Journal of Retailing 92 (2, 2016) 133–146

Journal of Retailing

Pricing Strategies for Hybrid Bundles: Analytical Model and Insights

Jeffrey Meyer[a], Venkatesh Shankar[b,*]

[a] Department of Marketing, College of Business, Bowling Green State University, Bowling Green, OH 43403, United States
[b] Coleman Chair in Marketing, Mays Business School, Texas A&M University, College Station, TX 77843, United States

Available online 7 January 2016

Abstract

Retailers are increasingly offering hybrid bundles—products that combine both good(s) and service(s). Some hybrid bundles, such as Lowe's flooring that combines flooring material (good) and flooring installation (service) are sold in traditional stores, while others, such as Best Buy's bundle that includes a computer (good) and tech support (service) are also offered online. The pricing strategy of a hybrid bundle is critical to its success. While pricing strategies for a goods bundle have been well-studied, those for a services bundle have been underexplored. Hybrid bundles, which fundamentally differ from bundles of goods or bundles of services, primarily with regard to quality variability and scalability, have received even less attention. Drawing from the pricing and bundling literatures for both goods and services, we develop an analytic model of optimal pricing for hybrid bundles by a monopolist retailer. We derive and illustrate many useful propositions, several of which are counter-intuitive. Our results show that an increase in quality variability of the service is associated with a higher optimal hybrid bundle price and a lower optimal price of the good, but a lower overall bundle profit. Our findings also reveal that the optimal price of the service (good) in a hybrid bundle is higher (lower) when the good has diminishing unit cost and the service has constant unit cost (i.e., the good is more scalable than the service). Our results also show that higher unit costs incurred to achieve lower service quality variability can result in higher (lower) profits when the cost increase is low (high). We discuss important implications of these insights for researchers and practitioners.

Keywords: Services marketing; Pricing; Retail bundling; Analytic models

Introduction

Retailers are increasingly developing and marketing hybrid bundles—products that combine both good(s) and service(s). Hybrid bundles are prevalent in both traditional and online retail environments. For instance, in the traditional space, Lowe's flooring sells as a hybrid offering both the flooring material, such as carpet, and the flooring installation. Similarly, in the online space, Best Buy sells computers and tech support together in a single offering.

We formally define a hybrid bundle as a single retailer's offering that combines one or more goods with one or more services, creating greater customer benefit than if the good(s) and service(s) were available separately.[1] This definition is adapted from a definition of a hybrid innovation, which is essentially a hybrid bundle that is new to the firm introducing that bundle (Shankar, Berry, and Dotzel 2009). Our hybrid bundle definition contains two key criteria. First, the same retailer must sell both the good and the service. This criterion ensures that the retailer receives revenues from both the good and the service. This criterion also eliminates simple complementary goods or services that are sold by different parties. Second, when a customer uses the good and service together, the benefit he/she receives is greater than the benefit he/she receives from using the good and service separately.

Hybrid bundles differ from bundles of goods or bundles of services in at least three important ways. First, unlike goods, most services offered by retailers are people-intensive; thus, quality variability, that is, differences in expected quality among consumers, is typically greater for services than it is for goods. Second, because most services' delivery involves people, services' scalability—the ability to sell high volumes at low unit cost—is lower than the scalability of goods. Thus, within a hybrid bundle, the levels of quality variability and scalability are mixed, whereas within a bundle of pure goods and a bundle of pure services, the levels of quality variability and scalability are

* Corresponding author. Tel.: +1 979 845 3246.
E-mail addresses: jdmeyer@bgsu.edu (J. Meyer), vshankar@mays.tamu.edu (V. Shankar).

[1] For expositional ease, we use the terms, customer and consumer, interchangeably throughout the paper.

http://dx.doi.org/10.1016/j.jretai.2015.12.001
0022-4359/

similar. These differences have important pricing implications for hybrid bundles. Third, hybrid bundles differ from traditional bundles in the way the prices are presented to the consumer. For hybrid bundles, prices are often provided with separate prices for the good and the service. For example, in a hybrid bundle from Lowe's, the price of the good (flooring) is presented as a price per square foot, while the price of the service (installation) is listed separately as either a price per square foot or as a flat price. In contrast, traditional bundles often give a single price for the bundle. For example, the price of Microsoft Office, a traditional bundle, containing word processing, spreadsheet and database management software components is presented as a single bundle price, without a breakout of the prices of the components. Therefore, determination of the optimal prices of the components is more relevant for hybrid bundles than for traditional bundles.

The pricing of a hybrid bundle is critical to its success. Consider once again Lowe's hybrid bundle that includes the flooring material (the good) and the installation (the service). Over the years, Lowe's has used many different prices for the service component in its quest to be successful, from a unit square foot price to a per room price to a whole house price. The frequent price changes beg the question: Is Lowe's optimally pricing its hybrid bundles? Many hybrid bundles are initially offered in a monopoly setting. Furthermore, many hybrid bundles such as home improvement bundles are offered by marketers, who behave like monopolists in their local geographical markets. Therefore, it is important to determine the optimal pricing strategies for hybrid bundles in a monopoly.[2]

Despite the importance of hybrid bundle pricing, little is known about it. The bundling literature in marketing has primarily examined bundles of goods, but some research considers factors relevant to quality variability (a critical dimension in a hybrid bundle) and complementarity (e.g., Balachander, Ghosh, and Stock 2010; Basu and Vitharana 2009; Ghosh and Balachander 2007; Kopalle, Krishna, and Assunção 1999; Venkatesh and Kamakura 2003). The bundling-related literature in operations management (e.g., Bala and Carr 2009; Bitran and Ferrer 2007; Rabinovich, Maltz, and Sinha 2008) has also not examined hybrid bundles but addressed component cost, which is germane to scalability (another key dimension in a hybrid bundle). However, prior research has not explicitly addressed the pricing of a combination of goods and services. Importantly, the effects of differential quality variability and scalability across goods and services on optimal hybrid bundle pricing have not been explored. These effects have important implications for pricing the good, the service and the hybrid bundle.

To address these gaps in research, we examine three main research questions. First, how does greater quality variability of a service relative to that of a good affect the monopolist's optimal pricing strategies for hybrid bundles? Second, how does lower scalability of the service relative to that of the good influence the monopolist's hybrid bundle pricing strategies? Third, how do potential cost increases due to a reduction in quality variability impact the monopolist's pricing strategies for hybrid bundles?

Our research extends the literatures on bundling and pricing in three important ways. First, extant research focuses on either the bundling of goods or the bundling of services, but not on the bundling of a good and a service together. Our research offers important insights into the optimal pricing of hybrid bundles. Second, our research is the first to provide insights into the effects of the distinctive characteristics of services (namely, greater quality variability and lower scalability relative to goods) on optimal bundle pricing. Third, it is the first to analyze the combined effects of quality variability and scalability in conjunction with autonomy of the good and the service on the joint pricing decisions of these components in the hybrid bundle.

Conceptual Development and Relevant Literature

The inherent differences between the service and good components drive a hybrid bundle's pricing (Shankar, Berry, and Dotzel 2009). The first main difference, quality variability, is from the demand perspective. Variability in the quality of a service may differ from that for a good. Many services are people-intensive and involve human actors in the production of the service. The performance of these actors may exhibit greater variability in outcome than goods (Berry 1980; Murray and Schlacter 1990). In contrast, for most goods, customer expectations of variance in quality should be considerably smaller. Consider again a representative hybrid bundle—flooring (the good) and installation (the service) from home improvement stores. In this bundle, the quality variability is likely greater for the service than the good because of the people-intensive nature of the installation process. In addition, consumers' expectations of quality will also likely vary more for the service than the good because prior to purchase, consumers are generally unfamiliar and uncertain about the skills and attitudes of the people who would install the flooring. In contrast, consumers can touch and feel the actual quality of the flooring, the good. Consumers' expectations of quality will be inevitably related to their willingness to pay (Bolton, Grewal, and Levy 2007). Thus, greater variability in consumers' expectations of service quality translates to greater variability in consumers' reservation prices for those services. Fig. 1a represents this scenario graphically.

The second major difference is from the supply perspective, and it is scalability or economies of scale.[3] Economies of scale exist when unit production costs decrease as the number of units produced increases (Tirole 1988). Most people-intensive services have lower scalability than goods (Johnson and Selnes 2004). This situation results in very different cost structures for goods and services as shown by the graph of total variable costs in Fig. 1b. Unlike a good, for a service in a hybrid bundle, scalability may be hard to achieve because cost savings from serving an additional customer may be very small. For a home

[2] Although hybrid bundles are offered in monopoly and competitive contexts, because little is known about the hybrid bundle pricing, a natural place to start is a monopoly setting. We do not have any reason a priori to believe our findings will substantively differ in a competitive setting.

[3] We use the terms scalability and economies of scale interchangeably.

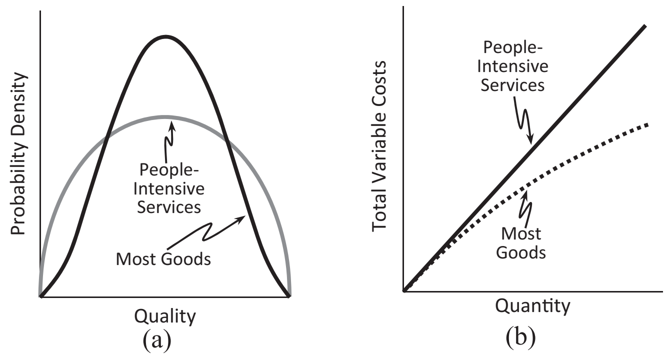

Fig. 1. Differences in quality variability and scalability between goods and services.

improvement store offering a flooring and installation hybrid bundle, the service is not as scalable as the good because it can perform only a limited number of installations in a given time frame as the pool of qualified installers is not big.[4]

The third difference, autonomy, can also affect the revenue potential and optimal prices for the good, the service, and the hybrid bundle. Autonomy is the extent to which the good and the service are available and can be used separately from the other. For example, in Sears' hybrid bundle comprising garage door opener (the good) and professional installation (the service), the consumer determines the level of autonomy, that is, chooses either to purchase Sears' professional installation or to do her own installation. Alternatively, the consumer can assemble a garage door opener herself and use Sears' professional installation. Thus, both the good and the service are autonomous within this hybrid bundle.

While autonomy and bundling form (Stremersch and Tellis 2002) share some similarities, they exhibit important differences as well. First, bundling form focuses on only the purchase of the components, not their use. Autonomy considers both purchase and use. Thus, simply being able to purchase the good and service within a hybrid bundle separately does not necessarily mean the components are autonomous. Second, while much prior research treats bundling form as a retailer's decision, our concept of autonomy allows it to be exogenous to the retailer, recognizing that consumers often decide whether to use the components separately or together. Finally, autonomy allows for asymmetry between the components of the bundle. Thus, we can have good-only (service-only) autonomy in which the service (good) cannot be purchased and used separately. This asymmetry is important in settings with network externalities (Prasad, Venkatesh, and Mahajan 2010) and asymmetrically valued independent goods (Bhargava 2013). Consider again the flooring and installation example. A consumer can install the flooring without using the retailer's installation service. However, the consumer can use the retailer's installation service only if she also buys the flooring from that retailer. In this case, we have good-only autonomy. In contrast, with Costco's hybrid bundle of a water cooler (the good) and water delivery (the service), a consumer can use Costco's water delivery service with any brand of water cooler. However, the consumer can use Costco's water cooler only in conjunction with its water delivery service. In this case, we have a service-only autonomy.

Prior research offers some guidance on pricing of bundles in general. Much work focuses on the conditions under which bundling improves profitability of goods bundles or services bundles (e.g., Schmalensee 1984). Models of bundling argue that the profitability of bundling depends on consumer reservation prices and costs. From the marketing or demand viewpoint, consumer reservation prices drive the profitability of bundling form and the optimal bundle price. Basu and Vitharana (2009) show that higher component prices are generally more profitable when there is greater variability in reservation price among consumers due to the extra profit generated by selling individual components at a premium price to consumers that highly value only one of the components. However, they do not consider differences in scalability. Balachander, Ghosh, and Stock (2010) show that a discount on the bundle can help a retailer retain customers with low reservation prices, increasing the proportion of customers served and profits.

With respect to costs, Bitran and Ferrer (2007) argue that more attractive, lower cost bundles dominate less attractive, higher cost bundles. On the service quality front, Rabinovich, Maltz, and Sinha (2008) find high quality service allows a marketer to charge higher prices for the good. Cao, Geng, and Zhang (2015) find that bundling helps retailers extract a lower wholesale price.

While analytical bundling models do not address hybrid bundles, an empirical analysis by Bharadwaj and Ter Hofstede (2006) of services that augment goods shows that reducing the prices of services encourages customers to spend those savings on the good and that customers purchase more goods if they spend more on services. It also shows that service margin affects the purchase of the good more than the opposite, and that customers who spend more on the service are more sensitive to the good's price. However, they did not study the optimal prices of the good and the service within a bundle.

A summary of selected relevant research on analytical models of bundling appears in Table 1. Taken together, they show that reservation prices and costs affect bundling form as well as optimal bundle pricing. Although each study makes an important contribution to the bundle pricing literature, none addresses a hybrid bundle. The bundling literature also does not address quality variability and scalability, the unique dimensions of a hybrid bundle's optimal pricing. In the hybrid bundle context, we expect quality variability and scalability, together with autonomy, to significantly affect optimal pricing.

Model

To address the research questions, we develop an analytic model under monopoly conditions that is based on three distinct segments in a market of size N: (1) consumers who buy the hybrid bundle (size N_{HB}); (2) consumers who buy only the good (size

[4] Although differences between the bundle components in quality variability and scalability are not limited to hybrid bundles, they are much larger in hybrid bundles than traditional bundles. Furthermore, these two dimensions have received little attention in the bundling literature.

Table 1
Comparison of selected relevant analytical research on pricing of bundles.

Reference	Focus	Key findings/insights	Limitations
Kopalle, Krishna, and Assunção (1999)	Bundling strategy amid market expansion	• As the scope for marketing expansion decreases, pure components strategy becomes the optimal bundling strategy.	• Differences in quality variability not considered
Venkatesh and Kamakura (2003)	Pricing of bundles for complements and substitutes	• Pure components, pure bundling, and mixed bundling all have areas of optimality depending on complementarity, substitutability, and costs.	• Equal marginal costs • Reservation prices drawn from same distribution
Ghosh and Balachander (2007)	Conditions under which competitors resort to bundling	• Generalists can gain by offering a pure bundle to avoid head-to-head competition. • Intense price competition can prevent a specialist from forming alliance and bundling when differences between brands are low.	• Bundled products need not be complements
Basu and Vitharana (2009)	Bundling strategy with different levels of customer knowledge	• High knowledge customer exhibit greater variation in valuations. • With a greater number of high knowledge customers, higher component prices are generally more profitable.	• Bundled products need not be complements • Equal marginal costs
Balachander, Ghosh, and Stock (2010)	Profitability of bundle discounts in a competitive setting	• Bundle discounts can increase profits in a competitive market through endogenous loyalty.	• Bundled products need not be complements • Equal marginal costs
Bhargava (2012)	Bundling of separate manufacturers' goods by a downstream retailer	• Component selling is better than bundling when a downstream retailer bundles goods from separate manufacturers due to both horizontal and vertical channel conflict.	• Bundle components are not complements
Bhargava (2013)	Mixed bundling of independently valued goods	• With sufficiently asymmetric valuations for two independently valued goods, a partial mixed bundle, where only one good is sold separately, is an optimal solution.	• Bundle components are not complements
This paper (2015)	Optimal pricing of hybrid (good + service) bundles	• An increase in quality variability for the service is associated with higher optimal hybrid bundle price and lower optimal price for the good, but lower overall bundle profit. • Optimal prices for the service (good) in a hybrid bundle are higher (lower) when the good is more scalable than the service.	• Competition not modeled

N_G); and (3) consumers who buy only the service (size N_S).[5] The sizes of the three customer segments depend on a variety of factors, including: the prices of the hybrid bundle, service, and good (P_{HB}, P_S, P_G); the reservation prices for the good and service for consumer i (R^i_G, R^i_S), which are a function of their quality levels[6]; the degree of complementarity for consumer i (θ^i); the autonomy of the good and the service; and the number of potential consumers in the market (N).

In traditional bundling, we assume that there is a single reservation price for consumer i for the bundle (R^i_B). Consistent with Venkatesh and Kamakura (2003), the degree of complementarity affects the bundle reservation price. Hybrid bundles are different from traditional bundles with regard to how the price is presented. Thus, consumer i will have a reservation price for the good given that the service will be purchased/used and a reservation price for the service given that good will be purchased/used ($R^i_{G|S}$, $R^i_{S|G}$). The degree of complementarity for consumer i is given by:

$$\theta^i = \frac{(R^i_{G|S} + R^i_{S|G}) - (R^i_G + R^i_S)}{R^i_G + R^i_S}. \quad (1)$$

From this expression, the combined reservation prices of consumer i for the hybrid bundle is given by:

$$R^i_{G|S} + R^i_{S|G} = (1 + \theta^i)(R^i_G + R^i_S). \quad (2)$$

As stated earlier, the consumer has a reservation price for each component, the good and the service. The consumers' reservation prices will, in part, be determined by the quality expectations of the good and the service. To model this difference, we use the distribution of reservation prices. We argue that the distribution of reservation prices for people-intensive services has a wider variance than the distribution of reservation prices for goods (see Fig. 1a). While this approach appears similar to Basu and Vitharana (2009), there is a fundamental difference. In Basu and Vitharana (2009), customer knowledge affects a specific customer's reservation price but does not affect the minimum or maximum reservation prices across all customers. In our model, a change in quality variability affects all consumers equally by changing the width of permissible reservation prices.

[5] A fourth segment, consumers that buy nothing, also exists. Its size is $N-(N_{HB}+N_G+N_S)$.

[6] Reservation prices can be shown to be a linear function of quality expectations. Let consumer i's utility be $V_i=\alpha+\beta Q_i-P_i$, where Q_i is quality expected by the consumer. Consumer i purchases if $(\alpha+\beta Q_i-P_i>0)$. In terms of reservation price, consumer i purchases if $(R_i-P_i)>0$. By equating the probabilities of purchase from these two perspectives, it can be shown that $\kappa_i(\alpha+\beta Q_i-P_i)=R_i-P_i$, where κ_i is a linear multiplier. Without loss of generality, assume $\kappa_i=1$. Then $R_i=\alpha+\beta Q_i$, making R_i a linear function of Q_i. Therefore, as quality expectations widen, so does the distribution of reservation prices across consumers.

Table 2
Segment size and objective function for each autonomy condition.

1.	**Full autonomy (i.e., hybrid bundle, good, or service can be purchased/used)**
1.1	$N_{HB} = N \times Pr\,[(1+\theta)(R_G + R_S) \geq P_{HB} \cap (1+\theta)(R_G + R_S) - P_{HB} \geq R_G - P_G \cap (1+\theta)(R_G + R_S) - P_{HB} \geq R_S - P_S]$
1.2	$N_G = N \times Pr\,[R_G \geq P_G \cap R_G - P_G > R_S - P_S \cap R_G - P_G > (1+\theta)(R_G + R_S) - P_{HB}]$
1.3	$N_S = N \times Pr\,[R_S \geq P_S \cap R_S - P_S > R_G - P_G \cap R_S - P_S > (1+\theta)(R_G + R_S) - P_{HB}]$
1.4	$\max_{P_{HB}, P_G, P_S} \Pi = [P_{HB} \times N_{HB} + P_G \times N_G + P_S \times N_S - C_G(N_{HB}, N_G) - C_S(N_{HB}, N_S)]$
2.	**Good-only autonomy (i.e., hybrid bundle or good can be purchased/used)**
2.1	$N_{HB} = N \times Pr\,[(1+\theta)(R_G + R_S) \geq P_{HB} \cap (1+\theta)(R_G + R_S) - P_{HB} \geq R_G - P_G]$
2.2	$N_G = N \times Pr\,[R_G \geq P_G \cap R_G - P_G > (1+\theta)(R_G + R_S) - P_{HB}]$
2.3	$\max_{P_{HB}, P_G} \Pi = [P_{HB} \times N_{HB} + P_G \times N_G - C_G(N_{HB}, N_G) - C_S(N_{HB})]$
3.	**Service-only autonomy (i.e., hybrid bundle or service can be purchased/used)**
3.1	$N_{HB} = N \times Pr\,[(1+\theta)(R_G + R_S) \geq P_{HB} \cap (1+\theta)(R_G + R_S) - P_{HB} \geq R_S - P_S]$
3.2	$N_S = N \times Pr\,[R_S \geq P_S \cap R_S - P_S > (1+\theta)(R_G + R_S) - P_{HB}]$
3.3	$\max_{P_{HB}, P_S} \Pi = [P_{HB} \times N_{HB} + P_S \times N_S - C_G(N_{HB}) - C_S(N_{HB}, N_S)]$
4.	**No autonomy (i.e., only hybrid bundle can be purchased/used)**
4.1	$N_{HB} = N \times Pr\,[(1+\theta)(R_G + R_S) \geq (P_{HB})]$
4.2	$\max_{P_{HB}} \Pi = [(P_{HB}) \times N_{HB} - C_G(N_{HB}) - C_S(N_{HB})]$

In the traditional bundling literature, costs are often assumed to be linear (i.e., constant unit cost) and the same for each item in the bundle (e.g., Venkatesh and Kamakura 2003). The assumption of equality of component costs is more realistic in a goods bundle or a services bundle than in a hybrid bundle. However, an equality of component costs assumption may not be appropriate for a hybrid bundle due to differences in the scalability of goods and services.

Returning to the three segments that purchase, we now define the size of each segment for each autonomy condition. For example, under full autonomy, consumer *i* purchases the hybrid bundle if she gets a positive surplus from the hybrid bundle and if the surplus derived from purchasing the hybrid bundle is greater than the surplus generated from buying the good only or the service only. At the aggregate level, the sales of the hybrid bundle segment are given in Eq. (3).

$$N_{HB} = N \times Pr \begin{bmatrix} (1+\theta)(R_G + R_S) \geq P_{HB} \cap \\ (1+\theta)(R_G + R_S) - P_{HB} \geq R_G - P_G \cap \\ (1+\theta)(R_G + R_S) - P_{HB} \geq R_S - P_S \end{bmatrix} \tag{3}$$

In the segment of consumers purchasing only the good (service), $N_G(N_S)$, a consumer *i* purchases the good (service) if the surplus from purchasing the good (service) is positive and is greater than the surplus from purchasing the service (good) or the hybrid bundle. In this case, the sales of the good and service are given by Eqs. (4) and (5), respectively.

$$N_G = N \times Pr\,[R_G \geq P_G \cap R_G - P_G > R_S - P_S \cap R_G - P_G > (1+\theta)(R_G + R_S) - P_{HB}] \tag{4}$$

$$N_S = N \times Pr\,[R_S \geq P_S \cap R_S - P_S > R_G - P_G \cap R_S - P_S > (1+\theta)(R_G + R_S) - P_{HB}] \tag{5}$$

The monopolist sets the optimal price of the hybrid bundle, the good, and the service to maximize profits using the following objective function:

$$\max_{P_{HB}, P_G, P_S} \Pi = [P_{HB} \times N_{HB} + P_G \times N_G + P_S \times N_S - C_G(N_{HB}, N_G) - C_S(N_{HB}, N_S)] \tag{6}$$

where N_{HB}, N_G, and N_S are as defined in Eqs. (3)–(5) and Π represents profits.

The same procedure can be done for each autonomy condition, which defines the objective function for each. The size of each segment and the objective function for each autonomy condition are shown in Table 2. We drop the superscript for consumer *i* for expositional clarity. For the first three autonomy conditions in Table 2, within each $Pr[\cdot]$, the first term guarantees that the individual participation (IP) constraint is met, while the second and third terms guarantee incentive compatibility (IC). In the objective functions found in Table 2, the costs for the good and the service are left as generic functions of the size of the various segments. As described earlier, complementarity affects the size of each segment through the reservation prices for the good and the service within a hybrid bundle. For simplicity, and consistent with past research (e.g., Venkatesh and Kamakura 2003), we assume that the degree of complementarity is the same for all consumers.

This framework offers closed-form solutions under certain conditions. Full autonomy, good-only autonomy, and

Table 3
Optimal hybrid bundle prices under no autonomy.

P^*_{HB}	$= \dfrac{2\delta(1+\theta)+C_S+C_G+\sqrt{(C_S+C_G)^2+(1+\theta)^2(6a^2-2\delta^2-12a\delta)-2\delta(C_S+C_G)(1+\theta)}}{3}$	for $\dfrac{C_G+C_S}{1+\theta} \le \dfrac{(a-3\delta)^2}{2(a-2\delta)}$
	$= \dfrac{3a(1+\theta)+2(C_S+C_G)}{4}$	for $\dfrac{(a+4\delta)}{2} \le \dfrac{C_G+C_S}{1+\theta} \le \dfrac{(a-3\delta)^2}{2(a-2\delta)}$
	$= \dfrac{(2a-\delta)(1+\theta)+2(C_S+C_G)}{3}$	for $\dfrac{C_G+C_S}{1+\theta} \ge \dfrac{(a+4\delta)}{2}$

service-only autonomy are similar to mixed bundling. While prior research does not provide closed-form solutions for mixed bundling, we can derive closed-form solutions for the no autonomy condition, where the consumer must purchase and/or use both the good and the service together, serving only the N_{HB} segment. To allow for differences in quality variability for the service and good, we draw reservation prices (R_G, R_S) from the joint uniform distribution such that $f(x,y)=1/(a^2-2a\delta)$ for $0 \le R_S \le a$ and $\delta \le R_G \le a-\delta$, where δ represents the quality variability differential between the service and the good. Thus, the service and good have the same quality variability when $\delta=0$, while the good has less quality variability than the service when $\delta>0$. The size of the segment served is given by Equation 4.1 in Table 2. Assuming a constant unit cost function for both the good and the service, the monopolist's problem can be defined as:

$$\max_{P_{HB}} \Pi = [(P_{HB}-C_G-C_S)\times N_{HB}]\,. \tag{7}$$

Solving for P_{HB}, we find the optimal hybrid bundle price shown in Table 3 (see Appendix 1 for a derivation). Broadly speaking, the three conditions that produce optimal prices can be viewed as low costs, medium costs, and high costs conditions. When $\delta=0$, the middle costs condition disappears and the low and high costs conditions are equal to those found in Venkatesh and Kamakura (2003). Consistent with Venkatesh and Kamakura (2003), the optimal price of the hybrid bundle is increasing in complementarity and costs of the good and/or service. We can also examine the effects of changes in the quality variability of the good using δ. Interestingly, the middle costs condition is not affected by δ. When $\delta>0$, the quality variability of the good is lower than the quality variability of the service. For both the low and high costs conditions, the optimal price of the hybrid bundle is lower when $\delta>0$.

Aside from the no autonomy case, the monopolist's objective function does not lend itself to closed-form solutions. Consistent with previous research on mixed bundling (Adams and Yellen 1976; Kopalle, Krishna, and Assunção 1999; Schmalensee 1984; Venkatesh and Kamakura 2003), we adopt a numerical method to solve for the optimal good and service prices. In addition, hybrid bundles, by definition, have moderate to high levels of complementarity. Thus, we only look at two levels, which we deem to be low ($\theta=0.3$) or high ($\theta=0.7$). For each scenario involving service quality variability, scalability, complementarity, and autonomy, we follow the method of Venkatesh and Chatterjee (2006) by creating 40,401 synthetic consumers in a two-dimensional ($R_G \times R_S$) grid representing consumer reservation prices. Each consumer in the grid has a unique combination of good and service valuations (R_G, R_S), ranging from (0, 0) to (1, 1) based on the particular distribution used for that scenario.

We capture the differences in quality variability between goods and services by drawing consumers' reservations prices from a joint beta distribution. While past research has often used a joint uniform distribution (e.g., Venkatesh and Kamakura 2003), we require a distribution that allows us to manipulate the variance in reservation prices, while keeping both the mean reservation price and the domain of the distribution function the same for the good and the service. The joint beta distribution fits this need nicely. Moreover, the uniform distribution is a special case of the beta distribution, so past research results can be nested within our research results. Higher service quality variability (relative to the good), and thus expectations in quality, is represented by service quality variability following a wide beta B(1.5,1.5) distribution and quality variability of the good following a narrow beta B(3,3) distribution. We compare the unequal quality variability distributions with a base case of equal low quality variability, with both the service and the good following a narrow beta B(3,3) distribution. In all cases, the reservation prices are drawn to reflect independence between the valuations of the good and the service within the hybrid bundle.

To operationalize the different degrees of scalability for the good and the service that lead to the different cost structures, we consider two different conditions. In the first condition, equal scalability, both the good and the service have equal, constant unit variable costs of 0.25, resulting in total variable costs of $0.25\times(N_{HB}+N_G)$ for goods and $0.25\times(N_{HB}+N_S)$ for services. In the second condition, unequal scalability, the good enjoys economies of scale while the service does not. Here, we assume that the good's total variable costs follow an exponential distribution function, while the service's unit costs are constant as before.

Along with the quality variability and scalability conditions, we also take into account the four autonomy conditions mentioned earlier (i.e., full, good-only, service-only, and no autonomy) and the low and high complementarity conditions. Thus, based on different levels of service scalability, quality variability, autonomy, and complementarity, there are $4\times2\times3\times2=48$ scenarios to consider.

To determine the optimal prices and profits for each scenario, we use a grid search procedure. Within each scenario, we vary the appropriate prices of the hybrid bundle, the good, and the service, P_{HB}, P_G and P_S, over the feasible range in increments of 0.001. For each combination of prices, we determine if synthetic consumer i purchases the hybrid bundle (under all autonomy conditions), the good only (under full and good-only autonomy), the service only (under full and service-only autonomy), or does not purchase at all. With this set up, we determine the size of each segment served for that given condition by summing across all 40,401 synthetic consumers. We substitute these segment sizes into the appropriate objective function from Table 2 to calculate the profit under the specific service scalability and autonomy conditions for each scenario. We then identify the prices for which the profits are maximized.

Propositions on Optimal Prices, Proportion of Buyers, and Profit

In this section, we derive a series of propositions on the optimal prices and profits associated with hybrid bundles. We focus on the effects of quality variability and scalability on the optimal prices, proportion of buyers, and profits across the various autonomy conditions.

The Effect of Quality Variability of the Good and Service

Proposition 1. Compared to equal low quality variability for the good and the service, high quality variability for the service and low quality variability for the good is associated with:

a. a higher optimal price for the hybrid bundle;
b. a higher optimal price for the service;
c. a lower optimal price for the good;
d. a lower optimal proportion of buyers; and
e. a lower optimal profit.

From the demand standpoint, we examine higher service quality variability by comparing a condition of equal low quality variability for the good and the service with a condition where the good remains as low quality variability while the service has high quality variability. To explain what happens in this case, consider Fig. 2. The curve in 2a represents the distribution of service reservation prices under low service quality variability, while the curves in 2b and 2c represent the distribution of reservation prices under high service quality variability. Under low service quality variability (2a), suppose that for the given conditions, the optimal service price is 0.60. At this price, the retailer maximizes profits while serving approximately 32 percent of the customer base. Now, suppose that service quality variability increases. In the high quality variability condition, with a service price of 0.60, the retailer would now serve approximately 37 percent of the customer base (Fig. 2b). However, this is not the profit-maximizing optimal service price for the high quality variability condition. In this case, the retailer should increase the service price such that it can extract higher margins from serving fewer customers with higher reservation prices than in the case of low quality variability. That is, higher quality variability means there is greater customer heterogeneity, so the retailer can raise prices. This result is shown in 2c, where the optimal service price is higher than in 2a under lower service quality variability. Generally, fewer customers served at higher margins result in lower overall profits.

The optimal hybrid bundle price moves in sync with the higher quality variability of the service (*Proposition 1a*). The intuition is as follows. When the quality variability for the service increases, reservation prices for the service are more variable. Hybrid bundle reservation prices, which are a function of good and service reservation prices, are also more variable. With more consumers located at the high and low ends of the distribution of reservation prices for the hybrid bundle, the retailer prices it higher to maximize profit from the greater customer heterogeneity. Fig. 3 shows the effect of higher quality variability for the service on the optimal hybrid bundle price through a representative example. This effect occurs across all autonomy conditions for both high and low complementarity.

With respect to the optimal price for the service (*Proposition 1b*), it is generally optimal for the retailer to increase the price of the service when the quality variability of the service increases. The intuition behind this proposition is as follows. With higher quality variability for the service, the reservation price for the service is more variable with more consumers located at the high and low ends of the distribution. Here, the retailer prices the service higher to maximize profit. This is similar to a situation of an increase in quality variability of single product (i.e., not within a bundling context). Consider a product with reservation prices, R, drawn from the uniform distribution such that $f(x) = 1/a$

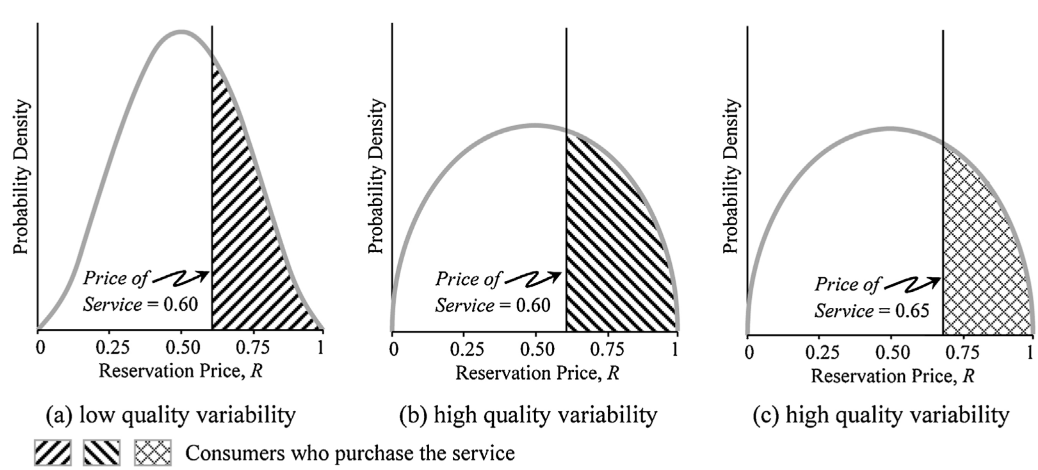

Fig. 2. Distributions of service quality for different levels of variability.

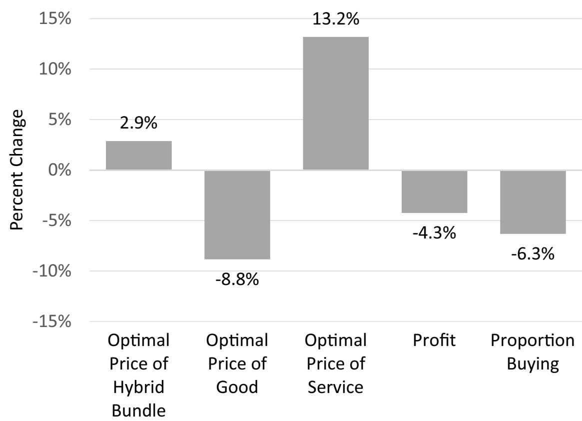

Fig. 3. Effects of higher quality variability for the service in a hybrid bundle. *Note*: Percent change represents the change from equal, low quality variability for both the good and the service to low quality variability for the good and high quality variability for the service.

for $\lambda \leq R \leq a - \lambda$, where λ represents the product's quality variability such that as λ increases, quality variability decreases. Assuming a constant unit cost, the optimal price of the product is $P^* = (a + C - \lambda)/2$. Thus, the optimal price is decreasing in λ; that is, when λ increases, quality variability decreases resulting in lower optimal prices for the product (see Appendix 2 for a derivation).

Consider a casual dining retailer such as Olive Garden that provides both food and delivery service. Because its restaurant customers are more heterogeneous in size, type of cuisine and style of dining in large metros than in small cities, their expectations of service quality also vary considerably more in metros than in small cities. Consistent with this proposition, Olive Garden charges higher prices for its services in larger cities than in smaller towns. Fig. 3 shows a representative example. This effect occurs whenever the service is available separately (i.e., full autonomy and service-only autonomy) for both high and low complementarity conditions.

Regarding the optimal price for the good (*Proposition 1c*), it is optimal for the retailer to decrease the price of the good when the quality variability of the service is higher. This result can be explained by the following reasoning. With an increase in optimal hybrid bundle price (*Proposition 1a*), fewer consumers purchase the hybrid bundle. These former hybrid bundle purchasers have a slightly lower density of consumers with higher valuations for the good. If the retailer were to hold the price of the good constant, many of these former hybrid bundle purchasers would be captured as good-only purchasers. However, this is not the optimal decision, as the good becomes less elastic with the increase in the price of the hybrid bundle. Therefore, it is optimal for the retailer to lower the price of the good to maximize profits. Fig. 3 shows a representative example. This effect occurs whenever the optimal solution has the good available separately (i.e., full autonomy and good-only autonomy) for both high and low complementarity conditions.

The proportion of buyers and overall retailer profit (*Propositions 1d and 1e*) move in the opposite direction of the quality variability of the service. When the quality variability for the service increases, fewer customers purchase and the retailer has lower profits. We can explain this result for each of the four autonomy conditions. Under full autonomy, higher service quality variability results in higher prices on the hybrid bundle and service, serving fewer customers at a higher margin but a lower profit. At the same time, the retailer lowers prices on the good, serving more customers at a lower margin but a higher profit. The decrease in hybrid bundle and service-only consumers overshadows the increase in good-only consumers. The end result of serving fewer consumers is lower profit.

Under good-only autonomy, higher service quality variability increases hybrid bundle prices, but decreases the price of the good. However, the net effect is fewer customers purchasing and a lower total profit. Under service-only autonomy, higher service quality variability increases the price of the hybrid bundle and the service, attracting fewer customers and leading to a lower profit. Finally, under no autonomy, only the hybrid bundle can be purchased. An increase in quality variability for the service raises hybrid bundle prices, attracting fewer consumers and resulting in a lower profit. Fig. 3 shows representative examples for profit and proportion buying.

The Effect of Scalability of the Good and Service

Proposition 2. Compared to equal unit cost for the good and the service, when the good has diminishing costs and the service has constant unit cost,

a. optimal hybrid bundle price is lower;
b. optimal price of the service is higher;
c. optimal price of the good is lower;
d. optimal proportion of buyers is higher; and
e. optimal profit is higher.

From the supply perspective, we represent the scalability of the service relative to the good using two different cost function conditions. The first condition assumes that both the good and the service have equal, constant unit costs. The second condition assumes that the good has diminishing unit costs and the service has constant unit costs as before.

Optimal hybrid bundle prices are lower when the good has diminishing unit costs than when it has constant unit costs (*Proposition 2a*). The intuition for this proposition is as follows. Because the hybrid bundle costs are additive in the component costs, the lower costs for the good directly lower the cost of the hybrid bundle. By lowering the price of the good, the retailer can increase demand and serve more customers at similar margins. Fig. 4 shows a representative example. These effects occur under all autonomy conditions for both high and low complementarity.

With respect to optimal prices for the good and service (*Propositions 2b and 2c*), diminishing unit costs for the good (compared to constant unit costs) results in a decrease in the optimal price of the good, but an increase in the optimal price of the service. This proposition's intuition is as follows. For the good, the diminishing unit costs of the good directly lower the optimal price for the good as the retailer leverages the lower costs to

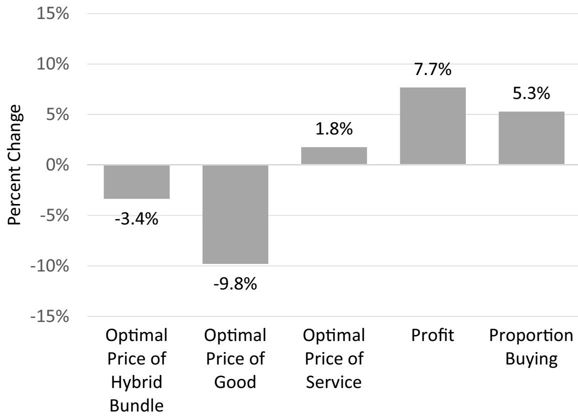

Fig. 4. Effects of higher scalability for the good in a hybrid bundle. *Note*: Percent change represents the change from equal, constant unit costs for both the good and the service to diminishing unit costs for the good and constant unit costs for the service.

capture more of the good-only market. For the service, the diminishing unit costs of the good have an indirect effect of increasing the optimal price for the service. Diminishing unit costs for the good lowers the optimal hybrid bundle price (*Proposition 2a*), inducing some consumers who previously only purchased the service to now purchase the hybrid bundle. The service valuations of the remaining consumers who buy only the service are even higher than the previous set of service-only consumers. That is, the group of consumers who value the service higher than the good have even higher evaluations for the service than when the unit cost of the good is not diminishing in volume. Thus, by increasing the price of the service to serve these remaining service-only customers, the retailer can obtain a higher margin. The effect on the optimal price of the service can also be explained by examining the price elasticity of demand for the service. When the good has diminishing costs, which lowers the price of the hybrid bundle, we find that the demand for the service alone becomes less elastic. Fig. 4 shows representative examples for the good and the service.

With respect to the proportion of buyers and overall profits (*Proposition 2d and 2e*), when the good has diminishing unit costs compared to constant unit costs, both the proportion of buyers and overall profit is higher. Again, we provide the intuition for each autonomy condition. Under full autonomy, the lower costs for the good lead to lower hybrid bundle prices, lower prices for the good, and higher prices for the service. Thus, we have more customers purchasing the hybrid bundle and the good, but fewer purchasing the service, although at a higher margin. The increase in the number of consumers purchasing the hybrid bundle and only the good eclipses the decrease in the number of consumers purchasing only the service, resulting in higher overall profits.

Under good-only autonomy, lower costs for the good lead to lower hybrid bundle prices and lower prices for the good, resulting in more consumers purchasing and higher profit. Under service-only autonomy, lower costs for the good lead to lower hybrid bundle prices, but higher prices for the service. Thus, we have more consumers purchasing the hybrid bundle, but fewer consumers purchasing the service, although at a higher margin. The number of consumers being added to the hybrid bundle segment is greater than the number leaving the service-only segment. The net effect is a higher proportion of buyers and higher profit. Finally, under no autonomy, the lower costs for the good lead to lower hybrid bundle prices. Thus, we have more consumers purchasing the hybrid bundle and higher profit. Fig. 4 shows representative examples for profit and proportion buying.

The Effect of the Cost of Decreasing Service Quality Variability

The propositions stated previously show that, *ceteris paribus*, optimal prices are lower and profits are higher for a hybrid bundle with low service quality variability compared to high service quality variability. However, this does not mean that it is always in the retailer's best interest to lower quality variability of the service in order to extract higher profits by serving more customers. Cost side implications exist such that the cost of providing the service with less quality variability is likely increasing. The cost side implications for reducing quality variability is similar in vein to the notion that the cost of providing goods or services is increasing in quality (Mussa and Rosen 1978). Thus, the retailer has some control over quality variability, and by expending more resources in areas such as personnel training, the retailer can indeed reduce quality variability.

To examine this aspect, we conduct additional simulations using the same procedure as before. In this set of simulations, we held the quality variability of the good constant at the low level, while allowing the quality variability of the service to vary from high to low, representing a decrease in service quality variability. As with other simulations, we assume constant unit costs for the service. However, we allowed unit costs for the service to increase by five, 10, 20, 40, or 80% in the low quality variability condition to reflect the higher costs for a lower quality variability. Thus, we compare seven conditions for the service component: high quality variability and constant unit costs; low quality variability and constant unit costs; and five conditions of low quality variability and higher constant unit costs (5, 10, 20, 40 and 80%). We examined these conditions for each autonomy condition.

Proposition 3. Compared to high service quality variability and constant unit costs for the service,

a. optimal hybrid bundle prices are lower (higher) with a low (high) cost to decrease service quality variability;
b. optimal price of the service is lower (higher) with a low (high) cost to decrease service quality variability;
c. optimal price of the good is higher (lower) with a low (high) cost to decrease service quality variability;
d. optimal proportion of buyers is higher (lower) with a low (high) cost to decrease service quality variability;
e. optimal profits are higher (lower) with a low (high) cost to decrease service quality variability.

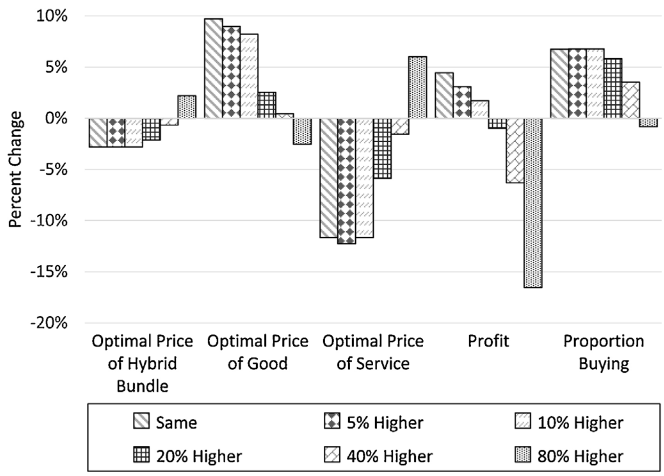

Fig. 5. Effects of higher service costs to decrease in service quality variability. *Note*: Percent change represents the change from high service quality variability to low service quality variability at various changes to the costs of the service.

Optimal prices behave as expected based on the prior propositions. First, a low cost decrease in the quality variability of the service results in lower optimal prices for the hybrid bundle, higher optimal prices for the good, and lower optimal prices for the service. This finding is in line with Proposition 1. However, as the cost to decrease service quality variability gets higher, optimal hybrid bundle prices and optimal service prices become higher, eventually exceeding the optimal prices prior to the quality variability decrease. Similarly, optimal prices for the good decrease as the cost to decrease service quality variability increase, eventually falling below the optimal prices prior to the quality variability decrease. This result is consistent with expectations based on Proposition 2. A representative example appears in Fig. 5. These results hold for all autonomy conditions for both high and low levels of complementarity.

With regard to profits, only a low cost decrease in the quality variability of the service is worthwhile to implement. When unit costs for the service are about 10% higher due to a decrease in quality variability, profits suffer, falling below profits under the higher service quality variability condition. Thus, retailers may be better off forgoing the decrease in quality variability for higher profits. A representative example appears in Fig. 5. The results are similar across all autonomy conditions.

Proposition 1 suggests that profits are higher with a low quality variability service than with a high quality variability service. However, managers need to be cognizant of the costs associated with decreasing the quality variability of the service through more training, more thorough hiring practices, and more employee oversight. Depending on the increase in costs associated with lower service quality variability, the optimal strategy may or may not be to decrease the quality variability of the service. For reasonable costs associated with decreasing the quality variability of the service, it is beneficial to actively reduce the quality variability. However, for hybrid bundles with very high costs associated with decreasing the quality variability of the service, it is likely beneficial to maintain the status quo.

Results Summary and Contributions Relative to Literature

A summary of the key results from the propositions appears in Table 4. The key results relate to the effects of quality variability and scalability and the interaction of quality variability and costs on optimal prices and profits. When quality variability is higher for the service than for the good, the optimal hybrid bundle and/or service price is higher. Although the bundle and service-only buyers generate higher margins, retailers are not able to offset the loss in revenues from the overall lower proportion of buyers, resulting in lower profits. The greater scalability of the good over the service, however, allows for a lower optimal price for the hybrid bundle and/or the good, but a higher price for the service. In this case, the monopolist serves a higher proportion of buyers at approximately equal or higher margins, resulting in net higher profits. When a monopolist retailer incurs higher unit service costs due to a conscious decision to decrease the quality variability of the service, it is optimal to have lower hybrid bundle and service prices, but higher prices for the good. In this case, profits improve only when the costs associated with decreasing the quality variability of the service are relatively low.

Our results extend the bundle pricing literature (e.g., Ghosh and Balachander 2007; Kopalle, Krishna, and Assunção 1999; Venkatesh and Chatterjee 2006; Venkatesh and Kamakura 2003) in many ways. First, to our knowledge, our research is the first to examine the effects of different quality variability levels for the components within a bundle. Because of the inherent differences between goods and services, differences in quality variability between the components in a bundle are more likely in a hybrid bundle than in a goods-only or a services-only bundle. Consumers are aware of this variability and form their expectations before purchase. Our findings counter-intuitively suggest that when quality variability for the service is greater than that for the good, the optimal bundle price is higher, but overall profit is lower.

Second, our results also expand on the bundling-related research from the supply perspective. While some prior studies have included costs in their analysis (e.g., Bala and Carr 2009; Bitran and Ferrer 2007), they assume costs to be the same for all the components in a bundle and do not consider different levels of scalability between the components. Our findings show that the higher scalability of the good over the service in a bundle leads to lower optimal prices of the good and the hybrid bundle, but higher optimal price for the service and a greater overall profit.

Third, our results examine new avenues of bundling research by looking at the combined effects of the costs associated with changing quality variability. No prior studies have examined this unique aspect of hybrid bundles. Our findings show that it can be optimal to incur moderately higher costs to decrease quality variability.

Discussion and Managerial Implications

We now discuss the managerial implications of the answers to the two main research questions. Our findings on optimal prices

Table 4
Summary of propositions.

	Optimal price of the hybrid bundle	Optimal price of the service	Optimal price of the good	Optimal proportion of buyers	Optimal profit
Proposition 1					
Higher service quality variability is associated with. . .	(a) Higher	(b) Higher	(c) Lower	(d) Lower	(e) Lower
Proposition 2					
Diminishing costs for the good in a hybrid bundle is associated with. . .	(a) Lower	(b) Higher	(c) Lower	(d) Higher	(e) Higher
Proposition 3					
A low cost decrease in service quality variability is associated with. . .	(a) Lower	(b) Lower	(c) Higher	(d) Higher	(e) Higher
A high cost decrease in service quality variability is associated with. . .	(a) Higher	(b) Higher	(c) Lower	(d) Lower	(e) Lower

due to the difference in quality variability between goods and services relating to the first research question are counter-intuitive. Compared to a base case of equal quality variability for the good and service, the findings suggest that a profit-maximizing monopolist retailer should increase the price of the hybrid bundle and the price of the service as service quality variability increases. However, while this strategy is optimal, an increase in service quality variability leads to fewer consumers purchasing and lower overall profit than that when service quality variability is low. For hybrid bundles that include people-intensive services, service quality has a wider variation than the quality of the good, leading to a wider distribution of reservation prices for the service than the good. As noted earlier, with higher service quality variability, the reservation price for the service varies more with more consumers located at the high and low ends of the distribution. To account for this situation, managers should consider pricing the service and the hybrid bundle relatively higher, while pricing the good relatively lower.

Retailers may want to lower service quality variability as higher optimal prices of the service and the bundle is counterproductive to overall profit. Even with a moderate increase in costs, the lower quality variability for the service is more profitable. In practice, retailers do try to influence quality variability. Over the years, fast food restaurants such as McDonald's, which offer food (the good) and service, have been able to reduce quality variability in service by following standardized practices (e.g., consistent method of greeting, order-taking, cleaning, fulfilling orders across customers). The lowered variability in the quality of service and the good has enabled such restaurants to lower the bundle price, attract more customers, and boost overall profit. However, as the costs associated with decreasing the quality variability of the service become higher, overall profitability suffers.

The trade-off between service quality variability reduction and increasing costs has important implications for service guarantees. For example, restaurants like Romano's Macaroni Grill and retail pizza chains such as Domino's have tried implementing service guarantees to reduce service quality variability and signal higher service quality. Typically, such guarantees promise money back if the food is not delivered within a specified time. For Romano's Macaroni Grill, service quality variance reduction through its guaranty improved the efficiency of its staff and helped attract more customers and enhance profits. In contrast, Domino's could not lower the variability in delivery time to its promised levels, so the cost of its service guarantees outstripped any incremental customer revenues that its service guaranty brought. Eventually, it abandoned its service guaranty.

In setting hybrid bundle prices, retailers must take into account the interaction between scalability and autonomy of the good and the service within a hybrid bundle. The answer to the second research question is: *ceteris paribus*, the optimal prices for the hybrid bundle and the good (service) are lower (higher) when the good has diminishing costs than when it has constant costs. When the service is less scalable than the good and when the service is available autonomously, retail managers should consider pricing the service higher to maximize profits. Increased scalability of the good generally leads to relatively lower prices for the hybrid bundle and the good. Retailers can thus increase the price of the service to extract a higher margin on the service-only customers without sacrificing the total number of customers served. For example, suppose an outdoor spa hot tub retailer, who is a monopolist in a local market, offers a hybrid bundle of a spa hot tub and installation service, but also sells the hot tub and installation separately. In this case, the more scalable component (hot tub) should lead to lower prices for both the hybrid bundle and the hot tub. When this outcome occurs, more consumers will purchase the hybrid bundle or the hot tub. This situation allows the retailer to increase the price of the installation-only service without sacrificing overall profit. While the retailer may be serving fewer maintenance-only customers, in doing so, it derives a higher margin.

Limitations and Future Research

Our research is a first attempt at developing a pricing model for hybrid bundles. Naturally, it has limitations, offering opportunities for future research. The limitations in our research relate mostly to the assumptions we made for parsimony and tractability of simulations. First, we assume that the degree of complementarity between the good and the service in a hybrid bundle is the same for all consumers. Future research could relax this assumption by allowing complementarity to vary by consumer. For example, in addition to the good and service reservation prices following a beta distribution, one could allow the complementarity to also follow a beta distribution.

Second, in our simulations, we assume that autonomy between the good and service is dichotomous, creating four autonomy conditions. However, autonomy could be continuous or be a consumer level parameter. For example, for some hybrid bundles, technologically savvy consumers may be able to use a good (service) more separately from the service (good) than other consumers.

Third, we explored scalability by varying the cost structure of the good. We did not explore the possibility of highly-scalable digital services. In addition, we only considered two different cost conditions to keep the number of simulations reasonable. Future research could explore highly-scalable digital services as well as look at the effects under different levels of good and service marginal costs.

Fourth, our research focus is limited to a monopolist retailer. This setting is realistic for many new-to-the-market hybrid bundles and is a useful start in the analysis of all hybrid bundles. The analysis could be extended to duopoly and other competitive settings for greater generalizability (e.g., Chen 1997; Ghosh and Balachander 2007).

Finally, our research examines a single period. Many hybrid bundles involve a single purchase of a good with a subscription service. Over multiple periods, the good may be replaced and prices of the subscription service may change. A model with multiple periods would also offer valuable insights.

In closing, our results show that an increase (decrease) in quality variability for the service (good) is generally associated with higher (lower) optimal prices for the hybrid bundle and lower optimal price for the good, but lower (higher) overall profits. They also reveal that the optimal service (good) price in a hybrid bundle is higher (lower) when the good has a diminishing unit cost and the service has a constant unit cost (i.e., the good is more scalable than the service). These results have several useful implications for further research in hybrid bundling and for retailer bundling decisions.

Acknowledgements

We thank participants at the Marketing Science Conference and the Editor and three anonymous reviewers for helpful comments.

Appendix 1. Derivation of Closed-Form Solution for Optimal Price of Hybrid Bundle under No Autonomy

With no autonomy, the monopolist sells only the hybrid bundle, serving only the N_{HB} segment. The size of this segment is given by:

$$N_{HB} = N \times Pr\left[(1+\theta)(R_G + R_S) \geq P_{HB}\right]. \tag{A.1}$$

Assuming a constant unit cost function for both the good and the service, the monopolist's problem can be defined as:

$$\max_{P_{HB}} \Pi = \left[(P_{HB} - C_G - C_S) \times N_{HB}\right]. \tag{A.2}$$

We draw reservation prices, (R_G, R_S), from the joint uniform distribution such that

$$f(x, y) = 1/(a^2 - 2a\delta) \quad \text{for} \quad 0 \leq R_S \leq a \quad \text{and} \quad \delta \leq R_G \leq a - \delta. \tag{A.3}$$

We now derive the optimal price of the hybrid bundle in three cases, as shown in Fig. A1.

Case 1: $\frac{P_{HB}}{1+\theta} \leq a - \delta$

The size of N_{HB} is given by:

$$N_{HB} = N \times \frac{2(1+\theta)^2(a^2 - 2a\delta - \delta^2) + 2P_{HB}(1+\theta) - P_{HB}^2}{2a(a-2\delta)(1+\theta)^2}. \tag{A.4}$$

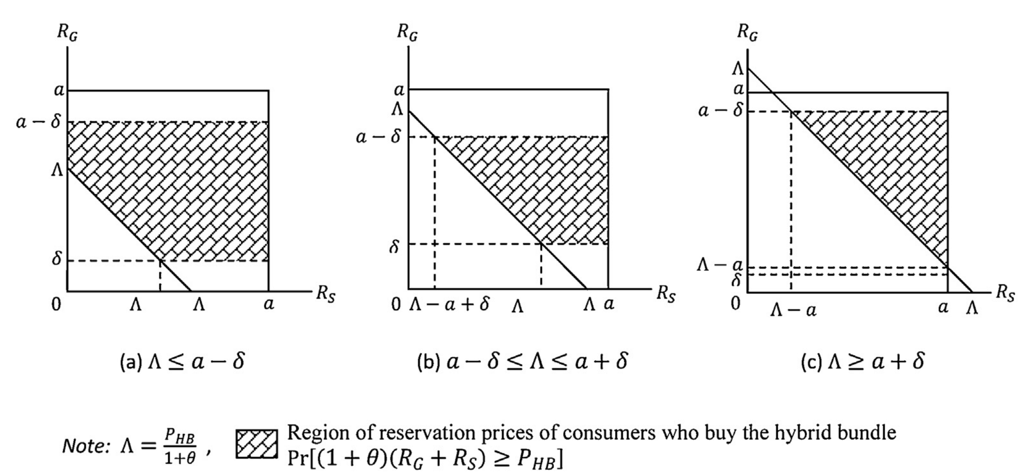

Fig. A1. Graphical depictions of closed-form solutions for hybrid bundle pricing under no autonomy.

The monopolist's problem is given by:

$$\max_{P_{HB}} \Pi = \left[(P_{HB} - C_G - C_S) \times N \times \frac{2(1+\theta)^2(a^2 - 2a\delta - \delta^2) + 2P_{HB}(1+\theta) - P_{HB}^2}{2a(a-2\delta)(1+\theta)^2} \right] \tag{A.5}$$

First Order Condition (simplified):

$$\frac{d\Pi}{dP_{HB}} = 0 = \frac{2(1+\theta)^2(a^2 - 2a\delta - \delta^2) + 2P_{HB}(1+\theta) - P_{HB}^2 + (P_{HB} - C_G - C_S)(2\delta(1+\theta) - 2P_{HB})}{2a(a-2\delta)(1+\theta)^2} \tag{A.6}$$

Second Order Condition (simplified):

$$\frac{d^2\Pi}{dP_{HB}^2} = \frac{-3P_{HB} + 2\delta(1+\theta) + C_G + C_S}{a(a-2\delta)(1+\theta)^2} < 0 \tag{A.7}$$

Solving for P_{HB}:

$$P_{HB}^* = \frac{2\delta(1+\theta) + C_S + C_G + \sqrt{(C_S + C_G)^2 + (1+\theta)^2(6a^2 - 2\delta^2 - 12a\delta) - 2\delta(C_S + C_G)(1+\theta)}}{3} \tag{A.8}$$

This solution holds for "low costs":

$$\frac{C_G + C_S}{1+\theta} \le \frac{(a-3\delta)^2}{2(a-2\delta)} \quad \text{and} \quad \delta < \frac{5a}{11} \tag{A.9}$$

Case 2: $a - \delta \le \frac{P_{HB}}{1+\theta} \le a + \delta$

The size of N_{HB} is given by:

$$N_{HB} = N \times \frac{3a(1+\theta) - 2P_{HB}}{2a(1+\theta)}. \tag{A.10}$$

The monopolist's problem is given by:

$$\max_{P_{HB}} \Pi = \left[(P_{HB} - C_G - C_S) \times N \times \frac{3a(1+\theta) - 2P_{HB}}{2a(1+\theta)} \right] \tag{A.11}$$

First Order Condition (simplified):

$$\frac{d\Pi}{dP_{HB}} = 0 = \frac{3a(1+\theta) - 4P_{HB} + 2(C_G + C_S)}{2a(1+\theta)} \tag{A.12}$$

Second Order Condition (simplified):

$$\frac{d^2\Pi}{dP_{HB}^2} = \frac{-2}{a(1+\theta)} < 0 \tag{A.13}$$

Solving for P_{HB}:

$$P_{HB}^* = \frac{3a(1+\theta) + 2(C_S + C_G)}{4} \tag{A.14}$$

This solution holds for "medium costs":

$$\frac{(a+4\delta)}{2} \le \frac{C_G + C_S}{1+\theta} \le \frac{(a-3\delta)^2}{2(a-2\delta)} \quad \text{and} \quad \delta < \frac{a}{2} \tag{A.15}$$

Case 3: $\frac{P_{HB}}{1+\theta} \ge a + \delta$

The size of N_{HB} is given by:

$$N_{HB} = N \times \frac{(1+\theta)^2(\delta - 2a)^2 + P_{HB}(1+\theta)(2\delta - 4a) + P_{HB}^2}{2a(a-2\delta)(1+\theta)^2} \tag{A.16}$$

The monopolist's problem is given by:

$$\max_{P_{HB}} \Pi = \left[(P_{HB} - C_G - C_S) \times N \times \frac{(1+\theta)^2(\delta - 2a)^2 + P_{HB}(1+\theta)(2\delta - 4a) + P_{HB}^2}{2a(a-2\delta)(1+\theta)^2} \right] \tag{A.17}$$

First Order Condition (simplified):

$$\frac{d\Pi}{dP_{HB}} = 0 = \frac{(1+\theta)^2(\delta - 2a)^2 + P_{HB}(1+\theta)(2\delta - 4a) + P_{HB}^2 + (P_{HB} - C_G - C_S)((1+\theta)(2\delta - 4a) + 2P_{HB})}{2a(a-2\delta)(1+\theta)^2} \tag{A.18}$$

Second Order Condition (simplified):

$$\frac{d^2\Pi}{dP_{HB}^2} = -\frac{-3P_{HB} + 4a(1+\theta) - 2\delta(1+\theta) + C_G + C_S}{a(a-2\delta)(1+\theta)^2} < 0 \tag{A.19}$$

Solving for P_{HB}:

$$P_{HB}^* = \frac{(2a - \delta)(1+\theta) + 2(C_S + C_G)}{3} \tag{A.20}$$

This solution holds for "high costs":

$$\frac{C_G + C_S}{1+\theta} \ge \frac{(a+4\delta)}{2} \quad \text{and} \quad \delta < \frac{a}{3} \tag{A.21}$$

Appendix 2. Effects of Quality Variability Changes on the Optimal Price of a Single Product

The monopolist sells the product, serving a portion of the overall market. The size of buying segment is given by:

$$N_B = N \times Pr[R \ge P]. \tag{B.1}$$

Assuming a constant unit cost function, the monopolist's problem can be defined as:

$$\max_{P} \Pi = [(P - C) \times N_B]. \tag{B.2}$$

We draw reservation prices, R, from the uniform distribution such that

$$f(x) = 1/a \quad \text{for} \quad \lambda \leq R \leq a - \lambda. \tag{B.3}$$

Thus, the size of N_B is given by:

$$N_B = N \times \left(\frac{a - \lambda - P}{a} \right) \tag{B.4}$$

The monopolist's problem is given by:

$$\max_P \Pi = \left[(P - C) \times N \times \left(\frac{a - \lambda - P}{a} \right) \right]. \tag{B.5}$$

The First Order Condition (simplified) is:

$$\frac{d\Pi}{dP} = 0 = \left(\frac{a + C - \lambda - 2P}{a} \right) \tag{B.6}$$

The Second Order condition (simplified) is:

$$\frac{d^2\Pi}{dP^2} = -\frac{2}{a} < 0 \tag{B.7}$$

Solving for P:

$$P^* = \frac{a + c - \lambda}{2} \tag{B.8}$$

The comparative static for λ is given by:

$$\frac{dP^*}{d\lambda} = -\frac{1}{2} \tag{B.9}$$

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