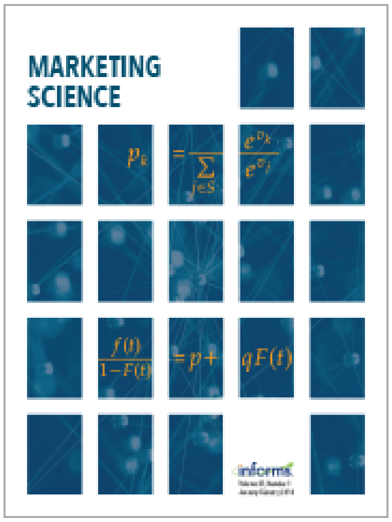

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Research Note

Impact of Customer Knowledge Heterogeneity on Bundling Strategy

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We consider a marketer of components who can select one of three alternative pricing strategies: (1) a pure component strategy (i.e., the customer can only buy the components individually), (2) a pure bundling strategy (i.e., the components must be purchased together), or (3) a mixed bundling strategy (i.e., the customer may buy a component individually, or buy the bundle). We consider a market where customer knowledge of components varies and propose that a high-knowledge customer can determine with greater certainty whether a given component is useful to her. Consequently, more knowledgeable customers have higher variability in their reservation price of a component. Using an analytical model, we identify the conditions under which each of the three pricing strategies maximizes profit and show that three factors determine the optimal strategy: marginal costs of components, distribution of knowledge over the customer population, and relative sizes of customer segments where each segment is interested in the same subset of components. Managerial implications and directions for future research are discussed.

Key words: components; bundling; pricing
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1. Introduction

Bundling is the practice of offering two or more products as a package (Ghosh and Balachander 2007). Bundling strategy has interested researchers for a long time, and a rich literature stream with ever-widening scope has followed the seminal works of Adams and Yellen (1976) and Schmalensee (1984).

Bundling may benefit both the customer and the marketer. The customer gains from reduced search and transaction costs (Harris and Blair 2006, Yadav and Monroe 1993), and the marketer can generate greater profits through price discrimination and demand expansion (Hitt and Chen 2005, Venkatesh and Mahajan 1993, Eppen et al. 1991, Schmalensee 1984, Adams and Yellen 1976). Bundling also enables the marketer to reduce risk in introducing new products, lessen consumer uncertainty about product quality, exploit product complementarity, and achieve economies of scope (Hitt and Chen 2005, Venkatesh and Kamakura 2003, Simonin and Ruth 1995, Venkatesh and Mahajan 1993, Eppen et al. 1991). Stremersch and Tellis (2002) provide a comprehensive review of the bundling literature. Some of the key contributions to research on bundling include the examination of information products (Bakos and Brynjolfsson 1999, 2000a, b; Geng et al. 2005; Venkatesh and Chatterjee 2006), services (see Rust and Chung 2006 for a review), and intertemporal bundling (Radas and Shugan 1998, Sankaranarayanan 2007).

Several researchers examine when a marketer should adopt a pure component (sell each component individually), pure bundling (sell only the bundle), or mixed bundling (the customer may buy any individual component or the bundle) strategy. For example, using an empirical study involving a series of music/dance performances, Venkatesh and Mahajan (1993) demonstrate that mixed bundling can be more profitable than pure component or pure bundling strategies. Hanson and Martin (1990) formulate optimal bundle price using a mixed integer linear program. Venkatesh and Kamakura (2003) examine the impact of demand interdependencies among components on bundling strategy.

We consider a marketer selling components who can select a pure component, pure bundling, or a mixed bundling strategy. Our research relates closely to Schmalensee (1984) and Bakos and Brynjolfsson (1999). Similar to their work, we consider the distribution of reservation prices of components over the customer population, and posit that a new variable, customer knowledge of components (knowledge), affects this distribution. Customer knowledge plays an important role in purchase behavior (Alba and Hutchinson 1987, Sujan 1985). We argue that prior to purchase, high-knowledge customers can assess the value of a component more accurately than a low-knowledge customer. Hence, if a high-knowledge customer finds a component (not) useful, she would have a (lower) higher reservation price for the component than low-knowledge customers. Therefore, the gap between the reservation prices for "useful" and "not useful" components would increase with customer knowledge, resulting in greater variation of reservation price. An empirical study we conducted supports this position. (Details and findings of the study are available on request.)

It is easy to find both consumer and business product categories where such variation in reservation price may occur:

- A software developer for business applications is deciding which specific software components she needs to buy. She must determine how the available components match her application requirements.
- A professor is deciding which modules of the statistical software SAS she should lease.
- A customer is considering purchase of the components of a home entertainment system such as a TV, VCR, DVD player, stereo receiver, and speakers.
- An automobile owner is choosing between purchasing a suite of services, or specific items such as oil change and tire rotation.

In all these cases, a more knowledgeable customer can better assess the value of a component to herself.

The assumption that the gap between high and low valuations of a component depends on knowledge allows us to consider scenarios very different from those examined by prior researchers. For instance, the classic work of Schmalensee (1984) assumes that the reservation prices of the bundle components follow a multivariate normal distribution, where the contour of equal probability is an ellipsoid, and the distribution is denser near the centroid of the ellipsoid. Our framework is more flexible. For instance, a prevalence of high-knowledge customers gives us a dumb-bell shaped equal probability contour where customers have either high or low valuations.

In their analysis of bundle pricing, Bakos and Brynjolfsson (1999; 2000a, b) do not consider differences in the variance of the reservation price between multiple consumer groups. Their rationale is based on the "law of large numbers," which assures that the deadweight loss per good and the consumer surplus per good in the bundle converge to zero, hence maximizing the marketer's profit. In contrast, by considering customer knowledge, we can find the profit maximizing pricing strategy without invoking the law of large numbers.

We show that three factors determine the nature of the optimal pricing plan: marginal costs of the components, the distribution of knowledge over the customer population, and the relative sizes of customer segments where each segment is interested in the same subset of components. (For instance, for two components, the segments are customers interested in both components, only the first component, only the second component, and neither component.) We find that

1. If marginal costs are very low, profit is maximized by a pure bundling plan with a medium or a low price. As marginal costs become somewhat higher, the pure bundling plan continues to be optimal as long as customer knowledge is generally low.
2. If marginal costs are high and high-knowledge customers are present in abundance, two cases may arise. If customers tend to be interested in a majority of the components at once, a pure component plan that offers each component at a high price is optimal. In contrast, if customers tend to be interested in a minority of the components and not interested in the rest, a mixed bundling plan that offers the bundle at a medium or low price, but offers the components at even higher prices than the pure component plan, is optimal.

The paper is organized as follows. In the next section, we develop a framework to show how valuations of a component may differ among customers of different knowledge categories, thus giving the marketer an opportunity to segment the market based on customer knowledge. We then develop an analytical model of customer choice of components and use it to show that all three strategies (pure component, pure bundling, mixed bundling) may be appropriate in different contexts. The findings are illustrated with a numerical example. In §4, we summarize our findings, discuss the managerial implications of our research, and outline future research directions. Proofs are provided in the Technical Appendices available at http://mktsci.pub.informs.org.

2. Conceptual Framework and Model Development

We consider a monopolist marketer who sells two components of similar value and wants to maximize expected profit. (In the concluding section, we discuss the implications of our findings for competitive strategy.)

2.1. Customer Choice

We assume that a customer would purchase at most one unit of each component and that, given alternative product offerings, she would select the offer that gives her the highest surplus, defined as reservation price minus price. The no-purchase option is always available to her, which offers zero surplus. Thus, an offering by the marketer is selected only if its surplus is at least zero. Given two options with equal surplus, we assume that the customer can be given a slight inducement to select the offering that is more profitable to the marketer.

We make the following assumptions about the reservation prices of customers:

1. We assume that the components are of similar value to customers. For a given customer, a component may or may not be useful. The true value of the component to a customer is $(1+D)$ if the component is useful, and $(1-D)$ if the component is not useful, where $0 < D \le 1$. We assume that D is common across customers. If $D = 1$, the component has no value to the customer if it is not useful; otherwise, it has some residual value. The average of the high and low true values, which we call "medium valuation," is chosen to be unity.

Customers vary in their ability to determine whether a component is truly useful before purchase. If the customer feels a component is useful, she assigns a probability $\frac{1}{2}(1+\alpha)$ that it is really useful, and a probability $\frac{1}{2}(1-\alpha)$ that it is really not useful, where $\alpha \in [0, 1]$ is an individual specific variable. If the customer does not feel the component is useful, she assigns a probability $\frac{1}{2}(1-\alpha)$ that it is really useful, and a probability $\frac{1}{2}(1+\alpha)$ that it is really not useful.

A larger α indicates greater ability to determine whether the component is useful prior to purchase. For instance, if $\alpha = 1$ and the customer feels a component is useful, she assigns a 100% probability the component is useful, and a 0% probability the component is not useful. In contrast, if $\alpha = 0$, the customer assigns only a 50% probability that the component is useful.

We assume that the customer is risk neutral; that is, the reservation price of a component is its expected value before purchase. Thus, the reservation price of a component is $(1+\alpha D)$ if, prior to purchase, the customer thinks the component is useful, and $(1-\alpha D)$ if she does not. Denoting αD by a, a customer's reservation price of a component is $(1+a)$ if she thinks the component is useful, and $(1-a)$ if she thinks it is not useful. Because $a = \alpha D$ increases with a customer's ability to determine whether a component is useful, a is a proxy for the customer's knowledge of components.

We assume that there are at least some customers with $a > 0$, and define $K = \max a$. The parameter K captures how far the reservation price of a component can deviate from the "medium reservation price" of unity. We assume that K is same for both components. Thus, for either component, $a \in [0, K]$, where $K > 0$.

2. Following common practice (e.g., Adams and Yellen 1976, Schmalensee 1984), we assume that the reservation price of the bundle is equal to the sum of the reservation prices of the two components.[1]

[1] A notable exception is Venkatesh and Kamakura (2003) who model the reservation price of a bundle in terms of the demand interdependency among the components.

2.2. Customer Segments and Demand

We assume a market of unit size with demands equal to probabilities. The reservation price of a given component to a customer of type a is either $(1+a)$ (high valuation) or $(1-a)$ (low valuation). Thus, there are four customer segments, high-high (HH), high-low (HL), low-high (LH), and low-low (LL), with reservation prices as shown below.

	Reservation price of		
Segment	Component 1	Component 2	Bundle
HH	$1+a$	$1+a$	$2(1+a)$
HL	$1+a$	$1-a$	2
LH	$1-a$	$1+a$	2
LL	$1-a$	$1-a$	$2(1-a)$

We denote the probabilities of the four segments by Q_{HH}, Q_{HL}, Q_{LH}, and Q_{LL}, respectively, and make the following assumptions about the four customer segments:

1. The cumulative distribution function of a, denoted by $F(a)$, is the same for all four segments.

2. The high-low and low-high segments are equal in size, that is, $Q_{HL} = Q_{LH}$. This is equivalent to assuming that both components have the same marginal probability, $(Q_{HH} + Q_{LH})$, of being considered useful.

2.3. Marketer's Problem

We assume that each component has the same constant marginal cost c, and that the marginal cost of the bundle is $2c$. We denote the prices of component 1 and component 2 by P_1 and P_2, respectively, and the price of the bundle by P_B. Note that we can always create a mixed bundling plan that generates the same expected profit as any pure component or pure bundling plan by combining the latter with an alternative so unattractive that it is never chosen. Thus, it is important to determine when a mixed bundling plan can generate *more* profit than any pure component or pure bundling plan.

In Technical Appendix TA1 (available at http://mktsci.pubs.informs.org), we examine the special case in which all customers have the same value of a, and show that

1. The mixed bundling plan never generates greater profit than all pure component and pure bundling plans.

2. The optimal plan is a pure component plan that sells each component at $(1+a)$ if a is high, a pure bundling plan with a bundle price of 2 if a is medium, and a pure bundling plan with a bundle price of $2(1-a)$ if a is low.[2] Thus, if a is high, some customers

[2] Specifically, the pure component plan with component price $(1+a)$ is optimal if

$$a \ge \max\left[\frac{(1-c)Q_{LH}}{(Q_{HH}+Q_{LH})}, \frac{(1-c)\{1-(Q_{HH}+Q_{LH})\}}{\{1+(Q_{HH}+Q_{LH})\}}\right],$$

are ready to pay high prices, and it is optimal to sell individual components to only high value customers. Otherwise, it is optimal to expand the market by offering a medium or low priced bundle.

It is therefore meaningful to examine mixed bundling plans *only if* a varies across customers. Also, the results for the special case imply that if knowledge is concentrated in a narrow zone, the pure component plan is optimal when knowledge is high and the pure bundling plan is optimal when knowledge is low. Thus, to provide a neutral background for the comparison of strategies, we assume that a is uniformly distributed over $[0, K]$; that is,

$$F(a) = \frac{a}{K} \quad \text{if } 0 \le a \le K, \quad \text{and 0 otherwise.} \tag{1}$$

Under this assumption, the demand function closely corresponds to the commonly used linear demand function. The results are presented in the next section.

3. Profit Maximizing Strategies for Uniform Distribution of Knowledge

In this section, we discuss profit maximizing strategies when customer knowledge a follows the uniform distribution given by Equation (1). The three strategies under consideration (pure component, pure bundling, mixed bundling) include many possible combinations of prices. The following proposition allows us to focus on a relatively small set of plans.

Proposition 1. *If a is uniformly distributed over $[0, K]$, $K > 0$, then one of the following three classes of pricing plans always includes the profit maximizing plan*:

C1. *Symmetric High Pure Component Plan*: $P_1 = P_2 = 1 + x$, *where* $x \ge 0$.

B1. *Medium-Low Pure Bundling Plan*: $P_B = 2(1 - z)$, *where* $z \ge 0$.

M1. *Symmetric High Component/Medium-Low Bundling Mixed Bundling Plan*: $P_B = 2(1 - z)$, $P_1 = P_2 = 1 + x$, *where* $z \ge 0$, $x \ge -z$.

The proof of Proposition 1 is provided in Technical Appendix TA available at http://mktsci.pubs.informs.org. There, we show that for any pure component plan not in C1, or a pure bundling plan not in B1, there is a plan in either C1 or B1 that generates equal or greater expected profit.[3] We also show that for any mixed bundling plan not in M1, there is always a plan in C1, B1, or M1 that generates equal or greater expected profit. Thus, taken together, C1, B1, and M1 always include the profit maximizing plan. (A plan not included in these three classes may also generate the maximum expected profit.)

From Proposition 1, it is sufficient to consider bundling plans with bundle prices not exceeding 2. If $c \ge 1$, a bundle price of 2 or less never generates a positive contribution, and hence the pure component plan is optimal. We henceforth assume that $c < 1$. The difference $(1 - c)$ measures the contribution margin if a component unit is sold at the medium reservation price and plays an important role in subsequent discussions.

3.1. Results on Classes of Plans Examined

We first describe these three classes of plans and identify the best (profit maximizing) plan within each class. Then, we compare the results and identify the profit maximizing plan. The derivations are provided in Technical Appendix TA2 available at http://mktsci.pubs.informs.org.

Class C1. For this plan, demands in the four segments and the expected profit (Π_{C1}) are summarized below.

Segment HH	Buy both components if $a \ge x$, buy nothing if $a < x$
Segment HL	Buy component 1 if $a \ge x$, buy nothing if $a < x$
Segment LH	Buy component 2 if $a \ge x$, buy nothing if $a < x$
Segment LL	Buy nothing

$\Pi_{C1} = 2(1 + x - c)\{Q_{HH} + Q_{LH}\}\{1 - F(x)\}$

The profit maximizing premium (x^*_{C1}), and the maximum expected profit (Π^*_{C1}) are presented in Table 1.

Here, x is the premium charged per component over the medium valuation of unity. At $x = 0$, all HH customers buy both components, and all HL and LH customers buy one component each, at a margin of $(1-c)$ per component. Every 1% increase in margin from this level reduces demand by $(1 - c)/K$%. Thus, $x^*_{C1} = 0$ if $K \le (1-c)$ (i.e., $(1-c)/K \ge 1$), and $x^*_{C1} > 0$ if $K > (1-c)$ (i.e., $(1-c)/K < 1$). Intuitively, if K is small, an increase in premium from zero reduces demand sharply, and

the pure bundling plan with bundle price 2 is optimal if

$$(1 - c)Q_{LL} \le a \le \frac{(1 - c)Q_{LH}}{(Q_{HH} + Q_{LH})},$$

and the pure bundling plan with bundle price $2(1 - a)$ is optimal if

$$a \le \min\left[(1 - c)Q_{LL}, \frac{(1 - c)\{1 - (Q_{HH} + Q_{LH})\}}{\{1 + (Q_{HH} + Q_{LH})\}}\right].$$

[3] This result holds for any distribution of a. If a follows the uniform distribution given by Equation (1), we have the stronger result that a pure component plan not in C1 or a pure bundling plan not in B1 can match the expected profit of the best plan in C1 and B1 combined only if one of the following occurs: (1) $Q_{LH} = 0$, and (2) the profit maximizing price of an individual component is the clearance price $(1 - K)$.

Table 1 Profit Maximizing Prices and Expected Profits for Plans

Pure component plans in Class C1		
Case	Premium/component (x^*_{C1})	Expected profit (Π^*_{C1})
1(a) $K \le (1-c)$	0	$2(1-c)(Q_{HH}+Q_{LH})$
1(b) $K > (1-c)$	$\frac{1}{2}[K-(1-c)]$	$\frac{K}{2}\left[1+\frac{(1-c)}{K}\right]^2(Q_{HH}+Q_{LH})$

Pure bundling plans in Class B1		
Case	Discount/component (z^*_{B1})	Expected profit (Π^*_{B1})
2(a) $\frac{Q_{LL}*(1-c)}{K} \le (1-Q_{LL})$	0	$2(1-c)(Q_{HH}+2Q_{LH})$
2(b) $(1-Q_{LL}) < \frac{Q_{LL}*(1-c)}{K} < (1+Q_{LL})$	$\left(\frac{1-c}{2}\right)-\left[\frac{K*(1-Q_{LL})}{2Q_{LL}}\right]$	$\left\{\frac{K*Q_{LL}}{2}\right\}\left[\left(\frac{1-c}{K}\right)+\left(\frac{1-Q_{LL}}{Q_{LL}}\right)\right]^2$
2(c) $\frac{Q_{LL}*(1-c)}{K} > (1+Q_{LL})$	K	$2(1-K-c)$

Mixed bundling plans in Class M1			
Case	Premium/component for individually offered component (x^*_{M1})	Discount/component for bundle(z^*_{M1})	Expected profit (Π^*_{M1})
3(a) $K \le (1-c)$	$\ge K-2z^*_{B1}$	z^*_{B1}	Π^*_{B1}
3(b) $K > (1-c)$	$\frac{1}{2}[K+(1-c)]-2z^*_{B1}$	z^*_{B1}	$\Pi^*_{B1}+\left(\frac{K*Q_{LH}}{2}\right)\left[1-\left(\frac{1-c}{K}\right)\right]^2$

profit is maximized at zero premium. However, if K is large, the presence of high value customers allows the marketer to charge a premium above zero, and profit increases as K increases. Also, as HH customers buy both components while HL and LH customers buy one component, a plan in Class C1 performs better if Q_{HH} is larger compared to Q_{LH}.

Class B1. For this plan, z is a discount per component from the medium valuation. Demands in the four segments and the expected profit (Π_{B1}) are summarized below.

Segments HH, HL, LH	All customers buy bundle
Segment LL	Buy bundle if $a \le z$, buy nothing otherwise

$$\Pi_{B1} = 2(1-z-c)[\{Q_{HH}+2Q_{LH}\}+Q_{LL}*F(z)]$$

The profit maximizing discount per component (z^*_{B1}) and the maximum expected profit (Π^*_{B1}) are presented in Table 1. Compared to the pure component plan C1, the pure bundling plan B1 expands demand by always selling the bundle to all HH, HL, and LH customers. The profit maximizing discount level is determined by the trade-off between attracting customers from the LL segment (size $= Q_{LL}$) and losing margin from the captive HH, HL, and LH segments (combined size $= 1-Q_{LL}$). If the discount z increases from zero, every 1% reduction in margin from $(1-c)$ corresponds to gaining $((1-c)/K)$% of the LL segment. The comparison of $(1-Q_{LL})$ and $((1-c)/K)Q_{LL}$ determines whether a discount is offered.

If the LL segment is small, the profit maximizing strategy is to ignore the LL segment and set the bundle price at 2 (zero discount). However, if the LL segment is large, it is profitable to set a bundle price lower than 2 to attract some of the low value customers. This option is particularly meaningful if K is small, and a small discount is enough to induce a significant part of the LL segment to buy the bundle.

Class M1. For this plan, demands in the four segments and the expected profit (Π_{M1}) are summarized below.

Segment HH	All customers buy bundle
Segment HL	Buy component 1 if $a > x+2z$, buy bundle otherwise
Segment LH	Buy component 2 if $a > x+2z$, buy bundle otherwise
Segment LL	Buy bundle if $a \le z$, buy nothing if $a > z$

$$\Pi_{M1} = 2(1-z-c)[Q_{HH}+2Q_{LH}F(x+2z)+Q_{LL}F(z)] + 2(1+x-c)Q_{LH}\{1-F(x+2z)\}$$

Table 2 Profit Maximizing Plan

Case	Condition	Profit maximizing plan
1. $K \le (1-c)$	All possible segment sizes	Pure bundling
2. $K > (1-c)$		
(a) $\frac{Q_{LL}(1-c)}{K} \le (1-Q_{LL})$	$\frac{2Q_{LH}}{1-Q_{LL}}$	
(Area 1 in Figure 1)	$< \frac{(1-\{(1-c)/K\})^2}{1+((1-c)/K)^2}$	Pure component
	$= \frac{(1-\{(1-c)/K\})^2}{1+((1-c)/K)^2}$	Pure component and mixed bundling (tie)
	$> \frac{(1-\{(1-c)/K\})^2}{1+((1-c)/K)^2}$	Mixed bundling
(b) $\left(\frac{1-c}{K}\right)^2 \le \frac{1-Q_{LL}}{Q_{LL}} < \left(\frac{1-c}{K}\right)$	$\frac{2Q_{LH}}{1-Q_{LL}}$	
(Area 2 in Figure 1)	$< \frac{[(Q_{LL}/(1-Q_{LL}))-1][((1-Q_{LL})/Q_{LL})-((1-c)/K)^2]}{1+((1-c)/K)^2}$	Pure component
	$= \frac{[(Q_{LL}/(1-Q_{LL}))-1][((1-Q_{LL})/Q_{LL})-((1-c)/K)^2]}{1+((1-c)/K)^2}$	Pure component and mixed bundling (tie)
	$> \frac{[(Q_{LL}/(1-Q_{LL}))-1][((1-Q_{LL})/Q_{LL})-((1-c)/K)^2]}{1+((1-c)/K)^2}$	Mixed bundling
(c) $\frac{1-Q_{LL}}{Q_{LL}} < \left(\frac{1-c}{K}\right)^2$		Mixed bundling
(Area 3 in Figure 1)		

The profit maximizing levels of x and z, denoted by x^*_{M1} and z^*_{M1}, respectively, and the maximum expected profit (Π^*_{M1}) are provided in Table 1.

For any $z \ge 0$, x can be set so large that the customer never purchases an individual component. Then, the mixed bundling plan reduces to a pure bundling plan in Class B1. Hence, the best mixed bundling plan in M1 never generates less profit than the best pure bundling plan in B1.

To determine whether a plan in M1 can generate more profit than the best plan in B1, consider a mixed bundling plan in class M1 and a pure bundling plan in Class B1 with the same discount, z, per component. The two plans generate the same response except for customers in the HL and LH segments with $a > x+2z$ who purchase one component under M1 and the bundle under B1. Also, the margin from selling one component at price $(1+x)$ exceeds the margin from selling the bundle at price $2(1-z)$ if and only if $x+2z > 1-c$. Thus, the M1 plan can be more profitable than the B1 plan only if there are HL and LH customers with $a > 1-c$.

If $K \le (1-c)$, there are no customers with $a > 1-c$, and Π^*_{M1} cannot exceed Π^*_{B1}. Then, the best plan in M1 offers the same discount as the best plan in B1 and sets individual component prices so high that an individual component is never selected.

If $K > (1-c)$, there are customers with $a > 1-c$, and $\Pi^*_{M1} > \Pi^*_{B1}$ as long as $Q_{LH} > 0$. The bundle is offered at the same discount as the best plan in B1 ($z^*_{M1} = z^*_{B1}$), but individual components are priced higher than in a pure component plan ($x^*_{M1} > x^*_{C1}$). This happens because under the mixed bundling plan, individual components are purchased only by fringe customers ready to pay a high price for a component to avoid buying the other component.

3.2. Profit Maximizing Plan

Table 2 presents the profit maximizing plan. There are two main cases.

Case 1. $K \le (1-c)$: Here, the pure bundling plan is optimal regardless of segment sizes; mixed bundling offers no advantage over a pure bundling plan. Also, the best plan in Class C1 sets $P_1 = P_2 = 1$, and sells both components to customers in HH and one component to customers in HL and LH. Because a pure bundling plan with price 2 sells both components to all customers in HH, HL, and LH, it follows that a plan in B1 is at least as profitable as the best plan in C1 and strictly more profitable if $Q_{LH} > 0$.

Two reasons favor the pure bundling plan here. First, marginal cost is low, and the marketer can obtain a reasonable margin even when he sets a medium or low price. Second, the gap between high and low valuations is not large; hence, it is not profitable to focus only on high value customers. Instead, it is optimal to expand demand by adopting a medium or low bundling strategy. If the LL segment is large, the bundle is offered at a price lower than the medium valuation. Otherwise, the bundle is priced at the medium valuation.

Case 2. $K > (1-c)$: Here, the profit maximizing plan is either a pure component or a mixed bundling plan, and the optimal plan is determined by three ratios:

(1) $2Q_{\mathrm{LH}}/(1-Q_{\mathrm{LL}})$, which is the size of the market interested in *only one* component as a fraction of the market interested in *one or both* components.

(2) $(1-Q_{\mathrm{LL}})/Q_{\mathrm{LL}}$, which is the size of the market interested in one or both components as a multiple of the size of the market interested in neither component.

(3) $(1-c)/K$, which plays two roles. First, an increase in this ratio makes it more attractive to expand demand using a medium or a low priced bundle than serve only high value customers with a premium price. Second, since $K > (1-c)$, only a fraction $(1-c)/K$ of LL customers have reservation prices exceeding marginal cost. Thus, a larger $(1-c)/K$ increases the profit potential of the LL segment.

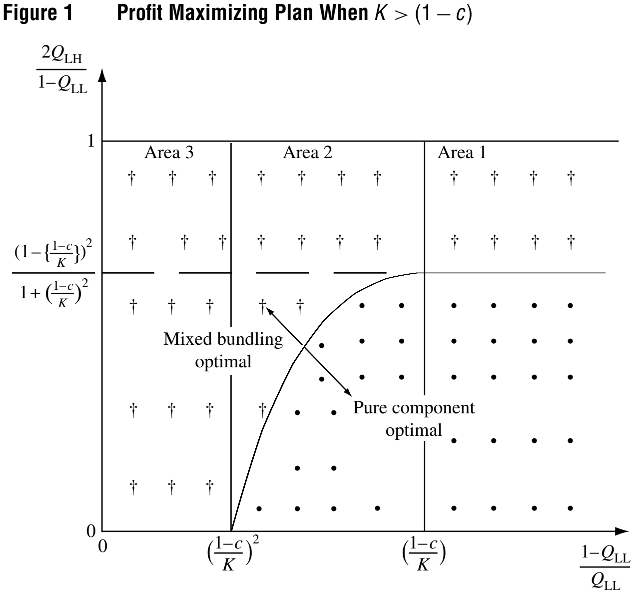
Figure 1 illustrates how the optimal plan depends on these three ratios.

The pure component plan never serves LL customers. As shown in Figure 1, we have three distinct areas depending on the size of the LL segment.

Area 1. Here, the LL segment is not significantly larger than the remaining segments combined, and the mixed bundling plan does not serve the LL segment ($z^*_{\mathrm{M1}} = 0$). The pure component plan sells both components to HH customers and benefits from a larger HH segment. In contrast, the mixed bundling plan generates the profit of the pure bundling plan plus an increment proportional to Q_{LH}. Thus, if Q_{HH} is larger compared to Q_{LH}, the pure component plan performs better relative to the mixed bundling plan.

The pure component plan is optimal as long as $2Q_{\mathrm{LH}}/(1-Q_{\mathrm{LL}})$ is lower than a ceiling that depends only on $(1-c)/K$. An increase in $(1-c)/K$ makes the pure bundling plan more attractive, and hence reduces the profitability of the pure component plan relative to the mixed bundling plan. For instance, if $(1-c)/K = 0.1$, the pure component plan is optimal if $2Q_{\mathrm{LH}}/(1-Q_{\mathrm{LL}}) \le 0.802$; that is, Q_{HH} is at least 0.4938 times Q_{LH}. However, if $(1-c)/K = 0.5$, Q_{HH} must be at least eight times as large as Q_{LH} for the pure component plan to be optimal.

Figure 1 **Profit Maximizing Plan When $K > (1-c)$**



Area 2. The LL segment is now larger, and the mixed bundling plan offers a discount to attract LL customers ($z^*_{\mathrm{M1}} > 0$). If either Q_{LL} or $(1-c)/K$ increases, the LL segment becomes more profitable to serve, and the pure component plan, which does not serve the LL segment, becomes less profitable relative to the mixed bundling plan. Thus, the ceiling of $2Q_{\mathrm{LH}}/(1-Q_{\mathrm{LL}})$ for the pure component plan to be optimal is lower than in Area 1, and decreases if either $(1-c)/K$ or Q_{LL} increases. As $(1-Q_{\mathrm{LL}})/Q_{\mathrm{LL}}$ approaches $((1-c)/K)^2$, the ceiling becomes zero.

Area 3. The LL segment is now very large, and the mixed bundling plan is always more profitable than the pure component plan.

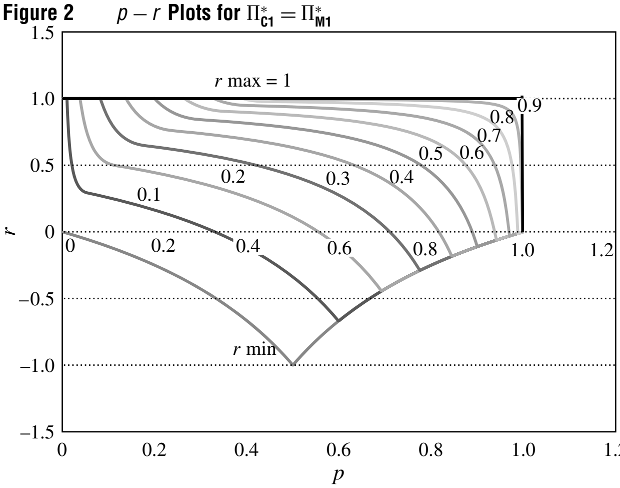
3.3. Numerical Example

We now construct a numerical example to show how often pure component and mixed bundling plans are optimal when $K > (1-c)$. Let p denote the marginal probability that either component is considered useful, and r the correlation between the two binary variables u_1 and u_2 where $u_i = 1$ if component i is considered useful, and $u_i = 0$ if not. r is positive when customers tend to either find both components useful, or both components not useful. r is negative when customers tend to be interested in one component but not the other. r can take any value from $-\min(p/(1-p), (1-p)/p)$ to 1.

In Technical Appendix TA3 (available at http://mktsci.pubs.informs.org), we show that for any value of $(1-c)/K$, we can always make $\Pi^*_{\mathrm{C1}} < \Pi^*_{\mathrm{M1}}$ by making p very small, and $\Pi^*_{\mathrm{C1}} > \Pi^*_{\mathrm{M1}}$ by making p very large. For intermediate values of p, there is a level of r where the pure component strategy and the mixed bundling strategy are equally profitable. If r exceeds this level, the pure component strategy is more profitable, and if r is below this level, the mixed bundling strategy is more profitable.

Figure 2 shows, for nine levels of $(1-c)/K$ ranging from low to high (0.1 to 0.9, in steps of 0.1), the graph of r where $\Pi^*_{\mathrm{C1}} = \Pi^*_{\mathrm{M1}}$ against p. The area bounded by $p = 0$, $p = 1$, $r = -\min(p/(1-p), (1-p)/p)$ and $r = 1$ represents all valid combinations of p and r. For each value of $(1-c)/K$, the graph divides this area into two zones: the pure component plan is optimal to the right of the graph, and the mixed bundling

Figure 2 $p-r$ **Plots for** $\Pi^*_{C1}=\Pi^*_{M1}$



Notes. $r\max=1$; $r\min=-\min(p/(1-p),\ (1-p)/p)$. From bottom left to top right, the plots are for $(1-c)/K=$ 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9, respectively.

plan is optimal to the left of the graph. Note that as $(1-c)/K$ increases, the zone where the pure component plan is optimal shrinks, and vanishes as $(1-c)/K$ approaches 1.

4. Conclusion

4.1. Summary of Findings

We examine the pricing problem of a profit maximizing monopolist marketer who sells two components. We develop a model of customer response based on the idea that customers vary in their knowledge of components, and higher knowledge corresponds to a greater difference between a high valuation and a low valuation of a component by the customer. We show that the choice of strategy depends on (1) marginal costs of components, (2) distribution of knowledge among customers, and (3) the relative sizes of customer segments interested in the same subset of components. We find

1. If the marginal cost of a component is low, and the difference between a high valuation and a low valuation is not large, then a pure bundling strategy with a medium or low bundle price is optimal. The objective of this strategy is to induce customers who value only one component to buy both components as a bundle. That strategy is appropriate here because (a) the low marginal cost allows sufficient margin even when a discounted bundle is offered, and (b) an individual component cannot be sold at a premium price because reservation prices are never high.

Bakos and Brynjolfsson (1999, 2000b) show the optimality of a pure bundling strategy when the number of components is large. Our results show when this strategy is optimal if the number of components is small.

2. If the marginal cost is high or the gap between high and low valuations can be large, then either a pure component strategy or a mixed bundling strategy is appropriate. Both these strategies aim to sell individual components at a higher price to high value customers. However, the two strategies have important differences.

The mixed bundling plan includes the pure bundling plan in a menu and generates at least as much profit as the pure bundling plan. It also generates extra profit by selling individual components at a premium price to high value customers in the HL and LH segments. (High value customers in the HH segment select the discounted bundle.) Hence, this strategy is suitable when the HL and LH segments are large, which happens when the customers tend to be interested in only one of the two components.

In contrast, the pure component plan sells both components to high value customers interested in both components, and only one component to high value customers interested in only one component. Thus, a larger HH segment favors the pure component plan. As long as the LL segment is not very large, either the pure component or the mixed bundling strategy may be optimal depending on the relative sizes of two customer segments: customers, who value both components, and customers who value only one component. If the former segment is large, then the pure component strategy is optimal; otherwise, the mixed bundling strategy is more profitable. Also, the mixed bundling strategy sells individual components to higher value customers than the pure component strategy and sets higher prices for them.

If the LL segment is very large, the mixed bundling plan, which serves the LL segment, is always more profitable than the pure component plan.

4.2. Managerial Implications

Our findings show that for a component marketer, the bundling strategy depends on marginal costs as well as knowledge dispersion, and thus vary from one product category to another. The following cases illustrate such variation.

1. For a marketer of software components, the following scenarios may emerge.

If the marketer is selling proprietary software components, marginal costs will be low because digital products can be copied and distributed at very low cost. Then, a pure bundling strategy is clearly appropriate.

However, if the marketer is a third party vendor who distributes some other company's software, it likely has to pay royalties to the owner of the software. In such cases, marginal cost is likely to be significant. There can now be two distinct situations.

(a) If the software component has many different applications, then it has some value even for customers who do not use it often. In that case, the range of reservation prices should be low, and a pure bundling strategy would still be appropriate.[4]

(b) In contrast, if a software component only has a very specialized application, there will be greater variation in its reservation price. This will favor a pure component strategy or a mixed bundling strategy.

2. Software (e.g., SAS) and information products (e.g., subscription to databases). As these are digital products with low marginal costs, the managerial implications are the same as those for software components, and favor a pure bundling strategy unless large royalties are involved.

3. High technology products such as stereo components. If a customer is knowledgeable about the product category, she is likely to be knowledgeable about each component, and the proposed model would apply. In this case, marginal costs should be high in general, making a pure component or mixed bundling strategy more appropriate than a pure bundling strategy.

4. Service products, such as automotive service. These products are usually labor intensive with high marginal costs. The appropriate strategy depends on the complexity of the product.

If the service involved is simple (such as oil and filter change or tire rotation), virtually all customers can evaluate a service component easily and are thus high-knowledge customers. Because customer knowledge is concentrated, mixed bundling is not necessary. Two cases may arise. If the need for service components arise independently (such as tire repair or windshield wiper replacement), a pure component strategy is appropriate. If, on the other hand, the need for service components arises simultaneously (for example, oil and filter may degrade together and need replacement at the same time), a bundle may be offered for convenience.

If the service is complex (such as fuel injector or electric system repair), high-knowledge customers should exhibit greater variation in valuations compared to low-knowledge customers. As marginal costs are high, the pure component or mixed bundling strategies are appropriate.

Table 3 presents these managerial implications in a 2×2 knowledge dispersion/marginal cost matrix. Note that these results lend themselves easily to empirical testing. We hope future research will examine these issues systematically.

[4] A software component with many applications may itself be a bundle of functionalities. Thus, the marketer may have to make bundling decisions in multiple stages. We thank an anonymous reviewer for the intuition.

Table 3 Summary of Managerial Implications for Different Product Categories

Marginal cost	Knowledge dispersion: Low	Knowledge dispersion: High
Low	Information goods, basic software, digital entertainment products Examples: Electronic journals, digital music Appropriate strategy: Pure bundling unless royalties are high	Software components for component-based software design, advanced statistical software Examples: SAS modules Appropriate strategy: Pure bundling unless royalties are high
High	Basic automotive service Examples: Tire rotation, oil change Appropriate strategy: Pure bundling for convenience if service components are needed simultaneously, otherwise pure component	Complex automotive service, expensive electronic goods Examples: Fuel injection repair, high-end stereo Appropriate strategy: Pure component, or mixed bundling

4.2.1. Implications for Competitive Strategy. While we examine a monopolist marketer, the proposed framework can be applied to examine competitive strategy. Consider a duopoly of two marketers, 1 and 2, both offering two components at similar marginal costs. Suppose at present both use a medium-low pure bundling strategy. If marketer 2 unilaterally shifts to a high price pure component strategy, it would lose all HH customers who would buy the bundle offered by the rival, and its market would be limited to HL and LH customers who are ready to pay a high price for one component. Marketer 2 would do better to shift to mixed bundling to retain its HH customers. Thus, the proposed framework implies that pure or mixed bundling strategies are likely to be the competitive equilibria unless marginal costs are high. Clearly, a thorough examination of competitive equilibrium should incorporate possible cost asymmetries and demand interdependencies. We leave this to future research.

4.3. Limitations and Directions for Future Research

We analyzed a symmetric case involving two components with the same medium valuation, same gap between high and low valuations, same marginal cost, and the same marginal probability of being considered useful. Similarly, we assumed that the customers are equally knowledgeable about both components. It will be interesting to study how results change when the number of components increases. It will also be interesting to introduce asymmetry in one or more dimensions. For instance, if a customer has high-knowledge of component 1 but low knowledge of component 2, then the gap between high and low valuations will be different for the two components. Then, there will be fewer customers willing to pay high prices for an individual component, making the pure component and mixed bundling strategies less attractive. Also, the reservation price of the bundle will now vary over a range, thus affecting the optimal bundle price. It will be interesting to examine these issues in future research.

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