Capacity-based Service and Product Bundle Differentiation in a Supply Chain

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A stylized economic model is proposed to study a supply chain of both capacity-based services (such as wireless services) and service-enabling products (such as mobile phones). The model captures the tradeoffs of the supply chain when it provides a service/product bundle line and therefore helps readers understand how the supply chain positions and prices its services and products. The impact of physical products on the intangible services has been demonstrated: when physical products are bundled with capacity-based service, multiple levels of bundle (or bundle line) can be offered while pure services tend to be offered only at a single level. The conditions for companies to provide multiple-levels of service/product bundles depend on the market cannibalization, costs of providing products and services, and the supply chain bargaining power of each partner.

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I. INTRODUCTION

Service sector has long been dominating the U.S. economy. According to CIA world factbook, service is estimated 77.6% of the GDP of U.S. in 2015 (CIA 2016). In recent decades, a particular type of services that I call capacity-based services is growing very fast.

Services become capacity-based when the quality of the services is primarily driven by the service capacity, instead of by the variable service efforts. Capacity-based services usually provide intangible services through an infrastructure with limited capacity. Examples of capacity-based services are cellular voice and data services, such as the services provided by Verizon, T-Mobile, AT&T, etc. Cellular services are two-directional and are sometimes personal. The quality of the cellular services, including the availability of the services, the speed and the delay of data transfer, are determined by the capacity of the infrastructure, including the network of base stations, circuit switches, etc. Another examples are internet services, such as the services provided by Comcast Business, Time Warner Cable, Charter Communications, etc. Those services are also two-directional. The quality of those services are determined by the bandwidth of their network.

For capacity-based services, the service capacity determines the service quality and acquiring the capacity is the primary cost. On the other hand, the variable cost of providing those services is negligible since the services are intangible and many of the services are in the format of analog or digital signal. The opposite examples of capacity-based services are effort-based services, such as personal tax return, food catering, etc. The primary determinant of the service quality for effort-based services is the variable efforts incurred in each service rendered and the primary cost of the effort-based service is the variable cost that is in proportion to the quantity of service rendered. The fixed cost of effort-based services does not affect the service quality. In between those two types of services, I call them mixed services. Examples of mixed services are logistic services that both have significant variable cost and significant fixed capacity cost.

Capacity-based services are often offered at multiple service levels, or as a line of services. For example, in the wireless services Verizon wireless have S (1GB/$30), M (3GB/$45), L (6GB/$60), XL (12GB/$80), and XXL (18GB/$100) plans for its postpaid customers (Verizon 2016). However, there is only one level of voice/text service since all plans include unlimited talk and text. Similarly, Sprint offers its postpaid plans starting from XS (1GB/$20), S (3GB/$30), M (6GB/$45), L (12GB/$60), XL(24GB/$80), XXL (40GB/$100), to Unlimited ($75), all with unlimited talk & text (Sprint 2016). AT&T offers 9 postpaid wireless service with shared data ranging from 300 MB ($20) to 50 GB ($375), all with unlimited domestic calls and messaging (AT&T 2016). T-Mobile offers less levels of postpaid service: 2 GB ($50), 6 GB ($75), 10 GB ($80), and unlimited ($95), again all with unlimited calls and text (T-Mobile 2016).

Readers may still recall the time when most of the wireless plans have limited amount of airtime during daytime and most companies offer multiple levels of service with different airtime. Nowadays, almost all the postpaid plan available on the market only offer one level of service for calls and texts: unlimited. In the meantime, although companies are still differentiating their data service by usage, more and more companies start to allow unlimited data usage at lower speed after customers run out of their high-speed data. Will the same change (from multiple levels of service to just one level) in calls & texts services happens to the data services in the future? It is also interesting to notice that this change of wireless postpaid services from multiple service levels to just one level (unlimited) happens coincidentally with the change of the way the cellphones are sold through the wireless carriers. Previously highly subsided cellphones that require customers to sign on one or multiple-year contracts are now no longer bundled with the services. Therefore, the wireless carriers become pure service providers and according to the result of this paper they will be more willing to provide only one service level. This observation provides insights to help the service providers in their decision-making.

Capacity-based services are often enabled by products that also need to be provided to the consumers. Examples are smartphones for wireless service, modems and routers for internet service. In most cases, those service enabling products are not manufactured by the service providers but, instead either purchased from their supply chain partners, as in the cases of all the wireless services, or provided by independent manufacturers outside the supply chain, such as the modems and routers for internet service.

On the demand side, the consumers of the capacity-based service are heterogeneous in their willingness to pay for services. Just like products are designed and offered in product lines, services are often offered in service lines with multiple service levels. With many differences between the nature of services and products, and between the cost of the services and the products, it is imperative to study the services differently from the literature for products.

However, compared to the literature of product line, the service line literature is relatively limited and new. The product line literature starts with the classic paper by Mussa and Rosen (1978), and popularized by Moorthy (1984) and Moorthy and Png (1992). Numerous other papers have been published afterwards studying the product line or product family in different industries and with different assumptions. More recent example is Qian

(2011) with various cost structures and functions considered. A most relevant study is Vish and Zhu (2006) on development-intensive-products. Their development-intensive-products have similar cost structure to the capacity-based services in this paper.

There are very few studies in the service line in management literature. Hosanagar, Krishnan, Chuang, and Choudhary (2015) study the quality of service (QoS) in the caching services when multiple levels of service quality are offered. However, given the nature of the caching services, the cannibalization is not the same as most of the other industries. Most of the relevant literature are from engineering, especially in communications and computing. For example, Nagurney, Saberi, Wolf, and Nagurney (2015) propose a game theory model for differentiated service-oriented internet. Krämer (2009) finds out that bundling vertically differentiated service is more profitable. Mandjes (2004) uses a queuing theory model to study the pricing in differentiated services. Katzmarzik (2011) studies how to differentiate the software as a service (SaaS). Although in Katzmarzik (2011)'s paper the SaaS is very close to the capacity-based services, there are a few important differences. The most important difference is that Katmarzik assumes there is a software reproduction costs. The demand assumption in Katzmarzik (2011) is also totally different from this paper. Litjens and Hendriks (2014) studies a similar subject to this paper: the cellular network. They use simulation model to demonstrate the impact of service differentiation on service quality and system capacity.

The majority of these studies in engineering literature use numeric analysis or simulation to illustrate the solutions to their problems since the close-form solutions are too difficult to derive.

In this paper, I try to answer the following research questions:

1. If a service provider offers only the capacity-based services, how does the service provider position and price its services and differentiated its services if multiple service levels are offered?
2. If the capacity-based services are offered as packages of service/product bundles, will the inclusion of products change the decision-making of the service provider? If so how are the decisions affected by the inclusion of products in the bundles?
3. Will the supply chain of the service/product bundles, more specifically, the relative strength of bargaining power between the product manufacturer and the service provider affect the bundling decision?

This paper contributes to the literature in multiple ways. First, an important type of services that I call capacity-based services is identified since their cost structure and delivery methods are so different from other services such as effort-based services. Therefore, the service providers of the capacity-based services should also have different strategies to manage the services. Second, the impact of having physical products included in service packages is demonstrated. The results of this research are also confirmed by anecdotal observations in wireless industry.

In next section, I will first define capacity-based services and service-enabling products and outline the cost of providing the service and the products at different quality levels. Then I will describe the assumptions on the market demand and consumer utility functions. In the main model, I will study two scenarios: a pure service provider and a supply chain of service/product bundles. In both scenarios, I will formulate three strategies: multiple levels of services or bundles (service line or bundle line strategy), single level of service or bundle for all consumers (one-size-fit-all service or bundle strategy), and single level of service or bundle only for high-end

consumers (niche service or bundle strategy).
Figure 1 below summarizes the three strategies:

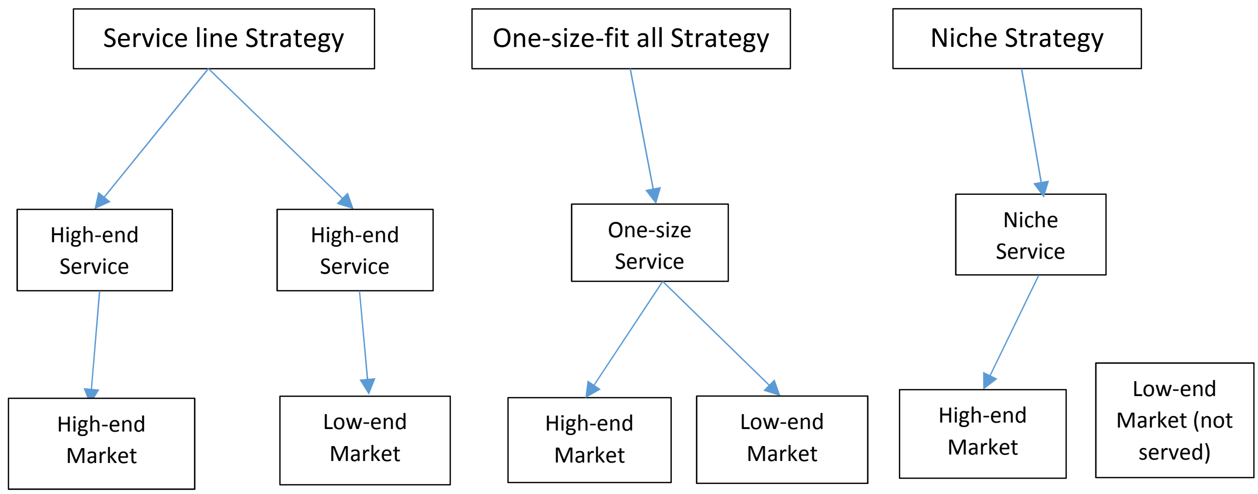

FIGURE 1. THREE STRATEGIES.

Finally, I will derive the conditions under which one of the strategies dominates others. In the last section I will summarize the results of this paper and bring out the managerial implications of those results. Additional suggestions as how to extend this research in the future are also provided at the end of the paper.

II. MODEL AND ANALYSIS

2.1. Capacity-based Services and Service-enabling Products

Consider a service provider who offers a capacity-based services (hereafter simply refer to as "services") with quality (service) level of s. Here the service quality or service level refers to a vertical differentiated attribute, for which all consumers agree on the ranking of the attributes. Examples of the quality level are the minutes of voice talk, number of texts, or amount of data in cellular services. Therefore, the service quality we use here is not conformance quality.

The consumption of the capacity-based services requires service-enabling products. A manufacturer produces the products with quality level of q. Similarly, the quality level of the products refers to a vertical differentiated attribute, such as features and functionality, not the conformance quality.

The cost of providing capacity-based services with quality level of s is primarily in term of fixed cost (fixed only in term of not in proportion to the quantity of service provided) to acquire the service capacity: $c_s s^2$, where c_s is the marginal cost coefficient of providing the service quality.

The cost of providing the service-enabling products with quality level of q, however, is primarily in term of the variable cost (in proportion to the quantity of products sold) to manufacture the products: $c_p q^2$ per product, where c_q is the marginal cost coefficient of providing the product quality.

The above two cost function assumptions are commonly used in the literature (Mussa and Rosen 1978, Moorthy

1984, Moorthy and Png 1992, Banker, Khosla, and Sinha 1998, Chambers, Kouvelis, and Semple 2006). However, as long as the cost function is concave, the essential results of this paper will be preserved.

2.2. Consumers

Without loss of generality, we assume the heterogeneous consumers consisted of two market segments: high-end segment and low-end segment, with market size of n_H and n_L, respectively. Within each market segment, however, consumers are homogeneous in their willingness to pay for products and services. The service provider may choose to provide either a single level of service, or two types of capacity-based services: high-end and low-end service with quality of s_H and s_L. respectively. Consumers are heterogeneous of their willingness to pay for service. Similarly, the manufacturer also provides two types of products: high-end and low-end product, with quality of q_H and q_L, respectively. The utility function of a consumer of type i ($i = H, L$) is modeled as $u_i s_j$ and $v_i q_k$ when the consumer purchases service of type j ($j = H, L$) and product of type k ($k = H, L$), where v_i is the marginal willingness to pay for the services and u_i is the marginal willingness to pay for the products. When the service provider offers a service line of high-end and low-end services, it incurs risk of service cannibalization, i.e., the risk of the low-end services being purchased by the high-end customers. We define $R_s = \frac{n_h}{n_{hl}}(\frac{u_h}{u_l} - 1)$ as market cannibalization index for service since it reflects how strong the cannibalization risk is. In order to prevent high-end consumers from buying the low-end service (i.e., cannibalization), companies have to lower the price of their high-end services and lower the quality of their low-end service. R_s is the degree of quality reduction of the low-end quality. We will see why we define the cannibalization index in this way in next section. Similarly, we define $R_p = \frac{n_h}{n_{hl}}(\frac{v_h}{v_l} - 1)$ as the market cannibalization index for products.

2.3. Pure Service Provider

First let's consider a service provider that offers only services to its customers. The consumers will have to purchase the products through independent retailers. The service provider has three options: offering a service line consisting of a high-end service and a low-end service for the high-end and low-end market segments respectively; offering a one-size-fit-all service for both market segments; or offering only a high-end service only for the high-end market segment.

In order to offer both the high-end and the low-end service so that the self-selecting consumers will purchase the service design for them, two conditions need to be satisfied: the incentive compatible (IC) conditions and individual rationality (IR) condition (Moorthy 1984). The IC condition makes sure that the customers will voluntarily purchase the service designed for them, i.e., their utility function will be higher when purchased the services designed for them than when they purchase the services not designed for them. IR condition ensures that all customers will participate, i.e., their utility functions are none-negative when they purchased the service designed for them.

The pure service provider's problem of service line (SL) is to choose optimal qualities and optimal prices for its service line in order to maximize its profit function as follows:

$$\prod_{SP}^{SL} n_h p_h + n_l p_l - c_s s_h^2 - c_s s_l^2. \qquad (1)$$

$s.t.$
IC1: $u_h s_h - p_h \geq u_h s_l - p_l$.
$IC2$: $u_l s_l - p_l \geq u_l s_h - p_h$.
$IR1$: $u_h s_h - p_h \geq 0$.

$IR2: u_l s_l - p_l \geq 0.$

The optimal service levels are $s_h = \frac{u_h}{c_s}$ and $s_l = \frac{n_l u_l(1-R_s)}{c_s}$, where $R_s = \frac{n_h}{n_{hl}}(\frac{u_h}{u_l} - 1)$. Clearly the condition for problem (1) to have a feasible line of services is when $R_s < 1$.

The service provider's problem when it offers a one-size-fit-all service (OS) is to choose optimal quality and price of the service in order to maximize its profit as follows:

$$\prod_{SP}^{OS}(n_h + n_l)p_o - c_s s_o^2. \tag{2}$$

$s.t.$
IR: $u_l s_0 - p_0 \geq 0.$

The service provider's problem when it offers a high-end niche service (NS) is to choose optimal quality and price of the niche service in order to maximize its profit as follows:

$$\prod_{SP}^{NS} n_h p_o - c_s s_o^2. \tag{3}$$

$s.t.$
IR: $u_h s_0 - p_0 \geq 0.$

When $R_s < 1$, compare these three options by their optimal profit levels, it is easy to see the ranking is $\pi_{SP}^{OS} > \pi_{SP}^{SL} > \pi_{SP}^{NS}$. When $R_s \geq 1$, however, the ranking changes to $\pi_{SP}^{NS} > \pi_{SP}^{OS}$ since service line option is no longer available. The results are summarized below in Proposition 1.

PROPOSITION 1*: When a capacity-based service provider offers only service to its customers, it will only offer a single service level:*

1.1. When market cannibalization for service is low ($R_s < 1$), the service provider will offer a one-size-fit-all service for both the high-end and low-end market segments.

1.2. When market cannibalization for service is high ($R_s \geq 1$), the service provider will offer a niche product only for its high-end market segment.

1.3. Service line is never optimal to offer.

Proof of Proposition 1:

To solve problem (1), it is easy to see that the single-crossing condition is satisfied and therefore, the optimal solution happens when constraint IC1 and IR2 are binding. Replacing the two prices from the binding constraints: $p_l = u_l s_l$ and $p_h = u_h(s_h - s_l) + u_l s_l$ in the profit function (1), by FOC, we have the optimal qualities $s_h{}^* = \frac{u_h}{c_s}$ and $s_l{}^* = \frac{n_l u_l(1-R_s)}{c_s}$, and the optimal profit $\pi_{SP}^{SL} = \frac{(n_h+n_l)^2 u_l{}^2 - 2n_h n_l u_h u_l(1-R_s)}{4c_s}$, where $R_s = \frac{n_h}{n_{hl}}(\frac{u_h}{u_l} - 1)$.

To solve problem (2) and (3), it is easy to see that optimal solutions happens when the IR constraint binds. Again by FOC, we have the optimal solution for problem (2) as $s_o{}^* = \frac{(u_h+u_l)v_l}{c_s}$ and $s_N{}^* = \frac{n_h u_h}{c_s}$ for problem (3). The optimal profit for (2) is $\pi_{SP}^{OS} = \frac{(n_h+n_l)^2 u_l^2}{4c_s}$ and $\pi_{SP}^{NS} = \frac{n_h{}^2 u_h{}^2}{4c_s}$ for (3).

To compare these three optimal profit levels, it is easy to see that when $R_s < 1$, $\pi_{SP}^{OS} > \pi_{SP}^{SL} > \pi_{SP}^{NS}$. When $R_s \geq 1$, $\pi_{SP}^{NS} > \pi_{SP}^{SL}$ and service line strategy is no longer feasible, Q. E. D.

The example of pure service provider is Amazon prime video, it offers only one level of service and the service enabling products are not offered in Amazon's service package. Similarly, Netflix was offering only one service level before it started to have 4k video stream service. In wireless services, many companies in recent years start to offer only one service level (which is unlimited) for talks and texts for their postpaid customers.

2.4. Supply Chain of Product/Service Bundles with a Service Provider and a Manufacturer

In this subsection, a service provider offers service/product bundles. Consumers will be able to see the separate prices for services and for products and they are free to pick any product to bundle with their choice of service. In the service/product bundles, the products are purchased from a manufacturer. The product manufacturer charges the service provider a unit wholesale price w that is a fixed proportion of the retail price p: $w = \alpha p$, where $0 < \alpha < 1$ is the fixed proportion negotiated between the two supply chain partners. In this case, the manufacturer will be the one to determine the retail price although the service provider is the one to communicate the retail price to the end consumers.

The sequence of the decision-makings is showed in Fig. 2 as follows:

To differentiate the prices for the products and the prices for the services, superscript will be used (s for service and p for product). For example, p_h^s is the price of high-end service and p_l^p is the price of low-end product.

The service provider's problem of line of service/product bundle (BSPL) is to choose the optimal qualities and prices for its services in order to maximize its profit as follows:

$$\prod_{SP}^{BSPL} n_h(p_h^s + (1-\alpha)p_h^p) + n_l(p_l^s + (1-\alpha)p_l^p) - c_s s_h^2 - c_s s_l^2. \quad (4)$$

$s.t.$
$IC1: u_h s_h - p_h^s \geq u_h s_l - p_l^s.$
$IC2: u_l s_l - p_l^s \geq u_l s_h - p_h^s.$
$IR1: u_h s_h - p_h^s \geq 0.$
$IR2: u_l s_l - p_l^s \geq 0.$

On the other hand, the manufacturer's problem is to position and price its product in the bundled line (BPSL) in order to maximize its profit as follows:

$$\prod_{M}^{BPSL} n_h(\alpha p_h^p - c_p s q_h^2) + n_l(\alpha p_l^p - c_p s q_l^2). \quad (5)$$

$s.t.$
IC1: $v_h q_h - p_h^p \geq v_h q_l - p_l^p.$
$IC2: v_l s_l - p_l^s \geq v_l s_h - p_h^s.$
$IR1: v_h q_h - p_h^p \geq 0.$
$IR2: v_l s_l - p_l^s \geq 0.$

Solving the manufacturer's problem (5), the optimal product quality $q_h = \alpha v_h / 2c_p$ and $q_l = \alpha(1-R_p) v_l / 2c_p$ when $R_p < 1$. It will be easy to show that the manufacturer will only offer the high-end product when $R_p \geq 1$ and the one-size-fit-all single product for both segments is never optimal.

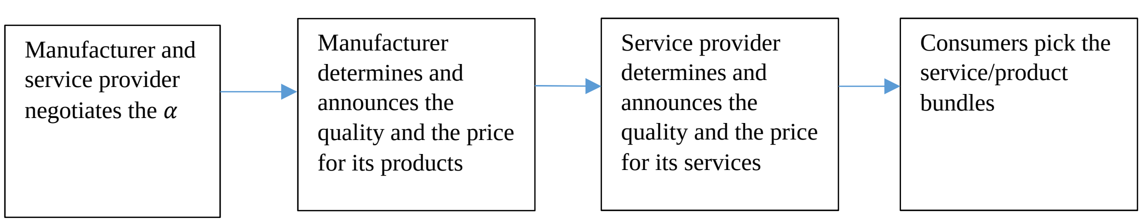

FIGURE 2. SUPPLY CHAIN DECISION-MAKING PROCESS.

On the other hand, solving the service provider's problem (4), the service provider's optimal service levels are still the same as in problem (1) of the pure service provider. However, the optimal profit is not the same.

Again, the service provider's alternatives to the service/product bundle line are one-size-fit-all service/product bundle strategy, and the high-end niche service/product bundle strategy.

The service provider's problem of bundled one-size-fit-all service service/product (BOSP) is to choose optimal quality and price for its service in the bundle in order to maximize its profit as follows:

$$\prod_{SP}^{BOSP}(n_h+n_l)(p_o^s+(1-\alpha)p_o^p)-c_s s_o^2. \tag{6}$$

$$s.t.$$
$$u_l s_o - p_0^s \geq 0.$$

The manufacturer's problem of BOSP is to choose optimal quality and price for its product in the bundle in order to maximize its profit as follows:

$$\prod_{M}^{BOSP}(n_h+n_l)(\alpha p_o^p - c_p q_o^2). \tag{7}$$

$$s.t.$$
$$v_l q_o - p_o^p \geq 0.$$

The service provider's problem of bundled niche service/product (BNSP) is to choose optimal quality and price for its service in the niche bundle in order to maximize its profit as follows:

$$\prod_{SP}^{BNSP} n_h(p_N^s+(1-\alpha)p_N^p)-c_s s_N^2. \tag{8}$$

$$s.t.$$
$$u_l s_N - p_N^s \geq 0.$$

The model of the manufacturer's problem of BNSP is to choose optimal quality and price for its product in the niche bundle in order to maximize its profit as follows:

$$\prod_{M}^{BNSP} n_h(\alpha p_N^p - c_p q_N^2). \tag{9}$$

$$s.t.$$
$$v_l q_N - p_N^p \geq 0.$$

Again, we compare the service provider's profit for three strategies: bundled line, one-size-fit-all bundle, and niche bundle, we have the following proposition 2:

PROPOSITION 2*: When a capacity-based service provider offers service/product bundles, it may offer a line of product/service bundles or a single level of bundle depending on the supply chain structure, market cannibalization on both the products and services, and the cost structure of the products and services.*

2.1. Service/product bundle line dominates the one-size-fit-all or niche bundle strategy when condition 10 satisfied.

2.2. Supply chain bargaining power (α) affects the above-mentioned condition 10 on when bundle line can be dominating.

2.3. Bundle line strategy dominates only when cannibalizations are not high (when $R_s < 1$ and $R_s < 1$) for product or service. When service cannibalization is too high ($R_s \geq 1$), bundle line strategy is no longer available.

2.4. Increasing service cost coefficient (c_s) will increase the region for bundle line strategy being dominating while *increasing product cost coefficient (c_p) will decrease the region for the bundle line strategy being dominating.*

2.5. One-size-fit-all bundle strategy can be the dominating strategy when condition 11 is satisfied.

2.6. Niche bundle strategy can also be the dominating strategy when condition 12 is satisfied.

Proof of proposition 2:

The solution process for problem (4) and (5) is similar to (1) and (2). First solving problem (5), the optimal solutions are ${q_h}^* = \frac{\alpha v_h}{2c_p}$ and ${q_l}^* = \frac{\alpha v_l(1-R_p)}{2c_p}$. Plugging these two optimal product qualities in problem (4), by FOC, the optimal service qualities are still the same as in (1) and they are ${s_h}^* = \frac{u_h}{c_s}$ and ${s_l}^* = \frac{n_l u_l(1-R_s)}{c_s}$. Therefore, when $R_s \geq 1$, bundle line is no longer available. However, when $R_p \geq 1$ but while $R_s < 1$, bundle line still exist except that in both bundles the product is the same high-end product. The optimal profit of bundle line for service provider is as follows:

$$\pi_{SP}^{BSPL} = \frac{c_p\left((n_h+n_l)^2 {u_l}^2 - 2n_h n_l u_h u_l(1-R_s)\right) + 2\alpha(1-\alpha)c_s(n_h+n_l)\left(n_h(v_h-v_l)^2 + n_l {v_l}^2\right)}{4c_p c_s}$$

Similarly, solving the optimal solutions for manufacturer's problem (7) and (9), and plugging back to the service provider's problem (6) and (8), the optimal profit of one-size-fit-all bundle for service provider is as follows:

$$\pi_{SP}^{BOPL} = \frac{(n_h+n_l)\left(c_p(n_h+n_l){u_l}^2 + 2\alpha(1-\alpha)c_s {v_l}^2\right)}{4c_p c_s}$$

The optimal profit of niche bundle for service provider is as follows:

$$\pi_{SP}^{BNPL} = \frac{n_h\left(c_p n_h {u_h}^2 + 2\alpha(1-\alpha)c_s {v_h}^2\right)}{4c_p c_s}$$

Comparing the above three optimal profit levels, it is easy to see that when bundle line exists $\pi_{SP}^{BSPL} > \pi_{SP}^{BNPL}$ is always true since the condition is $c_p {n_l}^3 {u_l}^2 (1-R_s)^2 + 2\alpha(1-\alpha)c_s {n_l}^2 {v_l}^2 (1-R_p)^2 > 0$.

Therefore, the condition for bundle line to be dominating is when $\pi_{SP}^{BSPL} > \pi_{SP}^{BOPL}$, and the condition is as follows:

$$\alpha(1-\alpha)\frac{c_s(n_h+n_l){R_p}^2 {v_l}^2}{c_p {n_l}^2 u_h u_l(1-R_s)} > 1 \qquad (10)$$

It is easy to see that when α is too high or too low, the above condition will not be satisfied. The best scenario for (10) to be true is when bargaining power being equal, or $\alpha = 1/2$. It is also easy to see that when both cannibalization index are high it is more likely for condition 10 to be satisfied. Similarly, the ratio of cost coefficient contributes to the above condition: cost of service helps and cost of product works against the condition (10).

The condition for $\pi_{SP}^{BOPL} > \pi_{SP}^{BNPL}$ when bundle line is not dominating are as follows:

$$2\alpha(1-\alpha)c_s\left((n_h+n_l){v_l}^2 - n_h {v_h}^2\right) + c_p\left((n_h+n_l)^2 {u_l}^2 - {n_h}^2 {u_h}^2\right) > 0$$

and $\alpha(1-\alpha)\frac{c_s(n_h+n_l){R_p}^2 {v_l}^2}{c_p {n_l}^2 u_h u_l(1-R_s)} \leq 1$ (11)

Therefore, the condition for $\pi_{SP}^{BNPL} > \pi_{SP}^{BOPL}$ when bundle line is not dominating are as follow:

$2\alpha(1-\alpha)c_s((n_h+n_l){v_l}^2 - n_h {v_h}^2) + c_p((n_h+n_l)^2 {u_l}^2 - {n_h}^2 {u_h}^2) \leq 0$ and $\alpha(1-\alpha)\frac{c_s(n_h+n_l){R_p}^2{v_l}^2}{c_p {n_l}^2 u_h u_l (1-R_s)} \leq 1$ (12)

Q. E. D.

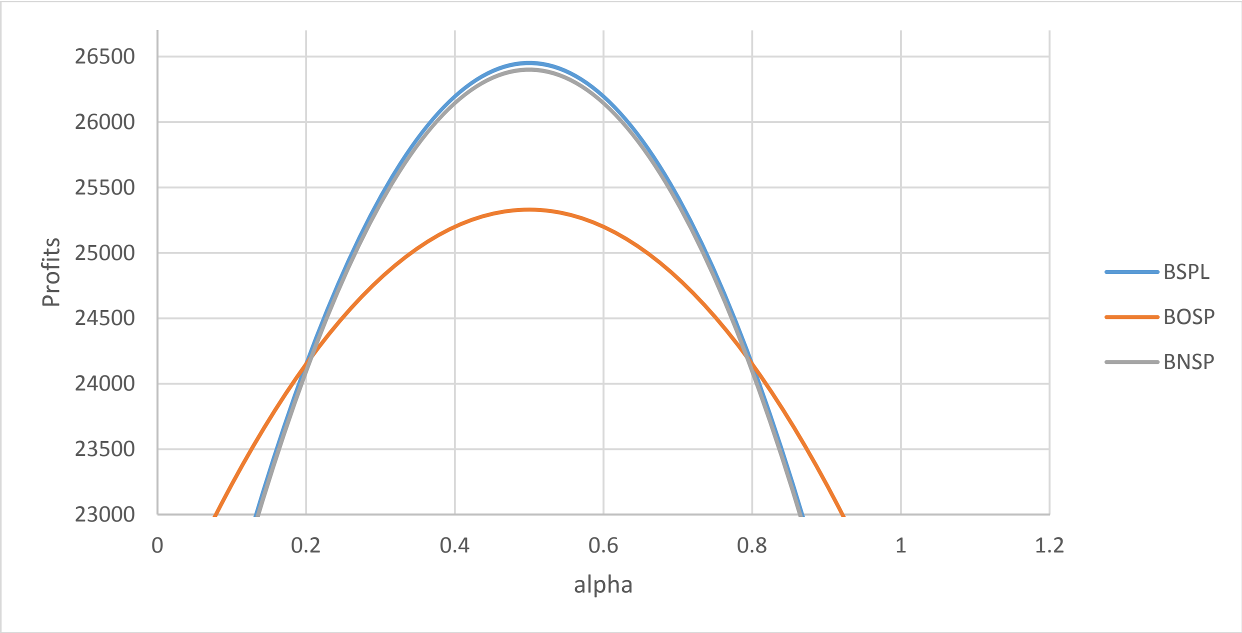

FIGURE 3. PROFITS OF BUNDLE LINE, ONE-SIZE-FIT-ALL, AND NICHE BUNDLE.

To illustrate condition (10), I run a numeric example with $n_h = 1000$, $n_l = 1000$, $u_h = 4$, $u_l = 2.1$, $v_h = 16$, $v_l = 8.1$, $c_p = 5$, $c_s = 200$. The profit of $\pi_{SP}^{BSPL}, \pi_{SP}^{BOPL}, \pi_{SP}^{BNPL}$ changing with α is illustrated in Fig. 3 below:

Now, let's double the low-end segment market size $n_l = 2000$ with all other parameters remain the same, the three optimal profits changing with α are showed in Fig. 4 below:

In general, the product component in the service/product bundles changes the decisions of the service provider. Providing multiple levels of service/product bundles can be more profitable. However, the market cannibalization in the service cannot be easily mitigated by adding the product components in the service package. From the practice in wireless industry, it is common for wireless companies to either provide additional low-end options or allow Mobile Virtual Network Operator (MVNO) to provide the low-end options to the consumers ignored by the postpaid plans. The low-end options are prepaid plans, sometimes in the forms of pay as you go (PAYG). In this way, serving low-end consumers will have minimal cannibalization effects on the postpaid plan customers.

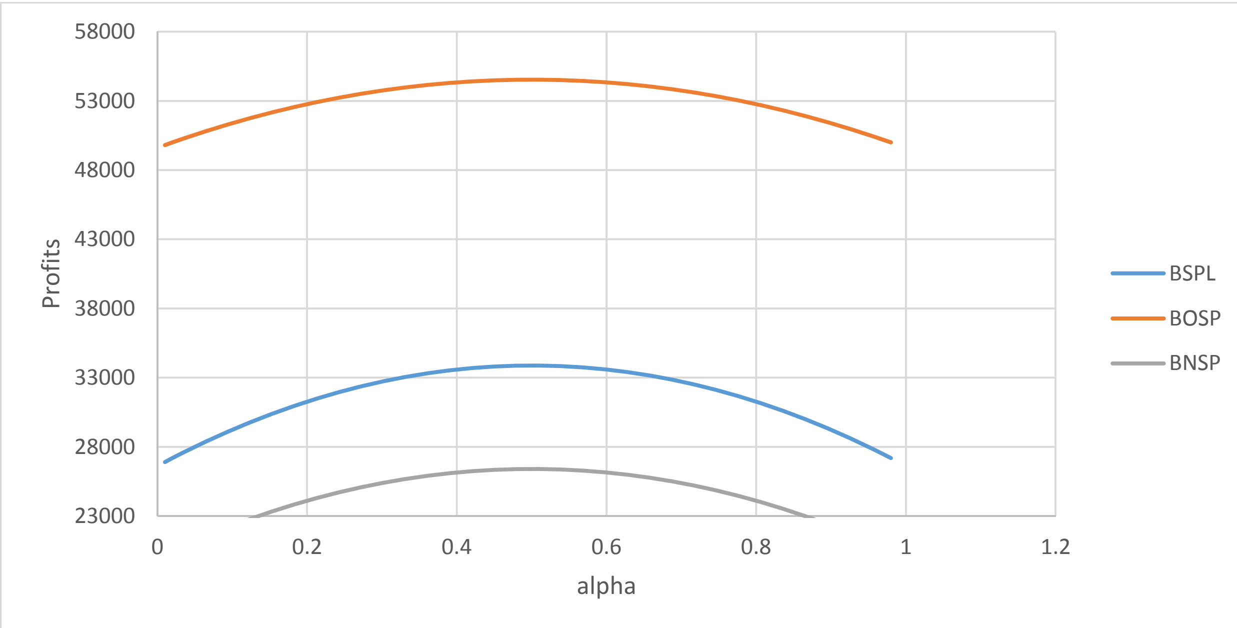

FIGURE 4. PROFITS OF BUNDLE LINE, ONE-SIZE-FIT-ALL, AND NICHE BUNDLE.

III. MANAGERIAL IMPLICATIONS AND FUTURE RESEARCH

Product line design has been an important decision for companies facing heterogeneous consumers. Most of the existing literature on product line design focus on the development of physical products and for those very few studies on service line design they do not differentiate service by their different nature.

In this paper, I identify an important type of services: capacity-based service. Many examples of capacity-based services are in fast growing industries, such as the wireless communication, cloud storage service, online video streaming service, etc. Companies in those fast growing industries must make important decisions, such as how to develop, position, and price their service or service/product bundle offerings.

I propose a stylized game theory model to capture those decision-making process with specific modeling of the unique nature of capacity-based service: the variable cost of delivering capacity-based service is almost zero.

On the other hand, since the capacity-based service requires service-enabling products the service providers often offer product/service bundles. The inclusion of physical products, with their primary cost being the variable production cost, totally change the decision-making equation.

Let's take a look at the example of wireless communication industry. In its early years when voice call and texts are the primary forms of consumer services, companies such as AT&T provides wireless service bundled with cell phones. The service plans are differentiated by usage, i.e., minutes of airtime. Later when data communication become popular because of the phone such as Blackberry, and especially when smartphones such as iPhones bring more apps to increase the data usage, service plans start to have more dimensions of differentiation: data usage and data speed. However, the service/product bundling becomes possible because of two important conditions: fixed term contract for one year or even multiple years of service, and the locking of the cellphones to the carrier's network. As a matter of fact, many cellphone manufacturers actually produce cellphone models specifically designed for one wireless company's network.

In recently years, however, because of the market competition and the FCC regulation changes, those two conditions are no longer popular or available. More and more wireless companies are offering their service without the commitment of contract. In this way, selling cellphones without subsidy gives wireless companies no advantage in price. Wireless companies are becoming more like pure service providers. This give the rise of unlimited calls & texts in the service offerings. In another words, service providers tend to offer only one level of services to all postpaid consumers.

Another important implication from this paper is the prediction for data service. Currently, wireless companies are still in the process of expanding their infrastructure for higher demand of data usage. Therefore, in order to avoid the capacity bottle-neck, companies are still charging different prices by different service levels of data usage. For example, AT&T was trying to persuade some of their customers to transfer from their grandfathered unlimited data plan to limited data plans (Brodkin 2015). However, once the equilibrium of capacity has been reached, this paper predicts that most wireless companies will again offer unlimited data to all their postpaid customers, unless the wireless companies find new ways to bundle their services with smartphones or some new devices.

The intuition behind the reason why a pure capacity-based service provider would offer a one-size-fit-all service is that when there is little variable cost to provide service and all the cost are fixed (albeit only fixed in term of quantity of service, it is still a function of service quality), it is more profitable to expand your capacity and offer the same level (in some case, unlimited) of service to everyone.

For companies with ability to bundle service with products, providing multiple service levels can be more profitable. However, it also depends on other factors, including the bargaining power between the manufacturer and the service provider, the market cannibalization of services and of products, the costs of providing services vs providing products.

This paper does have a few important assumptions that can lead to the future research directions. First, the discrete market segmentation models can be extended to a continuous distribution model. Second, the service usage per consumer can be more explicitly modeled to include more factors not considered in this paper, such as usage induced by applications, price sensitivity of usage, etc. Third, the supply chain relationship can be modeled differently when market segmentation is no longer modeled as discrete. Fourth, it will be interesting to see the impact of competition on service provider's service line decisions.

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