Bundling and Pricing of Product with After-sale Services

S. Kameshwaran
N. Viswanadham[*]
Centre for Global Logistics and Manufacturing Strategies,
Indian School of Business,
Gachibowli, Hyderabad 500032
Email: Kameshwaran_S@isb.edu, N_Viswanadham@isb.edu
[*]Corresponding Author

Vijay Desai
Department of Industrial Engineering and Operations Research,
Columbia University,
NY 10027-6699.
Email: vvd2101@columbia.edu

Abstract: Bundling is the sale of two or more products in combination as a package. In this paper we consider the bundling and pricing of a complex durable product with the after-sales repair and maintenance services. The product and service are two different, but related markets for this scenario. The problem of bundling and pricing are considered for two product market structures: *monopoly* and *duopoly*. In the monopoly case, the decision framework is an optimization problem, whereas for the duopoly, the strategic interactions of the two firms are modeled as a two stage non-cooperative game. These decision frameworks enable the manufacturing firms to decide upon the product-service bundling and pricing.

Biographical Notes: S. Kameshwaran is currently a senior researcher at the Indian School of Business. Prior to this, he worked as a Research Engineer in The Logistics Institute-Asia Pacific, Singapore and as a post doctoral fellow in INRIA Lorraine, France. He received his Ph.D in Computer Science from the Indian Institute of Science, Bangalore in 2004. His research interests are in the areas of algorithmic operations research, discrete optimization, and game theory with applications in supply chain management and e-commerce.

Professor N. Viswanadham is the Executive Director of Centre of Excellence for Global Logistics and Manufacturing Strategies at the Indian School of Business. Prior to this, he was the Deputy Executive Director of The Logistics Institute-Asia Pacific and also Professor in the Department of Mechanical and Production Engineering at the National University of Singapore. He is the recipient of the IBM Faculty Award for 2006. He was a GE Research Fellow and Tata Chemicals Chair Professor at the Indian Institute of Science, Bangalore and was also a faculty member at the Indian Institute of Science till 1998. Professor Viswanadham is a Fellow of a number of professional societies and academies such as the IEEE, INSA, IASc, INAE, and the TWAS. He is the author of three textbooks, six edited volumes, over eighty journal articles and more than hundred conference papers on automation.

Vijay Desai is currently a PhD student at Dept. of IEOR in Columbia University. He holds a Bachelors degree from Indian Institute of Technology, Bombay and Masters degree from Singapore-MIT Alliance. He has worked as a research engineer at The Logistics Institute - Asia Pacific. His research interests are in the area of revenue management and optimization.

1   Introduction

Integration of service with product is considered as one of the innovative supply chain initiatives of the next decade (Anderson and Delattre, 2002). At the outset, it can be seen as the merging of the *old* economy (manufacturing) with the *new* economy of service industries. However, the manufactured products are linked to services via the competitive strategies of individual firms (Marceau and Martinez, 2002). The service can be linked to the product at various stages in the supply chain. In this paper, we consider the linking at the final stage of distribution and marketing. In particular, the focus is on the packaging of a complex durable product with its after-sales repair and maintenance services as a single bundle.

Manufacturing has traditionally meant the production of tangible goods, but for today's customers it is the bundling of the tangible product with an array of intangible services that makes for the most desirable *service-enhanced product* (Lester, 1998). With more customers seeking solutions instead of specific products or brands, a growing number of products are becoming commodities. Thus the emphasis of customer satisfaction is on total cost of ownership, which is determined not only by the product but also by the after-sales service. Companies can provide good quality after-sales service to make product usage as hassle free as possible. Towards this end, offering product-service bundles would be attractive to both customers and manufacturers. The customers are freed from the burden of looking after upkeep of product and has more control over the total cost of ownership. The manufacturers on the other hand, will earn additional revenue with the sale of every product in terms of after-sales service. Numerous studies (Alexander et al., 2002; Dennis and Kambil, 2003) show that service tends to be a high margin activity and bundling of products and services can be a good strategy for entering the service market.

There is an interdependence between product and service sales, and decision making should focus on the profitability from both sale of products and after-sales services, rather than on per-transaction or per-period profitability. For example, an article in San Jose Mercury News (Nauman, 1994) reported that new car sales represented 59.9% of dealers revenue but only 1% of profit, while the service and parts department generated 14.7% of their total revenue and two-thirds of their total profits. Manufacturers such as Epson and Hewlett-Packard sell their printers at loss to secure continuing profits from the sale of toner cartridges. Study by Cohen (Cohen et al., 1997) indicate that manufacturers in electronics/computing industry are acting aggressively for service revenue (through maintenance contracts) after relatively short warranty periods. Thus across various industries, companies are beginning to regard initial product sales primarily as positioning opportunities for pull through sales and service. In this context, product-service bundle pricing becomes an important problem.

In this paper, we adopt a strategic framework to analyze the problem of product-service bundling and pricing between two competing firms. The product and after-sales service are two different markets with various players. A product manufacturer who intends to enter the after-sales service market should take into account the strategic behavior of the players in both the markets. In particular, the manufacturer should make the following decisions: (1) should he enter the after-sales service market?, (2) if so, should he bundle it with the product?, and (3) at what prices to offer the product and service?. Our focus is on complex durable products that are economically attractive to maintain and service rather than replace. The product could be an automobile, a farm equipment, or an elevator. It may be noticed that all of these products require after sales support for preventive maintenance, spare parts for repair and emergency breakdown servicing. We analyze this problem in a representative setting of monopoly and duopoly product markets. The decision making in the monopoly market is an optimization problem. The duopoly market has strategic competitors and the decision making is modeled as a two stage non-cooperative sequential game. The subgame-perfect Nash equilibrium in pure strategies is used as the solution concept. A preliminary version of this work was presented in (Kameshwaran et al., 2007).

The remainder of the paper is organized as follows. Section 2 briefly explains and reviews the literature in the integration of manufacturing and service. The model for the product market and the service market, with the consumers' preferences are explained in Section 3. The decision making framework for the monopoly situation is considered in Section 4 and the duopoly game model is solved in Section 5. The model assumes that consumers valuation for the product is deterministically known to the manufacturers. This assumption is relaxed with the valuation to be uniformly distributed in Section 6. In Section 7, we conclude the paper with the promising avenues for future research.

2   Integration of Manufacturing and Service

The service industry is difficult to define because it includes many diverse activities. Although there is no consensus on the definition of a service industry, there is a broad agreement about the attributes of its outputs: they are not tangible; they are consumed at the same time they are produced; they have intangible value added; they are labor intensive (Karaomerlioglu and Carlsson, 1999). However, these attributes do not necessarily apply all at once to all service industries. Services also serve different markets: consumer markets, intermediate (producer) markets, and state or public service markets, and involve different production processes, including the transformation of the state of physical objects, people or codified information (Miles, 1994). The services that are commonly incorporated within manufacturing include assembly, testing, system integration, material purchasing, design, labelling, distribution, repair and maintenance. The after-sales repair and maintenance accounts for much apparent consumer spending on *services* (Marceau and Martinez, 2002). In (Howells, 2000), the trend within manufacturing industry firms towards bundling together their physical products and associated services is described. Many manufacturing firms are increasing the proportion of their turnover earned from selling services by bundling, as a single package or as *add-ons* to products at different times.

There are three major strategies used by firms in product-service packaging (Marceau and Martinez, 2002):

- *Product-service integration*: Service in incorporated through the different stages of the production process.

- *Product-service bundling*: Service is packaged with the product at or after the point of sale.

- *Service enterprises*: These are firms that package products produced by others with a raft of services.

In product-service integration, service components are added during the production process, influencing the characteristics and/or physical composition of the product itself. Such service components may involve extra input of R&D, design, technical or engineering services from clients in the downstream of the supply chain. Many of these are knowledge intensive. In contrast, less knowledge intensive services are bundled at the point of sale with the product. The financial services and the after-sales repair and maintenance services belong to this category. Some firms adopt both product-service integration and bundling strategies. In (Viswanadham et al., 2005), manufacturing and service were integrated in a single network to investigate the impact of manufacturing and service phases on each other, when product-service bundles are being offered. Service enterprises do not manufacture products but provide after-sales services to products manufactured by other firms. For example, there are engineering service enterprises that provide repair and maintenance service for home appliances, manufactured by different firms, as authorized service providers. In addition to the warranty provided by the manufacturers, these enterprises provides extended warranty by collecting a premium from the consumer. This is equivalent to selling of service but there is no bundling involved. In this paper, we focus on the selling of product-service bundles by the manufacturing firm.

Bundling is the sale of two or more products in combination as a package. The bundled products are assumed to have separate markets so that at least some consumers buy or want to buy the products separately. Bundling has been studied from various perspectives in the literature: consumer evaluation of bundles (Herrmann et al., 1999; Johnson et al., 1999; Soman and Gourville, 2001; Yadav, 1994); optimality of bundling (Eppen et al., 1991; Guiltinan, 1987); pricing of bundles (Hanson and Martin, 1990; Ansari et al., 1996); optimality of bundling for monopolists (Adams and Yellen, 1976; Schmalensee, 1982); and equilibrium theory of bundling (Chen, 1997). Bundling was suggested as an alternative technique for price discrimination for monopolists (Stigler, 1968), which was further analyzed in (Adams and Yellen, 1976). It was shown with stylized examples that a multiproduct monopolist can gain by selling the different products in bundles, when the reservation values are negatively correlated. Bundling was shown to be profitable even if the reservation values are uncorrelated or positively correlated (Schmalensee, 1984). It reduced the effective dispersion of reservation values and thereby the seller can extract a greater fraction of the potential surplus. The conditions under which bundling is an optimal strategy was investigated in (McAfee et al., 1989) for a multiproduct monopolist. A graphical analysis of bundling in (Salinger, 1995) showed the interaction between the cost effects and demand effects, which in turn can be used to predict the conditions under which bundling is profitable. Bundling has also been studied with varying assumptions on market structure of the bundled products. In (Schmalensee, 1982), market of the first product is assumed to be a monopoly and that of the second product to be in perfect competition. It was shown that in such a scenario, the monopolist can never gain by bundling the product from the first market with that from the second market. In (Whinston, 1990), the second market had an oligopoly structure and the result showed that the bundling can be profitable because of the strategic effect in the second market.

The focus of bundling can be *product bundling* or *price bundling* or both (Stremersch and Tellis, 2002). Price bundling is the sale of two or more separate products in a package at a discount, without any integration of the products. As there is no integration of products, bundling itself does not create added value to consumers, and thus a discount must be offered to motivate at least some consumers to buy the bundle. This kind of bundling is usually used to sell unpopular products along with the product ones and for also introducing a new product in the market, which is bundled initially with a popular product.

Product bundling is the integration and sale of two or more separate products at any price. This integration provides at least some consumers with added value. Thus product bundling is more of a long-term differentiation strategy than price bundling, which is a short-term promotional tool. In this paper, our focus is on bundling of a complex durable product with after-sales repair and maintenance services. Clearly, the product and the service are two different *products*, as there exist different markets for each of them and consumers can buy them separately. Further, this is *product bundling* as there is integration between the product and the after-sales service that is provided by the product manufacturer. In general, after-sales service market has numerous players (service providers), due to the relatively less entry barriers in terms of technology and cost than that of the manufacturing sector. It is not uncommon for the manufacturer to have a service station, thus acting as a common player in both the markets. Thus the decision of bundling the service with the product for a given manufacturer should take into account the competition he faces from both the markets (the other manufacturers and the service providers). The markets are populated with non-cooperative players, who try to maximize their individual profits. This leads to the use of game theory as the decision tool. In the next section, we describe the model mathematically.

3 The Model

3.1 Product and Service Markets

We consider a complex durable product P, which is economically attractive to maintain and service, than to replace. The product P is not identified by its brand or model but by its *type*, which explains its usage. For example, an automobile can be categorized as *luxury* or *sports* or *utility* vehicle. We consider a particular category, which defines the product P and assume that all consumers value the P at $v = \overline{V}$. This simple assumption of deterministic reservation value is later relaxed in Section 6, where the valuation v is assumed to be uniformly distributed in range $[\underline{V}, \overline{V}]$.

The intention of bundling the after-sale services with the product is to offer the entire package as a commodity. Thus for the manufacturer, entering the service market is not just opening a service center, but providing the service for a designated *lifetime* of the product, for a previously agreed upon cost. The lifetime can be just considered as a fixed period of time, until which the consumer would definitely use the product. Currently, for many durable products, the service market is populated with small independent service providers. In any city, one can find several electrical equipment service centers for repairing refrigerators and air conditioners of various brands and models. Similarly there are several service centers for handling automobiles from different manufacturers. The cost and the quality of the service vary across such service centers and consumers choose the ones that meet their service requirements and budget constraints. We model our service market similar to the above scenario. The service market for the P has several small independent service providers, who provide the service at a cost that depends on the quality of the service. At any given point of time, a consumer would choose a service provider who meets her service requirements and cost constraint.

Let w be the total cost a consumer is willing to pay for servicing the product during its lifetime. We model the variation in consumer's willing to pay for the service by assuming w to be uniformly distributed in range $[\underline{W}, \overline{W}]$. The w denotes a consumer's *willingness to pay* (WTP) for the lifetime service. This total spend for the service is distributed across the lifetime of the product and possibly across many service providers. The service providers service similar products produced by different manufacturers. We do not assume the independent service providers to be strategic players in the market. This is because the independent service providers do not service the product for its entire lifetime for a previously agreed upon cost. Thus a manufacturer need not take into account the cost of service of the independent service providers for making his strategic decisions. However, the presence of such independent service providers ensures that a consumer will always be able to avail the service for her WTP $w \in [\underline{W}, \overline{W}]$ for the lifetime. A consumer can thus choose to buy the service from the manufacturer or can avail it across different independent service providers during the lifetime.

3.2 Manufacturing Firm and the Consumers

The marginal cost of producing the product is assumed to be a constant c_P. For a manufacturing firm (henceforth referred simply as firm) to survive in such a market, the cost $c_P \leq v$ and the price of the product α should be such that $c_P \leq \alpha \leq v$. Let the constant marginal cost of providing the lifetime service for the firm be $c_S \in [\underline{W}, \overline{W}]$. If the firm provides the lifetime service for price β, then all the consumers with WTP $w \geq \beta$ will buy the service from the manufacturer for the entire product lifetime. This is because the quality of service provided by the manufacturer can be assumed to be higher than any of the independent service provider and hence the consumers with $w \geq \beta$ would prefer the service from the manufacturer directly. The WTP w and the price β are money values for the service that is provided during the lifetime of the product. Since the money value would change during the lifetime of the product, they are assumed to be suitably discounted using a common discounting factor for both the manufacturer and consumers. This assumption of common discount factor for both manufacturers and con-

Offering	Firm	Consumer
P	$\alpha - c_P$	$v - \alpha$
$P + S$	$\alpha + \beta - c_P - c_S$	$v + w - \alpha - \beta$
PS	$\gamma - c_P - c_S$	$v + w - \gamma$

Table 1: Unit payoffs to the firm and a consumer with WTP w for service

sumers may not hold true while calculating profits, as the manufacturer with high investments and endowments may value the money very differently from a consumer. However, the same discount factor is acceptable within the scope of this model.

We assume a continuum of consumers of total measure one. We use the term *offerings* to denote the set of commodities offered by the firm for sale. Three basic offerings are considered in this paper: P, $P + S$, and PS. P denotes the offering of product only, $P + S$ denotes the offering of providing P and S independently, and PS denote the product service bundle (henceforth referred simply as *bundle*). For the offering $P + S$, it is possible for the firm to sell the product P separately, whereas with offering PS, the firm can only provide the bundle. One of the decisions to be made by a firm is to choose one of the above three basic offerings. If the firm chooses P, then it does not enter the service market. With $P + S$ or PS as the offerings, the firm enters the service market but for PS, it sells only the bundle, whereas for $P + S$, it also sells the product without service. This decision is based on numerous parameters like cost, price, and other players in the market. Let α, β, and γ be the decision variables that denote respectively the unit price for product, service, and the bundle. The payoffs resulting from one unit of the offerings to the firm and a consumer with WTP $w (\in [\underline{W}, \overline{W}])$ is shown in Table 1. It is assumed that the consumers value the product and service independently, and hence the payoffs for $P + S$ and PS are linearly additive in terms of individual payoff from P and S, without any *bundling effect*. Note that providing service S alone is not considered, as the firm is already providing the product P.

The offerings P, $P + S$, and PS are the three basic offerings and the other possible *mixed* offerings are $P \& P + S$, $P \& PS$, $P + S \& PS$, and $P \& P + S \& PS$. For example, the offering $P \& PS$ means that the firm can sell the product alone and also as a bundle with the service. One can easily see that all these mixed offerings need not be considered as possible strategies, as they provide the same revenue as the offering $P + S$. Given the above setup, we consider two scenarios in the product market: *monopoly* and *duopoly*. In the monopoly case, there is a single manufacturer of the product and in the duopoly case, there are two manufacturers who produce the same product.

4 Monopoly in Product Market

In this scenario, there is a single firm that manufactures the product P. The firm faces no competition and hence the decision making is an optimization problem with the objective of maximizing the payoff.

$$\max_{j \in \{P, P+S, PS\}} \pi_j \tag{1}$$

The firm is required to choose one of the three basic offerings that will maximize its payoff. The payoff π_j for the offering j depends on the price of the offering. First, we determine the payoffs for these basic offerings.

As it is a monopoly market, for the offering P, the firm can capture the entire market for any price $\alpha \leq v$. Hence the optimal price $\alpha^* = v$ and the total payoff to the firm is

$$\pi_P = v - c_P \tag{2}$$

The firm, being a monopoly, is best off by charging the maximum price and the consumers are worse off in this scenario. For the offering $P + S$, the firm can provide P and S independently. Like the previous case, $\alpha^* = v$. The consumer with $v + w \geq \alpha^* + \beta$ will also buy the service S. Thus the number of consumers who would buy S is $\frac{\overline{W} - \beta}{\overline{W} - \underline{W}}$. The other consumers (with $w < \beta$) will buy the service from the independent service providers at their respective w. The firm has to choose the optimal β^* that maximizes the total payoff.

$$
\begin{aligned}
\pi_{P+S} &= (v - c_P) + \max_{\beta}(\beta - c_S)\left(\frac{\overline{W} - \beta}{\overline{W} - \underline{W}}\right) & (3) \\
&= (v - c_P) + \frac{1}{\overline{W} - \underline{W}}\left(\frac{\overline{W} - c_S}{2}\right)^2 & (4)
\end{aligned}
$$

The optimal $\beta^* = \frac{\overline{W} + c_S}{2}$ maximized the above payoff. Consider the offering PS. In this case, a consumer can buy only the bundle. For a price γ, only consumers with nonnegative payoff will buy the bundle. From the Table 1, a consumer with $w \geq \gamma - v$ would buy the bundle and hence the number of consumers who will buy the bundle is $\frac{\overline{W} - \gamma + v}{\overline{W} - \underline{W}}$.

$$
\begin{aligned}
\pi_{PS} &= \max_{\gamma}(\gamma - c_P - c_S)\left(\frac{\overline{W} - \gamma + v}{\overline{W} - \underline{W}}\right) & (5) \\
&= \frac{1}{\overline{W} - \underline{W}}\left(\frac{v - c_P + \overline{W} - c_S}{2}\right)^2 & (6)
\end{aligned}
$$

It can be easily verified that the above payoff is maximized by $\gamma^* = \frac{\overline{W} + v + c_P + c_S}{2}$. The payoff from the offering $P + S$ is greater than that from P. Among the strategies $P + S$ and PS, more customers would buy the service in case of PS.

5   Duopoly in the Product Market

In this section we consider the duopoly in the product market. The P and S are complementary products as both are required for the consumers. Bundling of complementary products in duopoly were considered in (Einhorn, 1992) and (Matutes and Regibeau, 1992). In (Matutes and Regibeau, 1992), the consumer can combine the products from different firms, which is not possible in our case. A firm will not provide service to product manufactured from a competing firm. Similar assumption was made in (Einhorn, 1992) and the focus was whether the firms should produce compatible products, with relevance to computer industry. In (Chen, 1997), duopoly was considered but the products need not be complementary. The second product had perfect competition and the focus was on whether the firms that produce the first product should bundle the second product. Our focus here is similar as the whether the firms that manufacture P should bundle along with it the S.

Consider two firms 1 and 2, which manufacture the same product and the valuation for the products manufactured by these two firms are the same v for the consumers. This homogenous valuation for the P is relaxed in the next section. Both the firms are aware of the advantages of entering the service market. But given the competition both face against each other, the decision of entering the service market should take into account the mutual interdependence of the decisions of both firms. Assuming that the firms are non cooperative, the strategic interaction can be modeled as a two stage non-cooperative game. A *multi-stage game* is a finite sequence of stage-games, each one being a game of complete but imperfect information (a simultaneous move game). These games are played sequentially by the same players, and the total payoffs from the sequence of games will be evaluated using the sequence of outcomes in the games that

were played. We model our problem as a two stage game. In the first stage, each firm chooses an offering, which could be any of the basic offerings: P, $P + S$, and PS. Both firms choose their offerings simultaneously without the knowledge of the choice of the competing firm. We call this as the *offerings game*. Both the firms observe the outcome of this stage, and this information structure is common knowledge. In the second stage, both firms choose the price for the choice made at the first stage. Both firms choose the price simultaneously without the knowledge of the price chosen by the competing firm. Thus we have a two stage game, where the games in each stage is a simultaneous move game.

5.1 The Two-stage Game

Following are the assumptions of the two stage game:

1. Both the firms have the same constant marginal cost of producing the product c_P and the same constant marginal cost of providing the service (for the lifetime) c_S.

2. The service provided by a firm can be only utilized for the product of the same firm.

3. The consumer will choose the offering that maximizes her payoff (given in Table 1).

The first assumption treats both the competing firms as identical with respect to their manufacturing and service capabilities. The second assumption is more of a realistic constraint where a firm need not provide service to its competing product. This may also be due to the technological constraints. It should be noted that the products offered by the two firms being homogeneous does not mean that the products are exactly the same. It only implies that the products are substitutable and the valuations of the consumers are the same. This assumption also implicitly points out that a firm will not provide service alone, devoid of manufacturing the product.

Stage 1: Offerings

The firms 1 and 2 are capable of producing the product P and providing the service S. In the first stage, both the firms choose the offering. The possible offering for each firm are the basic offerings: *product only* (P), *product and service independently* ($P + S$), and *product and service bundle only* (PS). These offerings are the strategies available for the firms in the first stage and each choose one of the strategies simultaneously. It is also assumed that each firm's offering decision cannot be reversed once it is made. Thus stage 1 is a finite non-cooperative simultaneous game, with nine possible outcomes.

Stage 2: Pricing

In the second stage, each firm chooses a price for their respective offering made in the first stage. The firm i ($i = 1, 2$) chooses the prices $q_j(i)$ ($j = \{P, S, PS\}$, wherever applicable). For example, if firm 1 chooses the offering PS and firm 2 chooses $P + S$ in stage 1, then the strategies in stage 2 are $\gamma(1)$ for firm 1 and $\alpha(2)$ and $\beta(2)$ for firm 2. There are nine possible pricing games, one for each of the nine possible outcomes of the stage 1. Unlike the stage 1, the available strategies for the firms are infinite in the pricing game. For the firms to make non-zero profit and for the consumers to obtain non-zero payoffs, the prices should satisfy the following conditions: $c_P \leq \alpha \leq v$, $c_S \leq \beta \leq \overline{W}$, and $c_P + c_S \leq \gamma \leq v + \overline{W}$.

The solution concept or the equilibrium used in the paper is the *subgame-perfect Nash equilibrium* (Mas-Colell et al., 1995). Such an equilibrium is a pair of strategies that constitutes a Nash equilibrium (NE) (Nash, 1951) in each pricing game as well as in the full game. We will be restricting only to the pure strategy NE, that is, randomization of strategies (mixed strategies) will not be considered. Since, stage 1 is a finite game and stage 2 is an infinite

game[1], the subgame-perfect NE will exist only if NE exists in the infinite game. The subgame-perfect equilibrium is determined by the *backward induction* procedure: the NE of the stage 2 is first determined and based on the outcomes, the equilibrium of stage 1 is determined. Let the pricing subgame be denoted by an ordered pair (j_1, j_2), when firm 1 and 2 provide the offerings j_1 and j_2, respectively. The NE in such a pricing subgame, is a pair of strategies $(q_{j_1}^*(1), q_{j_2}^*(2))$ such that, the price $q_{j_1}^*(1)$ maximizes the payoff to 1, if $q_{j_2}^*(2)$ is the strategy for 2 and $q_{j_2}^*(2)$ maximizes the payoff to 2, if $q_{j_1}^*(1)$ is the strategy for 1. The payoffs of NE outcomes of the pricing subgames of stage 2 become the payoffs to the respective offerings game in stage 1. The NE strategies (j_1^*, j_2^*) in stage 1 is similarly obtained: j_1^* maximizes the payoff to 1, if j_2^* is the strategy of 2 and j_2^* maximizes the payoff to 2 if j_1^* is the strategy of 1. The NE outcomes of the pricing subgames in stage 2 are first determined.

5.2 Pricing Subgames

Stage 2 has nine pricing subgames, but due to the symmetry of the firms in terms of costs and offerings, only six distinct games need to be examined. For example, the games (P, PS) and (PS, P) are symmetric. The Nash equilibrium of each of them are determined in the following.

Proposition 1 *In the pricing subgames with the same offering by both firms, the Nash equilibria yields zero outcome to both the firms.*

Proof: The proof is based on the lines of *Bertrand Duopoly* (Varian, 1992) situation. The offering of both the firms are the same and hence the consumers would buy from the firm which offers the lowest price(s) for the offering. To attract all the customers and make more profit, each firm will try to price the offering less than that of the competitor. Since both firms have the same cost of production and service, the NE is to price the offerings at these costs: $\alpha(1) = \alpha(2) = c_P$, $\beta(1) = \beta(2) = c_S$, and $\gamma(1) = \gamma(2) = c_P + c_S$. Thus both firms earn zero profits if they provide the same offering. ∎

The above result is due to the non-cooperative nature of the game, leaving both the firms worse-off (the consumers are best-off in this scenario). If both firms can cooperate, then they both can charge the highest possible price and share the profits equally, leaving the consumers worse-off. The NE of the other pricing subgames are determined in the following. Let $\theta_j(i)$, where $i = 1, 2$ and $j = P, P + S, PS$, denote the payoff to the consumer for the offering j from firm i.

5.3 Pricing Subgame $(P + S, P)$

The strategy for firm 1 is $(\alpha(1), \beta(1))$ and the strategy for firm 2 is $\alpha(2)$. A consumer with WTP w for service will choose the offering from a firm that maximizes her payoff (the arg refers to both the offering and the firm):

$$\arg\max\{\theta_P(1), \theta_{P+S}(1), \theta_P(2)\}$$

The $\theta_j(i)$ is the payoff (see Table 1) to the consumer for a unit of the offering j from firm i. For the product, both firms face a Bertrand duopoly situation and hence the NE price is the minimum possible price: $\alpha^*(1) = \alpha^*(2) = c_P$ and earn zero profits. However, firm 1 can obtain non-zero profit in the service market. All consumers with $w \geq \beta(1)$ will obtain the product and service from 1 (by assumption 2). The optimal pricing by firm 1 is similar to the monopoly situation and hence $\beta^*(1) = \frac{\overline{W} + c_S}{2}$ and the payoff is $\frac{1}{\overline{W} - \underline{W}}(\frac{\overline{W} - c_S}{2})^2$.

---

[1]Finiteness refer to the finiteness of the available strategies.

5.4 Pricing Subgame (PS, P)

The strategy for firm 1 is $\gamma(1)$ and for firm 2 is $\alpha(2)$. The consumer with WTP w will choose the offering that maximizes her payoff:

$$\arg\max\{\theta_{PS}(1), \theta_P(2)\}$$

Hence the consumers with WTP $w < \gamma(1) - \alpha(2)$ will choose to buy the product from firm 2 (and the service from the independent service provider) and the rest of the consumers will buy the bundle PS from firm 1. Given the $\alpha^*(2)$, the best response of firm 1 is to choose $\gamma^*(1)$ that maximizes his payoff:

$$\max(\gamma(1) - c_P - c_S) \left(\frac{\overline{W} - \gamma(1) + \alpha(2)}{\overline{W} - \underline{W}} \right) \tag{7}$$

Similarly, given $\gamma^*(1)$, the best response of firm 2 is to choose $\alpha^*(2)$ that maximizes his payoff:

$$\max(\alpha(2) - c_P) \left(\frac{\gamma^*(1) - \alpha(2) - \underline{W}}{\overline{W} - \underline{W}} \right) \tag{8}$$

The best responses of firm 1 and 2, respectively, are:

$$\gamma^*(1) = \frac{\alpha^*(2) + \overline{W} + c_p + c_S}{2} \tag{9}$$

$$\alpha^*(2) = \frac{\gamma^*(1) - \underline{W} + c_P}{2} \tag{10}$$

Solving the above two linear equations, we have

$$\gamma^*(1) = \frac{2\overline{W} - \underline{W} + 2c_S + 3c_P}{3} \tag{11}$$

$$\alpha^*(2) = \frac{\overline{W} - 2\underline{W} + c_S + 3c_P}{3} \tag{12}$$

The NE payoffs to firm 1 and 2 are $\frac{1}{\overline{W} - \underline{W}} \left(\frac{2\overline{W} - \underline{W} - c_S}{3} \right)^2$ and $\frac{1}{\overline{W} - \underline{W}} \left(\frac{\overline{W} - 2\underline{W} + c_S}{3} \right)^2$, respectively. It can be easily seen that both the firms earn non-zero profit. If $\overline{W} - c_S > c_S - \underline{W}$ then firm 1 makes more profit and vice versa.

5.5 Pricing Subgame $(PS, P + S)$

In this pricing game, firm 1 chooses $\gamma(1)$ and firm 2 chooses $\alpha(2)$ and $\beta(2)$. The consumer with WTP w would choose the bundle PS from 1 or P from 2 or $P + S$ from 2, depending on the offering that maximizes her payoff:

$$\arg\max\{\theta_{PS}(1), \theta_P(2), \theta_{P+S}(2)\}$$

The firms 1 and 2 will face Bertrand type duopoly competition for the offerings PS and $P + S$, and hence $\gamma^*(1) = \alpha^*(2) + \beta^*(2) = c_P + c_S$ with both firms earning zero profits from these offerings. However, firm 2 can make positive profit by suitably pricing the P and S. Customers with WTP $w < c_P + c_S - \alpha(2)$ (because $\gamma^*(1) = \alpha^*(2) + \beta^*(2) = c_P + c_S$)) would buy the P from firm 2. Thus the optimal price $\alpha^*(2)$ is the solution of the following maximization problem:

$$\max_{\alpha(2)}(\alpha(2) - c_P) \left(\frac{c_P + c_S - \alpha(2) - \underline{W}}{\overline{W} - \underline{W}} \right) \tag{13}$$

The optimal price that maximizes the above quadratic function is $\alpha^*(2) = \frac{2c_P + c_S - \underline{W}}{2}$ and the profit to firm 2 is $\frac{1}{\overline{W} - \underline{W}}(\frac{c_S - \underline{W}}{2})^2$. Hence the optimal price for service is $\beta^*(2) = \frac{c_S + \underline{W}}{2}$, which is less than the service cost c_S. Here the firm provides the service at a loss to gain non zero profits by increasing the product price.

			(2)	
		P	$P+S$	PS
	P	$0,\ 0$	$0, \dfrac{\left(\frac{\overline{W}-c_S}{2}\right)^2}{\overline{W}-\underline{W}}$	$\dfrac{\left(\frac{\overline{W}-2\underline{W}+c_S}{3}\right)^2}{\overline{W}-\underline{W}}, \dfrac{\left(\frac{2\overline{W}-\underline{W}-c_S}{3}\right)^2}{\overline{W}-\underline{W}}$
(1)	$P+S$	$\dfrac{\left(\frac{\overline{W}-c_S}{2}\right)^2}{\overline{W}-\underline{W}}, 0$	$0,\ 0$	$\dfrac{\left(\frac{c_S-\underline{W}}{2}\right)^2}{\overline{W}-\underline{W}}, 0$
	PS	$\dfrac{\left(\frac{2\overline{W}-\underline{W}-c_S}{3}\right)^2}{\overline{W}-\underline{W}}, \dfrac{\left(\frac{\overline{W}-2\underline{W}+c_S}{3}\right)^2}{\overline{W}-\underline{W}}$	$0, \dfrac{\left(\frac{c_S-\underline{W}}{2}\right)^2}{\overline{W}-\underline{W}}$	$0,0$

Figure 1: Stage 1 game in normal form

5.6 Offerings Game

The NE outcomes of the pricing subgames will be used to obtain the NE of the stage 1 offerings game. The stage 1 game in *normal form* is shown in Figure 1. The row strategies are for firm 1 and the column strategies are for firm 2. The outcomes to different strategy combinations are entered in the corresponding cell of the matrix. The first entry in the ordered pair outcome is the payoff to firm 1 and the second entry is for the firm 2. Note that these ordered pair entries are NE outcomes of the corresponding pricing games of stage 2. The NE of stage 1 can be determined from the above normal form. If firm 2 provides P, then the best response offering from 1 is PS and if firm 2 provides PS, then the best response of 1 is P. For offerings $P+S$, all offerings of firm 1 earn zero profits. Thus is can be easily seen that the NE strategies are (P, PS) and (PS, P), both earning nonzero profits to both the firms. The game has two symmetric NE, which shows that the firms should differentiate their offerings by one firm providing only the product and the other firm providing only the bundle. This result is similar to the one shown in (Chen, 1997).

The above model can easily be extended to allow for sequential entry into the market, rather than simultaneous entry. Without loss of generality, let firm 1 enter the market first, followed by firm 2. The pricing subgames and their outcomes will be same as above. However, in this game there will be a unique NE. If $\overline{W} - c_S > c_S - \underline{W}$ then firm 1 will provide the bundle PS and firm 2 will follow with P, otherwise the NE will be (P, PS). Note that, the game was analyzed with the assumption that firm 1 is aware of firm 2's entry in the near future. If firm 1 is not aware of this entry, then it will decide based on the monopoly model. It can be seen that if firm 1 uses $P+S$ strategy from the monopoly model, it will forbid the entry of firm 2 into the market, as firm 2 will earn zero outcome against $P+S$ strategy of 1. Thus $P+S$ can be used to retain monopoly in the market.

6 Heterogeneous Preferences for the Product Market

In this section, we relax the assumption that the valuation for the P is deterministically known as $v = \overline{V}$ and instead to be uniformly distributed in the range $[\underline{V}, \overline{V}]$. The marginal cost of production c_P is assumed to be $c_P \in [\underline{V}, \overline{V}]$. It can be easily seen that Proposition 1 holds true with the above assumption. In the following, we graphically analyze the the three symmetric pricing subgames. The horizontal and vertical axes in figures 2-4 are for the product and service, respectively. The rectangle that spans $\underline{V}$ and $\overline{V}$ to $\underline{W}$ and $\overline{W}$ is the support of the joint
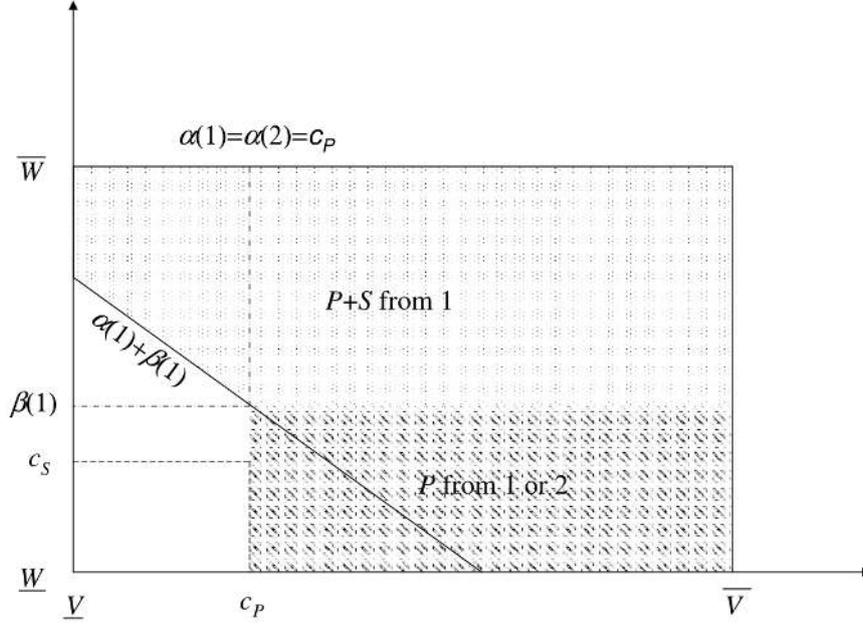
Figure 2: Pricing subgame $(P + S, P)$

probability distribution of consumers with valuations for product in $[\underline{V}, \overline{V}]$ and for service in $[\underline{W}, \overline{W}]$.

6.1 Pricing Subgame $(P + S, P)$

The strategies for firm 1 are $\alpha(1)$ and $\beta(1)$ and that for firm 2 is $\alpha(2)$. For the product, both firms face a Bertrand duopoly situation and hence the NE price is the minimum possible price: $\alpha^*(1) = \alpha^*(2) = c_P$ and earn zero profits. But firm 1 can obtain non-zero profit in the service market. Consumers with v and w satisfying the following conditions would buy $P + S$ from 1:

$$v + w \geq \alpha(1) + \beta(1) \tag{14}$$
$$w \geq \beta(1) \tag{15}$$

The condition (15) is due to the reason that a consumer would prefer $P + S$ from 1 over P from 2 if $v + w - \alpha(1) - \beta(1) \geq v - \alpha(2)$. Consumers with $v \geq c_P$ and $w < \beta(1)$ would buy P from either 1 or 2. This is shown in Figure 2. The optimal price $\beta^*(1)$ can be found by solving the optimization problem that maximizes the overall profit to firm 1 (where unit profit is $\beta(1) - c_S$). Similar to the game with deterministic valuation v, firm that provide $P + S$ makes non-zero profit, whereas the firm that offers P makes no profit.

6.2 Pricing Subgame (PS, P)

Figure 3 shows the pricing subgame with firm 1 choosing $\gamma(1)$ for the bundle PS and firm 2 choosing $\alpha(2)$ for P. Consumers in the following region of the support will buy PS from 1:

$$v + w \geq \gamma(1) \tag{16}$$
$$w \geq \gamma(1) - \alpha(2) \tag{17}$$

It can be easily seen that for a given $\alpha(2) \geq c_P$, firm 1 can choose $\gamma(1) > c_P + c_S$ and thus benefit non-zero profit. Similarly, for a given $\gamma(1) \geq c_P + c_S$, firm 2 can choose $\alpha(2) > c_P$. Thus
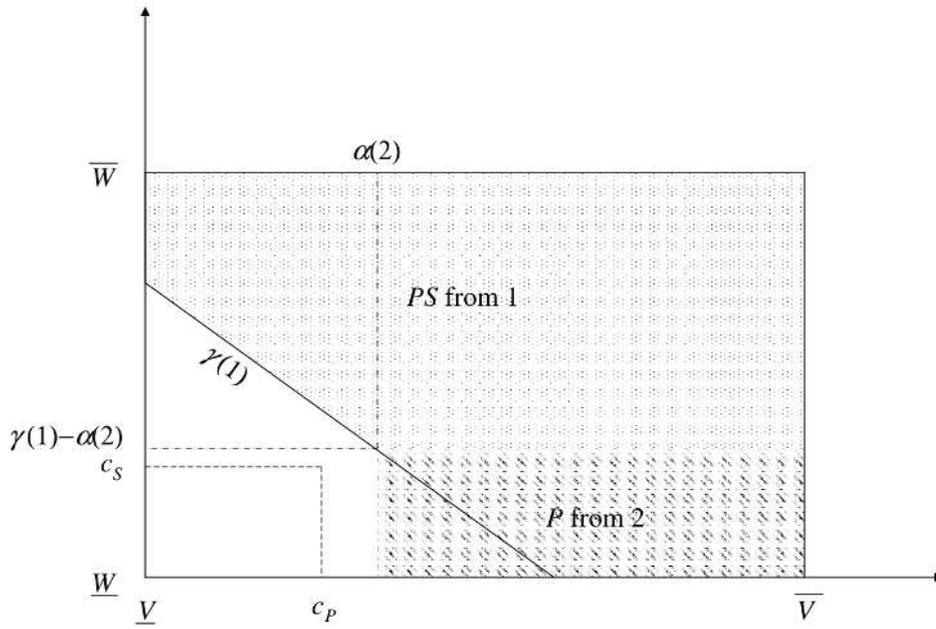
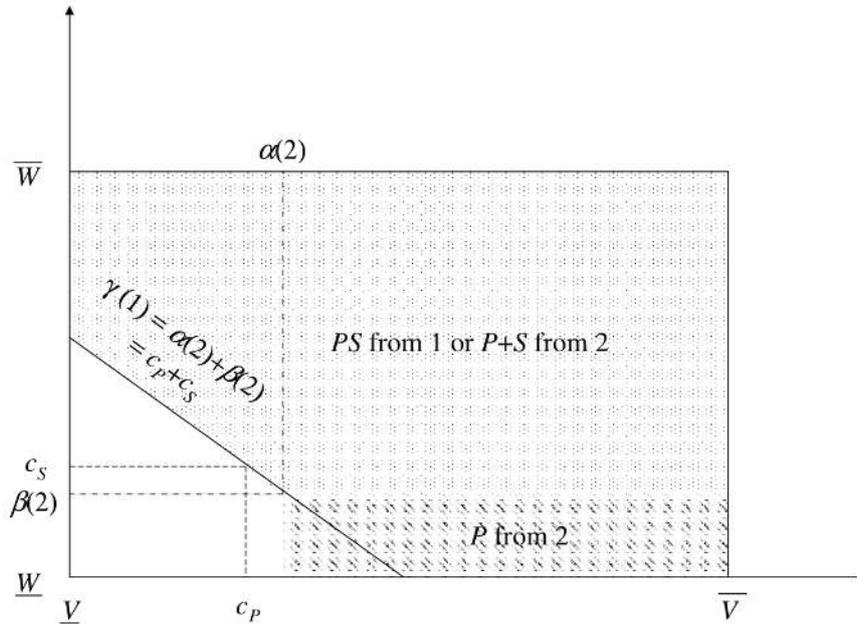Figure 3: Pricing subgame (PS, P)

Figure 4: Pricing subgame $(PS, P + S)$

both the firms make non-zero profits. The existence of a unique NE pair $(\gamma^*(1), \alpha^*(2))$ and an algorithm to find such a pair requires further investigation.

6.3   Pricing Subgame $(PS, P + S)$

Clearly, the prices of the offering from both the firms should satisfy the following condition at NE: $\gamma^*(1) = \alpha^*(2) + \beta^*(2) = c_P + c_S$. However, as shown in figure 4, firm 2 can obtain non-zero profit by selling P to consumers who cannot afford the bundle or $P + S$. Thus in this case, the firm that offers the bundle makes no profit.

The results are similar to the previously discussed case with deterministic valuation for P. Both the firms make non-zero profit by differentiating their offerings (one provides P and the other PS). Similarly $P + S$ can be used to forbid the entry of other firms as it will yield zero profits irrespective of the strategies used by the other firm.

7   Conclusions

Integration of service with product is considered as one of the innovative supply chain initiatives of the next decade. A product and its after-sale repair and maintenance service are two different, yet related markets for many kinds of products. Hence the decision of product-service integration and also to sell it as a bundle should take into account the market structure of both the product and the service. In this paper, we analyzed product-service integration and bundling in restricted scenarios of a manufacturing firm that faces monopoly and duopoly in the product market. The service market was considered to be populated with independent service providers, similar to an automobile market. The decisions to be made by the firm are (1) whether to enter the service market, (2) if so, whether to provide the service independently or as a bundle, and (3) at what prices to offer the product and service?. The above decisions were compactly represented in terms of offerings P, $P + S$, and PS, which represent respectively *product only*, *product and service independently*, and *product and service bundle*. It was also shown that the above offerings compactly represent the entire decision space. The decision making problem was then to choose one of the offerings and then an optimal price for it. A consumer's WTP for the lifetime service was assumed to be uniformly distributed. For the monopoly situation in the product market, the decision making is an optimization problem. It was found that it is advantageous for the firm to enter the service market and the condition under which PS will be favorable to $P + S$ was derived.

In the duopoly situation, the competing firm was assumed to produce the same product and have the same marginal cost of production and service. The firms were assumed to be non-cooperative and hence the interactions were modeled as a two stage non-cooperative game. The subgame perfect Nash equilibrium was used as the solution concept. The game had two symmetric Nash equilibria, which showed that one of the firms should offer P and the other should offer PS to obtain non-zero profits. The fixed cost or the entry cost for the firm to enter the service market was not considered in the model. Inclusion of the entry cost for service would be an interesting extension of the model. Further the model considered a single product *type* and the competing firms were assumed to be *same* in terms production and servicing capabilities. It is worth investigating the model where both the firms have different production and service costs. One of the prospective research directions is to consider market segments with different reservation prices. Specifically, the model considered the service plan for a single time period as *lifetime*. Instead, different market segments can be identified based of different lifetimes, as perceived by the consumers. The model basically assumed the objective of the firms to be profit maximization. In contrast, the objective of market penetration would be an interesting variant of the model.

References

Adams, W. J., J. L. Yellen. 1976. Commodity bundling and the burden of monopoly. *The Quarterly Journal of Economics* **90** 475–498.

Alexander, W. L., S. Dayal, J. J. Dempsey, J. D. V. Ark. 2002. The secret life of factory service centers. *The McKinsey Quarterly* 107–115.

Anderson, D. L., A. J. Delattre. 2002. Five predictions that will make you rethink your supply chain. *Supply Chain Management Review* **5**.

Ansari, A., S. Siddarth, C. B. Weinberg. 1996. Pricing a bundle of products or services: The case of nonprofits. *Journal of Marketing Research* **33** 86–93.

Chen, Y. 1997. Equilibrium product bundling. *Journal of Business* **70** 85–103.

Cohen, M. A., Y.-S. Zheng, V. Agrawal. 1997. Service parts logistics: A benchmark analysis. *IIE Transactions* **29** 627–639.

Dennis, M. J., A. Kambil. 2003. Service management: Building profits after the sale. *Supply Chain Management Review* **January** 42–48.

Einhorn, M. A. 1992. Mix and match compatibility with vertical product dimensions. *The RAND Journal of Economics* **23** 535–547.

Eppen, G. D., W. A. Hanson, R. K. Martin. 1991. Bundling – New products, new markets, low risks. *Sloan Management Review* **32** 7–14.

Guiltinan, J. P. 1987. The price bundling of services: A normative framework. *Journal of Marketing* **51** 74–85.

Hanson, W. A., R. K. Martin. 1990. Optimal bundle pricing. *Management Science* **36** 155–174.

Herrmann, A., F. Huber, R. H. Coulter. 1999. Product and service bundling decisions and their effects on purchase intention. *Pricing Strategy and Practice* **5** 99–107.

Howells, J. 2000. The nature of innovation in services. *OECD/Australia Workshop on Innovation and Productivity in Services*. Sydney, Oct 31–Nov 3.

Johnson, M. D., A. Herrmann, H. H. Bauer. 1999. The effects of price bundling on consumer evaluation of product offerings. *International Journal of Research in Marketing* **16** 129–142.

Kameshwaran, S., N. Viswanadham, V. Desai. 2007. On bundling and pricing of the service with the product. *Proceedings of 3rd IEEE International Conference on Robotics and Automation*. Scottsdale, Arizona, September 22–25, 652–657.

Karaomerlioglu, D., B. Carlsson. 1999. Manufacturing in decline? a matter of definition. *Economy, Innovation, New Technology* **8** 175–196.

Lester, R. K. 1998. *The Productive Edge: How U.S. Industries Are Pointing the Way to a New Era of Economic Growth*. W. W. Norton, New York.

Marceau, J., C. Martinez. 2002. Selling solutions: Product-service packages as links between new and old economies. *DRUID Summer Conference on Industrial Dynamics of the New and Old Economy - Who is embracing whom?*. Copenhagen, June 6–8.

Mas-Colell, A., M. D. Whinston, J. R. Green. 1995. *Microeconomic Theory*. Oxford University Press, New York.

Matutes, C., P. Regibeau. 1992. Compatibility and bundling of complementary goods in duopoly. *The Journal of Industrial Economics* **40** 37–54.

McAfee, R. P., J. McMillan, M. D. Whinston. 1989. Multuproduct monopoly, commodity bundling, and correlation of values. *The Quarterly Journal of Economics* **104** 371–383.

Miles, I. 1994. Innovation in services. M. Dodgson, R. Rothwell, eds., *Handbook of Industrial Innovation*. Aldershot, UK and Brookfield, 243–256.

Nash, J. F. 1951. Non-cooperative games. *Annals of Mathematics* **54** 286–295.

Nauman, M. 1994. What's driving the leaders. *San Jose Mercury News* .

Salinger, M. A. 1995. A graphical analysis of bundling. *Journal of Business* **68** 85–98.

Schmalensee, R. 1982. Commodity bundling by single-product monopolies. *Journal of Law and Economics* **25** 67–71.

Schmalensee, R. 1984. Gaussian demand and commodity bundling. *Journal of Business* **57** S211–S230.

Soman, D., J. T. Gourville. 2001. Transaction decoupling: How price bundling affects the decision to consume. *Journal of Marketing Research* **38** 30–44.

Stigler, G. J. 1968. A note on block booking. G. J. Stigler, ed., *The Organization of Industry*. Homewood, Illinois: Richard D. Irwin, Inc.

Stremersch, S., G. J. Tellis. 2002. Strategic bundling of products and prices: A new synthesis for marketing. *Journal of Marketing* **66** 55–72.

Varian, H. R. 1992. *Microeconomic Analysis*. W. W. Norton & Company, London.

Viswanadham, N., V. Desai, R. Gaonkar. 2005. Bullwhip effect in integrated manufacturing and service networks. *Proceedings of 2005 IEEE International Conference on Robotics and Automation*. Edmonton, Canada, August 1–2, 2994–2999.

Whinston, M. D. 1990. Tying, foreclosure, and exclusion. *The American Economic Review* **80** 837–859.

Yadav, M. S. 1994. How buyers evaluate product bundles: A model of anchoring and adjustment. *Journal of Consumer Research* **21** 342–353.