\mu^* = 118.2$ units of service/hour is obtained. Consequently, the supermarket should charge $56.50 for a typical basket of goods, representing an 10% markup over cost. The optimal level of service quality, or mean time spent at the checkout counter, should be set at .0455 hours, or equivalently, 2.73 minutes. The capacity required to simultaneously meet demand at the stated service quality level is 103 services/hour. This figure could be used to approximate the number of checkout clerks required. For example, if the mean service time required for a clerk to process a typical basket of goods is $1/\mu_c$, then in order to meet the capacity requirement, μ/μ_C clerks would be required. As noted earlier, this would represent an approximation to the optimal solution.

4. Comparative Statics and Sensitivity Analysis

This section considers the sensitivity of optimal solutions with respect to changes in the problem's ex-ante declared parameters. In particular, we utilize the model to predict how the optimal values for the endogenous/choice variables (price, service quality) will respond to changes in some of the model's exogenous parameters (cost and demand coefficients). The results that follow can be derived from the comparative static results provided in Appendix C or developed directly from the optimal solutions.

$$\frac{\partial p^*}{\partial s} = 1 \tag{17}$$

$$\frac{\partial w^*}{\partial s} = \frac{-\left(\beta X + \dfrac{1}{w^2}\right)}{\dfrac{\beta^2 X}{\gamma} - \dfrac{2s}{w^3}} < 0 \qquad \forall w < \frac{\beta}{2} \tag{18}$$

It is clear from (17) that $\partial p^{*} \big/ \partial s > 0$, indicating that increases in unit capacity cost s will result in an increase in optimal price, p^{*}. Similarly, from (18) we observe that $\partial w^{*} \big/ \partial s < 0 \;\; \forall w < 2 \big/ \beta$. Hence, any increase in capacity cost s will result in a decrease in expected time in the checkout line, at optimal. Note that it is shown in Appendix B that any solution for the optimization problem must satisfy the requirement $w < 2 \big/ \beta$. In summary, the comparative statics results presented here indicate that an increase in capacity cost will increase service quality, but also increase price, at optimal.

Similar comparative statics results may be generated for exogenous demand parameters. For instance, consider the base demand parameter α. The following results can be derived from the results presented in Appendix C or developed directly from the optimal solutions:

$$\frac{\partial p^{*}}{\partial \alpha} = 0 \tag{19}$$

$$\frac{\partial w^{*}}{\partial \alpha} = \frac{-\left\{ \dfrac{\beta X^{2}}{\alpha} \right\}}{H} < 0 \quad \forall w < \frac{2}{\beta} \tag{20}$$

These results suggest that a change in the demand parameter α will not impact on optimal price. This result is also implied by (14), noting that optimal price is independent of the demand parameter α. Equation (20) indicates that any increase in α results in decreased time spent at the checkout counter. Hence, an increase in base demand has no impact on optimal price but a decrease in expected checkout time, or increased service quality.

A similar analysis applies to changes in the demand parameter γ, which corresponds to demand sensitivity to price. In this instance, the following results are obtained:

$$\frac{\partial p^{*}}{\partial \gamma} = \frac{-1}{\gamma^{2}} < 0 \tag{21}$$

$$\frac{\partial w^{*}}{\partial \gamma} = \frac{p \beta X^{2}}{H} > 0 \quad \forall w < \frac{2}{\beta} \tag{22}$$

These results indicate that as demand sensitivity parameter γ increases, optimal price will decrease based on (21) and optimal checkout time will increase, from (22). Table 1 illustrates numerically the impact of this demand sensitivity parameter γ on optimal solutions, with other parameters given as in (15):

Table 1. Sensitivity of optimal solutions to demand parameter γ ($\beta = .4$)

γ	p^* ($)	*Markup* (%)	w^* (minutes)	X (units)	μ^* (services/hr.)	Π^* ($)
.17	57.62	12.19	0.90	772.18	840.68	4,516
.19	57.00	11.00	1.55	273.12	311.88	1,423
.21	56.50	10.00	2.73	96.27	118.20	450
.23	56.09	9.21	4.84	33.73	46.14	142
.25	55.74	8.53	8.56	11.69	18.69	44

The results in Table 1 support the results of (21) and (22), indicating that increases in demand sensitivity γ result in: (a) lower prices, which is further illustrated in Figure 1. From (13) it is clear that as $\gamma \to \infty$, optimal price approaches marginal cost, which equals $v + s = 51.74$, and (b) lower service quality, as evidenced by the longer mean wait times.

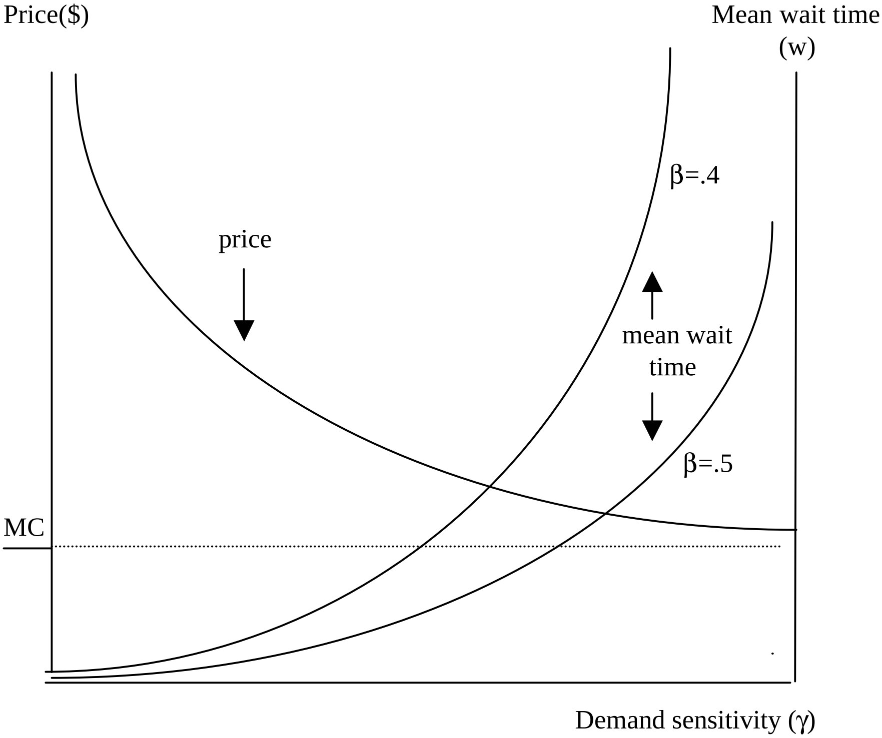
Table 2. Sensitivity of optimal solutions to demand parameter γ ($\beta = .5$)

γ	p^* ($)	*Markup* (%)	w^* (minutes)	X (units)	μ^* (services/hr.)	Π^* ($)
.17	57.62	12.19	0.78	771.68	848.60	4,510
.19	57.00	11.00	1.38	272.80	316.28	1,419
.21	56.50	10.00	2.45	96.06	120.57	448
.23	56.09	9.21	4.33	33.60	47.45	141
.25	55.74	8.53	7.69	11.61	19.41	43

This is attributable to the increased demand sensitivity to price with sensitivity to service quality (β) held constant, and suggests that management should decrease costs by allowing expected wait time to increase in order to compensate for the change in revenue brought about by the decrease in price. The increase in demand sensitivity also results in (c) decreases in both demand and resulting required capacity, where the decrease in demand is less pronounced as γ increases. Despite the compensatory decrease in costs associated with the lower level of service quality provided as γ increases, profits decrease. Corresponding solutions for this particular case are also generated for $\beta = .5$, and are shown in Table 2.

Numerical solutions in Table 1 and 2 are illustrated visually in Figure 1.

Figure 1. Impact of demand sensitivity on optimal price and service level



Solutions are illustrated visually for both estimates of the demand parameter β in order to demonstrate the impact of this demand parameter on optimal solutions. A comparison of results indicates that increased sensitivity to service quality results in (a) no change in optimal price, since for this particular demand distribution optimal price is a function of the price elasticity of demand, $\eta = -\gamma$, and is not a function of the parameter β, and (b) increases in service quality. The absolute increase in service quality is more pronounced for higher values of γ, indicating that service quality becomes increasingly important as price elasticity of demand increases. The increase in β results in a slight decrease in demand accompanied by increased capacity required to meet this demand at the higher required service quality level, and also results in a slight decrease in profits.

In summary, the comparative statics results and numerical example provided here illustrate how changes in exogenous parameters influence the values of the endogenous/choice variables, at optimal. The general model from which these comparative statics results are obtained further illustrates how optimal price, service quality, and capacity may be jointly determined utilizing the specific pricing, service quality, and operating variable rules discussed in section II, and derived in Theorem II. Specific results from the analysis indicate that increases in per unit capacity costs result in increased price and better service quality, while increases in base demand (α) result in better service quality with no change in price. Changes in the in price elasticity of demand (γ) result in lower price, and increased expected checkout time. The resulting changes in price from marginal cost are inversely related to the price elasticity of demand. Moreover, the resulting benefits of decreasing cost at optimal by lowering service quality (increasing expected checkout time) to compensate for increased sensitivity to price leads to a decrease in profits. Finally, when sensitivity to service quality increases (β), service quality becomes increasingly important for higher levels of price elasticity of demand.

5. Conclusions and Implications for Future Research

This paper has considered the joint determination of price, service quality, and a local operating variable for a firm whose objective is profit maximization. Although much attention has been paid to issues of cost and quality, as well as the impact of quality on demand or cost, the joint consideration of these issues has received less attention. This paper develops a model through which both price and quality of service may be determined, in addition to other variables more operational in nature, such as capacity. The model developed (1) assumes that service quality impacts on both demand for service as well as costs and (2) unifies both marketing and operations oriented system components, an omission in the literature that has been previously noted (Chase and Bowen, 1988; 1991).

Theoretical results indicate that profits are maximized when price is set greater than marginal cost, but where marginal cost represent the additional cost of meeting a per unit increase in demand. In general, this result is intuitive, but differs from traditional pricing results in that price is embodied within marginal cost as influenced by service quality. Marginal cost is derived utilizing the envelope theorem, within which the impact of service quality is considered. The percentage increase of price from marginal cost is inversely related to the price elasticity of demand, a result that has also been found to apply within a welfare-maximization framework and public utility pricing (Boronico, 1998). Other results are also supported theoretically: optimal service quality should be set so that the marginal costs of increasing service quality are equal to the marginal costs of doing so, and the local operating variable is set so that costs are minimized subject to meeting an ex-ante declared constraint on service quality. Theorem II provides a specific prescription from which optimal price, service quality, and operational variables may be set.

The methodology is illustrated on a empirical study of supermarket purchases. The analysis provides recommendations for supermarket management interested in determining a markup strategy for a basket of goods together with associated staffing and capacity recommendations. Service quality at the checkout counter is also jointly considered through the recommendation of an optimal mean wait time. This analysis has important implications to both management and marketing as it assists supermarket management in positioning themselves within the market through both price and quality considerations.

Prior to results becoming operational in practice, an investigation of factors limiting the applicability of this methodology should be considered. For example, empirical studies regarding alternative demand distributions and their impact on profits could be studied. The consideration of exact solutions for multiple channel queues, an investigation into the viability of the $M/M/C$ queuing process, and the consideration of general service time processes are also considerations for future research. Finally, time varying demand and peak load issues could be investigated as they impact on costs and capacity requirements.

In summary, the continued study of how service quality and price jointly impact on demand for services as well as cost is important due to increasing levels of competition found in many industries. These increases are partially attributable to technological advancements, which in turn will continue to contribute to the creation of a global market for many products and services. These issues, as well as related problems, pose a significant and clearly important area for future research.

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