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On Bundling and Pricing of the Service with the Product

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Abstract— **Integration of service with product is considered as one of the innovative supply chain initiatives of the next decade. In this paper we consider the problem of product-service bundling and pricing. The product and service are two different, but related markets. We consider a complex durable product, which is economically attractive to maintain and service, than to replace. We show that a manufacturing firm that intends to bundle its service with the product, should take into account the other players in the service market as well as the product market. 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.**

I. Introduction

The supply chain initiatives, from inventory management to e-procurement, are the outcomes of the companies' requirement to meet the ever-changing customer needs. 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. Integration of service with product is considered as one of the innovative supply chain initiatives of the next decade [1]. Manufacturers who have historically focused their attention on providing better quality products in terms of the functionalities, ease of use, and durability, are changing to a customer-focused service oriented approach. 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 [2], [3] 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.

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In [4], 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. 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 [5] 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 *et al* [6] 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 competitive market framework to analyze the problem of product-service bundling. The product and service are two different markets with various players. A product manufacturer who intends to enter the 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 service market?, (2) if so, should he bundle it with the product?, and (3) what is the price of the offerings?. 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.

The paper is structured as follows. The model for the product market and service market, with the consumers' preferences are explained in Section II. The decision making framework for the monopoly situation is considered in Section III and the duopoly game model is solved in Section IV. In Section V, we explain the implications of the results obtained in the paper.

II. The Model

Manufacturing and service are different, yet related markets for a given product. In general, service market has nu-

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merous players (service providers), due to the relatively less entry barriers in terms of technology and cost than that of the manufacturing sector. Its 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 competitive and non-cooperative players, who try to maximize their individual profits.

The concept of bundling from two different markets has been studied in the literature with varying assumptions on markets' structure. Schmalensee [7] assumed the first market to be a monopoly and the second market 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. Whinston [8] assumed that 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. Chen [9] assumed the first market had duopoly and the second market had perfect competition. The central idea of the results in the above paper showed that bundling enables competing firms to differentiate their products and reduce price competition, providing nonzero profits for both the firms.

A. *Product and Service Markets*

We consider a complex durable product P, which is economically attractive to maintain and service, than to replace. The product could be an automobile, a farm equipment, or an elevator. All of these products require after sales support for preventive maintenance, spare parts for repair and emergency breakdown servicing. 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 γ (reservation value).

The intention of bundling the service 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 β 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 β to be a realization of a random variable uniformly distributed in range $[\underline{c}, \overline{c}]$. The β denotes a consumer's *willingness to pay* (WTP) for the lifetime service. The consumer spends this β 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 $\beta \in [\underline{c}, \overline{c}]$ for the lifetime. A consumer with WTP β for the lifetime service, can thus choose to buy the service from the manufacturer or can avail it across different independent service providers during the lifetime. Thus the model assumes homogeneous preference for the product with valuation γ and heterogeneous valuation for service with valuations uniformly distributed in range $[\underline{c}, \overline{c}]$.

B. *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 as firm) to survive in such a market, the cost $c_P \leq \gamma$ and the price of the product q_P should be such that $c_P \leq q_P \leq \gamma$. Let the constant marginal cost of providing the lifetime service for the firm be c_S. If the firm provides the lifetime service for price q_S, then all the consumers with WTP $\beta \geq q_S$ 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 $\beta \geq q_S$ would prefer the service from the manufacturer directly. The WTP β and the price q_S 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 an appropriate discounting factor.

We assume a continuum of consumers of total measure one. The term *offerings* is used to denote the set of commodities offered by the firm for sale. The three basic offerings considered are 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

TABLE I
UNIT PAYOFFS TO THE FIRM AND A CONSUMER WITH WTP β FOR SERVICE

Offering	Firm	Consumer
P	$q_P - c_P$	$\gamma - q_P$
$P+S$	$q_P + q_S - c_P - c_S$	$\gamma + \beta - q_P - q_S$
PS	$q_{PS} - c_P - c_S$	$\gamma + \beta - q_{PS}$

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 can also sell the product without service. This decision is based on numerous parameters like cost, price, and other players in the market. Let q_P, q_S, and q_{PS} 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 $\beta(\in [\underline{c}, \overline{c}])$ is shown in Table I. 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* or synergy. 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. All these mixed offerings need not be considered as possible strategies, as they provide the same revenue as the offering $P+S$.

Theorem 1: The mixed offerings provide the same revenue to the firm as the offering $P+S$.

Proof: It is obvious that offering $P \,\&\, P+S$ provides the same revenue as $P+S$. Consider the offering $P \,\&\, PS$ with optimal prices q'_P and q'_{PS}. Let $q^*_P = q'_P$ and $q^*_S = q'_{PS} - q'_P$. The customers who bought just P at price q'_P, would have bought it if the price was q^*_P. Similarly, the consumers who bought the bundle PS at price q'_{PS} would have bought P and S independently if the prices were q^*_P and q^*_S, respectively. Hence, the mixed offering $P \,\&\, PS$ provide the same revenue as $P+S$. Let q'_P, q'_S, and q'_{PS} denote the optimal prices for the mixed offerings $P+S \,\&\, PS$. If $q'_P + q'_S > q'_{PS}$, then it is equivalent to the mixed offering $P \,\&\, PS$, as no one would buy P and S independently. If $q'_P + q'_S \leq q'_{PS}$, then it is equivalent to providing $P+S$. Hence, in any case, $P+S \,\&\, PS$ is equivalent to the offering $P+S$. From the above, it can be easily seen that $P \,\&\, P+S \,\&\, PS$ is also equivalent to $P+S$. ■

Given the above setup, we consider two scenarios in the product market: *monopoly* and *duopoly*.

III. 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 $q_P \leq \gamma$. Hence the optimal price $q^*_P = \gamma$ and the total payoff to the firm is

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

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, $q^*_P = \gamma$. The consumer with $\gamma + \beta \geq q^*_P + q_S$ will also buy the service S. Thus the number of consumers who would buy S is $\frac{\overline{c} - q_S}{\tilde{c}}$, where $\tilde{c} = \overline{c} - \underline{c}$. The other consumers (with $\beta < q_S$) will buy the service from the independent service providers. The firm has to choose the optimal q^*_S that maximizes the total payoff.

$$\begin{aligned} \pi_{P+S} &= (\gamma - c_P) + \max_{q_S}(q_S - c_P)\left(\frac{\overline{c} - q_S}{\tilde{c}}\right) && (3) \\ &= (\gamma - c_P) + \frac{1}{\tilde{c}}\left(\frac{\overline{c} - c_S}{2}\right)^2 && (4) \end{aligned}$$

The optimal $q^*_S = \frac{\overline{c} + c_S}{2}$ maximized the above payoff. For the offering PS, a consumer can buy only the bundle. For a price q_{PS}, only consumers with $\beta \geq q_{PS} - \gamma$ would buy the bundle and hence the number of consumers who will buy the bundle is $\frac{\overline{c} - q_{PS} + \gamma}{\tilde{c}}$.

$$\begin{aligned} \pi_{PS} &= (q_{PS} - c_P - c_S)\left(\frac{\overline{c} - q_{PS} + \gamma}{\tilde{c}}\right) && (5) \\ &= \frac{1}{\tilde{c}}\left(\frac{\gamma - c_P + \overline{c} - c_S}{2}\right)^2 && (6) \end{aligned}$$

It can be easily verified that the above payoff is maximized by $q^*_{PS} = \frac{\overline{c} + \gamma + c_P + c_S}{2}$. 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, but it will be profitable only if $\gamma - c_P > 4\tilde{c} + 2(c_S - \underline{c})$. Hence, it is always profitable for the monopoly firm to enter the service market.

IV. DUOPOLY IN THE PRODUCT MARKET

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 γ for the consumers. Both these 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. The theorem 1 is true also for each of the firms in the strategic game situation considered in this model. 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.

A. 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 I).

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 $q_{PS}(1)$ for firm 1 and $q_P(2)$ and $q_S(2)$ for firm 2. There are nine possible pricing games, one for each of the nine possible outcomes of the stage 1. For the firms to make non-zero profit and for the consumers to obtain non-zero payoffs, the prices should satisfy the following conditions: $c_P \leq q_P \leq \gamma$, $c_S \leq q_S \leq \overline{c}$, and $c_P + c_S \leq q_{PS} \leq \gamma + \overline{c}$. Hence unlike the stage 1, the available strategies for the firms are infinite in the pricing game.

The solution concept or the equilibrium used in the paper is the *subgame-perfect Nash equilibrium* [10]. Such an equilibrium is a pair of strategies that constitutes a Nash equilibrium (NE) [11] 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 (finite number of strategies)and stage 2 is an infinite game, 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.

B. 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. The Nash equilibrium of each of them are determined in the following.

Theorem 2: 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* [12] 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: $q_P(1) = q_P(2) = c_P$,$q_S(1) = q_S(2) = c_S$, and $q_{PS}(1) = q_{PS}(2) = c_P + c_S$.

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.

1) Pricing Subgame $(P+S, P)$*::* The strategy for firm 1 is $(q_P(1),\, q_S(1))$ and the strategy for firm 2 is $q_P(2)$. A consumer with WTP β 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 I) 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: $q_P^*(1) = q_P^*(2) = c_P$ and earn zero profits. However, firm 1 can obtain non-zero profit in the service market. All consumers with $\beta \geq q_S(1)$ will obtain the product and service from 1 (by assumption 2). The optimal price price $q_S^*(1)$ maximizes the following quadratic function:

$$\max_{c_S \leq q_S(1) \leq \overline{c}} (q_S(1) - c_S)\left(\frac{\overline{c} - q_S(1)}{\tilde{c}}\right) \tag{7}$$

The first term is the profit to the firm 1 for providing service to one consumer and the second term is the fraction of the consumer segment that will buy the service from firm 1. It can be easily seen that $q_S^*(1) = \frac{\overline{c}+c_S}{2}$ and the payoff to firm 1 is $\frac{1}{\tilde{c}}(\frac{\overline{c}-c_S}{2})^2$.

2) Pricing Subgame (PS, P)*::* The strategy for firm 1 is $q_{PS}(1)$ and for firm 2 is $q_P(2)$. The consumer with WTP β will choose the offering that maximizes her payoff:

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

Hence the consumers with WTP $\beta < q_{PS}(1) - q_P(2)$ 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 $q_P^*(2)$, the best response of firm 1 is to choose $q_{PS}^*(1)$ that maximizes his payoff:

$$\max(q_{PS}(1) - c_P - c_S)\left(\frac{\overline{c} - q_{PS}(1) + q_P^*(2)}{\tilde(c)}\right) \tag{8}$$

Similarly, given $q_{PS}^*(1)$, the best response of firm 2 is to choose $q_P^*(2)$ that maximizes his payoff:

$$\max(q_P(2) - c_P)\left(\frac{q_{PS}^*(1) - q_P(2) - \underline{c}}{\tilde{c}}\right) \tag{9}$$

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

$$q_{PS}^*(1) = \frac{q_P^*(2) + \overline{c} + c_p + c_S}{2} \tag{10}$$

$$q_P^*(2) = \frac{q_{PS}^*(1) - \underline{c} + c_P}{2} \tag{11}$$

Solving the above two linear equations, we have

$$q_{PS}^*(1) = \frac{\tilde{c} + \overline{c} + 2c_S + 3c_P}{3} \tag{12}$$

$$q_P^*(2) = \frac{\tilde{c} - \underline{c} + c_S + 3c_P}{3} \tag{13}$$

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

3) Pricing Subgame $(PS, P+S)$*::* In this pricing game, firm 1 chooses $q_{PS}(1)$ and firm 2 chooses $q_P(2)$ and $q_S(2)$. The consumer with WTP β 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 $q_{PS}^*(1) = q_P^*(2) + q_S^*(2) = c_P + c_S$ 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 $\beta < c_P + c_S - q_P(2)$ (because $q_{PS}^*(1) = q_P^*(2) + q_S^*(2) = c_P + c_S$)) would buy the P from firm 2. Thus the optimal price $q_P^*(2)$ is the solution of the following maximization problem:

$$\max_{q_P(2)}(q_P(2) - c_P)\left(\frac{c_P + c_S - q_P(2) - \underline{c}}{\tilde{c}}\right) \tag{14}$$

The optimal price that maximizes the above quadratic function is $q_P^*(2) = \frac{2c_P+c_S-\underline{c}}{2}$ and the profit to firm 2 is $\frac{1}{\tilde{c}}(\frac{c_S-\underline{c}}{2})^2$. Hence the optimal price for service is $q_S^*(2) = \frac{c_S+\underline{c}}{2}$, 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 cost.

C. 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 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

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

Fig. 1. Stage 1 game in normal form

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 [9].

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 $\overline{c} - c_S > c_S - \underline{c}$ 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.

V. Conclusions

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) what is the optimal price?. 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 willingness to pay for the lifetime service is β, which was assumed to be uniformly distributed in $[\underline{c}, \overline{c}]$. 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 to be non-cooperative and hence the interactions were modeled as a two stage non-cooperative game with the subgame perfect Nash equilibrium 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.

References

[1] D. L. Anderson and A. J. Delattre, "Five predictions that will make you rethink your supply chain," *Supply Chain Management Review*, September 2002.

[2] W. L. Alexander, S. Dayal, J. J. Dempsey, and J. D. V. Ark, "The secret life of factory service centers," *The McKinsey Quarterly*, no. 3, pp. 107–115, 2002.

[3] M. J. Dennis and A. Kambil, "Service management: Building profits after the sale," *Supply Chain Management Review*, vol. January, pp. 42–48, 2003.

[4] N. Viswanadham, V. Desai, and R. Gaonkar, "Bullwhip effect in integerated manufacturing and service networks," in *Proceedings of 2005 IEEE International Conference on Robotics and Automation*, 2005.

[5] M. Nauman, "What's driving the leaders," *San Jose Mercury News*, Januaury 23 1994.

[6] M. A. Cohen, Y.-S. Zheng, and V. Agrawal, "Service parts logistics: A benchmark analysis," *IIE Transactions*, vol. 29, no. 8, pp. 627–639, 1997.

[7] R. Schmalensee, "Commodity bundling by single-product monopolies," *Journal of Law and Economics*, vol. 25, pp. 67–71, 1982.

[8] M. D. Whinston, "Tying, foreclosure, and exclusion," *The American Economic Review*, vol. 80, no. 4, pp. 837–859, 1990.

[9] Y. Chen, "Equilibrium product bundling," *Journal of Business*, vol. 70, no. 1, pp. 85–103, 1997.

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

[11] J. F. Nash, "Non-cooperative games," *Annals of Mathematics*, vol. 54, pp. 286–295, 1951.

[12] H. R. Varian, *Microeconomic Analysis*. London: W. W. Norton & Company, 1992.