The Self-Service Strategy:

Linking Operations and Marketing

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Abstract

The growth of the so-called "self-service economy" emphasizes the increasing popularity of self-service in the design of service delivery systems. By using the co-productive nature of services production, self-service seems to offer the solution for providing cost-effective, high-quality service to consumers at a large scale. However, there has also arisen widespread doubt about the strategic impact of increasing self-service levels on a service provider's product positioning, customer segmentation, and customer retention and acquisition strategies. This paper proposes a general framework for modeling service coproduction and analyzing the "self-service strategy" wherein self-service is used to substitute for employee-delivered service. The central issue of the strategy is to decide on the optimal price and self-service level based on firm and customer characteristics (e.g., firm capacity and operating efficiency, customer efficiency, the value of time opportunity cost for the consumer, and individual preferences). The proposed model is then used to analyze the impact of the self-service strategy on product positioning and customer segmentation, retention and acquisition.

1 Introduction

Customer participation has always been an indispensable part of any service delivery process (Chase 1978; Lovelock and Young 1979; Karmarkar and Pitbladdo 1995). In many processes, the labor of the customers and the employees of the firm is, to some extent, substitutable. In recent years, the development of information technologies has made such substitution applicable at a mass production level in a variety of service markets. Internet, voice response units (VRU), automatic teller machines (ATM), self-service check-out counters, and self-service ticketing kiosks are all examples of such technologies. A number of success stories illustrate how a firm can involve customers in order to simultaneously improve process efficiency, customer satisfaction, and costs (Schonfeld 1998). The strong growth of the so-called "self-service economy" is evident from almost all major service industries (e.g., financial services, transportation, and retail). According the Airline IT Trends survey, 33% of airlines expect that by the end of 2004 more than 50% of their domestic customers will purchase their tickets using self-service kiosks (The Economist 2004). However, there are also cases of failure in pushing for more self-service in that this approach can alienate the customers and lead, ultimately, to the demise of the firm.

In many cases, the primary advantage of self-service lies in the promise of significant cost savings that will occur when work is shifted from the firm to the consumer as well as by the increase in customer satisfaction due to the availability of any-time, anywhere service. Also, offering self-service as an alternative to employee service can help to attract new customers and retain current customers who prefer self-service to employee-provided service. However, there are also reasons why outsourcing the job to the customer, the "ultimate outsourcing", may not always be optimal. First, self-service is not cost-free for the firm as it often requires an investment in a sophisticated technology infrastructure, though self-service is generally more cost-effective on a per-transaction basis when everything goes well. When problems arise during the service transaction, however, the cost of self-service can be quite expensive (think, for example, of your least-favorite help line that you call when an on-line transaction does not go according to plan). Second, while increasing self-service levels can lead to higher customer attraction and retention, it can also alienate customers who feel burdened by self-service or simply prefer employee-provided service to self-service. The problem is that while self-service technology is supposed to save a service provider money and a customer time, the latter doesn't always happen. The key is whether a customer can efficiently utilize the self-service infrastructure built by the service provider. In other words, in a service delivery environment characterized by coproduction (both the firm and the customer participate in the production), whether a customer is efficient is the key for having a win-win outcome. Finally, in a competitive market, how a service provider should use self-service to differentiate itself from its rivals and develop it into an operational core competency has yet to be studied in the literature. In practice, firms rarely make such decisions based on their own and their rivals' strengths and weaknesses, or guide the decision with a long term strategy for its own market positioning. Instead, the decision is often made based almost entirely on the promise of dramatic cost-savings and the pressure from competition. However, before firms jump onto the self-service bandwagon, there are a lot of issues that are worthy of careful deliberation.

Industry studies have found that the key for successfully deploying self-service is creating a win-win situation for both the service provider and the consumer by finding out "how much self-service is not too much" at certain price level and equipping customers with a well-designed, user-friendly system that allows them to serve themselves efficiently. Thus, the central issue facing a firm in an environment with self-service proliferation is deciding on what level of self-service to request at what price. The choice made defines the design of the service delivery system necessary to support this level. This design will, in turn, affect the cost structure of the firm. In addition, the self-service level is a key component in the design of the service delivery package offered to the consumer and thus, will influence demand. With all of these complex relationships considered, the key question for the firm is how to maximize its profit by offering the "right" bundle of fees and self-service level in the marketplace. In addition, the firm also needs the managerial tools to forecast the impact of the decision on its competition and subsequent customer retention and acquisition.

The published research on the managerial implications and consequences of increasing self-service levels has been largely limited to exploratory studies and lacks a general framework for analysis. The goal of this paper is to develop a comprehensive and yet analytically tractable model that can serve as a general framework to analyze the issues involved in designing service-service systems and to provide applicable managerial insights.

The rest of the paper is organized as follows: Section 2 reviews the related literature and the model is developed in Section 3. With this model, we analyze a service provider's self-service strategies with regard to retention, acquisition, and competition in Section 4. The major findings, managerial implications, and potential extensions are discussed in Section 5.

2 Literature Review

Our work is closely related to three streams of literature in service operations management, marketing and economics. The first stream considers the influence of a customer's participation on service operations. The second stream explores the impact of operations strategy on a firm's marketing function. The third stream includes works on outsourcing and vertical integration in operations management as well as in economics and marketing.

First, some previous work in the service operations management literature has been devoted to studying a customers' participation in service delivery processes. Chase (1978) discusses customers' involvement in service operations and its potential influence on the service delivery process. Lovelock and Young (1979) suggest that customers' participation can help a firm to increase its productivity with the appropriate design of self-service interfaces. The exploratory study in Bateson (1985) identifies time, control, effort, dependence, efficiency, human contact, and risk as the major criteria for decision making when a consumer needs to choose between self-service and full service. Mills and Morris (1986) discuss the "partial" employee roles that customers have been playing in some service organizations by undertaking part of the workload. Globerson and Maggard (1990) present a conceptual model of self-service. Karmarkar and Pitbladdo (1995) provide a comprehensive literature review on service market competition and a detailed discussion of the research agenda in this area. They point out that one of the important research topics is to understand how a customer's engagement in service delivery processes influences the design of the process and, in turn, the competition in the market. They also offer an illustrative model for service coproduction in which the output of the service coproduction is modeled as a function of the time contributed by the customer and the service provider; the model proposed herein is consistent with their approach. Heskett, Sasser and Schlesinger (1997) suggest that by encouraging customers to share responsibility, firms can not only reduce their costs but also improve service quality. Xue and Harker (2002) present the concept of customer efficiency to characterize a customer's role as a coproducer. This stream of literature has mainly focused on the strategic implications of service coproduction and most of the studies are exploratory and empirical.

Our work aims at exploring the managerial implications of a service provider's operations strategy (i.e., the design of the service delivery system) on its marketing function. There are previous works in service operations management literature that attempts the same synthesis. Aksin and Harker (1999) explore the trade-offs between service and sales in a call center in the presence of congestion. Gans (2002) develops a model of customer choice that incorporates random variations in quality in order to study the influence of service quality on customer loyalty; a normative model of the quality competition in an oligopoly market based on this choice model is also developed. Using principle-agent theory, Gunes and Aksin (2004) study the optimal incentive contract between the manager and the server in service-delivery settings where firms engage in value-creation activities (e.g., cross-sells) and offer customers different service levels based on their sales potential. They show that a market segmentation scheme that combines revenue generation concerns with their process design is essential for success. In their context, the level of service represents the amount of sales efforts (value creation activity) conducted by the server which cannot be directly observed by the manager. Note that this is different from what we later define as the level of employee service. In our model, employee service is just service upon customer request and there is no sales activity involved, although an extension to incorporate sales activity is of interest and will be pursued in future research.

Lastly, our work is also related to the outsourcing literature. McMillan (1990) and Venkatesan (1992) consider outsourcing as a cost-reduction strategy. Cachon and Harker (2002) show that scale economies provide a strong motivation for outsourcing even if the supplier's technology is no better than the firm's technology and the supplier is required to build dedicated capacity. In economics, transaction cost theory (Willamson 1979), incomplete contracts (Grossman and Hart 1986), and assets ownership (Baker, Gibbons and Murphy 2001) are used to explain the motivation for outsourcing. In marketing, migrating price competition is shown to be one major benefit for suppliers to outsource the retailing function (McGuire and Staelin 1983). To the best of our knowledge, outsourcing to customers has not been explicitly considered in the previous literature. Outsourcing to customers is unique and is significantly different from outsourcing to a third party as considered in the previous literature. When a customer has the dual roles of coproducer and patron, her influence on the outcome of the outsourcing is more complicated than that of a third party because of her direct influence on both production and demand.

3 A General Framework for Analyzing Self-Service Strategy

3.1 Market, Firm, and Consumer Characteristics

We consider a service market in which different service providers offer the same service product with a different bundle of fee and self-service level: (p_i, ρ_i) The underlying assumption is that the service providers can outsource part of the service job to the customer in the service market. Typically, such a job usually can also be completed by a employee of the firm. The self-service level, ρ_i, indicates the proportion of the workload to be completed by the customer, where $\rho_i \in [0, 1]$. In the market, service providers offer different bundles of fee p and self-service level ρ for the same service product. Assume that each service provider, Firm i ($i = 1, 2, ...$), offers one bundle of (p_i, ρ_i) for the service product. The underlying assumption is that a customer can be used as a substitute for employee labor with potentially different productivity or efficiency, and other quality dimensions. We incorporate a customer's evaluation of all the quality dimensions including efficiency into her costs per unit time spent for employee service and self-service, α and β, respectively. The total workload is normalized to one in our model. When the service is delivered through complete employee service (full service), $\rho_i = 0$. When the service is delivered through complete self-service, $\rho_i = 1$. When both self-service and employee service are required for the completion of service delivery, $0 < \rho_i < 1$. For example, in a grocery store, a customer can be checked out by a store clerk ($\rho_i = 0$), check out completely by herself ($\rho_i = 1$), or have the clerk scan the merchandises but pack them herself ($0 < \rho_i < 1$). In consulting services, it is often the case that the firm can do a certain task (e.g., information gathering and research) for the client, have the client to do it herself, or split the job with the client.

The relevant firm characteristics considered in the proposed model include capacity size measured by the full service rate μ_i, and operating efficiency measured by unit variable cost $n_i(\rho_i)$ and fixed cost $m_i(\rho_i)$. A firm with higher operating efficiency is expected to have a lower average cost, including allocated fixed cost and unit variable cost. The full service rate μ_i is treated as a predetermined parameter as we consider it as an important input factor for other strategic choices in a firm's operations. This is also because we view capacity size as a signal of a firm's market positioning. We want to explore, given a firm's strategic positioning in the market, how a firm should choose its self-service level. Unit variable cost $n_i(\rho_i)$ and fixed cost $m_i(\rho_i)$ are both prespecified functions of self-service level ρ_i. To maximize its profit, a firm simultaneously decides on two decision variables: price p_i and self-service level ρ_i in the proposed model.

A customer is characterized by three metrics in our model: customer efficiency measured by self-service rate, e, costs for unit time spent for employee service, α, and for self-service, β. While a customer's self-service rate indicates her efficiency or productivity as a coproducer of the service product, her costs for self-service and employee service reflect her wealth and social economic status and individual preference, which underscores her role as a consumer. A customer can have utility ($\alpha < 0$, $\beta < 0$) or disutility ($\alpha > 0$, $\beta > 0$) for the time spent for each type of service. In the current paper, in order to simplify the discussion, we assume that customers have disutility for time spent for service delivery, $\alpha > 0$, $\beta > 0$. The relation between α and β indicates customer's preference between the two types of service. If $\beta > \alpha > 0$, it implies that the time spent for employee service costs less than the time spent for self-service. The reason for this difference could be that one feels that passive waiting for employee service is less irritating than the active involvement required for self-service. However, the opposite can also be true. For a customer who enjoys doing self-service, she would have a lower cost per unit time for self-service than her cost per unit time for employee service. In short, the values of α and β represent the economic value of unit time spent in the two types of service for an individual consumer.

3.2 A Customer's Cost for Service Coproduction and Demand Function

Due to the co-productive nature of service, in order to purchase and consume a service product, a customer not only pays the price charged by the service provider but also incurs a cost for participating in the process (e.g., time opportunity and labor costs). Thus, we assume that the representative customer's cost for receiving the service from Firm i includes two parts: an explicit fee and an non-fee coproduction cost that is proportionate to her time spent in the service delivery process. The total time spent in the process includes the time spent in receiving employee service g_i and/or the time spent in self-service s_i. Customers are utility maximizers and makes purchase decisions according to the full price as defined below:

$$f_i(\lambda_i) = p_i + \alpha g_i(\rho_i, \lambda_i) + \beta s_i(\rho_i) \tag{1}$$

The full price is the sum of the fee p_i and the non-fee cost for service coproduction $\alpha g_i(\rho_i, \lambda_i) + \beta s_i(\rho_i)$. The time-based coproduction cost incorporates customers' opportunity cost, individual preferences, and other related expenses. Examples of such expenses include the overhead cost for Internet access when it is used as a self-service delivery channel. We recognize that a customer may have other costs which are not time-based, such as transportation cost to a bricks-and-motar outlet. In the current model, such costs are not explicitly included but are reflected in the customer's cost for unit time spent in the process. For example, if a customer has to travel a long distance to obtain employee service, with other things equal, she is likely to have a higher unit cost for time spent for employee service as a result. An extension of current model to explicitly incorporate non-time-based costs should be straightforward.

We assume that the representative customer's utility is a monotonically decreasing function of the full price. Consequently, the market demand function is also a monotonically decreasing function of the full price: $\lambda(f)$. In a monopoly market, the monopolist Firm i's demand function is just the aggregate market demand function: $\lambda_i(f_i) = \lambda(f_i)$. When there is more than one firm in the market, consumers only buy from the firm that charges the lowest price (Bertrand price competition). Following the notation in Vives (1999), the demand function for Firm i given its full price f_i in a market with a set of competitors L is

$$\lambda_i(f_i) = \left\{ \begin{array}{c} \frac{\lambda(f_i)}{z}, \text{if } f_j \geq f_i, \text{ for all } j \in L = \{1, 2, .., l\}, \text{ where } z = \#\{j \in L : f_j = f_i\} \\ 0, \text{ otherwise} \end{array} \right\}. \tag{2}$$

3.3 A Firm's Cost and Profit Functions

A service provider's total cost function is given by:

$$C_i(\rho_i, f_i) = m_i(\rho_i) + \lambda_i(f_i) n_i(\rho_i) \tag{3}$$

where $m_i(\rho_i)$ is the fixed cost and $n_i(\rho_i)$ is the unit variable cost. Some empirical research has shown that self-service has helped many firms to reduce their costs (McQuivey et al. 1998). However, further empirical investigations are needed to ascertain whether such a relationship generally holds at all self-service levels and across industries. Thus, we assume that both $m_i(\rho_i)$ and $n_i(\rho_i)$ are convex functions of ρ_i that exhibit diminishing returns in cost savings with increasing self-service levels. Note that in the current model, a firm's capacity influences its cost through its influence on the chosen level of self-service. That is, a firm finds its optimal self-service level at any given capacity which in turn determines its corresponding infrastructure and cost.

It is of interest to study the impact of self-service on operating efficiency or how a firm's ability to utilize self-service technology to improve its operating efficiency influences a firm's market positioning. We consider that a firm is more efficient in utilizing self-service technology if increasing the self-service level results in larger deductions or smaller increases of its average cost for $\rho \in [0, 1]$. That is, $n_i^{'}(\rho) + \frac{m_i'(\rho)}{d_i} < n_j^{'}(\rho) + \frac{m_j'(\rho)}{d_j}, \rho \in [0, 1]$. Accordingly two firms are considered as equally efficient in utilizing self-service if $n_i^{'}(\rho) + \frac{m_i'(\rho)}{d_i} = n_j^{'}(\rho) + \frac{m_j'(\rho)}{d_j}, \rho \in [0, 1]$.

We use (ρ_i, f_i) as Firm i's decision variables instead of (p_i, ρ_i) in its profit maximization problem in order to better study the role of a customer's total cost, f_i, which reflects the coproduction nature of services. Thus, Firm i's profit function can be stated as:

$$\pi_i(\rho_i, f_i) = \lambda_i(f_i)[f_i - \alpha g_i(\rho_i, f_i) - \beta s_i(\rho_i) - n_i(\rho_i)] - m_i(\rho_i) \tag{4}$$

We define $\phi_i(\rho_i, f_i) = \alpha g_i(\rho_i, f_i) + \beta s_i(\rho_i) + n_i(\rho_i)$ as the "unit coproduction variable cost", which includes the customer's non-fee cost and the firm's unit variable cost. Thus, the profit function can also be restated as:

$$\pi_i(f_i, \rho_i) = \lambda_i(f_i)[f_i - \phi_i(\rho_i, \lambda_i(f_i))] - m_i(\rho_i).$$

For duopoly and oligopoly markets, similarly, we have $\pi_i(\rho_i, f_i, f_j) = \lambda_i(f_i, f_j)[f_i - \phi_i(\rho_i, \lambda_i(f_i, f_j))] - m_i(\rho_i)$ and $\pi_i(\rho_i, f_1, ..f_{i-1}, f_i, f_{i+1}, .., f_l) = \lambda_i(f_1, ..f_{i-1}, f_i, f_{i+1}, .., f_l)[f_i - \phi_i(\rho_i, \lambda_i(f_1, ..f_{i-1}, f_i, f_{i+1}, .., f_l))] - m_i(\rho_i)$.

4 Optimal Self-Service Level and Pricing

Within the above framework, we further specify a queuing-based model that will be used later to study service providers retention, acquisition and competition strategies. The whole service system consists of two sub-systems: the employee service system and the self-service system depending on the self-service level. Since the current paper aims at providing a general framework for high-level strategic decisions in regard to self-service level and pricing, we propose a base model that can be developed to depict a specific and potentially more complex design.

The employee service system is modeled as a single server system with a single queue. λ_i is the expected arrival/demand rate that comes to the single employee server for $\rho_i \neq 1$. Thus, the expected time spent for employee service is $g_i(\rho_i, \lambda_i) = \frac{1-\rho_i}{\mu_i - \lambda_i(1-\rho_i)}$. The actual employee service rate is $\frac{\mu_i}{1-\rho_i}$ when $\rho_i \neq 1$, and zero otherwise. Correspondingly, we have $g_i > 0$ when $\rho_i \neq 1$, and zero otherwise. The change of the workload assigned to an employee server is reflected by the change in its service rate: to reduce the workload at an employee server by half results in a doubling of its service rate.

Each customer serves as her own server for the self-service. $s_i(\rho_i)$ is the expected time spent for self-service and $s_i(\rho_i) = \frac{\rho_i}{e_i}$. The corresponding self-service rate is $\frac{e_i}{\rho_i}$ when $\rho_i \neq 0$, and zero otherwise. Also, we have $s_i > 0$ when $\rho_i \neq 0$, and zero otherwise. Note that the waiting time is zero for self-service since there is no queue for self-service. This assumption is made to reflect the dramatic reduction of congestion due to the decentralization and ease of access of the self-service system. When the service task is outsourced to customers, it is usually completed at many self-service servers by individual customers at different times. As a result, the congestion that usually occurs at the employee server can be significantly reduced or even eliminated at an individual self-service server. The ease of access to the virtual self-service channels such as the Internet and Voice Response Units (VRU) that have almost no time and location limits also helps to remove the congestion at the self-service server. It is true the self-service servers are often connected to a central information system and there may be some queues at the central system or central server. However, with increasingly powerful central servers and Internet browsers, when customers uses the Internet to conduct self-service, waiting time is often negligible. For physical self-service channels such as self-service kiosks (e.g., ATMs), there may still be some queues especially during peak hours. But even in such a case, the waiting time for the self-service kiosks is expected to be significantly shorter the that for a human agent. This is a simplifying assumption but should not affect the results qualitatively. In addition, we impose no specific order of the services if both employee service and self-service are required so that the proposed framework can be tailored to fit a variety of service delivery designs.

Using this model, we analyze how firms decide on the optimal price and self-service level in monopoly, duopoly, and oligopoly markets. We assume that the customers are homogeneous, and later we use sensitivity analysis to explore how customer characteristics influence these decisions. We also assume that the demand function is linear and $\lambda_i^{'}(f_i) \leq 0$. To ensure a close form solution, we assume $\frac{\partial^2 \pi_i}{\partial f_i \partial \rho_i} = 0$ and $\frac{\partial^2 \pi_i}{\partial \rho_i \partial f_i} = 0$.

4.1 Monopoly Case

Assume that Firm i is the monopoly service provider in the market. Firm i chooses (ρ_i, f_i) to maximizes its profit by solving the following problem:

$$\max_{(\rho_i, f_i)} \pi_i(\rho_i, f_i) = \lambda_i(f_i)[f_i - \phi_i(\rho_i, \lambda_i(f_i))] - m_i(\rho_i), \tag{5}$$

where $0 \leq \rho_i \leq 1, f_i > 0$. Define the monopolist's optimal choice as $(\rho_i^m, f_i^m) = \arg\max_{(\rho_i, f_i)} \pi_i(\rho_i, f_i)$. The corresponding optimal fee is p_i^m.

Optimal Self-service Level Assuming that $n_i^{'}(\rho_i^m) + \frac{m_i^{'}(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e} > 0$, we have:

$$\rho_i^m = \left\{ \begin{array}{c} \frac{1}{\lambda_i(f_i^m)}\{\sqrt{\frac{\alpha\mu_i}{n_i^{'}(\rho_i^m) + \frac{m_i^{'}(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e}}} - \mu_i\} + 1 \\ 0 \\ 1 \end{array} \right\}, \text{if} \left\{ \begin{array}{c} \frac{\alpha}{n_i^{'}(\rho_i^m) + \frac{m_i^{'}(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e}} \leq \mu_i \leq \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\rho_i^m) + \frac{m_i^{'}(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e}}} + \lambda_i(f_i^m) \\ \mu_i \geq \lambda_i(f_i^m) + \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\rho_i^m) + \frac{m_i^{'}(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e}}} \\ \mu_i \leq \frac{\alpha}{n_i^{'}(\rho_i^m) + \frac{m_i^{'}(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e}} \end{array} \right\} \tag{6}$$

We assume that $\mu_i - \lambda_i(f_i) \leq \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\rho_i) + \frac{m_i^{'}(\rho_i)}{\lambda_i(f_i)} + \frac{\beta}{e_i}}} \leq \mu_i$ to ensure that $0 \leq \rho_i^m \leq 1$. According to this solution, the optimal self-service level largely depends on firm capacity size as measured by the full service rate. First, for a small firm with limited capacity for employee service, the optimal choice is to outsource the entire frontline service to the customer. This solution reduces the congestion at the employee server and shortens the delay, which is likely to occur at the service delivery point of a small firm due to their limited number of staff. It also allows the firm to save the expense of even having an employee-based delivery process. Cutting service delays and firm costs are both sources of increased profit. This finding can be linked to the success of many small businesses and individual firms who sell through Internet rather than through physical retail outlets. The results also suggest that a large firm should leverage its capacity advantage by providing full service. This implies that, although employee service is more expensive to offer compared to self-service, a firm with large employee service capacity should chose to provide full service for the sake of higher process efficiency and lower customer coproduction cost and, consequently, the capability to charge a higher fee. Finally, for a medium-sized firm, the optimal choice is to outsource part of the job to the customer. In this case, an efficient process is achieved by splitting the job appropriately between the customer and the employee.

Note that the optimal solution holds even when both $m_i^{'}(\rho_i) < 0$ and $v_i^{'}(\rho_i) < 0$ as long as $n_i^{'}(\rho_i^m) + \frac{m_i'(\rho_i^m)}{\lambda_i(f_i^m)} + \frac{\beta}{e} > 0$. So even if both the fixed cost and the unit variable cost monotonically decrease when self-service increases, it is still possible for full service or a mix of self-service and employee service to be the optimal choice as long as $\frac{\beta}{e}$ is sufficiently large, which can be a result of the customer either having a high unit cost for time spent for self-service or being inefficient in doing self-service, or a combination of both. This result underscores the limit of self-service proliferation that is essentially imposed by customer characteristics rather than the firm's cost structure. The managerial implication is as follows: as firms have invested significantly in developing self-service infrastructure, they need keep in mind that whether the firm can benefit from it financially relies on whether and how customers will use it. For that purpose, investments in helping customer to become more efficient in using self-service (e.g., offering financial incentives to use self-service and on-site training and assistance) should become part of the efforts to promote self-service and, eventually, to maximize one's profit at higher self-service levels.

Optimal Full Price

$$f_i^m = [\phi_i(\rho_i^m, \lambda_i(f_i^m)) + \lambda_i(f_i^m)\alpha g_i^2(\rho_i^m, \lambda_i(f_i^m))]\frac{\epsilon_i(f_i^m)}{\epsilon_i(f_i^m) + 1} \tag{7}$$

Here $\epsilon_i(f_i)$ is the price elasticity defined by $\epsilon_i(f_i) = \frac{f_i}{\lambda_i}\frac{d\lambda_i}{df_i}$. To ensure that $f_i > 0$, we assume that $\epsilon_i < -1$.

Whenever employee service is provided ($\rho_i^m \neq 1$, $g_i^m \neq 0$), the monopolist charges a full price including a term based on the congestion at the employee server. The term, $\lambda_i(f_i^m)\alpha g_i^2(\rho_i^m, \lambda_i(f_i^m))$, is the total increase of coproduction costs due to longer delays at the employee server created by the marginal increase in demand. Note that the marginal coproduction cost is $\frac{\partial \phi_i}{\partial \lambda_i} = \alpha g_i^2$. Since longer delays would result in an increase in a customer's delay cost, it undermines the monopolist's profitability. The presence of this term shows that the monopolist takes into account the effect on customer delay cost of marginal demand when computing the full price.

Optimal Fee

$$p_i^m = [n_i(\rho_i^m) + \lambda_i(f_i^m)\alpha g_i^2(\rho_i^m, \lambda_i(f_i^m))]\frac{\epsilon_i(f_i^m)}{\epsilon_i(f_i^m)+1} - [\alpha g_i(\rho_i^m, f_i^m) + \beta s_i(\rho_i^m)]\frac{1}{\epsilon_i(f_i^m)+1} \tag{8}$$

The explicit fee charged by the monopolist can be significantly higher than the regular monopoly fee based on marginal revenue: $n_i(\rho_i^m)\frac{\epsilon_i(f_i^m)}{\epsilon_i(f_i^m)+1}$. In fact, the monopolist charges two additional fees: $\lambda_i(f_i^m)\alpha g_i^2(\rho_i^m, \lambda_i(f_i^m))\frac{\epsilon_i(f_i^m)}{\epsilon_i(f_i^m)+1}$ and $[\alpha g_i(\rho_i^m, f_i^m)+\beta s_i(\rho_i^m)]\frac{-1}{[\epsilon_i(f_i^m)+1]}$. Note that given $\epsilon_i(f_i^m) < -1$, both terms are non-negative. The former term represents a fee for the increase of congestion at an employee server due to marginal demand, and the latter term represents a fee proportional to customer coproduction cost. The presence of this fee proportional to customer coproduction cost apparently contradicts the conventional wisdom that customers should be compensated for waiting. However, this pricing mechanism encourages efficient service delivery in that it rewards customers with a price discount if the process is more efficient. Thus, it offers incentives for both customers and the firm to work for higher efficiency: for the customer, a lower fee and for the firm, the ability to offer a more attractive price.

4.2 Duopoly Market

4.2.1 Homogeneous Firms

Assume that Firm i and Firm j are identical in every respect: $\mu_i = \mu_j, n_i(\rho) = n_j(\rho)$, $m_i(\rho) = m_j(\rho)$, and $n_i^{'}(\rho) + \frac{m_i^{\prime}(\rho)}{d_i} = n_j^{'}(\rho) + \frac{m_j^{\prime}(\rho)}{d_j}, \rho \in [0, 1]$. Firm i faces a demand function $\lambda_i(f_i, f_j) = \left\{ \begin{array}{c} \lambda(f_i), f_i < f_j \\ \frac{\lambda(f_i)}{2}, f_i = f_j \\ 0, f_i > f_j \end{array} \right\}$; Firm j's demand function is analogous. When the market reaches equilibrium, each firm will receive half of the market demand $\lambda(f_i)$, while charging the same price, $f_i = f_j$. Accordingly, Firm i's profit maximization problem is:

$$\max_{(\rho_i, f_i)} \pi_i(\rho_i, f_i) = \frac{\lambda(f_i)}{2}[f_i - \phi_i(\rho_i, \frac{\lambda(f_i)}{2})] - m_i(\rho_i), \tag{9}$$

Define Firm i's optimal choice in such a symmetric duopoly game as:

$$(\overline{\rho_i^d}, \overline{f_i^d}) = \arg\max_{(\rho_i, f_i)} \pi_i(\rho_i, f_i, f_j). \tag{10}$$

Then $\overline{f_i^d} = [\phi_i(\overline{\rho_i^d}, \frac{\lambda_i(\overline{f_i^d})}{2}) + \frac{\lambda_i(\overline{f_i^d})}{2}\alpha g_i^2(\overline{\rho_i^d}, \frac{\lambda_i(\overline{f_i^d})}{2})]\frac{\epsilon_i(\overline{f_i^d})}{\epsilon_i(\overline{f_i^d})+1}$;

$$\overline{\rho_i^d} = \left\{ \begin{array}{c} \frac{2}{\lambda_i(\overline{f_i^d})}\{\sqrt{\frac{\alpha\mu_i}{n_i^{'}(\overline{\rho_i^d})+\frac{2m_i^{\prime}(\overline{\rho_i^d})}{\lambda_i(\overline{f_i^d})}+\frac{\beta}{e}}} - \mu_i\} + 1 \\ 0 \\ 1 \end{array} \right\}, \text{if} \left\{ \begin{array}{c} \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\overline{\rho_i^d})+\frac{2m_i^{\prime}(\overline{\rho_i^d})}{\lambda_i(\overline{f_i^d})}+\frac{\beta}{e}}} \leq \mu_i \leq \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\overline{\rho_i^d})+\frac{2m_i^{\prime}(\overline{\rho_i^d})}{\lambda_i(\overline{f_i^d})}+\frac{\beta}{e}}} + \frac{\lambda_i(\overline{f_i^d})}{2} \\ \mu_i \geq \frac{\lambda_i(\overline{f_i^d})}{2} + \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\overline{\rho_i^d})+\frac{2m_i^{\prime}(\overline{\rho_i^d})}{\lambda_i(\overline{f_i^d})}+\frac{\beta}{e}}} \\ \mu_i \leq \frac{\alpha}{n_i^{'}(\overline{\rho_i^d})+\frac{2m_i^{\prime}(\overline{\rho_i^d})}{\lambda_i(\overline{f_i^d})}+\frac{\beta}{e}} \end{array} \right\};$$

and $\overline{p_i^d} = [n_i(\overline{\rho_i^d}) + \frac{\lambda_i(\overline{f_i^d})}{2}\alpha g_i^2(\overline{\rho_i^d}, \frac{\lambda_i(\overline{f_i^d})}{2})]\frac{\epsilon_i(\overline{f_i^d})}{\epsilon_i(\overline{f_i^d})+1} - [\alpha g_i(\overline{\rho_i^d}, \frac{\lambda_i(\overline{f_i^d})}{2}) + \beta s_i(\overline{\rho_i^d})]\frac{1}{\epsilon_i(\overline{f_i^d})+1}$. Firm j's optimal choices are the same in the symmetric equilibria. Such an equilibria is stable since neither firm has the motivation to cut its full price lower than $\overline{f_i^d}$ in attempt to "steal" market share. This is because when the two firms are identical, one can always match the other's price given that it is profitable. In this duopoly market, a firm's pricing mechanism is similar to the monopolist except they now expect a lower demand at any full price level. Thus, competition does not prevent the firms from charging for congestion and delay. The optimal self-service level still largely depends on firm capacity size.

4.2.2 Heterogeneous Firms

Let us now consider an asymmetric game with heterogeneous firms. Firm i and Firm j differ in their firm characteristics: size or operating efficiency. As a result, the two firms can have different optimal solutions. Assume $\overline{f_i^d} < \overline{f_j^d}$. Only when Firm i makes more profit in a two-firm equilibrium than the maximum profit that it can possibly make by pricing Firm j out of the market will a two-firm equilibria exist. The proposition below gives the conditions for a two-firm market equilibria to exist (The proofs for Proposition 1 and 2 are straightforward and therefore are omitted herein):

Proposition 1 *Suppose that* $\overline{f_i^d} < \overline{f_j^d}$. *Define* $\widehat{f_j^d} = \min\{f_j | \pi_j(\rho_j, f_j, f_i) = 0, f_i = f_j\}$. *Then for a two-firm equilibria to exist,* $\widehat{f_j^d} < \overline{f_i^d}$ *and* $\pi_i(\overline{\rho_i^d}, \overline{f_i^d}) > \max\limits_{(\rho_i, f_i)} \pi_i(\rho_i, f_i), \forall\ f_i \leq \widehat{f_j^d}$ *must hold.*

Note that $\widehat{f_j^d}$ is Firm j's lowest break-even price. With (ρ_j, f_i) fixed, $\pi_j(\rho_j, f_j, f_i)$ is a concave function of f_j since $\frac{\partial^2 \pi_j}{\partial f_j^2} \leq 0$. Thus, it is possible to have more than one value of f_j such that π_j equals zero. Denote the optimal choices in an asymmetric duopoly game for Firm i and Firm j as $(\widetilde{\rho_i^d}, \widetilde{f_i^d})$and $(\widetilde{\rho_j^d}, \widetilde{f_j^d})$. Then, in the two-firm equilibria, $\widetilde{f_i^d} = \widetilde{f_j^d} = \overline{f_i^d}$ if $\overline{f_i^d} < \overline{f_j^d}$. Consequently, for Firm i, $\widetilde{\rho_i^d} = \overline{\rho_i^d}$ and $\widetilde{p_i^d} = \overline{p_i^d}$. With its full price fixed at $\overline{f_i^d}$ and its demand fixed at $\frac{\lambda(\overline{f_i^d})}{2}$, Firm j solves the following profit maximization problem by adjusting its self-service level:

$$\max_{\rho_j} \pi_j(\rho_j) = \frac{\lambda(f_i^d)}{2}[f_i^d - \phi_j(\rho_j, \frac{\lambda(f_i^d)}{2})] - m_j(\rho_j), \tag{11}$$

Solving the problem, we have

$$\widetilde{\rho_j^d} = \left\{ \begin{array}{c} \frac{2}{\lambda(\overline{f_i^d})}\{\sqrt{\frac{\alpha\mu_j}{n_j'(\widetilde{\rho_j^d})+\frac{2m_j'(\widetilde{\rho_j^d})}{\lambda_j(\overline{f_i^d})}+\frac{\beta}{e}}}-\mu_j\}+1 \\ 0 \\ 1 \end{array} \right\}, \text{if} \left\{ \begin{array}{c} \sqrt{\frac{\alpha\mu_j}{n_j'(\widetilde{\rho_j^d})+\frac{2m_j'(\widetilde{\rho_j^d})}{\lambda_j(\overline{f_i^d})}+\frac{\beta}{e}}} \le \mu_j \le \sqrt{\frac{\alpha\mu_j}{n_j'(\widetilde{\rho_j^d})+\frac{2m_j'(\widetilde{\rho_j^d})}{\lambda_j(\overline{f_i^d})}+\frac{\beta}{e}}} + \frac{\lambda_j(\overline{f_i^d})}{2} \\ \mu_j \ge \frac{\lambda_j(\overline{f_i^d})}{2} + \sqrt{\frac{\alpha\mu_j}{n_j'(\widetilde{\rho_j^d})+\frac{2m_j'(\widetilde{\rho_j^d})}{\lambda_j(\overline{f_i^d})}+\frac{\beta}{e}}} \\ \mu_j \le \frac{\alpha}{n_j'(\widetilde{\rho_j^d})+\frac{2m_j'(\widetilde{\rho_j^d})}{\lambda_j(\overline{f_i^d})}+\frac{\beta}{e}} \end{array} \right\}$$

Thus, $\widetilde{p_j^d} = [n_j(\widetilde{\rho_j^d}) + \frac{\lambda(\overline{f_i^d})}{2}\alpha g_j^2(\widetilde{\rho_j^d}, \frac{\lambda(\overline{f_i^d})}{2})]\frac{\epsilon(\overline{f_i^d})}{\epsilon(\overline{f_i^d})+1} - [\alpha g_j(\widetilde{\rho_j^d}, \frac{\lambda(\overline{f_i^d})}{2}) + \beta s_j(\widetilde{\rho_j^d})]\frac{1}{\epsilon(\overline{f_i^d})+1}$. Therefore, the pricing mechanism is similar to the monopolist and the homogeneous firms in a duopoly market. Note that in the asymmetric equilibria, though their full prices are both equal to $\overline{f_i^d}$, Firm i and Firm j now differ in their self-service levels and fees as a result of their different firm characteristics.

4.3 Oligopoly

Assume there are l firms in the market and $l \ge 3$. We first consider the l firms as identical, and then, as heterogeneous. A firm always supplies the demand it faces as long as there is positive profit.

4.3.1 Symmetric Game

Similar to the duopoly game, in an l-firm symmetric equilibria, the firms share the market demand equally and charge the same full price. The optimal solution in this case is:

$\overline{f_i^o} = [\phi_i(\overline{\rho_i^o}, \frac{\lambda(\overline{f_i^o})}{l}) + \frac{\lambda(\overline{f_i^o})}{l}\alpha g_i^2(\overline{\rho_i^o}, \frac{\lambda(\overline{f_i^o})}{l})]\frac{\epsilon_i(\overline{f_i^o})}{\epsilon_i(\overline{f_i^o})+1}, i \in L = \{1, 2, ..., l\}$, and

$$\overline{\rho_i^o} = \left\{ \begin{array}{c} \frac{n}{\lambda(\overline{f_i^o})}\{\sqrt{\frac{\alpha\mu_i}{n_i'(\overline{\rho_i^o})+\frac{lm_i'(\overline{\rho_i^o})}{\lambda(\overline{f_i^o})}+\frac{\beta}{e}}}-\mu_i\}+1 \\ 0 \\ 1 \end{array} \right\}, \text{if} \left\{ \begin{array}{c} \sqrt{\frac{\alpha\mu_i}{n_i'(\overline{\rho_i^o})+\frac{lm_i'(\overline{\rho_i^o})}{\lambda(\overline{f_i^o})}+\frac{\beta}{e}}} \le \mu_i \le \sqrt{\frac{\alpha\mu_i}{n_i'(\overline{\rho_i^o})+\frac{lm_i'(\overline{\rho_i^o})}{\lambda(\overline{f_i^o})}+\frac{\beta}{e}}} + \frac{\lambda(\overline{f_i^o})}{l} \\ \mu_i \ge \sqrt{\frac{\alpha\mu_i}{n_i'(\overline{\rho_i^o})+\frac{lm_i'(\overline{\rho_i^o})}{\lambda(\overline{f_i^o})}+\frac{\beta}{e}}} + \frac{\lambda(\overline{f_i^o})}{l} \\ \mu_i \le \frac{\alpha}{n_i'(\overline{\rho_i^o})+\frac{lm_i'(\overline{\rho_i^o})}{\lambda(\overline{f_i^o})}+\frac{\beta}{e}} \end{array} \right\}.$$

Accordingly, we have

$p_i^o = [n_i(\overline{\rho_i^o}) + \frac{\lambda_i(\overline{f_i^o})}{l}\alpha g_i^2(\overline{\rho_i^o}, \frac{\lambda_i(\overline{f_i^o})}{l})]\frac{\epsilon_i(\overline{f_i^o})}{\epsilon_i(\overline{f_i^o})+1} - [\alpha g_i(\overline{\rho_i^o}, \frac{\lambda_i(\overline{f_i^o})}{l}) + \beta s_i(\overline{\rho_i^o})]\frac{1}{\epsilon_i(\overline{f_i^o})+1}$.

For the equilibria to exist, we need $\overline{p_i^o} > n_i(\overline{\rho_i^o}) + \frac{lm_i(\overline{\rho_i^o})}{\lambda_i(\overline{f_i^o})}$ so that firms make positive profits at

$(\overline{\rho_i^o}, \overline{f_i^o})$.

4.3.2 Asymmetric Game

If the l firms have different characteristics and, consequently, different $\overline{f_i^o}$, $i \in \{1, 2, ..l\}$, then the market price will be set by the one charging the lowest full price. Assume that Firm i, $i \in \{1, 2, ..l\}$, is the firm that has the lowest optimal full price, $\overline{f_i^o}$ when its demand is fixed at $\frac{1}{l}$ of the aggregate market demand for any price it charges. That is, $\overline{f_i^o} < \overline{f_k^o}$ for any $k \neq i, k \in \{1, 2, ..l\}$. Assume that Firm j, $j \in \{1, 2, ..l\}$, has the highest minimal break-even price among all the l firms: $\widehat{f_j^o} > \widehat{f_k^o}$, for any $k \neq j, k \in \{1, 2, ..l\}$. For an l-firm equilibria to exist, Firm i must make more profit in an l-firm equilibrium than in any other equilibria with less than l firms. The following proposition specifies the conditions for a l-firm equilibria to exist:

Proposition 2 *Suppose* $\overline{f_i^o} < \overline{f_k^o} \; \forall \; k \neq i, i, k \in \{1, 2, ..l\}$. *Define* $\widehat{f_j^o} = \min\{f_j | \pi_j(\rho_j, f_1, ..f_{j-1,} f_j, f_{j+1}, .., f_l) = 0, \; f_k = f_j \forall k \neq j, \; k \in \{1, 2, ..l\}\}, j \in \{1, 2, ..l\}$. *If* $\widehat{f_j^o} \geq \widehat{f_k^o} \; \forall \; k \neq j, k, j \in \{1, 2, ..l\}$. *Then for an l-firm equilibria to exist,* $\widehat{f_j^o} < \overline{f_i^o}$ *and* $\pi_i(\overline{\rho_i^o}, \overline{f_i^o}) > \max_{(\rho_i, f_i)} \pi_i(\rho_i, f_i), \forall \; f_i \leq \widehat{f_j^o}$ *must hold.*

In an l-firm equilibria, Firm i maximizes its profit at (ρ_i^o, f_i^o). The other firms maximize their profit by adjusting the self-service level with their full prices fixed at $\widetilde{f_j^o} = \overline{f_i^o}, j \neq i, j \in \{1, 2, ..l\}$, and its demand fixed at $\frac{\lambda(f_i^o)}{l}$. The resulting optimal self-service level is

$$\widetilde{\rho_j^o} = \frac{l}{\lambda(f_i^o)} \{ \sqrt{\frac{\alpha \mu_j}{n_j'(\overline{\rho_i^o}) + \frac{l m_j'(\overline{\rho_i^o})}{\lambda(\overline{f_i^o})} + \frac{\beta}{e}}} - \mu_j \} + 1, j \neq i, j \in \{1, 2, ..l\}.$$

In addition, we have

$$\widetilde{p_j^o} = [n_i(\widetilde{\rho_j^o}) + \frac{\lambda_i(\overline{f_i^o})}{l} \alpha g_i^2(\widetilde{\rho_j^o}, \frac{\lambda_i(\overline{f_i^o})}{l})] \frac{\epsilon_i(\overline{f_i^o})}{\epsilon_i(\overline{f_i^o}) + 1} - [\alpha g_i(\widetilde{\rho_j^o}, \frac{\lambda_i(\overline{f_i^o})}{l}) + \beta s_i(\widetilde{\rho_j^o})] \frac{1}{\epsilon_i(\overline{f_i^o}) + 1}, j \neq i, j \in \{1, 2, .., l\}.$$

5 The Impact of Self-Service on Marketing

In this section, using the model developed in Section 4, we analyze some important marketing issues facing service providers who are interested in utilizing self-service to offer quality and cost-effective services to the mass market. The purpose of these examples are to illustrate how the proposed framework can be used to analyze self-service strategies rather than offering definitive answers to these specific questions. However, the insights gained shed lights into these long-standing issues that are crucial to the proliferation of self-service technologies and the growth of the self-service economy.

5.1 Customer Retention and Acquisition

Knowing how the full price will respond to a change in the self-service level makes it possible to predict the corresponding change in demand which, in turn, provides a manager with a tool to estimate potential changes in sales when he adjusts the self-service level. Some managers are often concerned about whether increasing the self-service level will alienate the existing customers who are used to employee-provided services, while the others expect increasing self-service levels can help retain and attract customers who like to have more control of the service delivery process or value the convenience of self-service. In practice, full price can be difficult to measure directly and thus, it is especially important to understand the directional change in demand in response to a change in the self-service level. Since the full price is the overall cost that a customer has to pay for the service product, the results below also shed light on the impact of the change of self-service level on consumer utility.

Proposition 3 *Given firm and customer characteristics, under the assumption that* $|\frac{\partial \epsilon_i}{\partial f_i}|_{f_i=f_i^m} < \varepsilon$, $\frac{\partial f_i}{\partial \rho_i} \leq 0$ *and* $\frac{\partial \lambda_i}{\partial \rho_i} \geq 0$, *if* $\frac{m_i'(\rho_i)}{\lambda_i(f_i)} \geq 2\alpha g_i(\rho_i)\lambda_i(f_i)g_i'(\rho_i)$; *otherwise,* $\frac{\partial f_i}{\partial \rho_i} > 0$ *and* $\frac{\partial \lambda_i}{\partial \rho_i} < 0$.

According to Proposition 2, if the marginal fixed cost per unit demand is above certain threshold, increasing self-service levels will actually lead to lower full price and higher market demand. (See the appendix for the proofs for the propositions in this section.) To better understand the proposition above, it is worth noting that at the optimal self-service level, $\frac{m_i'(\rho_i)}{\lambda_i(f_i^*)} = -\phi_i'(\rho_i)$, where $\frac{m_i'(\rho_i)}{\lambda_i(f_i)}$ is the marginal change of the allocated fixed cost per unit demand (average allocated fixed cost) and $\phi_i'(\rho_i) = n_i'(\rho_i) + \alpha g_i'(\rho_i) + \beta s_i'(\rho_i)$ is the marginal change of coproduction variable cost with respect to the change in the self-service level. Thus the marginal changes of full price and market demand in response to the change in the self-service level depend on the marginal changes of the allocated fixed cost per unit demand and the coproduction variable cost. Note that since $g_i'(\rho_i) < 0, 2\alpha g_i(\rho_i)\lambda_i(f_i)g_i'(\rho_i) \leq 0$. Thus, $\frac{m_i'(\rho_i)}{\lambda_i(f_i)} \geq 2\alpha g_i(\rho_i)\lambda_i(f_i)g_i'(\rho_i)$ always holds when $\phi_i'(\rho_i) \leq 0$. Thus if increasing self-service increases the allocated fixed cost per unit demand and accordingly reduces the unit coproduction variable cost, then lower full price and higher demand will follow. However, if the allocated fixed cost per unit demand decreases and the unit coproduction variable cost increases in response to increasing self-service levels instead, then the full price will drop and the market demand will rise only when the absolute value of the cost change is small enough; otherwise the opposite is true. There will be no change for price and demand if the unit coproduction variable cost doesn't change in response to the change in the self-service level.

Thus, increasing the self-service level can retain existing customers and attract new customers if it reduces coproduction variable cost while raising allocated fixed cost per unit service. This suggests that to change to a service delivery infrastructure with a higher allocated fixed cost and accordingly lower variable coproduction cost per unit service leads to market growth. The technology-driven self-service delivery channels such as the Internet are clearly more capital-intensive and less labor intensive in comparison with the labor–intensive employee service delivery channel, e.g., the bricks-and-motar storefronts. Thus, the proposition predicts that to shift from an employee service-oriented infrastructure to a self-service oriented design will bring market growth for the service provider. One possible economics explanation for such market growth is that the change to the self-service oriented infrastructure allows the service provider to benefit from economies of scale. Because of the dramatic reduction of congestion at the self-service server, the service provider is able to offer consumers efficient quality service at a mass production level at a low price, which stimulates more demand for its service.

5.2 Customer Segmentation: Differential Self-Service Level and Pricing

Our analysis has been conducted under the assumption that customers are homogeneous. As discussed before, one application of such assumption will be when the service provider has targeted a particular customer segment. By conducting sensitivity analysis on the influence of the representative customer's characteristics, insights on how consumer characteristics can affect optimal fee and self-service level can be obtained. The findings can serve as basis for customer segmentation when the firm competes in different markets for different consumer groups, or for the strategic adjustment of price and self-service levels when the targeted customer base change their characteristics (e.g., their becoming more efficient because of more experience with self-service or changing their preference between employee service and self-service). Since in a competitive market, full price is set by the market leader, the firm that has the lowest optimal full price, we consider a firm's customer segmentation strategy with the full price fixed. That is, we explore without risking losing customers, how a service provider should differentiate its offering of self-service level and price based on customer characters.

5.2.1 Differential Self-Service Level

The proposition below explores the sensitivity of the optimal self-service level with respect to changes in firm and customer characteristics. Note that the assumptions $m_i^{"}(\rho_i) = 0$ and $n_i^{"}(\rho_i) = 0$ in Proposition 4 below are made to facilitate the discussion but are not necessary for the results in Proposition 4 to hold. Under these assumptions, the rate of cost change per unit change of the self-service level are constants for both fixed and variable costs. That is, $m_i^{'}(\rho_i)$ and $n_i^{'}(\rho_i)$ are constants for $\rho_i \in [0, 1]$.

Proposition 4 *At a given full price f_i, assume $m_i^{"}(\rho_i) = 0$ and $n_i^{"}(\rho_i) = 0$, then $\frac{\partial \rho_i}{\partial \mu_i} < 0, 0 \frac{\partial \rho_i}{\partial e_i} > 0, \frac{\partial \rho_i}{\partial \alpha_i} > 0, \frac{\partial \rho_i}{\partial \beta_i} < 0$.*

According to Proposition 4, at a given full price level, higher self-service efficiency or higher cost for unit employee service time leads to a higher optimal self-service level. However, larger employee service capacity or higher cost for unit self-service time prompts the firm to keep more work in the employees' hands. The result offers some important strategic guidances for customer segmentation while highlighting the trade-offs. It shows that without changing the overall full price, the service provider can require a higher self-service level from the more efficient customer segment. The implication is that, in such a case, increasing the self-service level will not turn those customers away.

It is no surprise that the customers who have higher disutility for employee service will be willing to do more self-service and customers who have higher disutility for self-service should be offered more employee service. However, there is an implicit conflict behind this apparently straightforward result. As well established in the economics literature, a wealthier consumer is expected to have higher value of time opportunity cost. In this setting, with other things equal, a wealthier customer is expected to have higher values of both α and β than a less wealthy customer. However, as shown above, the directions of the marginal changes of optimal self-service levels are in opposite directions in response to the changes of α and β. This makes it impossible to differentiate self-service level based on the wealth factor alone. Thus, while the wealth factor imposes conflicting influences on the optimal level of self-service, customer efficiency and customer preferences become crucial in determining the aggregate change of the optimal self-service level in response to the change of wealth.

Overall, the results emphasize that the service provider must weigh the customer efficiency factor and individual preference factor in addition to the wealth factor in its customer segmentation strategy rather than simply relying on the wealth factor alone. The decision about how much self-service to request or how much employee service to provide along with prices should be determined based on all three factors instead of one. This calls for a departure from the current practice that segments customers almost solely based on the wealth factor.

5.2.2 Differential Pricing

When a firm differentiates self-service levels among different customer segments, it often has the option to charge different prices for different self-service levels; i.e., price discrimination based on product differentiation. One question of managerial importance is whether increasing self-service level necessarily leads to a reduction in price. The conventional belief is that customers expect a fee discount for contributing to the process. It is also expected that a firm would willingly offer such a price deduction since increasing self-service level saves a firm money. The managerial implications herein are significant. If this holds, increasing the self service level makes consumers financially better off. Meanwhile it provides the service providers with the incentive to enter low-income markets, since it is possible for a firm to profit from such a market by offering affordable quality service (Letelier, Flores, and Spinosa 2003). Many firms have traditionally chosen to either stay out of the low income market segment or offer a downgraded product. If consumers are able to deliver a quality service to themselves with adequate support from the firm, it creates a win-win situation: consumers across different income segments get access to high quality service at a relatively low price, and the firm expands its market share into the largely unexplored market segment - the low-income market segment.

The proposition below gives the specific condition under which such "rewards" for self-service to a customer can be expected:

Proposition 5 *At a given full price f_i, $\frac{\partial p_i}{\partial \rho_i} \leq 0$, if $\frac{\alpha \mu_i}{[\mu_i - \lambda_i(f_i)(1-\rho_i)]^2} \leq \frac{\beta}{e}$; and $\frac{\partial p_i}{\partial \rho_i} > 0$ otherwise.*

Increasing self-service is accompanied by a reduction in price only when the customer is expected to "suffer" as a result of increasing self-service level. That is, the condition for a lower price is that a customer is expected to have a positive marginal cost for increasing self-service level. Note that $\frac{\partial s_i}{\partial \rho_i} = \frac{1}{e} > 0$ and $\frac{\partial g_i}{\partial \rho_i} = -\frac{\mu_i}{[\mu_i - \lambda_i(1-\rho_i)]^2} < 0$. Therefore, for the a customer's overall marginal cost to be positive, the increase in her cost for self-service needs to be greater than the decrease in her cost for employee service. On the other hand, if a customer has a negative overall marginal cost for more self-service, which suggests her utility improves as a result of increasing self-service level, she will instead be charged a higher price. So the service provider offers a price deduction for increasing self-service levels only when a customer is expected to have disutility rather than utility for engaging in more self-service.

The results have several important managerial implications. First, while customers are treated equally (paying the same full price), the service provider can charge them different prices based on different self-service levels. In particular, it can be profit maximizing for the service provider to charge a lower price and ask for a higher self-service level. This offers the economic incentive for firms to serve the lower income consumer population with quality service. In the meantime, it also shows that self-service does not have to be used as a low-price or low-end substitute for employee service. The self-service channel offers customers a convenient and efficient way to obtain services from the service provider. It often provides customers with better decision-making and information processing by utilizing the most advanced information technology. It allows the customer to gain more control of the process and, consequently, the quality of the service. Therefore, it is reasonable to expect some customers will experience utility improvements as a result of increasing the self-service level. The model shows that in such a case, the firm can expect the customer to pay a higher price for doing more self-service. For example, some banks charge customers for using on-line bill payment.

5.3 Service Product Positioning in a Competitive Market

In this subsection, we analyze how a firm uses self-service to position itself strategically in a competitive market based on its own characteristics and the targeted customer segment characteristics. We first look into a duopoly market with two heterogeneous firms, Firm i and Firm j. We consider two different scenarios where the two firms differ either in their capacity for employee service or in their capability in utilizing self-service to improve their operating efficiency.

1. Two firms with different capacity size but the same capability in utilizing self-service to improve their operating efficiency:

Proposition 6 *Assume* $m_i^{"}(\rho_i) = m_j^{"}(\rho_j) = 0$ *and* $n_i^{"}(\rho_i) = n_j^{"}(\rho_j) = 0$, *if* $\mu_i > \mu_j, n_i^{'}(\rho) + \frac{m_i'(\rho)}{d_i} = n_j^{'}(\rho) + \frac{m_j'(\rho)}{d_j}, \rho \in [0,1]$, *then* $\widetilde{\rho_i^d} < \widetilde{\rho_j^d}$. *If, in addition, the customer has a positive marginal co-production cost with respect to increasing self-service, then* $\widetilde{p_i^d} > \widetilde{p_j^d}$.

Thus, in the asymmetric market equilibria, if the two firms have the same efficiency in utilizing self-service, the firm with the smaller capacity requires a higher self-service level. If additionally increasing self-service level leads to a higher coproduction cost for the customer, then the firm with smaller capacity will charge a lower price. On the other hand, in such a case the firm with larger capacity will offer more personal employee service and charge a higher price for it. However, if a customer's coproduction cost decreases as a result of more self-service, the firm with smaller capacity will offer a more self-service oriented product and charge a higher price for it.

2. Two firms with the same capacity size but different capability in utilizing self-service to improve their operating efficiency:

Proposition 7 *Assume* $m_i^{"}(\rho_i) = m_j^{"}(\rho_j) = 0$ *and* $n_i^{"}(\rho_i) = n_j^{"}(\rho_j) = 0$,*if* $\mu_i = \mu_j, n_i^{'}(\rho) + \frac{m_i'(\rho)}{d_i} < n_j^{'}(\rho) + \frac{m_j'(\rho)}{d_j}, \rho \in [0,1]$, *then* $\widetilde{\rho_i^d} > \widetilde{\rho_j^d}$. *If, in addition, the customer has a positive marginal cost with respect to increasing self-service, then* $\widetilde{p_i^d} < \widetilde{p_j^d}$.

The proposition above shows with the same capacity for employee service, if a firm is more efficient in utilizing self-service, it will require a higher self-service level. Thus, when the market reaches equilibrium, for firms with the same capacity for employee service, the self-service level they require indicate their efficiency in utilizing self-service technology: a higher self-service level suggests a more desired impact on operating efficiency.

Now consider two firms that are equally efficient in offering full service, $n_i(0) + \frac{m_i(0)}{d_i} = n_j(0) +$

$\frac{m_j(o)}{d_j}$. Assume that Firm i is more efficient in utilizing self-service. That is, $n_i^{'}(\rho_i) + \frac{m_i'(\rho_i)}{d_i} < n_j^{'}(\rho_j) + \frac{m_j'(\rho_j)}{d_j}, \rho_i, \rho_j \in [0,1]$. It can be shown in such a case Firm i has a higher operating efficiency, or a lower average cost for $\rho \in (0,1]$. The proposition above shows that in such a case, Firm i would have a higher optimal self-service level than Firm j. Thus, if one firm has higher operating efficiency because it utilizes self-service better, it will require a higher self-service level in the market. If they are known to be equally efficient for operating full service, then higher self-service level required indicates higher operating efficiency for the service product that includes some degree of or complete self-service. This contradicts the conventional wisdom that to offer more employee service is always an indicator of higher operating efficiency. The result shows that the opposite can be true.

The two propositions above also hold in the oligopoly market. The following propositions describe the characteristics of the market equilibria:

Proposition 8 *Assume* $m_i^{"}(\rho_i) = m_j^{"}(\rho_j) = ... = m_l^{"}(\rho_l) = 0$ *and* $n_i^{"}(\rho_i) = n_j^{"}(\rho_j) = ... = n_l^{"}(\rho_l) = 0$, *if* $\mu_1 > \mu_2 > ... > \mu_l, n_i^{'}(\rho) + \frac{m_i'(\rho)}{d_i} = n_j^{'}(\rho) + \frac{m_j'(\rho)}{d_j} = ... = n_l^{'}(\rho) + \frac{m_l'(\rho)}{d_l}, \rho \in [0,1]$, *then* $\widetilde{\rho_1^o} < \widetilde{\rho_2^o} < ... < \widetilde{\rho_l^o}$. *If, in addition, the customer has a positive marginal co-production cost with respect to increasing self-service, then* $\widetilde{p_1^o} > \widetilde{p_2^o} > ... > \widetilde{p_l^o}$.

Proposition 9 *Assume* $m_i^{"}(\rho_i) = m_j^{"}(\rho_j) = ... = m_l^{"}(\rho_l) = 0$ *and* $n_i^{"}(\rho_i) = n_j^{"}(\rho_j) = ... = n_l^{"}(\rho_l) = 0$, *if* $\mu_1 = \mu_2 = ... = \mu_l, n_1^{'}(\rho) + \frac{m_1'(\rho)}{d_1} < n_2^{'}(\rho) + \frac{m_2'(\rho)}{d_2} < ... < n_l^{'}(\rho) + \frac{m_l'(\rho)}{d_l}, \rho \in [0,1]$, *then* $\widetilde{\rho_1^o} > \widetilde{\rho_2^o} > ... > \widetilde{\rho_l^o}$. *If, in addition, the customer has a positive marginal co-production cost with respect to increasing self-service, then* $\widetilde{p_1^o} < \widetilde{p_2^o} < ... < \widetilde{p_l^o}$.

6 Summary and Discussions

Self-service is becoming a crucial lever in improving both productivity and quality in service delivery systems. However, there are some important strategic questions facing service providers who are interested in adopting a more self-service oriented service delivery system. At the center of the issues is the optimal level of self-service and pricing. The paper presents a framework for analyzing service coproduction and develops a queuing based model within this framework. The model is then used to study optimal pricing and self-service level in monopoly, duopoly, and oligopoly markets. Using sensitivity analysis, we analyze the implications of increasing self-service on customer segmentation, retention and acquisition, and market positioning, which are all crucial for the success of the self-service strategy.

One interesting finding herein is that even if fixed and unit variable costs both monotonically decrease as the self-service level increases, it is not necessary to have an optimal self-service level equal or close to one. In fact, it is shown that the optimal self-service level mainly depends on the firm's service delivery capacity for employee service; i.e., a large firm should provide full service, a small firm should require complete self-service, and a medium size firm should choose a combination of both employee service and self-service. Thus, the results suggest that small firms should outsource the frontline service delivery to the customer rather than struggling to staff these operations sufficiently. On the other hand, a firm with large capacity should leverage their advantage of more efficient employee service. Industry observations and empirical research seem to support this finding. For example, small businesses have been much more actively utilizing self-service channel such as Internet to sell directly to the consumers than large businesses (e.g., Many small businesses use Ebay.com to sell, while large retailers sell mainly through bricks-and-mortar stores). Another example can be found in Lunberorg and Nielsen (2003) where they find that the positive effect of using self-service technology such as Internet is the strongest in small banks though the large banks often have more sophisticated technology applications.

One of the most controversial issues surrounding self-service proliferation is its impact on customer retention and acquisition. The model shows that to change to a more self-service oriented infrastructure that is more capital intensive but less labor intensive brings market growth rather than loss. The finding is significant in that it shows that when its service delivery system changes from employee service oriented to self-service oriented, with the corresponding change to its cost structure from labor intensive to capital intensive, a service provider gains economies of scale and market growth. Therefore, self-service brings an similar impact on service to what mass production had brought manufacturing: to deliver quality service to a mass market with significantly lower unit cost. This offers the economic basis for long term growth of a self-service economy and, accordingly, the investment in self-service technology. Thus we find that outsourcing to the customer offers not only direct cost-reductions but also economies of scale that was unavailable with employee-delivered service. In fact, the lack of economies of scale has been regarded as a major difference between service production and manufacturing production. But with self-service scale economies are now available for service production, which could pave the way for service providers to offer customized, high-quality and cost-effective service to a mass market, a potential revolution for service industries.

The model offers some new insights for customer segmentation strategy. Traditionally, customer segmentation has been largely based on personal wealth or recorded profitability. Our model suggests that a new segmentation strategy will call for a comprehensive evaluation of customer efficiency and the preference between self-service and employee service in addition to wealth before deciding on how much personal employee-delivered service to offer or how much self-service to require from the consumer. In contrast to the conventional wisdom that believes that wealthier customers should be served with more personal service, our model predicts that it is sometimes optimal for the firm to have a higher self-service level for a wealthier customer than a less wealthy customer depending on customer efficiency and preference.

Another interesting finding herein is the relationship between the optimal fee and optimal self-service level. The conventional belief is that, since a firm saves cost by using self-service to substitute for employee service, it is expected to reward the customer with a lower fee for doing more self-service. The results suggest that the relationship between the fee and the self-service level is more complex. When a market reaches equilibrium, with or without competition among the firms, a firm that requires more self-service will charge a lower fee only when a customer's coproduction cost is expected to increase as a result. The managerial implications of this result are two-fold. First, it shows that firms can be profitable at a relatively low price as long as customer labor can be used appropriately to substitute for employee labor. This suggests that a firm can enter a low-income market segment, provide a quality service at a low price by utilizing self-service, and make a profit. Second, it shows that a firm's optimal strategy is not necessarily to reward customers for engaging in more self-service with price reductions. During the Internet bubble era, many Internet retailers attempted to compete with bricks-and-mortar retailers by offering a substantially lower price, and this lower price was justified with the following logic: since they do not need to maintain physical stores, Internet retailers should adopt a low price strategy. However, offering a lower price was not necessarily their profit-maximizing strategy as demonstrated in the market later. In fact, as indicated by the results from the model, as long as a customer experiences decreasing coproduction cost with self-service, a service provider should charge a higher price rather than a lower price for self-service oriented products. Thus, service providers need not position their self-service oriented products as the low-end products as long as customers perceive that the benefit of doing self-service exceeds the cost (e.g., more convenience, flexibility, direct control of the process, and better information gathering and processing for decision making.).

The sensitivity analysis of firms' positioning in a competitive market shows that both capacity and a firm's capability in utilizing self-service to improve its operating efficiency are important factors. On one hand, when the market reaches equilibrium, with the same capability in utilizing self-service to improve its operating efficiency, a smaller firm requires higher self-service levels and larger firms offers more employee service. On the other hand, with the same capacity, the firm with higher efficiency in utilizing self-service offers a more self-service oriented product. Those firms are also likely to enjoy a higher operating efficiency. This contrasts with the conventional wisdom that to offer more employee service always signals better operations, i.e., higher operating efficiency.

Several extensions of the current model are possible. In the current model, firms decide on both the fee and the self-service level. In practice, it is not uncommon for customers to decide on the self-service level while the corresponding fee is set by the firm; the model can be extended to incorporate this splitting of the decisions between the firm and customer. Also, customers are treated as homogeneous in the current model; a natural extension is to include customer heterogeneity. Finally, the full price in the current model includes the explicit fee and time-related costs. An extension to include other non-time-based customer costs would be useful. Empirical studies that test the results from the model are also necessary. Finally, as mentioned above, the current model focuses solely on the service aspect of customer-employee encounters, and to extend the model to include the sales aspects will be one direction for future research.

Appendix

Proof. Proposition 3

With firm and customer characteristics fixed, under the assumption that $|\frac{\partial \epsilon_i}{\partial f_i}|_{f_i=f_i^m} < \varepsilon$, we have

$$\frac{\partial f_i^m}{\partial \rho_i^m} = \frac{\frac{\mu_i(1+2g_i\lambda_i)\alpha}{[\mu_i-\lambda_i(1-\rho_i^m)]^2} - \frac{\beta}{e_i} - n_i^{'}(\rho_i^m)}{\frac{(1-\rho_i^m)^2\lambda_i^{'}(f_i^m)(1+2g_i\lambda_i)\alpha}{[\mu_i-\lambda_i(1-\rho_i^m)]^2} + \lambda_i^{'}(f_i^m)\alpha g_i^2 - \frac{(\epsilon_i+1)}{\epsilon_i}} \tag{12}$$

Since $\epsilon_i(f_i) < -1, \lambda_i^{'}(f_i) < 0$, we have $\frac{(1-\rho_i^m)^2\lambda_i^{'}(f_i^m)(1+2g_i\lambda_i)\alpha}{[\mu_i-\lambda_i(1-\rho_i^m)]^2} + \lambda_i^{'}(f_i^m)\alpha g_i^2 - \frac{(\epsilon_i+1)}{\epsilon_i} < 0$. Thus,

$$\frac{\partial f_i^m}{\partial \rho_i^m}\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} 0, \text{ if and only if } n_i^{'}(\rho_i^m)\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} \alpha\frac{\mu_i[1+2g_i(\rho_i^m)\lambda_i]}{[\mu_i-\lambda_i(1-\rho_i^m)]^2} - \frac{\beta}{e_i}. \tag{13}$$

That is,

$$\frac{\partial f_i^m}{\partial \rho_i^m}\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} 0, \text{ if and only if } n_i^{'}(\rho_i^m)+\alpha g_i^{'}(\rho_i^m)+\beta s_i^{'}(\rho_i^m)\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} -2\alpha g_i^{'}(\rho_i^m) g_i(\rho_i^m)\lambda_i(f_i^m). \quad (14)$$

Note that $g_i^{'}(\rho_i^m) < 0, s_i^{'}(\rho_i^m) > 0$. Since, according to the first-order conditions, at the optimal service level it must be the case that $n_i^{'}(\rho_i^m)+\alpha g_i^{'}(\rho_i^m)+\beta s_i^{'}(\rho_i^m) = -\frac{m_i'(\rho_i^m)}{\lambda_i(f_i^m)}$, we have

$$\frac{\partial f_i^m}{\partial \rho_i^m}\left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} 0, \text{ if and only if } \frac{m_i'(\rho_i^m)}{\lambda_i(f_i^m)}\left\{\begin{array}{c} < \\ = \\ > \end{array}\right\} 2\alpha g_i^{'}(\rho_i^m) g_i(\rho_i^m)\lambda_i(f_i^m). \quad (15)$$

■

Proof. Proposition 4

Under the assumptions that $n_i^{'}(\rho_i^m)+\frac{m_i'(\rho_i^m)}{\lambda_i(f_i^m)}+\frac{\beta}{e} > 0$ and $\mu_i - \lambda_i(f_i) \le \sqrt{\frac{\alpha\mu_i}{n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i(f_i)}+\frac{\beta}{e_i}}} \le \mu_i$, and $m_i^{"}(\rho)=0$ and $n_i^{"}(\rho)=0$ which means $m_i'(\rho)$ and $n_i^{'}(\rho)$ are both constants for $\rho\in[0,1]$, at a given f_i,

$$\frac{\partial \rho_i}{\partial \mu_i} = \frac{1}{2}\cdot\frac{\sqrt{\frac{\alpha}{[n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]\mu_i}}-1}{\{\lambda_i+\frac{1}{2}\sqrt{\frac{\alpha\mu_i}{[n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]^3}}[n_i^{"}(\rho_i)+\frac{m_i^{"}(\rho_i)}{\lambda_i}]\}} < 0 \quad (16)$$

$$\frac{\partial \rho_i}{\partial e} = \frac{1}{2\lambda_i}\cdot\frac{\beta}{e^2}\cdot\frac{\sqrt{\frac{\alpha\mu_i}{[n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]^3}}}{\{1+\frac{1}{2\lambda_i}\sqrt{\frac{\alpha\mu_i}{[n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]^3}}[n_i^{"}(\rho_i)+\frac{m_i^{"}(\rho_i)}{\lambda_i}]\}} > 0 \quad (17)$$

$$\frac{\partial \rho_i}{\partial \alpha} = \frac{1}{2\lambda_i}\cdot\frac{\sqrt{\frac{\mu_i}{\alpha[n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]}}}{\{1+\frac{1}{2\lambda_i}\sqrt{\frac{\alpha\mu_i}{[n_i^{'}(\rho_i)+\frac{m_i'(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]^3}}[n_i^{"}(\rho_i)+\frac{m_i^{"}(\rho_i)}{\lambda_i}]\}} > 0 \quad (18)$$

$$\frac{\partial \rho_i}{\partial \beta} = -\frac{1}{2\lambda_i}\cdot\frac{1}{e}\cdot\frac{\sqrt{\frac{\alpha\mu_i}{[n_i^{'}(\rho_i)+\frac{m_i^{'}(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]^3}}}{\{1+\frac{1}{2\lambda_i}\sqrt{\frac{\alpha\mu_i}{[n_i^{'}(\rho_i)+\frac{m_i^{'}(\rho_i)}{\lambda_i}+\frac{\beta}{e_i}]^3}}[n_i^{"}(\rho_i)+\frac{m_i^{"}(\rho_i)}{\lambda_i}]\}} < 0 \quad (19)$$

■

Proof. Proposition 5

Since $p_i = f_i - \alpha g_i - \beta s_i$, with f_i fixed, $\frac{\partial p_i}{\partial \rho_i} = -\alpha\frac{\partial g_i}{\partial \rho_i} - \beta\frac{\partial s_i}{\partial \rho_i} = \frac{\alpha\mu_i}{[\mu_i-\lambda_i(f_i)(1-\rho_i)]^2} - \frac{\beta}{e}$. ■

Proof. Proposition 6

In the two-firm equilibria, $\widetilde{f_i^d} = \widetilde{f_j^d}, \lambda_i(\widetilde{f_i^d}) = \lambda_j(\widetilde{f_j^d})$. Under the assumption $m_i^{"}(\rho_i) = m_j^{"}(\rho_j) = 0$ and $n_i^{"}(\rho_i) = n_j^{"}(\rho_j) = 0$, $n_i^{'}(\rho), m_i^{'}(\rho), n_j^{'}(\rho)$, and $m_j^{'}(\rho)$ are all constants. So if $\mu_i > \mu_j$, and $n_i^{'}(\rho) + \frac{m_i^{'}(\rho)}{d_i} = n_j^{'}(\rho) + \frac{m_j^{'}(\rho)}{d_j}, \rho \in [0,1]$, according to Proposition 4, $\widetilde{\rho_i^d} < \widetilde{\rho_j^d}$. If, in addition, the customer has a positive marginal cost with respect to increasing self-service ($\frac{\alpha\mu}{[\mu-\lambda(1-\rho)]^2} < \frac{\beta}{e}$ for both Firm $i$and Firm j), then according to Proposition 5, there also exists $\widetilde{p_i^d} > \widetilde{p_j^d}$. ■

Proof. Proposition 7

In the two-firm equilibria, $\widetilde{f_i^d} = \widetilde{f_j^d}, \lambda_i(\widetilde{f_i^d}) = \lambda_j(\widetilde{f_j^d})$. Also $\widetilde{\rho_i^d} = \frac{2}{\lambda_i(f)}\{\sqrt{\frac{\alpha\mu_i}{n_i^{'}(\widetilde{\rho_i^d})+\frac{2m_i^{'}(\widetilde{\rho_i^d})}{\lambda_i(f)}+\frac{\beta}{e}}} - \mu_i\} + 1, \widetilde{\rho_j^d} = \frac{2}{\lambda(f)}\{\sqrt{\frac{\alpha\mu_j}{n_j^{'}(\widetilde{\rho_j^d})+\frac{2m_j^{'}(\widetilde{\rho_j^d})}{\lambda_j(f)}+\frac{\beta}{e}}} - \mu_j\} + 1$. Under the assumption $m_i^{"}(\rho_i) = m_j^{"}(\rho_j) = 0$ and $n_i^{"}(\rho_i) = n_j^{"}(\rho_j) = 0$, $n_i^{'}(\rho), m_i^{'}(\rho), n_j^{'}(\rho)$, and $m_j^{'}(\rho)$ are all constants. Therefore, if $n_i^{'}(\rho) + \frac{m_i^{'}(\rho)}{d_i} < n_j^{'}(\rho) + \frac{m_j^{'}(\rho)}{d_j}, \rho \in [0,1]$, $n_i^{'}(\widetilde{\rho_i^d}) + \frac{2m_i^{'}(\widetilde{\rho_i^d})}{\lambda_i(f)} < n_j^{'}(\widetilde{\rho_j^d}) + \frac{2m_j^{'}(\widetilde{\rho_j^d})}{\lambda_j(f)}$. With $\lambda_i(\widetilde{f_i^d}) = \lambda_j(\widetilde{f_j^d})$, if $\mu_i = \mu_j$, there must be $\frac{2}{\lambda_i(f)}\{\sqrt{\frac{\alpha\mu_i}{n_i^{'}(\widetilde{\rho_i^d})+\frac{2m_i^{'}(\widetilde{\rho_i^d})}{\lambda_i(f)}+\frac{\beta}{e}}} - \mu_i\} + 1 > \frac{2}{\lambda(f)}\{\sqrt{\frac{\alpha\mu_j}{n_j^{'}(\widetilde{\rho_j^d})+\frac{2m_j^{'}(\widetilde{\rho_j^d})}{\lambda_j(f)}+\frac{\beta}{e}}} - \mu_j\} + 1$; that is, $\widetilde{\rho_i^d} > \widetilde{\rho_j^d}$. ■

The proofs of Proposition 8 and 9 are analogous to the proofs of Proposition 6 and 7 and, therefore, are omitted herein.

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