Quality Differentiation and Adoption Costs: The Case for Interorganizational Information System Pricing

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Abstract

Firms which employ a new technology to increase the quality of goods sold often require that customers adopt some aspect of the technology, and this adoption is typically costly. This study proposes a model of goods supported by interorganizational information systems (IOS) that captures the effects of increased quality and customer adoption costs. The model is developed for monopoly and duopoly, assuming non-IOS goods continue to be viable. Supporting the hypothesis that adoption costs act as a barrier to customers using IOS, our general results raise the possibility of a subsidy for IOS adoption, particularly when the added value after adoption is indispensable and when IOS adopters purchase similar or greater quantities to those they would purchase without IOS. Consistent with the notion that firms are better off with differentiated goods to reduce direct competition, duopoly results confirm that if one firm has an IOS then that firm should offer only the IOS-supported good and abandon the unsupported good to the competitor. These results also make clear that both firms can be made better off by only one introducing the IOS. Moreover, not only can the IOS result in benefits to both firms, but in aggregate customers may also be better off. In designing an IOS, any reduction in the cost of information technology inputs, or in the cost of increasing attributes such as timeliness, accuracy and fineness, results in a superior IOS offering, increasing the quality of the IOS-supported good. Prices for goods sold, however, do not necessarily increase with the quality of IOS support.

1 Introduction

Objective. The objective of this paper is to examine the impact of quality differentiation afforded by an interorganizational information system (IOS) and of customer IOS adoption costs on IOS pricing. We develop an industrial organization (IO) model of IOS design and pricing by suppliers to customers in monopoly and duopoly settings. To address both quality differentiation of goods traded through the IOS and customer IOS adoption costs, our models have suppliers selecting the level of IOS quality and setting a two part tariff. We draw implications for both IOS pricing, and in the duopoly setting, supplier and customer welfare. In addition to IOS, our results apply to the critical domains of electronic data interchange (EDI) and electronic funds transfer (EFT).

We consider three main questions. The first is whether, in the presence of customer adoption costs, the fixed tariff could take the form of a subsidy. Our result is that the optimal (in the case of monopoly), or equilibrium (in the case of duopoly) fixed tariff can in fact be a subsidy whereas the variable tariff always produces positive profits. The second question is whether in a duopoly setting suppliers will compete directly or will choose to partition the market. Our result is that the supplier with the IOS chooses to reduce competition by only offering the IOS-supported good, leaving the remainder of the market to the supplier without the IOS. This result implies that both suppliers are better off with only one offering the IOS. Moreover, in aggregate customers may also be better off because of the added value provided by the IOS. The third question is whether an increase in IOS quality increases prices. Our result is that a superior IOS does not necessarily mean that prices are higher. These questions and results are important because they provide a framework for understanding when a supplier might subsidize the adoption of an IOS and when suppliers, and perhaps customers, may be better off with only one introducing an IOS. The latter gives an alternative to the view of IOS as a strategic necessity (Clemons and Kimbrough, 1986). These questions and results are also important because they show that one should not always expect IOS improvements to be reflected in prices.

Background Examples. To ground our model in empirical observations we briefly describe four "paradigm" examples to motivate our arguments.

(1) American Hospital Supply Corporation (AHSC) used an order processing IOS, called ASAP, to link directly with their hospital customers (HBS Case Services, 1985).

(2) Pacific Pride Systems, a commercial fueling company, provided its "cardlock" IOS to customers, giving secure, 24 hour access to fuel, and improved reporting of fuel purchases. The cardlock operates like a banking automated teller machine (HBS Case Services, 1985; Nault and Dexter, 1992).

(3) McKesson Drugstore offered its order processing IOS called Economost to small independent drugstores, providing them with delivery and inventory advantages necessary to compete with larger drugstore chains (Clemons and Row, 1988).

(4) The Port of Singapore created TradeNet, an industry-wide platform to facilitate EDI-based processing of commercial trade documents. TradeNet is a partnership of government agencies and private sector firms for the electronic processing of goods shipments (HBS Case Services, 1990).

There is substantial case evidence that indicates IOS support improves the quality of a good by adding value. While these enhancements can be to the good itself, they more frequently result from improved transactions between suppliers and customers. For example, computer reservations systems in the airline industry provided airlines with a product advantage because passenger inquiries could be processed more quickly and effectively (Copeland and McKenney, 1988). Referring to our paradigm examples, as part of an overall materials management system, hospitals that adopted AHSC's ASAP benefitted from lower inventory, lower shrinkage and spoilage, reduced paper work, and assured and timely delivery of hospital supplies. Pacific Pride's cardlock system provided customers with convenience, control, and credit: access to fuel 24 hours a day across a broad network of locations without requiring drivers to carry cash or credit cards, quicker fueling time, detailed statements of fuel purchases throughout the network for monitoring and tracking, and credit similar to general purpose credit cards. McKesson's Economost allowed customers to enter the drugstore's complete order into a single hand held device and transmit the order directly to McKesson, reducing transaction costs. Drugstore inventories and stockouts were significantly reduced as deliveries were made the same or following day, and restocking was facilitated as the order arrived specially sorted for the particular drugstore's physical layout, with price stickers provided to reflect the specific drugstore's pricing policy. Economost also provided detailed management reports on the drugstore's purchases and sales. Finally, the companies using TradeNet experienced dramatic reductions in turnaround time for trade documents which led to much faster shipments to customers. Other benefits included more effective logistics and improvements in the use of human resources as there was no longer a need to courier documents to various offices or airports.

An IOS usually requires that the customer adopt new information technology (IT), and this adoption process is often costly. These costs take various forms, from cash outlays for equipment to the organizational costs of doing things differently. As a rule, these costs are lumpy. That is, rather than being ongoing, the bulk of these costs are incurred only once or over a short period of time.[1] Our examples clearly illustrate the nature of these costs.

(1) In the AHSC case, these start-up costs included the purchase of hardware and software, customizations to the ASAP software for a specific hospital's information system, ASAP

[1]For example, integrating the IOS into a firm's operations (Bakos, 1991), or terminating prior contractual arrangements (Chismar and Meier, 1992).

training, and the reorganization of inventory and procedures.

(2) For companies adopting the cardlock IOS the costs included training drivers to use Pacific Pride's cardlock equipment and to learn the whereabouts of new cardlock stations, issuing and distributing cardlock cards and overcoming driver resistance to change.

(3) For drugstores adopting McKesson's Economost, costs included relabeling inventory, data conversion, and data entry.

(4) Costs for Singapore's TradeNet adopters included hardware and software purchases, and implementing new procedures and protocols for trade documents.

We argue that the IOS supplier can influence the impact of quality differentiation and adoption costs through its choice of pricing. In addition to unit premiums or discounts for IOS-supported goods, the supplier may also charge for, or subsidize, IOS access. An access charge would add to the total costs customers face for adoption. In contrast, a subsidy would reduce barriers to adoption. The IOS supplier can directly affect quality differentiation through its choice of IOS design.

Examples of different unit prices for goods supported and not supported by IOS abound. AHSC charged a premium of between 1-2% on supplies sold through ASAP, even after competitors responded. Pacific Pride maintained a premium of between 5-12% of retail price for use of its cardlock system (Nault and Dexter, 1995). In contrast, unit discounts were given to independent drugstores purchasing through McKesson Drug's Economost. Tradenet customers could submit several EDI documents in a batch for the same submission fee as a single pre-Tradenet document, thereby realizing a quantity discount.[2] Of course, most of us experienced differential transaction fees at automated teller machines versus human tellers (Felgran and Ferguson, 1986).

[2] Personal communication, John L. King, may 1993.

Many examples also indicate that explicit fixed cost reductions through the use of implicit subsidies, in the form of customer support, have been used by suppliers to mitigate customer IOS adoption costs. In each of our paradigm examples, suppliers have devoted time and effort in order to ease customer's transitions to their IOS.

(1) AHSC staff helped physically rearrange inventory to get a hospital started on ASAP. Software was customized at no charge by AHSC to integrate ASAP into a customer's information system and ASAP itself was offered at no charge.

(2) Pacific Pride spent significant time meeting with the customers to train drivers, keeping customers informed of new stations, and managing the issuing of cardlock cards to help offset client costs of overcoming resistance to change.

(3) Competition led McKesson to bear the full cost of switching a drugstore onto its system, for example, relabeling inventory, entering and converting data.

(4) TradeNet is different because the state authority mandated EDI adoption for all trade transactions. Customers were forced to pay a one-time connection fee. In many cases, however, the Trade Development Board of Singapore provided incentives to small companies, those with the lowest perceived benefits, to adopt. These incentives included providing special EDI service centers, conveniently located and at minimal cost, to overcome barriers to adoption.

Similar offers have been observed in the deregulated telephone industry (Klemperer, 1987a).

Prior IOS Research Using IO Models. Models borrowed from IO can help us understand the related impacts of IOS on (i) industry concentration, (ii) intra- firm structure, and (iii) inter-firm competition, which we discuss in turn. IOS can affect industry concentration through changes the traditional measures of concentration related to the distribution of market power among firms in an industry, and through changes the structure of an industry, for example, adding or deleting intermediaries. IOS can also be used to improve the way a given firm or alliance is organized, making it more competitive. Finally, IOS can affect inter-firm competition along dimensions such as pricing, switching costs, investment, and introduction timing.

We begin with industry concentration. Using a stylized model of a single buyer facing linear demands and offering EDI to a group of suppliers with quadratic costs, Wang and Seidmann (1995) found that partial adoption of EDI by the supplier base may be optimal for the buyer, and because of the resulting cost differentials the buyer market may become more concentrated. Supporting these results Bakos and Brynjolfsson's (1993) findings suggest that as supplier noncontractible investments become more important, a buyer must precommit to purchasing from fewer suppliers in order to give each of the chosen suppliers sufficient investment incentives. Consistent with these results, in a model that specified investments in response to Nash bargaining between a supplier and many buyers, Clemons and Kleindorfer (1992) found that there may be a point at which an additional buyer does not add to individual buyer revenue, but this point will be passed as each buyer finds IOS participation to be a strategic necessity. In contrast, Riggins et al. (1994) assumed a buyer was better off the more suppliers adopted the IOS. As a result, they found that while it may be optimal for the buyer to subsidize adoption for later adopters, adopters have an incentive to wait for the subsidy.

Together, this group of papers illustrate the tensions at work in determining the effect of an IOS on market power: while the IOS offering works best with fewer firms, there are incentives for all firms to join. Published IO models of IOS affecting changes in industry structure are lacking to date. An example of promising work is the implications of search costs on intermediary-run electronic marketplaces.

Next we move to intra-firm structure. Using a franchising form of organization, Nault and Dexter (1994) showed that an IOS used to redistribute profits between franchises based on the improved tracking of activities the franchise controls increases investments across franchises and increases franchisor profits. In addition, because of the tension between the positive network externality from adoption and the negative investment externality from redistribution, universal adoption is not optimal except in extreme cases. In an analysis employing ownership as the basis for investments and resulting payoffs in an IOS network, Bakos and Nault (1995) showed that in absence of an indispensable participant, joint ownership is the best form of IOS ownership and assets that are essential to all should be owned together.

Both of these papers showed that an IOS can improve firm performance through increased investment incentives in the firm's activities. The second paper indicates that IOS investment incentives are critical to the performance of IOS. Particularly as network organizations become more important, there is continued work needed on issues relating to IOS impacts on firm centralization and on inter-firm coordination.

Finally, we examine inter-firm competition. Both Wang and Seidmann (1995) and Riggins et al. (1994) partially addressed pricing by incorporating an adoption subsidy in their models. In addition, Bakos and Bryjolfsson (1993) and Clemons and Kleindorfer (1992) include IOS investments as part of their model. The remaining issues of inter-firm competition are open to new work. The most promising opportunities are for combining the competitive effects such as pricing with switching costs, as we do in the present paper, perhaps incorporating these in a game of introduction timing. It is noteworthy that there is also little prior work on economic approaches to information systems design (for example Barua et al., 1989) and even less on IOS design.

Thus, our paper fits into this latter stream of inter-firm competition. While other studies employed subsidies, they did not consider whether a subsidy policy was the optimal *policy* in the sense that we allow for a fixed fee or subsidy. Moreover, they did not include an analysis of pricing of the supported goods, whereas the interaction between the fixed and variable pricing components is explicit in our model. Relating our work with IOS design, we argue that increases in quality are a result of increases in attributes associated with the information economics paradigm, that is, timeliness, accuracy and fineness (Feltham, 1968; Marschak and Radner, 1972; Hilton, 1979; Ahituv, 1980; Hilton, 1981). Quality differentiation incorporates the impact of providing customers with more timely, more accurate and finer information. These attributes, combined with decisions customers make, determine the amount of quality enhancement provided by the IOS. Improvements in each attribute can separately increase IOS quality.

While not part of this paper, the next stage of this line of work is to incorporate the introduction of successive generations of IOS. This requires an analysis of competition with more than one IOS, an analysis which can then be used to determine when, or how far apart, different generations should be launched. This later aspect requires the modelling of diffusion dynamics.

Another direction for future analysis is to generalize our model to the case where a buyer offers the IOS to suppliers, along the lines of GM and its suppliers with EDI. Other studies described above addressed this question in a limited way, but did not specify the pricing arrangements. Our present model would have to be adapted to accommodate the buyer setting the fixed price and the suppliers setting the variable price. We speculate that, in contrast with studies that suggest a subsidy, the buyer may be able to charge for IOS access. However, firm results await a more compete specification.

Previous Studies. Focusing on preemptive investment and entry, Judd (1985) showed that in a duopoly with differentiated goods, firms will choose not to compete head to head with the same good but rather will select different niches, even if an incumbent can begin by producing a range of goods. Shaked and Sutton (1982) found that under certain conditions a range of qualities could be sustained by an oligopoly in equilibrium.[3] In addressing the question of duopoly competition, our quality differentiation model incorporates the spirit of both the above models. In contrast to Judd (1985) we explicitly model customer willingness to pay, quality differentiation, adoption costs, and prices. As opposed to Shaked and Sutton (1982) we allow customers to purchase varying quantities and model adoption costs and a two part price.

Studies of adoption costs have focused on customers changing suppliers subsequent to initial adoption, studying the impact of switching costs on prices both before and after the first adoption. Results are equivocal. Some models suggest markets with switching costs are more competitive (von Weizsacker, 1984) in the sense that the difference in unit prices for differentiated goods offered by different suppliers is smaller, while others indicate the opposite (Klemperer, 1987b). These results hinge on the ability of suppliers to change unit prices after customers are locked in, where unit price changes can make the market less competitive. In an IT context, it has been shown that switching costs can have a negative impact on consumer welfare and that industry profits can either increase or decrease depending on the IT efficiency of the first-mover (Barua et al., 1991), and that switching costs cause friction that can increase or decrease industry profits (Davamanirajan et al., 1991). While we do not consider customers switching suppliers, IOS adoption costs in our model act as a barrier, causing some customers that would otherwise adopt to remain non-IOS based.

[3]Other studies include Mussa and Rosen (1978) on monopolist choice of quality, and Gal-Or (1983) on oligopoly. An analysis of IOS investment, the division of surplus between buyer and seller, and the stability of buyer-seller agreements can be found in Clemons and Kleindorfer (1992).

Because a unit price together with a fixed price constitutes a two part price, work on multipart pricing bears directly on our question of whether customer adoption costs influence the direction of the fixed price, that is, whether the fixed price is a charge or a subsidy. The main results from the literature on two part tariffs is that positive unit profits and a fixed charge constrained at the lower bound by zero are optimal (Schmalensee, 1981). More generally, the Goldman et al. (1984) study of nonuniform prices found Ramsey prices over different quantities, with the possibility of a fixed charge to customers entering the market, as optimal. Similar results were found while allowing for customers purchasing varying quantities at different levels of quality (Oren et al., 1982). Subsequent work focused on a symmetric Cournot oligopoly with a single homogeneous good where all firms predict market share captured by competitors and then each selects their own tariff assuming static competitor behavior (Oren et al., 1983). The main results suggest positive profits can be made in equilibrium for an oligopoly, with the polar cases of one supplier or infinitely many suppliers resulting in the usual monopoly and perfect competition solutions, respectively. In addition, with a fixed supplier cost per customer both a fixed charge and a minimum purchase quantity were obtained. None of this prior work considered customer adoption costs and differentiated goods.

Scope of the Analysis. This paper centers on the case of a market where suppliers offer two goods vertically differentiated by IOS, with adoption of the higher quality (IOS-supported) good incurring a fixed adoption cost on the part of customers. Customers are utility maximizers who differ along a continuum in their tastes for quality. Suppliers do not know and cannot observe individual customer's taste, but know the distribution of tastes. Suppliers can set an access fee or a subsidy for the adoption of the IOS as well as a unit price for the IOS-supported good (a two part tariff), and a unit price for the unsupported good. The analysis is general, that is, no assumptions of functional forms are necessary.

The paper is organized as follows. Section 2 examines the monopolist choice of prices. Section 3 considers the duopoly problem, studying the market structure, solving for prices and subsequently implications for suppliers and customers. Section 4 compares the monopoly and duopoly results. Section 5 analyzes the impact of choices made in IOS design on prices, and the Summary section concludes the paper. The Appendix includes proofs and many of the mathematical derivations.

2 Monopolist with IOS

We first consider a monopolist who has implemented an IOS, but also continues to offer the good to those customers who choose not to adopt the system. In contrast to Oren et al. (1982) where one customer can consume units of different quality, customers here select only one of the two types of goods. For example, if a customer adopts an IOS that supports order processing, then that customer will not continue to process orders manually. As customers face adoption costs for IOS access, the monopolist sets a corresponding two part tariff.

Demands. Customers are heterogeneous in their tastes for quality and these differences are represented by the taste parameter θ, $\theta \in \Theta$. θ follows the density function $f(\theta) > 0$ over the closed interval $[\underline{\theta}, \bar{\theta}]$. This density has a cdf $F(\theta)$, so $F(\underline{\theta}) = 0$ and $F(\bar{\theta}) = 1$. Subscripts 1 and 0 denote the IOS-supported and unsupported goods respectively. Preferences for the IOS-supported good follow $U_1(q_1, \theta)$ where

$$U_1(q_1, \theta) = \begin{cases} V_1(q_1, \theta) - R - p_1 q_1 - \kappa & \text{if } q_1 \geq 0 \\ 0 & \text{otherwise, } q_1 = 0. \end{cases}$$

Preferences for the unsupported good follow

$$U_0(q_0, \theta) = \begin{cases} V_0(q_0, \theta) - p_0 q_0 & \text{if } q_0 \geq 0 \\ 0 & \text{otherwise, } q_0 = 0. \end{cases}$$

$V_i(q_i, \theta)$ is the utility derived from quantity q_i by a customer with taste θ, in other words the customer's willingness to pay. $V_i(q_i, \theta)$ is twice continuously differentiable, increasing and concave in q_i, and increasing in θ. That is, willingness to pay is increasing in quantity at a decreasing rate, and higher taste customers are willing to pay more for an additional unit. $\frac{\partial^2 V_i(q_i,\theta)}{\partial q_i \partial \theta}$, is positive, and $V_i(0, \theta) = 0$. The adoption cost is $\kappa > 0$, $R + p_1 q_1$ is the two part tariff, and p_0 is the unit price of the unsupported good. The IOS- supported good is of higher quality; thus $V_1(q, \theta) > V_0(q, \theta)$ for a given θ and q. Customers select only one of the two types of good, for example EDI-supported versus paper-based purchasing, and we assume that income changes related to purchasing either good are negligible.[4]

Our preference structure, which is critical to our results, is both quasi-linear and supermodular. That is, willingness to pay and price are additively separable and marginal willingness to pay is increasing in taste. These restrictions, traditional in non- linear pricing research (Tirole, 1988), cause higher taste customers to have larger demands.[5]

We assume that at equilibrium prices the market is covered. In effect, all customers purchase one of the two goods. In addition, we assume a separation condition holds for all $\theta \in \Theta$:

$$\frac{\partial V_1(q_1(p_1, \theta), \theta)}{\partial \theta} > \frac{\partial V_0(q_0(p_0, \theta), \theta)}{\partial \theta}.$$

This condition implies that, at equilibrium values of the demands, $q_1(p_1, \theta)$ and $q_0(p_0, \theta)$, the distance between indifference curves of different customers is larger for the IOS-supported good. That is, the willingness to pay function for the IOS-supported good is more sensitive to differences in customer tastes than the unsupported good at equilibrium demands. Because this condition is required only at equilibrium demands and the market is covered, this

[4]This assumption is common (for example Leland and Meyer (1976), Oren et al. (1982), and Oren et al. (1983)).

[5]There is no unique way in which IOS affects the structure of $V_1(q_1, \theta)$ because IOS can have a variety of impacts ranging from added value to reduced costs (Nault and Dexter, 1992). We follow a tradition of capturing a variety of IOS effects (for example Barua et al., 1991) in our analysis in Section 5.

restriction is less severe than it may initially appear since demands are unlikely to be close to zero.[6]

Consider the customer's optimal choice of quantity for each type of good. Examining first the IOS-supported good, each customer with taste parameter θ chooses q_1 to maximize utility,

$$\max_{q_1} U_1(q_1, \theta) \quad \ni \quad q_1 \geq 0.$$

The first order (Kuhn-Tucker) conditions are

$$\frac{\partial V_1(q_1, \theta)}{\partial q_1} - p_1 \leq 0, \;\; q_1 \geq 0, \quad \text{and} \quad [\frac{\partial V_1(q_1, \theta)}{\partial q_1} - p_1]q_1 = 0.$$

An interior solution defines a demand function, $q_1(p_1, \theta)$, that is decreasing in p_1 and increasing in θ. The fixed component of the two part tariff, R, and the adoption cost, κ, do not affect individual demand, as they drop out of the first order conditions. Hence, the fixed component and adoption cost affect the decision of whether or not to adopt rather than how much to purchase. For the unsupported good, each customer maximizes utility by choosing q_0,

$$\max_{q_0} U_0(q_0, \theta) \quad \ni \quad q_0 \geq 0.$$

The first order (Kuhn-Tucker) conditions are

$$\frac{\partial V_0(q_0, \theta)}{\partial q_0} - p_0 \leq 0, \;\; q_0 \geq 0, \quad \text{and} \quad [\frac{\partial V_0(q_0, \theta)}{\partial q_0} - p_0]q_0 = 0,$$

with an interior solution defining, $q_0(p_0, \theta)$, that is decreasing in p_0 and increasing in θ. Each customer chooses which good to purchase by

$$\max\{U_1(q_1(p_1, \theta), \theta), U_0(q_0(p_0.\theta), \theta)\}$$

[6]A numerical example using a quadratic willingness to pay function where this separation condition is met is available from the author.

A customer who is indifferent between the IOS-supported good and the unsupported good, $\tilde{\theta}(R, p_1, p_0)$, is implicitly defined by the condition $U_1(q_1(p_1, \tilde{\theta}), \tilde{\theta}) = U_0(q_0(p_0, \tilde{\theta}), \tilde{\theta})$, or

$$V_1(q_1(p_1, \tilde{\theta}), \tilde{\theta}) - R - p_1 q_1(p_1, \tilde{\theta}) - \kappa = V_0(q_0(p_0, \tilde{\theta}), \tilde{\theta}) - p_0 q_0(p_0, \tilde{\theta}).$$

Using $\tilde{\theta}$ in place of $\tilde{\theta}(R, p_1, p_0)$ to save on notation, if $\tilde{\theta}$ exists, then all customers with taste parameters greater than the indifferent customer adopt the IOS, those with θ below $\tilde{\theta}$ do not. Uniqueness of $\tilde{\theta}$ and the separation of customers follows from the monotonicity of the utility functions, interior solutions to utility maximizations, and the separation condition.[7]

Normalizing the number of customers to unity, the fraction of customers who adopt the technology is

$$N(R, p_1, p_0) = \int_{\tilde{\theta}}^{\bar{\theta}} f(\theta) d\theta = 1 - F(\tilde{\theta}).$$

Aggregate demand, or total quantity purchased, of the IOS-supported and unsupported good are respectively

$$Q_1(R, p_1, p_0) = \int_{\tilde{\theta}}^{\bar{\theta}} q_1(p_1, \theta) f(\theta) d\theta$$

$$Q_0(R, p_1, p_0) = \int_{\underline{\theta}}^{\tilde{\theta}} q_0(p_0, \theta) f(\theta) d\theta.$$

Supplier Profit Maximization. The monopolist's profit maximization problem is an optimization over three price components: R, p_1, and p_0:

$$\max_{R, p_1, p_0} \pi(R, p_1, p_0) = \max_{R, p_1, p_0} [RN(R, p_1, p_0) + [p_1 - c_1] Q_1(R, p_1, p_0) + [p_0 - c_0] Q_0(R, p_1, p_0)],$$

where $c_1 > c_0$ are the constant marginal costs.[8] The resulting system is solved in Appendix 1.

[7] If $\tilde{\theta}$ does not exist then either all customers adopt the IOS or no customers adopt.

[8] c_1 would include marginal IOS costs as well as production costs. There is no loss of generality omitting a fixed IOS implementation cost and a fixed cost per additional subscriber.

Because of our focus on customer IOS adoption costs, it is of interest to divide profits from the IOS-supported good into variable profits from the unit component of the two part tariff, and profits from the fixed component. The following proposition, proved in Appendix 2, determine the signs of the variable profits and profits from the IOS-supported and unsupported goods respectively.

Proposition 1: *Variable profits from the IOS-supported good are positive. Profits from the unsupported good are positive.*

Proposition 1 implies that because positive variable profits are earned on the IOS- supported good, the fixed component may be used as a subsidy for adoption. In addition, Proposition 1 implies that in the extreme the monopolist may not wish to offer the unsupported good. This is because positive profits from the unsupported good means pricing above marginal cost, which may reduce $\tilde{\theta}$ below $\underline{\theta}$ with the result that all customers adopt the IOS.

The sign of the fixed component of the two part tariff, R, cannot be found. To see this, substitute the variable contributions for both the IOS-supported and unsupported goods into the equation for R:

$$R = \frac{N(R, p_1, p_0)}{f(\tilde{\theta})\frac{\partial \tilde{\theta}}{\partial R}} - q_1(p_1, \tilde{\theta})[p_1 - c_1] + q_0(p_0, \tilde{\theta})[p_0 - c_0].$$

Because both variable contributions are positive, and demands from the marginal customer, $\tilde{\theta}$, are positive, the sign of the fixed component is ambiguous. Therefore, it may be optimal for the monopolist to either *tax* or *subsidize* adoption.[9] From inspection of the pricing equations, a subsidy is likely to occur when the added value from the IOS after adoption is

[9] We tried two forms of quadratic willingness to pay functions, including one based on Leland and Meyer (1976). Neither yielded analytical results that could be signed and numerical analysis was inconclusive. In fact, closed form solutions of the type obtained by Leland and Meyer (1976) for a two part tariff can no longer be obtained from their specification after the addition of an adoption cost term.

indispensable and when IOS adopters purchase similar or greater quantities to those they would purchase without IOS. This situation occurs when IOS adoption more closely ties the production processes of the customer with those of the supplier, such as just-in-time inventory systems, and corresponds to higher margins from a lower price elasticity for the IOS-supported good, together with a small number of customers relative to quantities. These pricing results also emphasize that joint pricing, evident through the last two terms of R, is critical.

Discussion. Prior studies of single-good monopolists using two part tariffs have demonstrated that the fixed component would never be used as a subsidy (Schmalensee, 1981). It can be shown that in the presence of a fixed adoption cost this result no longer holds. In the single-good case, the fixed subsidy is limited by the adoption cost. In our model we have customers with an alternative choice: the unsupported good. This added option means that customers can derive positive benefit without adopting the IOS, that is, by purchasing the unsupported good. Therefore, the effectiveness of a subsidy to encourage IOS adoption is not necessarily limited by the customer adoption cost.

As compared to earlier work in IO (Schmalensee, 1981 and Tirole, 1988), the addition of a fixed adoption cost that is the same for all customers causes the previously conclusive result (that a fixed subsidy should never be paid) to become inconclusive. This comes about because of the seemingly innocuous assumption that all the action on the customer's side (that is, outside of the two-part tariff) is captured in a function which is zero when quantity is zero. Our fixed adoption cost is the simplest addition that could be made and is a feature associated with almost all adoptions of new technology. That these earlier results then fail indicates that the structure, and results that have been derived from it in the past, are more brittle than the literature suggests.

In essence, significant variable profits from greater margins and similar or larger purchase quantities allow for adoption subsidies. Moreover, in industrial markets, those with large volume purchases, case evidence strongly supports the use of implicit subsidies to overcome adoption costs (Nault and Dexter, 1992). Our examples, discussed in the introduction, confirm supplier adoption support. AHSC and McKesson helped reorganize their customer's inventory and bore the IT-related costs of purchase, installation and modification. Pacific Pride and the Port of Singapore also took active steps to secure a customer's IOS implementation. In yet another EDI example, larger customers of the IBM value added network have modified and provided at their own cost IBM PC-based EDI software to smaller clients.

3 Duopoly With One IOS

This model examines the case where only one supplier in a duopoly has the ability to offer an IOS. The formulation divides the game into two stages. In the first stage, the supplier with the IOS decides the basis of competition by selecting which portfolio of goods to offer. In the second stage, the suppliers compete in prices. This model bears similarity to the duopoly problem studied by Judd (1985). We collapse his first three stages into one decision, and fully specify the details of price competition.

Formulation. There are two suppliers, A and B, where supplier A has the IOS, and supplier B does not. The model is a two stage game where:

- Stage 1: Supplier A decides between three strategies: offering both the IOS- supported and unsupported goods, offering the IOS-supported good, or offering the unsupported good.
- Stage 2: Suppliers A and B compete in prices.

There is complete information, and the solution concept employed is subgame perfect equilibrium. Thus, each of the possible Stage 2 subgames must be characterized by a Nash equilibrium in prices.

The solution for the subgame perfect equilibrium is obtained by working backwards through the two stages of the game. Based on supplier A's strategies in Stage 1, there are three possible subgames at Stage 2 where suppliers compete in prices:

- S2.1: Supplier A offers both goods, supplier B offers the unsupported good.
- S2.2: Supplier A offers the IOS-supported good, supplier B offers the unsupported good.
- S2.3: Supplier A and B each offer the unsupported good.

We proceed to determine the equilibrium for each of these subgames.

Stage 2 Subgame: S2.1. Supplier A selects three prices: two components of the two part tariff, R and p_1, and the unit price of the unsupported good, p_0^A. Supplier, B, chooses p_0^B. Customers purchase from the supplier with the lowest price for a given good; thus the effective p_0 is

$$p_0 = \min\{p_0^A, p_0^B\}.$$

If $p_0^A = p_0^B$ then demand for the unsupported good is partitioned equally. Individual and aggregate demands are the same as those developed in Section 2.

Focus first on supplier B setting p_0^B. Supplier B faces contingent aggregate demands for the unsupported good, with a given R and p_1, for p_0^B relative to p_0^A:

$$Q_0^B(R, p_1, p_0) = \begin{cases} Q_0(R, p_1, p_0) & \text{if } p_0^B < p_0^A \\ Q_0(R, p_1, p_0)/2 & \text{if } p_0^B = p_0^A = p_0 \\ 0 & \text{if } p_0^B > p_0^A. \end{cases}$$

For supplier B, maximizing profits $\pi^B(p_0^B; R, p_1, p_0^A)$ means solving

$$\max_{p_0^B} \pi^B(p_0^B; R, p_1, p_0^A) = \max_{p_0^B}[[p_0^B - c_0]Q_0^B(R, p_1, p_0)].$$

Contingent on p_0^A, the possible outcomes to different choices of p_0^B are

$$\pi^B(p_0^B; R, p_1, p_0^A) = \begin{cases} [p_0^B - c_0]Q_0(R, p_1, p_0) & \text{if } p_0^B < p_0^A \\ [p_0 - c_0]Q_0(R, p_1, p_0)/2 & \text{if } p_0^B = p_0^A = p_0 \\ 0 & \text{if } p_0^B > p_0^A. \end{cases}$$

Studying $\pi^B(p_0^B; R, p_1, p_0^A)$, it is always optimal for supplier B to undercut p_0^A down to marginal cost. That is, the supplier with the unsupported good only is always better off undercutting the competition's price by an arbitrarily small amount than having to share demand, at unit prices above marginal cost. This result is the familiar Bertrand Paradox. Therefore, supplier B's reaction function is

$$\phi(p_0^A) = p_0^B = \begin{cases} p_0^A - \varepsilon & \text{if } p_0^A > c_0 \\ c_0 & \text{otherwise} \end{cases}$$

for $\varepsilon > 0$.

Now focus on supplier A. Supplier A faces aggregate demand in the unsupported good analogous to supplier B, given R and p_1, for p_0^A relative to p_0^B:

$$Q_0^A(R, p_1, p_0) = \begin{cases} Q_0(R, p_1, p_0) & \text{if } p_0^A < p_0^B \\ Q_0(R, p_1, p_0)/2 & \text{if } p_0^A = p_0^B = p_0 \\ 0 & \text{if } p_0^A > p_0^B \end{cases}$$

Using $\pi_i^A(R, p_1, p_0^A; p_0^B)$ to denote profits from good i, supplier A profit maximizing is

$$\begin{aligned} \max_{R, p_1, p_0^A} \pi^A(R, p_1, p_0^A; p_0^B) &= \max_{R, p_1, p_0^A}[\pi_1^A(R, p_1, p_0^A; p_0^B) + \pi_0^A(R, p_1, p_0^A; p_0^B)] \\ &= \max_{R, p_1, p_0^A}[\pi_1^A(R, p_1, p_0^A; p_0^B) + [p_0^A - c_0]Q_0^A(R, p_1, p_0)]. \end{aligned}$$

The three possible profit payoffs to supplier A selecting p_0^A relative to p_0^B are

$$\pi^A(R, p_1, p_0^A; p_0^B) = \begin{cases} \pi_1^A(R, p_1, p_0^A; p_0^B) + [p_0^A - c_0]Q_0(R, p_1, p_0) & \text{if } p_0^A < p_0^B \\ \pi_1^A(R, p_1, p_0^A; p_0^B) + [p_0 - c_0]Q_0(R, p_1, p_0)/2 & \text{if } p_0^A = p_0^B = p_0 \\ \pi_1^A(R, p_1, p_0^A; p_0^B) + 0 & \text{if } p_0^A > p_0^B. \end{cases}$$

From these payoffs supplier A's reaction function for p_0^A can de determined. It is clear that $p_0^A > p_0^B$ is dominated by both of the other alternatives when $p_0^B > c_0$. Here the supplier with both goods is always better off getting at least some of the unsupported good demand, given prices above marginal cost. Because the goods are substitutes, however, a lower priced unsupported good can cannibalize profits from the IOS-supported good. Thus, at some point this supplier may not wish to undercut the competition but only meet it. Therefore, supplier A's reaction function for p_0^A is

$$\phi(p_0^B) = p_0^A = \begin{cases} p_0^B - \varepsilon \text{ or } p_0^B & \text{if } p_0^B > c_0 \\ c_0 & \text{otherwise,} \end{cases}$$

for $\varepsilon > 0$. Thus,

$$\phi(p_0^A) = \phi(p_0^B) \text{ at } p_0^A = p_0^B = c_0$$

characterizes the Nash equilibrium p_0. The solution for the equilibrium R and p_1 are obtained as best responses to $p_0 = c_0$.

Supplier A's profit maximization for pricing the IOS-supported good is

$$\max_{R,p_1} \pi^A(R, p_1, c_0) = \max_{R,p_1} [RN(R, p_1, c_0) + [p_1 - c_1]Q_1(R, p_1, c_0)].$$

The necessary first order conditions result in a special case of Appendix 3 where $p_0 = c_0$.

Stage 2 Subgame: S2.2. Consider the case when supplier A offers the IOS-supported good, and supplier B offers the unsupported good. Supplier A maximizes profits by selecting R and p_1,

$$\max_{R,p_1} \pi^A(R, p_1, p_0) = \max_{R,p_1} [RN(R, p_1, p_0) + [p_1 - c_1]Q_1(R, p_1, p_0)].$$

Supplier B maximizes profits selecting p_0,

$$\max_{p_0} \pi^B(R, p_1, p_0) = \max_{p_0} [[p_0 - c_0]Q_0(R, p_1, p_0)].$$

The Nash equilibrium solution comes from a joint solution of the system of three first order conditions. The pricing equations are derived in Appendix 3.

Stage 2 Subgame: S2.3. In absence of the IOS, price competition between suppliers A and B in the unsupported good market is straightforward: the Bertrand Paradox is obtained where both suppliers price at marginal cost, $p_0^A = p_0^B = c_0$, and profits are zero.

Stage 1. At Stage 1 supplier A selects one of the three strategies, each represented by one of the subgames. In subgame S2.3 supplier A makes zero profits, and therefore, this strategy is dominated by either of the other two strategies in Stage 1. In subgame S2.1 supplier A also makes zero profits from the unsupported good in equilibrium. Thus, the comparison of subgames S2.1 and S2.2 hinges on the equilibrium profits from the IOS-supported good. The equilibrium two part tariff follows the same form in each of these subgames, except for the value of p_0. To compare subgames S2.1 and S2.2, and to address a possible adoption subsidy, we state Lemmas 1 and 2, analogous to Proposition 1. Lemma 1 is proved in Appendix 2, Lemma 2 has a proof analogous to the first part of Proposition 1.

Lemma 1: *In subgame S2.2 supplier B makes positive profits from the unsupported good.*

Lemma 2: *In subgames S2.1 and S2.2 variable profits from the IOS-supported good are positive.*

Addressing the fixed price, positive variable profits from the IOS-supported good make a fixed subsidy feasible. Similar to the monopoly model, the sign of R critically depends on the magnitude of the variable premium and the quantity purchased by the marginal customer:

$$R = \frac{N(R, p_1, p_0)}{f(\tilde{\theta})\frac{\partial \tilde{\theta}}{\partial R}} - q_1(p_1, \tilde{\theta})[p_1 - c_1]$$

As with the monopolist with two goods, this tax (subsidy) could be positive, negative, or zero. One can interpret this again as a case where the indispensability of the added value from the IOS reduces the price elasticity of the IOS-supported good, allowing a greater margin, as might be expected from more tightly bound production processes like just-in-time systems.

We can now determine the equilibrium of the game. Lemma 1 confirms that supplier B makes positive profits in subgame S2.2. Lemma 2 verifies that positive variable profits are made from the IOS-supported good in subgames S2.1 and S2.2, regardless of p_0. Because supplier A's profits are increasing in p_0 supplier A prefers subgame S2.2.

Proposition 2: *Supplier A offering the IOS-supported good and supplier B offering the unsupported good (S2.2) is the subgame perfect equilibrium.*

Proof: In subgames S2.1 and S2.3 the equilibrium $p_0 = c_0$. From Lemma 1 the equilibrium p_0 in subgame S2.2 is $p_0 > c_0$. Because $\tilde{\theta}$ is decreasing in p_0, supplier A makes larger profits in subgame S2.2 than in S2.1. □

Thus, the equilibrium of the game is supplier A offering the IOS-supported good, and supplier B offering the unsupported good. This raises two additional questions: under what conditions will both suppliers be better off as a result of the IOS- supported good, and when and by how much are customers better off in the aggregate as a result of the co-existence of the IOS and non-IOS supported good? [10] Intuitively, both suppliers will be better off in this equilibrium if each has purchasing customers because supplier B is pricing the unsupported good over marginal cost and supplier A must make positive profits otherwise it would price the IOS-supported good out of the market. That is, the IOS-supported good would be priced sufficiently high so that no customers purchase. Corollary 1 states a sufficient condition for both suppliers to be better off.

[10]We thank an anonymous colleague for encouraging us to pursue these questions.

Corollary 1: *A sufficient condition for both suppliers being better off as a result of the IOS-supported good is* $\tilde{\theta}\epsilon(\underline{\theta}, \bar{\theta})$.

Proof: Supplier B: In equilibrium $p_0 > c_0$ (Lemma 1) and $Q_0(R, p_1, p_0) > 0$, thus $\pi^B(R, p_1, p_0) > 0$. Supplier A: If in equilibrium $\pi^A(R, p_1, p_0) \leq 0$ then R and p_1 would not be optimal as either or both prices could be increased forcing $\tilde{\theta} \geq \bar{\theta}$. $\square$

Customers are not necessarily better off in the aggregate due to the presence of the two goods. As a baseline for comparison we consider marginal cost pricing for the unsupported good because this is what is obtained if the two suppliers engage in undifferentiated competition. Using the preference functions described earlier, we can state the condition under which customers are better off in the aggregate as a result of the co-existence of the two goods:

$$\int_{\tilde{\theta}}^{\bar{\theta}} [U_1(q_1(p_1, \theta), \theta) - U_0(q_0(c_0, \theta), \theta)]d\theta > \int_{\underline{\theta}}^{\tilde{\theta}} [U_0(q_0(c_0, \theta), \theta) - U_0(q_0(p_0, \theta), \theta)]d\theta.$$

The left hand side measures the extent to which customers that adopt the IOS are better off than they would be otherwise, that is, the value received purchasing optimal quantities of the IOS-supported good less the value received from purchasing optimal quantities of the unsupported good priced at marginal cost. The right hand side measures how much worse off customers that do not adopt the IOS are because of the premium over marginal cost charged for the unsupported good. Thus, only if the value gained by customers adopting IOS is greater than the value lost by those not adopting is the IOS beneficial to customers in the aggregate.

Discussion. The main result is that the two suppliers will segment the market, with one IOS supplier providing a supported good and the other supplier providing an unsupported good. The supplier with the IOS good extracts monopoly rents from that good, and does so by selling to customers with a greater preference for quality. The IOS supplier prefers not to sell the other good for that would cannibalize its own sales of the IOS good. Thus, price competition in the non-IOS good would dissipate profits from that good, and would cannibalize sales of the IOS good. The remaining supplier concentrates on the non-IOS good and becomes a monopolist in that market. This guarantees the other supplier a niche in the product market. This, however, reduces competition and might reduce the welfare of customers who prefer quality less strongly, as they now face a monopolist offering the non-IOS good.

The supplier with IOS is providing its competitor with an opportunity to make positive profits, and thus, in principle, both suppliers benefit from the IOS. This is consistent with IOS as a beneficial strategic necessity (Clemons and Kimbrough, 1986): IOS are strategically important - IOS affect industry structure and suppliers differ in their ability to exploit them. In addition, we find that IOS can yield competitive advantage not only for the innovating supplier but also for their competitor, an outcome that is inconsistent with the view of IOS as a strategic necessity, that is, all supplier must offer one. Our result depends on the suppliers being asymmetric in IOS technology. For if both suppliers had the same technology there would be greater competition and greater coordination problems in adoption.

The second insight is that not only are suppliers better off from the introduction of the IOS, but in aggregate customers may be better off. However, IOS, do not provide a Pareto improvement because those customers that do not adopt are faced with higher prices for the unsupported good. This again differs from the view that customers are always better off with IOS as long as they are not "forced" to adopt.

Returning to the issue of IOS implementation costs, if incurring these fixed costs are part of the Stage 1 strategy of offering the IOS-supported good, then for any strategy involving the IOS-supported good to be an equilibrium requires that profits from the IOS-supported good outweigh the fixed costs of implementation. This is analogous to a fixed cost of entry into a market (for example Judd, 1985).[11] If the assumption of a duopoly is abandoned, allowing for an oligopoly in the unsupported good market, then marginal cost pricing will be obtained in the unsupported good. Therefore, at Stage 1 the supplier with IOS will be indifferent between offering and not offering the unsupported good. Offering the IOS is still dominant. The equilibrium equations for the two components of the two part tariff remain the same. In this case all suppliers would not be better off, those without the IOS would continue to make zero profit. Customers, however, would be better off in the aggregate because those that do not adopt the IOS would not be penalized by higher unsupported good prices.

A potentially interesting situation is if the two unsupported goods were imperfect substitutes. Restricting our attention to cases where each customer purchases only one of the two types of goods, imperfect substitutes means the cross price elasticity between the two goods is not perfectly elastic: at any set of prices each of the goods have positive demand. As long as the quality added by the IOS does not increase this elasticity our result where only one supplier offers the IOS-supported good will still be obtained. This is because the IOS increases the differentiation between the two goods, thus mitigating competition allowing for higher prices.[12]

4 Comparison of Monopoly and Duopoly

Consider the pricing results obtained for the monopoly and duopoly models. In both cases the fixed component of the two part tariff could be either a tax or a subsidy. It is instructive to study these fixed components more closely. Employing the appropriate substitutions,

[11] If the supplier with IOS cannot cover the fixed implementation costs with profits from the IOS-supported good, it may be that the combined profits of both suppliers would more than cover these fixed costs.

[12] We thank an anonymous colleague for suggesting the case of imperfect substitutes.

Monopoly: $R = \frac{N(R,p_1,p_0)}{f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial R}} - q_1(p_1,\tilde{\theta})[p_1 - c_1] + q_0(p_0,\tilde{\theta})[p_0 - c_0].$

Duopoly: $R = \frac{N(R,p_1,p_0)}{f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial R}} - q_1(p_1,\tilde{\theta})[p_1 - c_1].$

Although $\tilde{\theta}$ is not equal in each case (different prices result) they have a similar structure. Recall that variable profits are positive (Proposition 1, Lemmas 1 and 2). We hypothesize that the fixed component is being used differently in the two cases: in the duopoly case the tax (subsidy) is lower in principle as the last term from the monopolist's fixed component is missing. As opposed to the monopolist, the duopolist accounts for competition by not forcing potential IOS adopters back, through increases in the fixed component, to the unsupported good.

There is no loss of generality in restricting our model to where all customers adopt one of the two goods as long as customers who purchase remain separated by $\tilde{\theta}$. Identical analytical results are obtained. The equations for the marginal contribution of the unsupported good changes with non-adopters as there is a lower bound on the customers served by the unsupported good which depends on unsupported good price.[13]

Implementability of this pricing approach depends on two issues. First is whether sufficient information can be obtained. While willingness to pay functions, individual demands at different prices, or the distribution of customer tastes may not be observable, prior observations of aggregate demands at different prices and qualities could be sufficient. Once a suitable form for the willingness to pay function is selected (for example, a quadratic), the form of the aggregate demands can be derived and the parameters estimated. Along with an estimate of customer adoption costs, prices could be found numerically. Perhaps the more difficult problem would be to impose a fixed tax on customers who have not previously been

[13] However, the concavity of the supplier's profit function may be more difficult to maintain with non-adopters, as non-adopters effectively form a third market (see Caplin and Nalebuff, 1991).

exposed to this pricing structure, or alternatively to convince supplier management that an adoption subsidy to customers is the correct strategy.

5 IOS Design

We now examine the impact of IOS design on supplier profits and prices. We focus on design decisions that are made prior to pricing decisions. To begin we develop some additional notation. Let the quality of the IOS be represented by the index $s \in S$, where increasing s is increasing quality. Using this index we can add to our earlier formulation of preferences for the IOS-supported good:

$$U_1(q_1, \theta, s) = \begin{cases} V_1(q_1, \theta, s) - R - p_1 q_1 - \kappa & \text{if } q_1 \geq 0 \\ 0 & \text{otherwise, } q_1 = 0. \end{cases}$$

In addition to our earlier assumptions, total and marginal willingness to pay are increasing in s, $\frac{\partial V_1(q_1,\theta,s)}{\partial s} > 0$ and $\frac{\partial^2 V_1(q_1,\theta,s)}{\partial q_1 \partial s} > 0$. An interior solution to utility maximization yields an individual demand function, $q_1(p_1, \theta, s)$, that is decreasing in p_1 and is increasing in θ and s. Thus, a higher quality IOS increases individual demand for the IOS-supported good.

The indifferent customer is defined as before except that it is now additionally a function of s, $\tilde{\theta}(R, p_1, p_0, s)$. To save space we will continue to write $\tilde{\theta}$ only. In Appendix 4 we show that both the fraction of customers that adopt, $N(R, p_1, p_0, s)$, and aggregate demand for the IOS-supported good, $Q_1(R, p_1, p_0, s)$ are increasing in s, while aggregate demand for the unsupported good, $Q_0(R, p_1, p_0, s)$, is decreasing in s.

Consider the IOS design choice. The supplier offering the IOS has to choose $s = \xi(\vec{x})$ where $\xi(\cdot)$ is a production function that converts IT inputs or attributes, $\vec{x}$, into an IOS with a particular functionality. The vector $\vec{x}$ can be viewed as "raw" inputs like hardware, software and telecommunications. $\vec{x}$ can also be seen as a set of information economics attributes which, as discussed earlier, can include timeliness, accuracy and fineness. The cost of the individual elements of $\vec{x}$, the factor input prices, are denoted by $\vec{w}$. The cost of implementing an IOS of quality s is defined as $\gamma(s, \vec{w}) \equiv \gamma(\xi(\vec{x}), \vec{w})$. We assume the function $\gamma(s, \vec{w})$ is linearly homogeneous in $\vec{w}$ and therefore costs are increasing in any element of $\vec{w}$. In addition, we assume $\gamma(s, \vec{w})$ is increasing and convex in s.

From the monopoly and duopoly pricing models examined in the previous sections we can express the profits of supplier A as $\Pi^A(R^*, p_1^*, p_0^*, s)$ where R^*, p_1^* and p_0^* are optimal, in the case of monopoly, or equilibrium, in the case of duopoly, prices. It is obvious that $\Pi^A(R^*, p_1^*, p_0^*, s)$ is increasing in s. We can write supplier A's problem of maximizing profits by choice of IOS design as

$$\psi(s) = \max_s [\Pi^A(R^*, p_1^*, p_0^*, s) - \gamma(s, \vec{w})].$$

The first derivative condition for maximizing profits is

$$\psi'(s) = \frac{\partial \Pi^A(R^*, p_1^*, p_0^*, s)}{\partial s} - \frac{\partial \gamma(s, \vec{w})}{\partial s} = 0.$$

This condition implicitly defines an optimal value function of IOS quality, $s(\vec{w})$. The sufficient condition for the second derivative to indicate a maximum is that $\Pi^A(R^*, p_1^*, p_0^*, s)$ is concave in s. Lemma 3 states our comparative static result on the impact of IT input prices on IOS design, and is proven in Appendix 5.

Lemma 3: *IOS quality is decreasing in IT input prices.*

Because of the decreasing costs of hardware and software technology, Lemma 3 implies that over time the level of IOS quality increases. We observe this in practice. The successive generations of AHSC's ASAP, for example, have consistently improved IOS support to the AHSC's customers.

In many cases it is natural to believe that prices increase with quality. Analysis by Klein and Leffler (1981) implies that *"... consumers can successfully use price as an indicator of quality."* (p. 634). In our model the optimal (monopoly) or equilibrium (duopoly) quality of the IOS can be effected by two exogenous factors. The first, captured by Lemma 3, is a decrease in input prices. The second is an improvement in the IOS production function, $\xi(\cdot)$. Both serve to increase the provision of quality. Consider the equilibrium unit price of the IOS-supported good from the duopoly solution in Appendix 3. This entails no loss of generality as the monopoly result is identical. The comparative static of the equilibrium p_1 with respect to s is

$$\begin{aligned}
&\frac{\partial p_1}{\partial s} = \\
&\quad [N(R,p_1,p_0,s)[\frac{\partial q_1(p_1,\tilde{\theta},s)}{\partial\tilde{\theta}}\frac{\partial\tilde{\theta}}{\partial s} + \frac{\partial q_1(p_1,\tilde{\theta},s)}{\partial s}] - \int_{\tilde{\theta}}^{\bar{\theta}} \frac{\partial q_1(p_1,\tilde{\theta},s)}{\partial s} f(\theta)d\theta]\sigma_1^{-1} \\
&\quad -[[N(R,p_1,p_0,s)q_1(p_1,\tilde{\theta},s) - Q_1(R,p_1,p_0,s)]\sigma_1^{-2} \\
&\quad [-\frac{\partial q_1(p_1,\tilde{\theta},s)}{\partial p_1} f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial s} + \int_{\tilde{\theta}}^{\bar{\theta}} \frac{\partial^2 q_1(p_1,\tilde{\theta},s)}{\partial p_1 \partial s} f(\theta)d\theta]].
\end{aligned}$$

This derivative cannot be signed, that is, unit price of the IOS-supported good is not necessarily increasing in IOS quality. This result balances two influences. Working in favor of an increased price is the gain in s, increasing individual demands, and the fraction of customers that adopt. This is represented in the first line. Working against an increased price is the price elasticity of demand, represented in the remaining terms. Thus, if customers are price elastic, then supplier A will not raise the price of the IOS-supported good but rather will increase profits from increases in quality through greater aggregate demand. The ambiguity about the effect of quality on the unit price of the IOS-supported good extends to both the fixed component of the two part tariff and the unit price of the unsupported good.

This result has important implications for both practice and empirical research. In practice, suppliers with IOS must recognize that increased profits can be attained through price and through quantity. Thus, increased prices for the IOS-supported good are not necessary. For empirical research there is evidence that IOS-supported goods can command price premiums, for example AHSC's ASAP and Pacific Pride's Cardlock system (Nault and Dexter, 1992; 1995). The presence of a price premium, however, is not sufficient evidence of IOS quality. Therefore, even in absence of an increase in the intensity of competition, higher quality of IOS support may not be manifested in the IOS-supported good prices.

6 Summary

The main objective of this paper has been to incorporate improved quality together with customer adoption costs in a model of IOS. Several results emerge. Variable profits are positive from the IOS-supported good, in both monopoly and duopoly. It is less clear that fixed profits from the IOS-supported good should be positive. In particular, when combined with customer adoption costs, a fixed subsidy rather than a tax may be a dominant strategy. Confirming the principle of differentiation, in a duopoly the supplier with an IOS is better off by not continuing to compete in the unsupported good.

While *explicit* subsidies are rare, cases of *implicit* subsidies in the form of customer support abound. For example, staff from AHSC often helped physically rearrange inventory to get a hospital started on IOS, and software customizations were often done to integrate their ASAP system into a hospital's information system (HBS Case Services, 1985). Competition between McKesson and a rival led to McKesson offering to bear the full adoption cost of their Economost IOS, which included relabelling inventory, data conversion, and data entry (Clemons and Row, 1988). We speculate this is because mitigation, for example the removal of adoption costs through customer support, is judged to be more valuable to the customer than compensation.[14]

[14]Studies in environmental economics suggest that, in certain cases, mitigation can be viewed as more

In a duopoly setting we find that suppliers choose to differentiate based on one introducing the IOS, leaving the non-IOS market to the other. As a result both suppliers are made better off by the IOS. Interestingly, customers in aggregate may also be made better off by IOS. Specifically, when the value gained by customers that adopt IOS outweighs the value lost through higher unsupported good prices by those that do not adopt, in aggregate customers are made better off. This betterment, however, cannot be a Pareto improvement because the non-adopting customers will be worse off.

An important assumption is that there are purchasing customers for both the IOS- supported and unsupported goods, our sufficient condition for both suppliers to be better off. This, of course, is not always true. Particularly for cases where the IOS yields large improvements in quality, there may be little or no market left for the unsupported good. Another assumption is that only one firm has the technological advantage. Should more than one firm use two part tariffs, each offering identical IOS-supported goods, a pure strategy Nash equilibrium may not exist, and if it does it will be at zero profit.[15]. Extensions to domains where one or both of these assumptions do not hold are fruitful areas for future research

We have also shown that a drop in the costs of IT inputs, or the cost of providing attributes such as timeliness, accuracy and fineness, will result in the design of a higher quality IOS. This increased quality, however, does not necessarily translate into higher prices for IOS-supported goods. Thus, in practice managers should not focus solely on price. Moreover, empirical research cannot make conclusions concerning IOS quality from studies of prices alone.

valuable than compensation (Knetch, 1990).

[15]This is in contrast with the analysis in Oren et al. (1983) which uses a Cournot model of competition.

7 Appendices

7.1 Appendix 1

The first order conditions for the monopolist offering both goods can be rearranged into the following system of equations

$$\frac{\partial N(R,p_1,p_0)}{\partial R}R+\frac{\partial Q_1(R,p_1,p_0)}{\partial R}[p_1-c_1]+\frac{\partial Q_0(R,p_1,p_0)}{\partial R}[p_0-c_0]=-N(R,p_1,p_0)$$

$$\frac{\partial N(R,p_1,p_0)}{\partial p_1}R+\frac{\partial Q_1(R,p_1,p_0)}{\partial p_1}[p_1-c_1]+\frac{\partial Q_0(R,p_1,p_0)}{\partial p_1}[p_0-c_0]=-Q_1(R,p_1,p_0)$$

$$\frac{\partial N(R,p_1,p_0)}{\partial p_0}R+\frac{\partial Q_1(R,p_1,p_0)}{\partial p_0}[p_1-c_1]+\frac{\partial Q_0(R,p_1,p_0)}{\partial p_0}[p_0-c_0]=-Q_0(R,p_1,p_0)$$

This system can be represented by the matrix equation $\Lambda\vec{y}=\vec{d}$ where

$$\vec{y}=\begin{pmatrix} R \\ p_1-c_1 \\ p_0-c_0 \end{pmatrix}$$

$$\vec{d}=\begin{pmatrix} -N(R,p_1,p_0) \\ -Q_1(R,p_1,p_0) \\ -Q_0(R,p_1,p_0) \end{pmatrix}$$

$$\Lambda=\begin{pmatrix} \frac{\partial N(R,p_1,p_0)}{\partial R} & \frac{\partial Q_1(R,p_1,p_0)}{\partial R} & \frac{\partial Q_0(R,p_1,p_0)}{\partial R} \\ \frac{\partial N(R,p_1,p_0)}{\partial p_1} & \frac{\partial Q_1(R,p_1,p_0)}{\partial p_1} & \frac{\partial Q_0(R,p_1,p_0)}{\partial p_1} \\ \frac{\partial N(R,p_1,p_0)}{\partial p_0} & \frac{\partial Q_1(R,p_1,p_0)}{\partial p_0} & \frac{\partial Q_0(R,p_1,p_0)}{\partial p_0} \end{pmatrix}.$$

In order to conserve space, let $\tilde{\theta}(R,p_1,p_0)$ be denoted as $\tilde{\theta}$ (i.e. dropping the arguments).

We assume the sufficient second order conditions are satisfied. The system can be solved using Cramer's rule. Solving for the determinant of Λ yields

$$|\Lambda|=-f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial R}\sigma_1\sigma_0<0.$$

Using the definition of $\tilde{\theta}$, the implicit function rule yields

$$\frac{\partial\tilde{\theta}}{\partial R} = 1/[\frac{\partial V_1(q_1(p_1,\tilde{\theta}),\tilde{\theta})}{\partial\theta} - \frac{\partial V_0(q_0(p_0,\tilde{\theta}),\tilde{\theta})}{\partial\theta}],$$

where $\sigma_1 = \int_{\tilde{\theta}}^{\bar{\theta}} \frac{\partial q_1(p_1,\theta)}{\partial p_1} f(\theta)d\theta$ and $\sigma_0 = \int_{\underline{\theta}}^{\tilde{\theta}} \frac{\partial q_0(p_0,\theta)}{\partial p_0} f(\theta)d\theta$.

From our assumption of the relative sizes of $\frac{\partial V_i(q_i(p_i,\theta),\theta)}{\partial\theta}$ this derivative is positive. Again using the implicit function rule

$$\frac{\partial\tilde{\theta}}{\partial p_1} = \frac{\partial\tilde{\theta}}{\partial R} q_1(p_1,\tilde{\theta}) > 0.$$

Through an almost identical analysis

$$\frac{\partial\tilde{\theta}}{\partial p_0} = -\frac{\partial\tilde{\theta}}{\partial R} q_0(p_0,\tilde{\theta}) < 0.$$

After substitutions and calling on Cramer's rule,

$$\begin{aligned} R = &\\ &\frac{N(R,p_1,p_0)}{f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial R}} - \frac{q_1(p_1,\tilde{\theta})[N(R,p_1,p_0)q_1(p_1,\tilde{\theta}) - Q_1(R,p_1,p_0)]}{\sigma_1} \\ &-\frac{q_0(p_0,\tilde{\theta})[N(R,p_1,p_0)q_0(p_0,\tilde{\theta}) + Q_0(R,p_1,p_0)]}{\sigma_0} \end{aligned}$$

$$p_1 - c_1 = \frac{N(R,p_1,p_0)q_1(p_1,\tilde{\theta}) - Q_1(R,p_1,p_0)}{\sigma_1}$$

$$p_0 - c_0 = -\frac{[N(R,p_1,p_0)q_0(p_0,\tilde{\theta}) + Q_0(R,p_1,p_0)]}{\sigma_0}.$$

7.2 Appendix 2

The proofs of Proposition 1 and Lemma 1:

Proof of Proposition 1: $q_1(p_1,\theta)$ is increasing in θ and decreasing in p_1. Hence, $p_1 - c_1 > 0$. $N(R,p_1,p_0)q_0(p_0,\tilde{\theta}) + Q_0(R,p_1,p_0) > 0$. $q_0(p_0,\theta)$ is decreasing in p_0. Therefore, $p_0 - c_0 > 0$. $\square$

Proof of Lemma 1: $Q_0(R,p_1,p_0) > 0$. $q_0(p_0,\theta)$ decreasing in p_0. In addition, $\frac{\partial\tilde{\theta}}{\partial p_0} < 0$ (Appendix 1). By definition, $f(\tilde{\theta}) \geq 0$. Therefore, $p_0 - c_0 > 0$. $\square$

7.3 Appendix 3

The necessary first order conditions for supplier A's profit maximization can be rearranged as

$$\frac{\partial N(R,p_1,p_0)}{\partial R}R + \frac{\partial Q_1(R,p_1,p_0)}{\partial R}[p_1 - c_1] = -N(R,p_1,p_0)$$
$$\frac{\partial N(R,p_1,p_0)}{\partial p_1}R + \frac{\partial Q_1(R,p_1,p_0)}{\partial p_1}[p_1 - c_1] = -Q_1(R,p_1,p_0).$$

The necessary first order condition for supplier B maximizing profit is

$$\frac{\partial Q_0(R,p_1,p_0)}{\partial p_0}[p_0 - c_0] = -Q_0(R,p_1,p_0).$$

We assume the sufficient second order conditions are satisfied for both suppliers. With $\Lambda\vec{y} = \vec{d}$, where $\vec{y}$ and $\vec{d}$ are as before,

$$\Lambda = \begin{pmatrix} \frac{\partial N(R,p_1,p_0)}{\partial R} & \frac{\partial Q_1(R,p_1,p_0)}{\partial R} & 0 \\ \frac{\partial N(R,p_1,p_0)}{\partial p_1} & \frac{\partial Q_1(R,p_1,p_0)}{\partial p_1} & 0 \\ 0 & 0 & \frac{\partial Q_0(R,p_1,p_0)}{\partial p_0} \end{pmatrix}.$$

Λ is non-singular because

$$|\Lambda| = [\sigma_0 + q_0(p_0,\tilde{\theta})f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial p_0}][-\sigma_1 f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial R}] \neq 0.$$

Using Cramer's rule and the relationships between derivatives of $\tilde{\theta}$ established in Appendix 1 the system can be solved,

$$R = \frac{N(R,p_1,p_0)}{f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial R}} - \frac{q_1(p_1,\tilde{\theta})[N(R,p_1,p_0)q_1(p_1,\tilde{\theta}) - Q_1(R,p_1,p_0)]}{\sigma_1}$$

$$p_1 - c_1 = \frac{N(R,p_1,p_0)q_1(p_1,\tilde{\theta}) - Q_1(R,p_1,p_0)}{\sigma_1}$$

$$p_0 - c_0 = \frac{-Q_0(R,p_1,p_0)}{\sigma_0 + q_0(p_0,\tilde{\theta})f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial p_0}}.$$

7.4 Appendix 4

The impact of a change in s on the indifferent customer is

$$\frac{\partial\tilde{\theta}(R,p_1,p_0,s)}{\partial s} = -\frac{\partial V_1(q_1(R,p_1,p_0,s),\theta,s)}{\partial s}\frac{\partial\tilde{\theta}(R,p_1,p_0,s)}{\partial R} < 0,$$

where the last term is as in Appendix 1 and the arguments include s. Again dropping the arguments to $\tilde{\theta}$

$$\frac{\partial N(R,p_1,p_0,s)}{\partial s} = -f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial s} > 0,$$

$$\frac{\partial Q_1(R,p_1,p_0,s)}{\partial s} = -q_1(p_1,\tilde{\theta},s)f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial s} + \int_{\tilde{\theta}}^{\bar{\theta}}\frac{\partial q_1(p_1,\theta,s)}{\partial s}f(\theta)d\theta > 0$$

and

$$\frac{\partial Q_0(R,p_1,p_0,s)}{\partial s} = q_0(p_0,\tilde{\theta})f(\tilde{\theta})\frac{\partial\tilde{\theta}}{\partial s} < 0.$$

7.5 Appendix 5

Proof of Lemma 3: $\psi'(s)$ is decreasing in any element of $\vec{w}$, because $\gamma(s,\vec{w})$ is linearly homogeneous in $\vec{w}$, and is decreasing in s. The result follows directly from the implicit function rule. $\square$

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