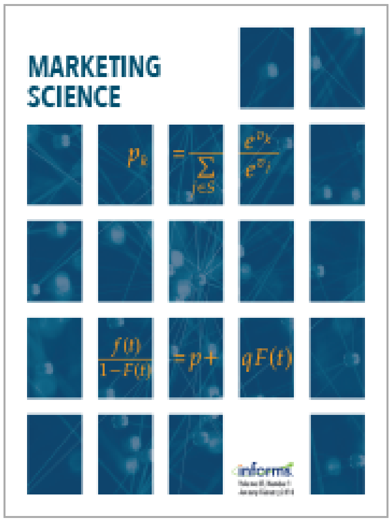

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Product Line Bundling: Why Airlines Bundle High-End While Hotels Bundle Low-End

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Abstract. Product lines are ubiquitous. For example, Marriott International manages high-end ultra-luxury hotels (e.g., Ritz-Carlton) and low-end economy hotels (e.g., Fairfield Inn). Firms often bundle core products with ancillary services (or add-ons). Interestingly, empirical observations reveal that industries with ostensibly similar characteristics (e.g., customer types, costs, competition, distribution channels, etc.) employ different bundling strategies. For example, airlines bundle high-end first class with ancillary services (e.g., breakfast, entertainment) while hotel chains bundle ancillary services (e.g., breakfast, entertainment) at the low-end. We observe, unlike hotel lines that are highly differentiated at different geographic locations, airlines suffer low core differentiation because all passengers (first-class and economy) are at the same location (i.e., same plane, weather, delays, cancellations, etc.). In general, we find product lines with low core differentiation (e.g., airlines, amusement parks) routinely bundle high-end while product lines with highly differentiated cores (e.g., hotels, restaurants) routinely bundle low-end. High-end bundling makes the high-end more attractive, increasing line differentiation (less intraline competition) while low-end bundling decreases line differentiation. Therefore, bundling allows optimal differentiation given a differentiation constraint (complex costs). Last, firms may use strategic bundling for targeting in their core products; e.g., low-end hotels bundle targeted add-ons unattractive to high-end consumers such as lower-quality breakfasts and slower Internet.

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1. Introduction

1.1. An Empirical Paradox

Shugan and Kumar (2012, 2014) present some empirical observations, which we verify, that reveal a small but interesting paradox. Service providers often sell a line of core services at different quality levels (Bitner et al. 1990). For example, Marriott International, like other hotel chains, offers a line of hotels that vary in quality including the super-luxury Ritz-Carlton, the high-end Renaissance, the mid-range Courtyard, and the economy-oriented Fairfield Inn and Suites (see Figure 1). In addition to core lodging services, Marriott offers a huge array of ancillary services, for example, breakfasts, Internet, irons, parking, premium entertainment, etc. Similarly, Delta Air Lines, like other airlines, has different core services that vary in quality including Delta One (First Class), Delta Comfort+, Main Cabin, and Basic Economy while providing many ancillary services (see Figure 2). Examples of product lines with ancillary products are ubiquitous in many industries: air transportation, financial services, cruises, retailing, packaged goods, live events, lodging, shipping, touring, etc.

A core service is often bundled with ancillary products (Wittmer et al. 2012). Interestingly, our empirical observations demonstrate that bundling often appears at different ends in a product line, i.e., some industries tend to bundle high-end while other industries bundle low-end. For example, the live event (e.g., concerts) industry tends to bundle high-end tickets with ancillary products (e.g., photographs, commemorative laminates, merchandise, hosting, backstage tours) while restaurants tend to bundle ancillary products (e.g., dinner salads, sides, desserts) at the low-end of their lines. Moreover, airlines often bundle high-end (see Table 1) while hotels often bundle low-end (see Figure 3). For example, the first-class airline service bundles meals, headphones, luggage handling, reservation assistance, seat selection, premium movies, alcoholic drinks, and priority security queues, while basic economy coach service usually does not (Carey 2011). By contrast, hotel chains that serve similar travelers often bundle

Figure 1. Marriott International Product Line

The Ritz-Carlton	The Ritz-Carlton: A worldwide symbol for the finest in accommodations and service
BVLGARI HOTELS & RESORTS	Bulgari Hotels & Resorts: Leading luxury hospitality collection in the world (Marriott managed)
JW MARRIOTT	JW Marriott: Elegant and luxurious brand, little touches add up to exceptional experiences
RENAISSANCE. HOTELS & RESORTS	Renaissance Hotels: Each offers its own personality, local flavor, distinctive style, and charm
Marriott	Marriott Hotels & Resorts: Provides consistent, dependable, and genuine caring experiences to guests on their terms
COURTYARD Marriott	Courtyard by Marriott: The quality you love in convenient locations throughout the world
SPRINGHILL SUITES Marriott	SpringHill Suites by Marriott: Spacious floor plans, dedicated workspaces at a price you'll love
FAIRFIELD INN Marriott	Fairfield Inn & Suites by Marriott: Provides everything you need to work productively

Notes. Logos are only intended to identify Marriott products. Their use does not reflect sponsorship or association of this article with Marriott Corporation.

ancillary services including parking and breakfast at low-end hotels. There are over 700 (low-end) Marriott Fairfield hotels and all bundle Wi-Fi regardless of (local) competition. In many other industries, ancillary products are bundled at either low-end or high-end (see Table 2).

Although airlines and hotels use different bundling strategies, both industries serve the same markets (i.e., leisure and business travelers) and face similar competitive market structures. Moreover, airlines and hotels have similar cost structures (i.e., high fixed costs and low variable costs). Finally, airlines and hotels use similar (often the same) distribution channels (e.g., online reservations), employ similar advertising, and face similar local add-on tax structures. Hence, it is difficult to explain why airlines and hotels employ different bundling strategies because those two industries are very similar in almost every respect. This paper provides an explanation for this possibly surprising empirical paradox and discusses important implications for product-line management with bundling.

Two types of "differentiation constraints" may help explain this empirical conundrum. First, firms cannot often achieve sufficient line differentiation only with the cores. For example, cruises offer different classes of accommodations (like hotels). However, without ancillary products, cruises find it difficult to differentiate their high-end services because passengers on the same cruise (like airlines) experience the same departure (arrival) time, staff, ship facilities, security, scenery, etc. Given this "high-end" differentiation constraint, it may not be profitable to develop a product line. In general, firms suffer similar differentiation constraints when services in the same line are constrained to a particular space (e.g., amusement parks, trains, concerts, etc.). This small core differentiation leads firms to

Figure 2. Delta Air Lines Product Line

Table 1. Airlines Unbundle Low-End and Bundle High-end (Delta Air Lines)

Ancillary services		Economy-class (low-end)	First-class (high-end)
Checked baggage	First checked bag	$25	Complimentary
	Second checked bag	$35	Complimentary
Flight change	Change your flight	$200	Complimentary
Same-day flight	Same-day confirmed	$50—Based on fare rules	Complimentary
	Standby fee	$50	Complimentary
In-flight entertainment	Snacks	$3–$5	Complimentary
	Meals on designated flights	$6–$10	Complimentary
	Alcoholic beverages	$5–$7	Complimentary
	Headsets	$2	Complimentary
	TV episodes	$1 for a TV episode	Complimentary
	HBO	$1 for an HBO episode	Complimentary
	Movies	$6 for a movie/TV bundle	Complimentary

Note. Fees reported in this table are based on flights less than 250 miles within the United States and Canada.

bundle high-end to achieve optimal line differentiation.

Second, firms can suffer from suboptimal low-end quality, i.e., a "low-end" differentiation constraint. For example, high-end hotels (e.g., Hyatt's Park Resorts, Marriott's Ritz-Carlton) can achieve optimal high-end quality at locations high-income travelers prefer, but low-end hotels (e.g., Hyatt's Place hotel, Marriott's Fairfield hotel) may be constrained by less desirable (lower rent) locations and lower core quality (e.g., less expensive systems and staff), i.e., the location and technology limit low-end quality. For instance, the lower-end Courtyard Waikiki Beach Hotel is a 12-minute walk from Waikiki Beach, while the higher-end Waikiki Beach Marriott Resort and Spa is a 1-minute walk. Low-end restaurants may employ much less expensive chefs than high-end restaurants, creating a constraint on their daily food variety and quality. Sometimes, although low-end quality could be initially optimal, aging technology or facilities may lower current (less durable) low-end quality below optimal levels. Firms suffer similar low-end constraints when their product lines consist of disparate cores that require different locations, technologies, equipment, or processes (e.g., beauty salons, electronics, tailors, etc.). Here, firms bundle low-end to achieve optimal line differentiation. Usually, the low-end bundle

Figure 3. Hotels Bundle Low-End and Unbundle High-End (InterContinental Hotels Group)

Staybridge Suites (low-end)

Complimentary services

1. Internet access
2. Wi-Fi
3. Laundry facility
4. Business services: Copier, printer, scanner
5. Fitness center
6. Pool
7. Evening reception: Three days per week

InterContinental Hotels (high-end)

Fees and surcharges

1. Package delivery fees: $3–$5
2. Holiday surcharges: $18–$45
3. Internet fees: $10–$25
4. Resort fees: $15–$30
5. Parking fees: $10–$50 per night
6. Fitness center fees: Up to $40 per day
7. Minibar restocking: $3–$5
8. Early check-in fees: Average $20–$50
9. Charitable donations: $1–$2
10. In-room coffee and tea: $2–$5 (tea bag)
11. Maid service: $2–$10 per room
12. Other: Porterage fees, bag storage fees, tourism fees, service charges, energy surcharges, luggage storage fees, and in-room safe fees

Table 2. Opposite Bundling Strategies in Different Industries

Industries routinely using high-end bundling (high-end core includes many ancillary services)	Industries routinely using low-end bundling (low-end core includes many ancillary services)
Airlines	Hotels
Cruises	Restaurant chains
Trains	Tailors
Concerts	Resorts/Casinos
Car washes	Electronics
Amusement parks	Tax consultants (flat rate on low-end)
Vacation packages	Beauty salons

includes ancillary products that are less attractive to high-end buyers (i.e., minimizing cannibalization); e.g., low-end hotels bundle lower-quality breakfasts, slower Internet, and outside self-parking. These two types of differentiation constraints relate to the complex costs of the quality provision.

1.2. Product Line Optimization

This section and Section 1.3 review related research on product lines and bundling, respectively. Full product line optimization is a very challenging combinatorial problem, involving both discrete (number of products) and continuous (quality and price) variables, seldom solvable via algebraic approaches. Thus, past studies often employ numerical approaches (Urban 1969, Green and Krieger 1985, Dobson and Kalish 1988, McBride and Zufryden 1988, Wilson and Norton 1989, Aydin and Ryan 2000, Belloni et al. 2008). For example, developing a simulated annealing code, Toubia et al. (2007) establish a procedure to optimize a product line (for reviews on product-line optimization, see Hauser et al. 2006 and Hauser 2011). Rather than taking a numerical (optimization) approach, however, we adopt an analytical (strategic) approach because we seek to explain a qualitative paradox (i.e., bundling at different ends of the line).

Although no articles consider bundling ancillary services with core products in a product line, the past literature does examine related product-line issues. For example, considering product-line competition, Katz (1984) finds that facing severe competition on some products in a product line, firms may not produce the entire line to maximize the profits from other products in the line. Anderson and Dana (2009) study the optimal number of qualities in a product line under quality constraints (Acharyya 1998, Johnson and Myatt 2003). Shugan (1989) explains why producers of super-premium quality offer smaller assortments than those of lesser quality. Desai (2001) studies quality decisions and their impact on line cannibalization. To prevent cannibalization, some researchers suggest lowering the quality of the lowest-quality product below the level preferred by the lower-valuation segment (Kumar et al. 2010). However, Desai (2001) finds conditions when cannibalization does not produce this effect. For example, Desai (2001) shows even a monopolist may find it optimal to provide efficient (desired) quality to each segment when the market is not fully covered. Villas-Boas (2004) shows communication costs affect product-line design. For example, when advertising is costly, it may be optimal to offer a small number of products in the line. Advertising costs can also lead to lower prices for the high-end and higher prices for the low-end. Orhun (2009) finds context effects created by a product line may cause firms to compress the range of qualities in the line. Coughlan (1987) finds manufacturers of narrow product lines tend to use independent intermediaries.

Similar to Desai (2001) and others (Mussa and Rosen 1978, Moorthy 1988, Zhao 2000), we consider sellers offering vertically differentiated product lines with at least two varieties (i.e., low-end and high-end). For example, airlines, high-speed trains, and cruises offer both economy and first-class accommodations. Hotel and restaurant chains often have budget and luxury locations; e.g., Darden Restaurants operates low-end steakhouses such as LongHorn Steakhouse and very expensive high-end steakhouses such as The Capital Grille. However, unlike prior research, considering differentiation constraints (i.e., optimal core differentiation is infeasible), our model predicts whether different industries will bundle low-end or high-end.

1.3. Bundling Ancillary Products

The definitions of core and ancillary services may depend on perceptions that can vary with prevailing laws, cultural norms, contexts, industry standards, historical traditions, and so forth. For example, there are spirited debates regarding whether airlines should ethically provide particular services, e.g., free carry-on bags, or whether restaurants should provide free restrooms as part of their core services. Extant research often lacks precise definitions.

We adopt simple operational definitions. Note, when a product or service is always bundled with a core, it might be operationally impossible to distinguish it from the core. For example, since airlines always bundle seatbelts with the cores, it may seem impossible to determine objectively whether seatbelts are part of the core service or they are one of the ancillary services. To avoid this somewhat philosophical debate, we define the core as the bundle of all products and services that all sellers in the market always provide at a single price. For example, hotels' core quality includes staffing, rooms, furniture, maintenance, security, and so on.

We define ancillary services as having three features. First, they have less value than the core. Second, they are sometimes but not always bundled with a core. Third, when unbundled, buyers can purchase the seller's ancillary service only with the corresponding core. For example, diners at a high-end restaurant (e.g., The Capital Grille) cannot get the low-end side salad from a low-end restaurant (e.g., LongHorn Steakhouse). We consider one ancillary service to model bundling strategies in a product line; however, the ancillary service can consist of many different services.

We investigate how firms bundle ancillary services with different cores in a vertical product line. No prior research studies this topic. However, the literature reveals conditions when bundling can be profitable. Stigler (1963) shows how negatively correlated consumer valuations for two goods can make bundling more profitable than unbundling even without demand complementarity or scope economies. Adams and Yellen (1976) expand on Stigler (1963), suggesting that mixed bundling (offering of both separate component goods and bundled goods) dominates pure bundling, but nearly any welfare outcome is possible with pure bundling. Schmalensee (1984) suggests that pure bundling can be more profitable than unbundling because bundling reduces the dispersion of consumer valuations, which allows an efficient extraction of consumer surplus. Particularly, mixed bundling is superior under general conditions (McAfee et al. 1989) because it retains any benefits from bundling while increasing the number of prices available to capture additional consumer surplus. However, mixed bundling might not apply to add-ons because, for example, airlines do not sell in-flight meals without the flight ticket. In general, when to bundle is complex. As Fang and Norman (2006, p. 946) note, "the profit-improving role of mixed bundling has nothing [to] do with exploiting negative correlations of valuation distributions." "The profitability issue still is not completely settled" (Chen and Riordan 2013, p. 51).

Moreover, past studies consider bundling in various interfaces. Balachander et al. (2010) consider the interface between price promotions and bundling, and find that bundle discounts can increase profits by creating endogenous loyalty. Lin (2016) argues that an optional add-on (e.g., Wi-Fi at high-end hotels) can intensify competition in contrast to standard conclusions in the literature (e.g., Ellison 2005). If both firms sell an optional add-on, they will price aggressively to compete for consumers who trade off the higher-quality base versus the lower-quality base plus the add-on. Shugan and Moon (2015) find bundling can act as a signal that the bundled add-on has wide appeal at current prices (unlike quality signaling). Rust and Chung (2006) consider customer relationships including the interface between bundling and service pricing, concluding that relationship models should focus on marketing interventions rather than the financial impact of customers. Considering bundling in auctions, Subramaniam and Venkatesh (2009) find that the auction of unbundled products is superior to that of bundled products for most substitutes.

2. Model: Product Lines Without Add-ons

Considering a firm that provides the core and ancillary services, we define a general decision sequence for bundling-within-line decisions. First, the forward-looking firm decides whether to have a single (core) product or a product line, i.e., two (core) products. Second, the firm decides whether to bundle or unbundle the ancillary service. Given a product line, the firm can bundle the ancillary service with the low-end core or high-end core; if not, the firm unbundles the ancillary service at both ends. Third, the firm chooses the quality of the core product(s) and ancillary service(s). Fourth, the firm sets prices for the core product(s) and, if unbundled, ancillary service(s). We start with a benchmark model without bundling. Section 3 incorporates bundling and derives the optimal product-line and bundling decisions.

2.1. Consumer Segments

This section models consumer choice involving various offers in a product-line context. To justify a product line, there must be at least two market segments (Moorthy 1984) so that the line induces self-selection (Kolay and Shaffer 2003). Consistent with Occam's razor (Kalt and Zupan 1984), we seek to explain observed market behavior with two (the minimum number of) segments that, of course, should still be realistic and consistent with empirical observations.

Consider two market segments: low-end (L) and high-end (H). Let $\theta > 0$ and $\theta + \alpha$ denote the willingness-to-pay (WTP) per unit quality for L and H, respectively, where $\alpha > 0$; L pays less for quality than H. Segment L may include families with many children, students, consumers with limited budgets, and simply those who only want the basic low quality. Segment H may include business travelers, high-income consumers, and those who merely obtain substantial utility from additional quality. Both segments buy at most one unit. We assume $\theta > \alpha$; otherwise (i.e., when L has very low WTP for quality), the firm has no incentive to maintain a low-end product for L, i.e., no product line exists. Without loss of generality, we assume consumers' reservation utility is zero. For simplicity, we consider each segment as one consumer.

The analysis occasionally requires unambiguous resolution of cases when consumers are indifferent between two options. In those cases, following standard conventions, we assume the firm can induce the purchase of the more profitable option with an infinitesimally small reduction in the price of that option. For example, when a consumer is indifferent between the low-end and high-end products, we assume the consumer buys the high-end product.

2.2. Firm's Problem Without Differentiation Constraints

We first consider the benchmark case when the firm suffers no (differentiation) constraints. Consistent with the traditional product-line literature, we assume that the firm's marginal cost of producing quality Q is cQ^2 for some constant $c > 0$. With a single product, the firm decides the quality (Q_S) and price (P_S) to maximize the single-product profits $\pi(P_S) = D_S(P_S - cQ_S^2)$, where $D_S = 2$ for $P_S \le \theta Q_S$, $D_S = 1$ for $\theta Q_S < P_S \le (\theta + \alpha)Q_S$, and $D_S = 0$ for $P_S > (\theta + \alpha)Q_S$. Given Q_S, the optimal price is $P_1 = \theta Q_S$ or $P_2 = (\theta + \alpha)Q_S$, yielding $\pi(P_1) = 2(\theta Q_S - cQ_S^2)$ and $\pi(P_2) = (\theta + \alpha) Q_S - cQ_S^2$. Accordingly, the optimal quality is $Q_1 = \theta/(2c)$ or $Q_2 = (\theta + \alpha)/(2c)$; thus, the optimal single-product profits are $\pi_1^* = \pi(P_1; Q_1) = \theta^2/(2c)$ or $\pi_2^* = \pi(P_2; Q_2) = (\theta + \alpha)^2/(4c)$, respectively.

With a product line (low-end/high-end), the firm chooses the low-end quality (Q_L) and the high-end quality ($Q_H > Q_L$), and the firm sets the prices P_L and P_H for the low-end and high-end, respectively. The firm's problem can be written as

$$\max_{P_L, P_H, Q_L, Q_H} \left\{P_L + P_H - cQ_L^2 - cQ_H^2\right\}$$

subject to $P_L \le \theta Q_L$, $P_H \le (\theta + \alpha)Q_H$, and $(\theta + \alpha)Q_H - P_H \ge (\theta + \alpha)Q_L - P_L$. Lemma 1 follows.

Lemma 1. *Without any constraints on quality, product-line profits are greater than single-product profits.*

Lemma 1 shows the traditional product-line model result; i.e., without quality constraints, a product line produces greater profits than a single product (Mussa and Rosen 1978, Moorthy 1984, Anderson and Dana 2009). Given Q_L and Q_H, it is optimal to sell the low-end product at L's WTP and set the high-end price such that it makes H indifferent between two products. Therefore, the optimal prices are $P_L = \theta Q_L$ and $P_H = (\theta + \alpha) \cdot Q_H - \alpha Q_L$; the product-line profits are $\Pi(Q_L, Q_H) = (\theta - \alpha)Q_L + (\theta + \alpha)Q_H - cQ_L^2 - cQ_H^2$; the optimal low-end and high-end quality is $Q_L^* = (\theta - \alpha)/(2c)$ and $Q_H^* = (\theta + \alpha)/(2c)$, respectively. Finally, the optimal product-line profits are $\Pi^* = (\theta - \alpha)^2/(4c) + (\theta + \alpha)^2/(4c)$, which is greater than both π_1^* and π_2^*. For more general demand functions, see Anderson and Celik (2015).

We can also derive the optimal product differentiation $\delta^* = Q_H^* - Q_L^* = \alpha/c$. However, the firm may not always achieve the desired-level of product differentiation using only the core. The prior literature recognizes technological constraints on quality (Schmidt-Mohr and Villas-Boas 2008, Anderson and Dana 2009). There may also be technological constraints on differentiation. As explained in Section 1.1, exogenous industry characteristics (e.g., technology, location, inherent design limitations, standards, and regulatory restrictions) and aging sometimes make the core differentiation too low (e.g., airlines, cruises) and other times too high (e.g., hotels, restaurants).

When the core differentiation is too low, we prove that price discrimination on core quality is less profitable than a single quality. However, we show that high-end bundling can increase product-line profits by making high-end products more attractive, thereby achieving the optimal differentiation. Airlines, for example, bundle their high-end seats with premium entertainment and executive lounges that offer complementary buffets, Wi-Fi, showers, spirits, and more.

When the core differentiation is too high, we prove that a product line is inferior to selling a single (highly profitable) product. Given this high core differentiation, the opportunity cost of selling low-end products to low-end buyers is too high, and thus it is optimal to sell a single product (with intermediate quality) to everyone. However, we show that the firm finds it optimal to offer two different cores when the firm produces the ancillary service because by low-end bundling, the firm can make the low-end product more attractive and decrease the line differentiation to the optimal level. Hotel chains, for example, bundle budget hotel rooms with parking, Wi-Fi, breakfasts, newspapers, mini-refrigerators (for personal use), and more.

2.3. Firm's Problem with Differentiation Constraints

Before considering bundling in the product line, we examine how differentiation constraints affect product-line profits. We consider two constraints: (1) $Q_H - Q_L \le \underline{\delta}$ for some constant $0 < \underline{\delta} < \delta^*$ and (2) $Q_H - Q_L \ge \bar{\delta}$ for some constant $\bar{\delta} > \delta^*$, where $\delta^* = \alpha/c$, the optimal unconstrained line differentiation derived in Section 2.2. The first (high-end differentiation) constraint implies that the firm can only achieve the product differentiation below the optimal level (δ^*). Analogously, the second (low-end differentiation) constraint implies that the firm can only achieve the product differentiation above the optimal level.

The two exogenous parameters, $\underline{\delta}$ and $\bar{\delta}$, represent the degree of the high-end and low-end differentiation constraints, respectively. Given a high-end (low-end) differentiation constraint, the firm's choices of core qualities become more restricted as $\underline{\delta}$ ($\bar{\delta}$) decreases (increases). For example, compare Florida's Disney World (Disney) with Busch Gardens. Disney has four theme parks, two water parks, one golf course, and one recreation complex, while Busch Gardens has two theme parks and two water parks. Both amusement parks may suffer high-end differentiation constraints because visitors have similar experiences in parks managed by the same company, in very close proximity, sharing many resources (e.g., weather, accommodations, transportation, technology, etc.). However, Busch Gardens may suffer a stricter differentiation constraint because it has less ability to create varied core tickets from only two parks. In general, firms with fewer core resources and less flexibility may suffer a more restrictive differentiation constraint. Proposition 1 follows.

Proposition 1. *Without add-ons (ancillary services), given $Q_H - Q_L \leq \underline{\delta}$, single-product profits are greater than product-line profits when $\underline{\delta} \leq \delta^*/4$; given $Q_H - Q_L \geq \bar{\delta}$, single-product profits are greater than product-line profits when $\bar{\delta} \geq 2\delta^*$.*

Proposition 1 proves that when the firm suffers a differentiation constraint, it can be optimal to offer a single quality rather than two qualities (i.e., a product line). With the high-end differentiation constraint (i.e., it is infeasible to design a high-end product such that it provides sufficiently high quality relative to a low-end product), the firm provides the optimal low-end quality (Q_L^*) while the firm can only produce quality $Q_L^* + \underline{\delta} < Q_H^*$ for the high-end. When the product differentiation is too small (i.e., $\underline{\delta} \leq \delta^*/4$), the profit loss caused by preventing the low-end product's cannibalization (i.e., a lower high-end price) exceeds the profit gain from the price discrimination in the product line. Therefore, the firm finds it optimal to produce a single product with intermediate quality ($Q_L^* < Q_1 < Q_H^*$).

Analogously, the low-end differentiation constraint limits low-end quality to $Q_H^* - \bar{\delta} < Q_L^*$ (i.e., too much differentiation) although the firm offers the optimal high-end quality Q_H^*. Without bundling, it is difficult to reduce the line differentiation to the optimal level given the (low-end) differentiation constraint ($\bar{\delta} \geq 2\delta^*$). Maintaining a low-end product (i.e., a product line) for L at a very low price can be less profitable than producing a single intermediate quality.

3. Model: Product Lines with Add-ons

We have shown that a differentiation constraint can make a single product more profitable than a product line. However, given a differentiation constraint, this section proves that a product line is more profitable than a single product when the firm provides ancillary services and adopts an optimal bundling strategy. More important, we also find the optimal bundling strategy depends on the type of differentiation constraint (i.e., high-end or low-end).

3.1. Bundling Decision

Considering the core and ancillary services, we incorporate bundling strategies into our product-line model. Given a product line, the firm has four bundling strategies: (1) bundling the ancillary service at both the low-end and high-end (BB), (2) unbundling the ancillary service at the low-end and bundling at the high-end (UB), (3) bundling the ancillary service at the low-end and unbundling at the high-end (BU), and (4) unbundling the ancillary service at both the low-end and high-end (UU). When bundling at the low-end or high-end, the firm chooses the bundled core quality for the low-end (Q_{BL}) or high-end (Q_{BH}), respectively. When unbundling at the low-end or high-end, the firm chooses both the unbundled core quality and the unbundled ancillary quality for the low-end (Q_L, q_L) or high-end (Q_H, q_H), respectively.

For bundling (B), instead of modeling what constitutes the bundle, for convenience, we assume firms consider the bundle as one product, i.e., the ancillary products are part of the core. This implies that to increase the core quality, the bundled ancillary products should match the core quality. For example, Delta Air Lines bundles Delta One (high-end) with high-end ancillary services including chef-curated meals, Master Sommelier selected wine pairings, and Tumi amenities. Choosing bundle quality Q as one product, the firm incurs bundle cost cQ^2.

For unbundling (U), similar to B, it incurs core cost cQ^2 given core quality Q. However, unlike B, the unbundled ancillary products are not part of the core, i.e., rather than increasing the core quality for all buyers, firms obtain extra ancillary profits from only some buyers. Hence, firms can choose unbundled ancillary products without the need to match the core quality so that unbundled ancillary products might differ from those that are bundled. For the prior example, the bundled high-quality (high-cost) ancillary products that match Delta One are often not available to Basic Economy, i.e., the low-end offers a different composition and quality of unbundled ancillary products. To capture this difference between B and U, let $\theta_a > 0$ denote consumers' WTP per unit quality of the unbundled ancillary products. We assume $\theta_a < \alpha$ because consumers' WTP for the (unbundled) ancillary products is less than that for the core. Last, given unbundled ancillary quality $q_U > 0$, the firm incurs additional ancillary cost cq_U^2, which reflects that the unbundled ancillary products are not part of the core. The online appendix provides more examples that support our utility and cost functions for B and U.

3.2. Single Core Product

In this section, we prove that with a single product, U (unbundling) dominates B (bundling). For B, given bundle quality Q_B, the optimal bundled core price is $P_{B1} = \theta Q_B$ or $P_{B2} = (\theta+\alpha)Q_B$. The single-product bundling profits are

$$\pi_B(P_S; Q_B) = \begin{cases} 2(\theta Q_B - cQ_B^2) & \text{for } P_S = P_{B1}, \\ (\theta+\alpha)Q_B - cQ_B^2 & \text{for } P_S = P_{B2}. \end{cases}$$

The optimal bundle quality is $Q_{B1} = \theta/(2c)$ and $Q_{B2} = (\theta+\alpha)/(2c)$ for $P_S = P_{B1}$ and $P_S = P_{B2}$. Thus, the optimal bundling profits are $\pi^*_{B1} = \pi(P_{B1}; Q_{B1}) = \theta^2/(2c)$ or $\pi^*_{B2} = \pi(P_{B2}; Q_{B2}) = (\theta+\alpha)^2/(4c)$.

For U, given core quality Q_U and unbundled ancillary quality q_U, the optimal core price is $P_{U1} = \theta Q_U$ or $P_{U2} = (\theta+\alpha)Q_U$, and the optimal unbundled ancillary price is $p_U = \theta_a q_U$. The single-product unbundling profits are

$$\pi_U(P_S, p_s; Q_U, q_U) = \begin{cases} 2(\theta Q_U - cQ_U^2 + \theta_a q_U - cq_U^2) \\ \quad \text{for } P_S = P_{U1}, p_s = p_U, \\ (\theta+\alpha)Q_U - cQ_U^2 + \theta_a q_U - cq_U^2 \\ \quad \text{for } P_S = P_{U2}, p_s = p_U. \end{cases}$$

The optimal core quality is $Q_{U1} = \theta/(2c)$ and $Q_{U2} = (\theta+\alpha)/(2c)$ for $P_S = P_{U1}$ and $P_S = P_{U2}$, and the optimal ancillary quality is $q^*_U = \theta_a/(2c)$; the optimal unbundling profits are $\pi^*_{U1} = \pi(P_{U1}, p_U; Q_{U1}, q^*_U) = \theta^2/(2c) + \theta_a^2/(2c)$ or $\pi^*_{U2} = \pi(P_{U2}, p_U; Q_{U2}, q^*_U) = (\theta+\alpha)^2/(4c) + \theta_a^2/(4c)$. Hence, the optimal single-product profits are $\pi^* = \max\{\pi^*_{U1}, \pi^*_{U2}\}$ because $\pi^*_{U1} > \pi^*_{B1}$ and $\pi^*_{U2} > \pi^*_{B2}$.

When the firm chooses the quality of both the core (whether bundled or unbundled) and (if unbundled) the ancillary service, unbundling is optimal. By unbundling, the firm can obtain additional ancillary sales while choosing an optimal core quality without the ancillary service.

3.3. Product-Line Bundling with Differentiation Constraints

This section derives our primary results, consistent with our empirical analysis, that bundling occurs at the high-end when the core differentiation is low, and vice versa. Given a product line, the firm has four bundling strategies: BB, UB, BU, and UU. For example, choosing a BB strategy, the firm decides the bundle quality for the low-end (Q_{BL}) and high-end (Q_{BH}) and sets the bundle prices for the low-end (P_{BL}) and high-end (P_{BH}).

The firm's product-line bundling problem can be written as

$$\begin{aligned} \max_{\Theta} \; &\left\{P_{BL} + P_{BH} - cQ_{BL}^2 - cQ_{BH}^2\right\} \\ &+ \lambda_L(P_L - cQ_L^2 + p_L - cq_L^2 - P_{BL} + cQ_{BL}^2) \\ &+ \lambda_H(P_H - cQ_H^2 + p_H - cq_H^2 - P_{BH} + cQ_{BH}^2) \end{aligned}$$

subject to

$$\begin{aligned} &\max\{\lambda_L P_L, (1-\lambda_L)P_{BL}\} \\ &\quad \le \max\{\lambda_L \theta Q_L, (1-\lambda_L)\theta Q_{BL}\}, && \text{(IR-1)} \\ &\max\{\lambda_H P_H, (1-\lambda_H)P_{BH}\} \\ &\quad \le \max\{\lambda_H(\theta+\alpha)Q_H, (1-\lambda_H)(\theta+\alpha)Q_{BH}\}, && \text{(IR-2)} \\ &\lambda_L p_L \le \lambda_L \theta_a q_L, \; \lambda_H p_H \le \lambda_H \theta_a q_H, && \text{(IR-3, IR-4)} \\ &\max\bigl\{\lambda_H[(\theta+\alpha)Q_H - P_H + \theta_a q_H - p_H], \\ &\qquad (1-\lambda_H)[(\theta+\alpha)Q_{BH} - P_{BH}]\bigr\} \\ &\ge \max\bigl\{\lambda_L[(\theta+\alpha)Q_L - P_L + \theta_a q_L - p_L], \\ &\qquad (1-\lambda_L)[(\theta+\alpha)Q_{BL} - P_{BL}]\bigr\}, && \text{(IC)} \end{aligned}$$

and a differentiation constraint ($Q_H - Q_L \le \underline{\delta}$ or $Q_H - Q_L \ge \bar{\delta}$), where $\lambda_L = 1$ for UB and UU and $\lambda_H = 1$ for BU and UU; otherwise, $\lambda_L = 0$ and $\lambda_H = 0$, and $\Theta = \{\lambda_i, P_{Bi}, P_i, p_i, Q_{Bi}, Q_i, q_i \text{ for } i = L, H\}$.

The product-line optimization problem involves bundling decisions under either the high-end or low-end differentiation constraint. Proposition 2 shows how a UB strategy can improve the product-line profits under the high-end differentiation constraint.

Proposition 2. *Given $Q_H - Q_L \le \underline{\delta}$, a UB strategy is optimal if and only if $\underline{\delta} < \delta^* - \theta_a/(2c)$. More specifically, the firm develops a product line. For the low-end, unbundling the ancillary service, the firm offers the core quality $Q^*_L = (\theta-\alpha)/(2c)$ at price $P^*_L = \theta Q^*_L$ and the ancillary quality $q^*_L = \theta_a/(2c)$ at price $p^*_L = \theta_a q^*_L$. For the high-end, bundling the ancillary service, the firm offers the bundle quality $Q^*_{BH} = (\theta+\alpha)/(2c)$ at price $P^*_{BH} = (\theta+\alpha)Q^*_{BH} - \alpha Q^*_L$. The optimal product-line profits are $\Pi^*_{UB} = \Pi^* + \theta_a^2/(4c)$.*

Proposition 2 predicts that when the firm is unable to achieve sufficient core differentiation, the firm will unbundle the ancillary service at the low-end and bundle it at the high-end. This case tends to occur when H has a much greater WTP than L (i.e., larger α and $\delta^* = \alpha/c$) because the product-line profits increase with α without differentiation constraints and, with bundling, the firm can increase the high-end bundle quality (Q_{BH}) to the optimal level despite the high-end differentiation constraint ($Q_H - Q_L \le \underline{\delta}$).

Under $Q_H - Q_L \le \underline{\delta}$, the firm has de facto no quality constraint on the low-end core, choosing the optimal low-end core quality $Q^*_L = (\theta-\alpha)/(2c)$ without bundling. Then, selling the unbundled ancillary service, the firm increases the low-end profits. However, for the high-end, the firm can only achieve (at most) quality $Q_H = Q^*_L + \underline{\delta} < Q^*_{BH}$ with only the core. Thus, the firm bundles the ancillary service to increase the high-end quality to the optimal level by adding ancillary quality of at least $q_H = Q^*_{BH} - (Q^*_L + \underline{\delta}) = \alpha/c - \underline{\delta}$. This implies that when differentiating the core is more difficult (i.e., smaller $\underline{\delta}$), additional high-end bundling becomes optimal.

Last, when consumers have a greater WTP for the ancillary service (larger θ_a), UU becomes more profitable than UB because the firm gains more profits from selling unbundled ancillary services than increasing the high-end quality by bundling high-quality (high-cost) ancillary services that match the high-end core (see the appendix for the proof). Proposition 3 shows analogous results when the firm suffers the low-end differentiation constraint ($Q_H - Q_L \geq \bar{\delta}$).

Proposition 3. *Given $Q_H - Q_L \geq \bar{\delta}$, a BU strategy is optimal if and only if $\bar{\delta} > \delta^* + \theta_a/(2c)$. More specifically, the firm develops a product line. For the low-end, bundling the ancillary service, the firm offers the bundle quality $Q^*_{BL} = (\theta - \alpha)/(2c)$ at price $P^*_{BL} = \theta Q^*_{BL}$. For the high-end, unbundling the ancillary service, the firm offers the core quality $Q^*_H = (\theta + \alpha)/(2c)$ at price $P^*_H = (\theta + \alpha)Q^*_H - \alpha Q^*_{BL}$ and the ancillary quality $q^*_H = \theta_a/(2c)$ at price $p^*_H = \theta_a q^*_H$. The optimal product-line profits are $\Pi^*_{BU} = \Pi^* + \theta_a^2/(4c)$.*

Proposition 3 predicts that when the core only allows high differentiation, it is optimal to bundle the ancillary service at the low-end and unbundle it at the high-end. This outcome tends to occur when consumers of both segments have a similar WTP (i.e., smaller α and $\delta^* = \alpha/c$) because the optimal quality difference (δ^*) in the line decreases without differentiation constraints, and bundling enables the firm to increase the low-end quality (i.e., reduce line differentiation) to the optimal level despite the low-end differentiation constraint ($Q_H - Q_L \geq \bar{\delta}$).

Under $Q_H - Q_L \geq \bar{\delta}$, the firm has no binding quality constraint on the high-end core, choosing the optimal high-end core quality $Q^*_H = (\theta + \alpha)/(2c)$ without bundling while selling the unbundled ancillary service at the high-end. However, at the low-end, the differentiation constraint only allows (at most) quality $Q_L = Q^*_H - \bar{\delta} < Q^*_{BL}$. Hence, increasing the low-end quality by bundling is optimal. The minimum ancillary quality the firm adds to the low-end by bundling is $q_L = Q^*_{BL} - (Q^*_H - \bar{\delta}) = \alpha/c + \bar{\delta}$. This implies that when the core differentiation exceeds the optimal level to a greater extent (larger $\bar{\delta}$), bundling more ancillary services with the low-end core is optimal.

When bundling low-end, firms may carefully choose low-end ancillary products that are unattractive to high-end buyers (i.e., not to cannibalize). For example, Figure 4 shows a bundled low-end (low-cost) breakfast that is less attractive to high-end buyers.

Last, with large θ_a, UU is more profitable than BU because the firm obtains more profits from selling high-quality unbundled ancillary services than increasing the low-end quality by bundling low-quality (low-cost) ancillary services that match the low-end core. In practice, UU might be rare because there might always be some ancillary services with small θ_a.

Table 3 encapsulates our theoretical results. Without add-ons, a single quality is optimal when a differentiation constraint is highly restrictive (i.e., small $\underline{\delta}$ or large $\bar{\delta}$). See Figure 5 (left panel, regions labeled Single Product). However, a larger α (more heterogeneous consumers) makes a product line more profitable. See Figure 5 (left panel, center triangular region labeled Product Line). When firms can bundle ancillary products, a product line dominates a single product because bundling allows an optimal line differentiation. Given a highly restricted high-end (low-end) differentiation constraint, i.e., small $\underline{\delta}$ (large $\bar{\delta}$), bundling high-end (low-end) is optimal. See Figure 5 (right panel, regions labeled UB and BU).

4. Empirical Analysis

Casual empirical observations in many industries suggest correlations between bundling and line (core) differentiation. This section shows, more formally, that our theoretical predictions are consistent with our preliminary empirical observations. Although we provide initial findings, our (highly significant) statistical results across several industries are very encouraging.

We collect publicly available data on product lines and ancillary services that exhibit large diversity in line differentiation, competition, and product

Figure 4. Low-End versus High-End Ancillary Products

Bundled low-end hotel breakfast

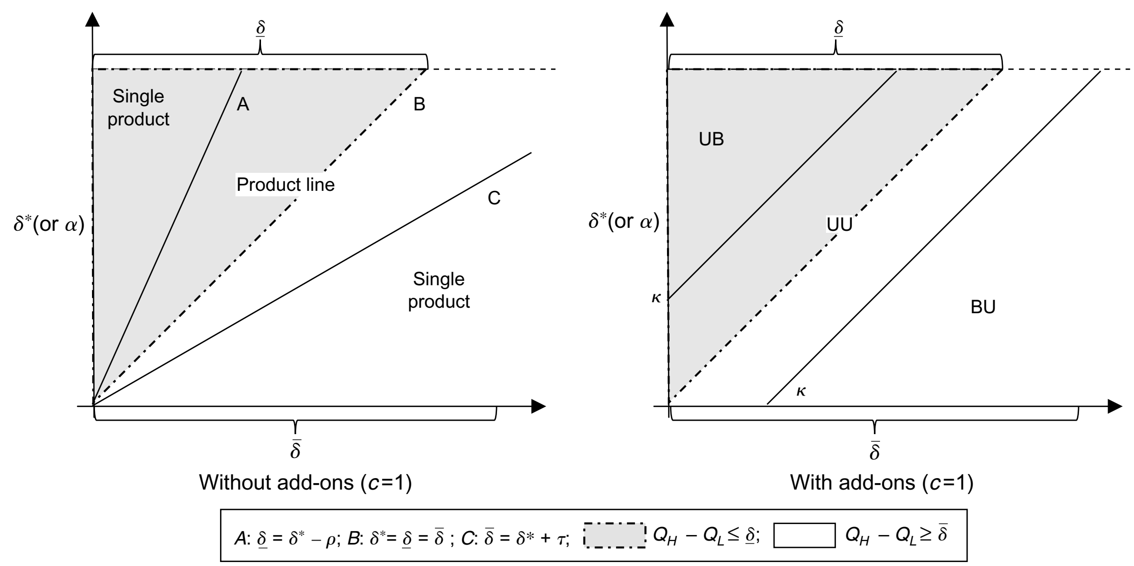
Unbundled high-end hotel breakfast

Table 3. Optimal Product-Line and Bundling Decisions

	Differentiation constraint			
	High-end ($Q_H - Q_L \le \underline{\delta}$)		Low-end ($Q_H - Q_L \ge \bar{\delta}$)	
	More restrictive	Less restrictive	More restrictive	Less restrictive
Without add-ons	$\underline{\delta} < \delta^* - \rho$ Single product	$\underline{\delta} > \delta^* - \rho$ Product line	$\bar{\delta} > \delta^* + \tau$ Single product	$\bar{\delta} < \delta^* + \tau$ Product line
With add-ons	$\underline{\delta} < \delta^* - \kappa$ UB	$\underline{\delta} > \delta^* - \kappa$ UU	$\bar{\delta} > \delta^* + \kappa$ BU	$\bar{\delta} < \delta^* + \kappa$ UU

Note. The expressions of $\rho > 0$, $\tau > 0$, and $\kappa > 0$ are in the appendix; $\partial\rho/\partial\alpha > 0$, $\partial\tau/\partial\alpha > 0$, and $\partial\kappa/\partial\alpha = 0$ (see Figure 5).

Figure 5. Optimal Product-Line and Bundling Decisions



type. We randomly select six firms each from eight industries (product categories) including airlines, car washes, amusement parks, concerts (live events), hotels (lodging), restaurants, guitars (musical instruments), and digital cameras (Table 4 shows the industry identifiers, and Table 5 describes our procedure to sample firms). In their product lines, we randomly select 271 core products (brands). Usually, firm websites, like Disney World, explicitly distinguish their cores (e.g., admission to different theme parks) from their ancillary services (e.g., parking, souvenirs, food, etc.).

All of our firms offer product lines. For example, Disney's product line consists of tickets with admission to different numbers of Disney parks (e.g., Magic Kingdom, Epcot, Hollywood Studios, Animal Kingdom, etc.). Park Place Car Wash has a product line consisting of Self Service, Full Service Washes, and Detail Packages. Moreover, firms in our industries

Table 4. Identifiers for Eight Industries

Identifier (k)	Industry	Identifier (k)	Industry
1	Airlines	5	Hotels (lodging)
2	Car washes	6	Restaurants
3	Amusement parks	7	Guitars (musical instruments)
4	Concerts (live events)	8	Digital cameras

Table 5. Description of Sampling Procedure

Industry	Number of sampled firms	Number of total firms	Search platform
Airlines	6	14	U.S. Department of Transportation
Car washes[a]	6	56	Google
Amusement parks[b]	6	25	TripAdvisor
Concerts	6	Over 1,000	Premium Seats USA
Hotels[c]	6	767	Expedia
Restaurants[d]	6	49	Wikipedia
Guitars	6	15	Amazon
Digital cameras	6	29	Amazon

Notes. From our search results, we randomly sample six firms that have a product line.

[a]Google finds 56 car wash services in Florida.

[b]TripAdvisor recommends 25 amusement parks in the United States.

[c]Expedia finds 767 hotels in Orlando, Florida.

[d]Wikipedia provides a list of 49 restaurant parent companies.

offer various ancillary products. For example, Yamaha, a guitar manufacturer, provides amplifiers, tuners, hard cases, stands, picks, and more. Sweetwater Car Wash provides ancillary products such as triple coat conditioner, clear coat sealer, total vehicle protectant, tire shine, and more.

We classify the industries based on the degree of core differentiation. The first four industries (airlines, car washes, amusement parks, and concerts) suffer high-end differentiation constraints because firms deliver services at the same geographic location, and products in their product lines share the same core technology, limiting the high-end core quality. By contrast, the remaining industries suffer low-end differentiation constraints because low-end products lack some of the technologies or locations available to high-end products. For example, it is not economical for low-end digital cameras to use magnesium alloy bodies, sophisticated metering, and cross-type sensors employed by high-end digital cameras. It is not economical for low-end restaurants to employ expensive celebrity chefs found at high-end restaurants. Based on this classification, we define eight differentiation-constraint indicators for eight industries

$$I_{k'}^{HDC}(k) = \begin{cases} 1 & \text{if } k = k' \text{ and industry } k \text{ exhibits} \\ & \text{high-end differentiation constraint,} \\ 0 & \text{otherwise,} \end{cases} \quad \text{for } k' = 1, \ldots, 4,\ k = 1, \ldots, 8,$$

$$I_{k''}^{LDC}(k) = \begin{cases} 1 & \text{if } k = k'' \text{ and industry } k \text{ exhibits} \\ & \text{low-end differentiation constraint,} \\ 0 & \text{otherwise,} \end{cases} \quad \text{for } k'' = 5, \ldots, 8,\ k = 1, \ldots, 8.$$

High-end differentiation constraints often occur when firms deliver both high-end and low-end services at the same location. For instance, whether flying first class or economy class on the same flight, passengers experience the same departure time, arrival time, in-flight delays, runway delays, weather, cancellations, diversions, turbulence, etc. Hence, airlines face technological constraints that limit their ability to differentiate their core (without add-ons). To increase line differentiation, airlines may bundle high-end. Similarly, concertgoers see the same concert at the same location. Bundling better seats with ancillary services (e.g., preshow parties, souvenirs, host services, etc.) creates more differentiated high-end products. Amusement park visitors may experience the same attractions and weather; however, bundling high-end tickets with ancillary services such as priority queues, meals, valet parking, and early admission increases line differentiation.

By contrast, low-end differentiation constraints can occur when firms deliver high-end and low-end services at different locations. For example, multibrand restaurant chains locate restaurants at different locations. High-end upscale steakhouses (e.g., Darden's The Capital Grille, Bloomin's Fleming's) locate in high-income (high-rent) locations with highly differentiated facilities from their low-end counterparts (e.g., Darden's LongHorn, Bloomin's Outback). Low-end restaurants have lower-paid chefs, less daily menu variety (and quality), and less fresh ingredients (e.g., frozen fish). Compensating for their low quality, low-end restaurants bundle salads, sides, desserts, etc. Similarly, luxury hotels (e.g., Hyatt's Park Resorts, Marriott's Ritz-Carlton) usually locate in areas desired by high-income travelers unlike their low-end counterparts (e.g., Hyatt's Place hotel, Marriott's Fairfield hotel). Moreover, as low-end (often less durable) facilities age, their quality levels may fall. For these industries, low-end bundling is the norm because bundling improves low-end profitability, making a product line optimal.

There is another possibly compelling reason for bundling ancillary products at the low-end. Consider a low-end Marriott hotel. In improving the low-end core quality (e.g., furnishings, rooms, amenities), the low-end Marriott can cannibalize Marriott's high-end hotels. In contrast, by bundling low-end add-ons (e.g., inexpensive breakfasts, moderate-speed Internet, outside self-parking, basic entertainment), the low-end Marriott can improve its quality without making it attractive to high-end buyers who do not value low-end add-ons as much as low-end buyers.

Our arguments about differentiation constraints may apply to many industries. For example, although cruises appear similar to hotels because cruises provide lodging services, cruises are actually more similar to airlines because passengers on the same cruise travel on the same ship with the same weather, departure (arrival) times, staff, ship facilities, and security regardless of their accommodations. Hence, we observe high-end bundling similar to airlines rather than low-end bundling similar to hotels. Typical high-end cruise accommodations include 24-hour butler service, Bvlgari toiletries, bathrobes, personalized stationary, wines, Blu-ray players, etc.

Since our bundling theory also depends on the target market (i.e., high-end versus low-end), we divide core products (brands) into three groups: high-end, intermediate, and low-end. When a core product's price belongs to the upper third in a product line, we categorize the core as high-end. When a core product's price belongs to the bottom third in a product line, we categorize the core as low-end. We consider the remaining as intermediate. Accordingly, we define a product-locality variable

$$\phi^{PL}(i) = \begin{cases} 3 & \text{if core } i \text{ is a high-end product,} \\ 2 & \text{if core } i \text{ is an intermediate product,} \\ 1 & \text{if core } i \text{ is a low-end product,} \end{cases} \quad \text{for } i = 1, \ldots, 271.$$

Although bundling could possibly change product locality, it is extremely rare. For example, Fairfield Inn cannot achieve the quality of Ritz-Carlton by merely bundling additional services. Hence, ϕ^{PL} is exogenous. We define eight industry indicators

$$J_{k'''}(k) = \begin{cases} 1 & \text{if } k = k''', \\ 0 & \text{if } k \neq k''', \end{cases} \quad \text{for } k''' = 1, \ldots, 8, \; k = 1, \ldots, 8.$$

Finally, the number of ancillary products (or services) bundled with core i in industry $k(AP_{ik})$ is used as our dependent variable (i.e., count data).

To examine whether firms bundle more ancillary products at the low-end or high-end given a differentiation constraint, we conduct the following Poisson regression:

$$\begin{aligned} &\log E[AP_{ik} \mid I_{k'}^{HDC}(k), I_{k''}^{LDC}(k), \phi^{PL}(i), J_{k'''}(i), \forall k', k'', k'''] \\ &= \beta_0 + \sum_{k'=1,\ldots,4} \beta_{k'} I_{k'}^{HDC}(k) \times \phi^{PL}(i) + \sum_{k''=5,\ldots,8} \beta_{k''} I_{k''}^{LDC}(k) \\ &\quad \times \phi^{PL}(i) + \sum_{k''' \neq 8} \gamma_{k'''} J_{k'''}(i). \end{aligned} \tag{1}$$

Controlling the industry averages, we regress the number of bundled ancillary products on the interactions between the differentiation-constraint type and product locality. We exclude ϕ^{PL} and J_8 from Equation (1) to avoid perfect multicollinearity problems. We estimate Equation (1) by the maximum likelihood estimation given that AP_{ik} follows a Poisson distribution.

Table 6 provides parameter estimates. We find industries exhibiting high-end differentiation constraints (e.g., airlines), consistent with our predictions, tend to bundle more at the high-end (e.g., $\beta_1 = 0.849$, $p < 0.01$) because bundling enables firms to increase high-end quality to the optimal level. Like the airline industry, Table 6 reveals positive interaction effects for the other industries exhibiting high-end differentiation constraints. By contrast, industries exhibiting low-end differentiation constraints (e.g., hotels), consistent with our predictions, tend to bundle more at the low-end (e.g., $\beta_5 = -0.372$, $p < 0.01$) because bundling enables them to increase low-end quality to the optimal level (possibly with items not attractive to high-end consumers).

We conclude this section by describing the product-line strategies of Disney to facilitate an understanding of actual business practices. Some might think that an amusement park has one core. However, many amusement parks (e.g., Universal, Busch Gardens, Six Flags, etc.) provide more than one core (i.e., a product line). For instance, Disney provides eight different cores. Table 7 shows four of these cores. Disney, which has multiple theme parks and other activities, develops a product line by using different combinations of these parks and activities. For example, the high-end Platinum Plus ticket includes admission to all parks and activities, the Silver ticket includes all theme parks except for water parks, and the Epcot ticket includes admission to the 300-acre Future World and World Showcase at Epcot theme park. Finally, the Water Parks ticket includes admission to only Disney's smaller water parks. Given different cores, Disney designs ancillary products for each core. Table 7 shows that Platinum (highest-end tickets currently priced at \$729) bundles six ancillary products (e.g., parking, photos, special discounts), Silver and Epcot (intermediate tickets currently priced at \$389 and \$249, respectively) bundle five and four ancillary products, respectively, and Water Parks (lowest-end tickets currently priced at \$115) bundles no ancillary products.

The Disney's product-line strategy is consistent with our theory. Although Disney develops a product line with different combinations of its parks, Disney may be unable to achieve the optimal level of line differentiation only with the cores because the Disney parks are in the same location and consumers in "Disney World" have similar experiences (e.g., weather, employees, souvenirs, fireworks, photos, transportation, accommodations, management, etc.), leading to lower line differentiation. To increase the line differentiation to the optimal level, Disney bundles ancillary benefits with high-end tickets. In doing so, consumers obtain sufficiently differential valuation, reducing the low-end cores' cannibalization. The online appendix shows that our findings accurately describe the product-line bundling strategies of three other firms in different

Table 6. Interaction Impact Between Differentiation Constraint and Product Locality (PL)

High-end differentiation constraint		Low-end differentiation constraint	
Airline × ϕ^{PL}	0.849** (0.115)	Hotel × ϕ^{PL}	−0.372** (0.130)
Car wash × ϕ^{PL}	0.532** (0.104)	Restaurant × ϕ^{PL}	−0.912* (0.376)
Amusement park × ϕ^{PL}	0.331** (0.120)	Guitar × ϕ^{PL}	−0.409** (0.053)
Concert × ϕ^{PL}	1.367** (0.196)	Digital camera × ϕ^{PL}	−1.886** (0.273)
Airline	−3.505** (0.451)	Hotel	−1.897** (0.422)
Car wash	−3.043** (0.419)	Restaurant	−2.422** (0.701)
Amusement park	2.524** (0.443)	Guitar	−0.445 (0.348)
Concert	−6.724** (0.632)	Constant (digital camera)	3.644** (0.333)
Likelihood ratio test (χ^2_{15})		1,211.52	
Pseudo R^2		0.48	

Note. Standard errors are in parentheses.
*Significant value at 5% level; **significant value at 1% level.

Table 7. Product Line of Disney

	Platinum plus	Silver	Epcot	Water parks
Monthly price ($)	55.37	25.20	12.77	—
Annual price ($)	729.00	389.00	249.00	115.00
Unlimited access for one year (*core*)				
Magic Kingdom Park	✓	✓		
Epcot: Future World	✓	✓	✓	
Epcot: International World Showcase	✓	✓	✓	
Disney's Animal Kingdom	✓	✓		
Disney's Hollywood Studios	✓	✓		
Typhoon Lagoon and Blizzard Beach	✓			✓
Disney's Oak Trail Golf Course	✓			
ESPN Wide World of Sports complex	✓			
Additional benefits (*ancillary*)				
Same day admission to all four Walt Disney World theme parks	✓	✓		
Complimentary magic bands	✓	✓	✓	
Exclusive passholder communications	✓	✓	✓	
Includes Disney PhotoPass downloads	✓			
Parking at Walt Disney World theme parks	✓	✓	✓	
Special discounts and limited-time offers for resort stays, dining, merchandise, and more	✓	✓	✓	

Note. This table reports prices that Disney charges in May 2016.

industries (MGM International Las Vegas Resorts, Delta Air Lines, and Park Place Car Wash).

5. Conclusion

Most service providers develop product lines consisting of core products that vary in quality. For example, cruise ships usually offer a product line of accommodations that differ in quality. Cunard cruise line offers both luxury staterooms as well as windowless bare-bones cabins. Many restaurant chains also have product lines with different core quality levels. The product line of Darden Restaurants consists of moderately priced steakhouses such as LongHorn Steakhouse and very expensive high-end steakhouses such as The Capital Grille. Most car washes offer less expensive self-service, moderately priced full-service, and very expensive detailing service in their product lines. Many industries also offer a variety of ancillary services (or add-ons) that are bundled (or unbundled) with a core. For example, Cunard cruise line bundles numerous ancillary services with high-end staterooms such as butler service, turndown surprise, concierge service, champagne, fresh fruit, bar (stocked with spirits/wines and soft drinks), pre-dinner canapés, books/atlas, and more.

Surprisingly, industries with ostensibly similar characteristics (e.g., cost structure, customer types, competition, and distribution channels) use different bundling strategies. For example, airlines usually bundle high-end international first class with ancillary services (e.g., premium entertainment, chef-curated breakfast, and executive lounges) while hotels usually bundle low-end locations with ancillary services (e.g., entertainment, breakfast, and on-site self-parking). Conversely, hotels tend to unbundle at the high-end and charge for ancillary services (e.g., recently released movies, gourmet breakfast, and valet parking) while airlines tend to unbundle at the low-end and charge for ancillary services (e.g., meals, baggage handling). There is no existing theory that explains why these similar industries adopt different bundling strategies.

We explain this apparent paradox by postulating an inherent difference in core differentiation between the low-end and high-end, which these empirical observations evidently demonstrate. Consider airlines offering air transportation as their core service. Although airlines can provide high-quality first-class seats (more legroom and storage), these seats are on the same plane as coach seats. For example, first class departs and arrives at the same time as economy class. Both classes experience the same delays, weather conditions, cancellations, diversions, time on the runway, in-flight turbulence, and so on. Thus, airlines face technological constraints when attempting to differentiate first class from coach. Similarly, industries in the first column of Table 2 exhibit relatively low levels of core differentiation because, again, technology (or location) limits the quality difference between the low-end and high-end cores. Given low core differentiation, firms may bundle additional exclusive services with their high-end core. For example, even though cruise ships provide lodging services like hotels, cruises are more similar to airlines because all passengers (steerage cabins and grand staterooms) are on the same ship. Consistent with our theory, high-end cabins include many bundled ancillary services (e.g., butler service). Our empirical analysis also finds, consistent with our theory, that high-end amusement park tickets bundle many ancillary services (e.g., priority queues, valet parking).

By contrast, industries in the second column of Table 2 exhibit high degrees of differentiation between their low-end and high-end cores. For example, low-end restaurants may employ much less expensive chefs than high-end restaurants creating a constraint on their daily menu variety and food quality. Of course, it is too costly for low-end restaurants to employ celebrity chefs who can create new gourmet menus each night. In this case, restaurants bundle low-end to achieve the optimal line differentiation. Rather than varying the menu, low-end restaurants bundle salads, sides, and desserts. In general, low-end restaurants bundle ancillary products that are less attractive to high-end customers (i.e., minimize cannibalization) such as regular salads, ready-made sides, and preprepared desserts. Similarly, by bundling lower-quality ancillary services, for example, moderate-speed Internet, inexpensive breakfasts, and outside parking, an aging low-end hotel can improve the low-end core quality without making it attractive to high-end buyers. High-end buyers may only value high-speed Internet, gourmet breakfasts, and garage parking. In those industries that exhibit high levels of line differentiation, low-end bundling is pervasive.

Our analysis reveals reasons for these paradoxical patterns and makes predictions regarding product-line bundling decisions for industries in Table 2 and beyond. In brief, there may be an optimal level of line differentiation. However, when the core differentiation is too low, having a product line may no longer be optimal because high-end buyers will buy the low-end product (i.e., price discrimination on quality becomes more difficult) and high-end product sales will suffer. Conversely, when the core differentiation is too high, the high-end product becomes very profitable, and the opportunity cost of maintaining the (very low quality) low-end for low-end buyers is too high. The optimal decision might be offering an intermediate quality to everyone. However, under these differentiation constraints, interestingly, firms can use ancillary services to optimize the product-line design because high-end bundling increases the line differentiation while low-end bundling reduces it. By bundling targeted ancillary (add-on) services at different ends, firms can achieve the optimal level of line differentiation.

Although we provide initial empirical support for our theory, our empirical analysis leaves many areas open to future research. First, we categorize firms based on whether they suffer differentiation constraints. Future research might use metric measures for the degree of core differentiation providing specific managerial guidelines on how to design the cores. Second, we count the number of bundled ancillary products (as reported by the firms themselves) and categorize cores based on their product locality (prices). Future research might use metric measures for ancillary quality (whether bundled or not) and core (bundle) quality, examining how much ancillary quality (in a dollar amount) is needed to achieve the optimal line differentiation given a core differentiation. Last, unlike our categorical variables, the bundle quality may be endogenous since the bundled ancillary quality affects the bundle quality. Making these decisions endogenous in an empirical model awaits future research.

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Appendix. Proofs

We have already shown Lemma 1 in Section 2.2. Hence, now we will prove Propositions 1–3.

Proof of Proposition 1. From Lemma 1, given Q_L and Q_H, $\Pi(Q_L, Q_H) = (\theta-\alpha)Q_L + (\theta+\alpha)Q_H - cQ_L^2 - cQ_H^2$; note $P_L = \theta Q_L$ and $P_H = (\theta+\alpha)Q_H - \alpha Q_L$. Under $Q_H - Q_L \le \underline{\delta}$, the optimal qualities are $Q_L^* = (\theta-\alpha)/(2c)$ and $Q_H^o = Q_L^* + \underline{\delta}$ (because of $\underline{\delta} < \alpha/c$ and $Q_L^* + \underline{\delta} < (\theta+\alpha)/(2c)$). Let $\Pi^o = \Pi(Q_L^*, Q_H^o) = (\theta-\alpha)^2/(4c) + (\theta+\alpha)Q_H^o - cQ_H^{o^2}$. From Lemma 1, note, $\pi_1^* = \theta^2/(2c)$ and $\pi_2^* = (\theta+\alpha)^2/(4c)$. Then, $\Pi^o < \pi_1^* \Leftrightarrow \underline{\delta} < (2-\sqrt{2})\delta^*/2$; $\Pi^o < \pi_2^* \Leftrightarrow \underline{\delta} < \delta^* - (\theta-\alpha)/(2c)$. Hence, the single-product profits are greater than the product-line profits if and only if $\delta \le \delta^* - \rho$, where $\rho = \min\{\sqrt{2}\delta^*/2, Q_L^*\}$. Similarly, given $Q_H - Q_L \ge \bar{\delta}$, the single-product profits are greater than the product-line profits if and only if $\bar{\delta} \ge \delta^* + \tau$, where $\tau = \sqrt{2}\delta^*/2$. Q.E.D.

Proof of Proposition 2–3. Under $Q_H - Q_L \le \underline{\delta}$, consider four possible cases: (1) BB: $\lambda_L = \lambda_H = 0$, (2) UB: $\lambda_L = 1$ and $\lambda_H = 0$, (3) BU: $\lambda_L = 0$ and $\lambda_H = 1$, (4) UU: $\lambda_L = \lambda_H = 1$.

Case I. BB: $\lambda_L = \lambda_H = 0$.

Maximize $P_{BL} + P_{BH} - cQ_{BL}^2 - cQ_{BH}^2$ subject to $P_{BL} \le \theta Q_{BL}$, $P_{BH} \le (\theta+\alpha)Q_{BH}$, $(\theta+\alpha)Q_{BH} - P_{BH} \ge (\theta+\alpha)Q_{BL} - P_{BL}$, and $Q_H - Q_L \le \underline{\delta}$. From Lemma 1, $\Pi_{\text{BB}} = \Pi^* = (\theta-\alpha)^2/(4c) + (\theta+\alpha)^2/(4c)$.

Case II. UB: $\lambda_L = 1$ and $\lambda_H = 0$.

Maximize $P_L - cQ_L^2 + P_{BH} - cQ_{BH}^2 + p_L - cq_L^2$ subject to $P_L \le \theta Q_L$, $p_L \le \theta_a q_L$, $P_{BH} \le (\theta+\alpha)Q_{BH}$, $(\theta+\alpha)Q_{BH} - P_{BH} \ge (\theta+\alpha)\cdot Q_L - P_L + \theta_a q_L - p_L$, and $Q_H - Q_L \le \underline{\delta}$. Given qualities, the optimal prices are $P_L = \theta Q_L$, $p_L = \theta_a q_L$, and $P_{BH} = (\theta+\alpha)Q_{BH} - \alpha Q_L$; thus, $\Pi(Q_L, Q_{BH}, q_L) = (\theta-\alpha)Q_L - cQ_L^2 + (\theta+\alpha)Q_{BH} - cQ_{BH}^2 + \theta_a q_L - cq_L^2$. The optimal product-line qualities are $Q_L = (\theta-\alpha)/(2c)$, $q_L = \theta_a/(2c)$, and $Q_{BH} = (\theta+\alpha)/(2c)$. The optimal profits are $\Pi_{\text{UB}} = \Pi^* + \theta_a^2/(4c)$.

Case III. BU: $\lambda_L = 0$ and $\lambda_H = 1$.

Maximize $P_{BL} - cQ_{BL}^2 + P_H - cQ_H^2 + p_H - cq_H^2$ subject to $P_{BL} \le \theta Q_{BL}$, $P_H \le (\theta+\alpha)Q_H$, $p_H \le \theta_a q_H$, $(\theta+\alpha)Q_H - P_H +$

$\theta_a q_H - p_H \geq (\theta+\alpha)Q_{BL} - P_{BL}$, and $Q_H - Q_L \leq \underline{\delta}$. Given qualities, the optimal prices are $P_{BL} = \theta Q_{BL}$ and $P_H = (\theta+\alpha)\cdot Q_H - \alpha Q_{BL} + \theta_a q_H - p_H$; thus, $\Pi(Q_{BL}, Q_H, q_H) = (\theta-\alpha)Q_{BL} - cQ_{BL}^2 + (\theta+\alpha)Q_H - cQ_H^2 + \theta_a q_H - cq_H^2$. The optimal product-line qualities are $Q_{BL} = (\theta-\alpha)/(2c)$, $Q_H = Q_{BL} + \underline{\delta}$, and $q_H = \theta_a/(2c)$. The optimal profits are $\Pi_{\text{BU}} = (\theta-\alpha)^2/(4c) + (\theta+\alpha)Q_H - cQ_H^2 + \theta_a^2/(4c)$.

Case IV. UU: $\lambda_L = \lambda_H = 1$.

Maximize $P_L - cQ_L^2 + P_H - cQ_H^2 + p_L - cq_L^2 + p_H - cq_H^2$ subject to $P_L \leq \theta Q_L$, $p_L \leq \theta_a q_L$, $P_H \leq (\theta+\alpha)Q_H$, $p_H \leq \theta_a q_H$, $(\theta+\alpha)Q_H - P_H + \theta_a q_H - p_H \geq (\theta+\alpha)Q_L - P_L + \theta_a q_L - p_L$, and $Q_H - Q_L \leq \underline{\delta}$. Similarly, $P_L = \theta Q_L$, $p_L = \theta_a q_L$, and $P_H = (\theta+\alpha) Q_H + \theta_a q_H - p_H - \alpha Q_L$. Then, $\Pi(Q_L, Q_H, q_L, q_H) = (\theta-\alpha) Q_L - cQ_L^2 + (\theta+\alpha)Q_H - cQ_H^2 + \theta_a q_L - cq_L^2 + \theta_a q_H - cq_H^2$. The optimal product-line qualities and profits are $Q_L = (\theta-\alpha)/(2c)$, $Q_H = Q_L + \underline{\delta}$, and $q_L = q_H = \theta_a/(2c)$; $\Pi_{\text{UU}} = (\theta-\alpha)^2/(4c) + (\theta+\alpha)Q_H - cQ_H^2 + \theta_a^2/(2c)$.

Clearly, $\Pi_{\text{UB}} > \Pi_{\text{BB}}$ and $\Pi_{\text{UB}} > \Pi_{\text{BU}}$; hence, the optimal bundling strategy in the product line is UB or UU. We can show that $\Pi_{\text{UB}} > \Pi_{\text{UU}}$ if and only if $\underline{\delta} < \delta^* - \kappa$, where $\kappa = \theta_a/(2c)$. We only need to show that the product-line profits are greater than the single-product profits. From Section 3.2, note that the optimal single-product profits are $\pi^* = \max\{\pi_{U1}^*, \pi_{U2}^*\}$, where $\pi_{U1}^* = \theta^2/(2c) + \theta_a^2/(2c)$ and $\pi_{U2}^* = (\theta+\alpha)^2/(4c) + \theta_a^2/(4c)$. For $\underline{\delta} < \delta^* - \theta_a/(2c)$, Π_{UB} is the optimal product-line profits, and $\Pi_{\text{UB}} > \pi^*$ (because of $\theta_a < \alpha$). For $\underline{\delta} > \delta^* - \theta_a/(2c)$, Π_{UU} is the optimal product-line profits. Note, $\Pi_{\text{UU}} > \pi_{U1}^* \Leftrightarrow \underline{\delta} > \delta^* - \sqrt{2}\alpha/(2c)$. Since $\theta_a < \alpha$, $\underline{\delta} > \delta^* - \theta_a/(2c) > \delta^* - \sqrt{2}\alpha/(2c)$; $\Pi_{\text{UU}} > \pi_{U1}^*$. Last, $\Pi_{\text{UU}} > \pi_{U2}^* \Leftrightarrow \underline{\delta} > \delta^* - \sqrt{(\theta-\alpha)^2 + \theta_a^2}/(2c)$. Since $\underline{\delta} > \delta^* - \theta_a/(2c) > \delta^* - \sqrt{(\theta-\alpha)^2 + \theta_a^2}/(2c)$, $\Pi_{\text{UU}} > \pi_{U2}^*$. Therefore, $\Pi_{\text{UU}} > \pi^*$. We can similarly show Proposition 3. Q.E.D.

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