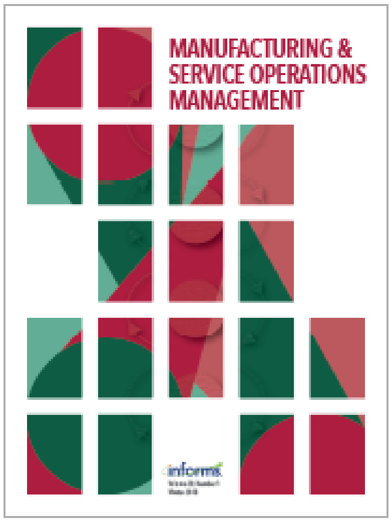

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Managing Customer Search via Bundling

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Abstract. ***Problem definition*:** Product bundling has been a pervasive marketing strategy, and its success has been largely attributed to its strength in reducing customers' valuation dispersion. Less is known about the efficacy of bundling in settings where customers are less sure about their valuations for a product, especially when that product is newly launched or has an experience nature, and can conduct costly search to learn the product content and discover their true valuations. In this paper, we investigate the interplay between product bundling and customer search and its implications for a monopolist's optimal pricing strategy. ***Academic/practical relevance*:** The existing search theory has focused on decision making that selects the best among multiple alternatives, with costly search being mandatory for the acquisition of each alternative. In this paper, we introduce a framework of *multiproduct demands* and *nonobligatory search*, where customers demanding multiple products strategically decide whether to conduct costly search to resolve valuation uncertainty, while reserving the right to purchase these products without having to search them first. ***Methodology*:** We apply a nonobligatory search framework to study two different markets: (1) a market of one mature and one new product, in which valuation uncertainty exists for the new product only; and (2) a market of two new products, in which valuation uncertainty exists for both products. The firm fully anticipates the customers' search behaviors, determines whether to bundle these products or unbundle them, and optimally sets prices. ***Results*:** We show that bundling cultivates search in a market of one mature and one new product, but inhibits search in a market of two new products. This contrast emerges as a result of market structures: Bundling reduces the appeal of search by making the search decisions sequential and path-dependent in the latter market, but is less effective in doing so due to the existing heterogeneity in the former market. Our results thus point to an intricate interplay between customer search, market heterogeneity, and prices and their joint impact on the monopolist's optimal bundling strategy. We also study mixed bundling and show that its economic benefits only carry through when customers' search cost is not too large. In this case, mixed bundling can lead to considerable revenue improvement in a market of one mature and one new product, but only tiny revenue improvement in a market of two new products. We also study the joint management of product return and product bundling and show that a positive refund should generally be offered for returned products to stimulate customers' no-search purchase. ***Managerial implications*:** Our paper provides guidance for firms selling multiple experience or new products. We propose product bundling to manage customer search, identifying regimes for its economic benefits and clarifying its implication for customer welfare.

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Keywords: multiproduct search • nonobligatory search • bundling • pricing

1. Introduction

Weitzman (1979) developed the first search model for a decision maker aiming to select the best among multiple alternatives and characterizes the optimal searching rule and stopping criterion. Since then, the search theory has been extended and enriched significantly in the fields of economics, marketing, and operations. This literature follows the framework of Weitzman (1979) and focuses on the goal of selecting the best alternative. However, less is known about settings where customers desire multiple products and actively search these products to resolve uncertainty. Notable exceptions are Zhou (2014), Rhodes and Zhou (2019), and Rhodes et al. (2021), which propose a framework to study customers' *multiproduct search* process and investigate various issues, such as competition and mergers. However, *product bundling* is generally missing in these studies, despite it being a pervasive marketing strategy in various industries. In this paper, we depart from these studies by developing a microscopic model that exposes the essential interplay between product bundling and customer search under multiproduct demands and its implications for a monopolist's pricing strategy. We clarify in more detail our contribution to the bundling and search literature in Section 2.

Our effort is of practical significance to a number of realistic settings. The emergence of review platforms has provided customers with a legitimate channel to search information for products they are less sure about, especially for those that are newly launched or have an experience nature. Knowing that customers are willing to search, it is common practice to employ a bundling strategy to sell multiple experience goods or newly introduced products together. Examples of bundling experience goods include CityPASS, which combines various sightseeing tours into a single package;[1] and the Buffet of Buffets pass, which entitles one to dine in multiple Las Vegas buffet restaurants.[2] Bundling new products is exemplified by "fukubukur" (lucky bags) frequently offered by Snidel & Gelato Pique[3] and compilation albums, such as "More Only," an extended play of Beyoncé that includes two newly recorded songs and four previously released remixes.

In the examples above, although customers have the desire to search, they are not obligated to search all products in a bundle. This is because, although information dissemination has been quicker and easier than ever, thanks to the emergence of review platforms, product reviews often abound on these platforms, and it may require a user significant time and effort to filter those reviews and find the most "helpful" review relevant to her personal preference. As a result, a traveler to New York City may decide to buy the CityPASS after searching only a short list of attractions (e.g., the Statue of Liberty), while leaving others unsearched (e.g., 911 Memorial) to save search costs. Doval (2018) terms such search processes, in which customers reserve the right to purchase products without having to search them first, as *nonobligatory search*.

In this paper, we apply a nonobligatory search framework to study a monopoly firm managing two different markets: (1) a market of one mature and one new product, in which valuation uncertainty exists for the new product only; and (2) a market of two new products, in which valuation uncertainty exists for both products. The firm fully anticipates the customers' search behaviors, determines whether to bundle the two products or unbundle them, and optimally chooses the prices accordingly. Our analysis identifies a novel strength of bundling in managing customer search, which critically depends on the magnitude of customers' search cost. In general, the search cost of a product is jointly determined by the inherent product characteristics (such as complexity of the product, communicability and observability of product benefits, and compatibility of the product with existing consumption), as well as sellers' manipulations of information (such as trialability, ranking, and sorting). Search costs are found to be significant in some online environments: Chen and Yao (2017) estimate a search cost of \$21.54 for hotels, and De los Santos and Koulayev (2017) estimate a similar search cost ranging from \$8.35 to \$55.23, as opposed to the average hotel price of \$230.

The goal of this paper is twofold: to understand how product bundling affects customer search and to understand how customer search affects the profitability of product bundling. We first study a market of *one mature and one new product* and show that bundling *cultivates* search and enlarges the parameter space where search takes place. This is because customers make identical search decisions under separate selling, whereas their search decisions under bundling are differentiated by their valuations for the mature product. Under separate selling, because distinct prices can be charged to each product, the firm chooses to set a low price for the new product to inhibit search. In contrast, it is less likely to eliminate search under bundling because there is already sufficient heterogeneity in the market. As a result, the firm charges a moderate bundle price so that the search region expands. In terms of revenue, we find that bundling dominates separate selling when the search cost is relatively small. In this region, the dominance of bundling is strengthened by a slight increase in the search cost, as the firm can leverage bundling to exploit the market heterogeneity and induce better search and purchase outcomes. However, when the search cost is relatively large, the dominance of bundling vanishes, and separate selling starts to take over by exploiting the valuation uncertainty underlying the new product.

We next study a market of *two new products* and show that bundling *inhibits* search in this market scenario, in contrast to the previous market of one mature and one new product. To understand this contrast, note that in a market of two new products, the search decisions are *sequential* and *path-dependent* under bundling in the sense that the decision on the second search depends on the realized valuation for the first product, but these two searches are independent under separate selling. By tying two products together, bundling reduces the appeal of search and allows the firm to keep customers in the dark, an outcome that translates to better revenue. We also find that bundling affects the optimal price in an intriguing way by comparing it to a benchmark, namely, twice as much as the optimal price under separate selling. The bundle price falls below this benchmark when the search cost is small, stays above it for an intermediate search cost, and is equal to it when the search cost is large. When the bundle price differs from the benchmark, bundling always generates a strictly higher revenue than separate selling. The driving forces can be very different though. The well-known pooling effect of bundling in reducing valuation dispersion and demand elasticity takes over when the search cost is small, whereas the newly identified effect of bundling in inhibiting customer search plays a dominant role when the search cost is intermediate. When the search cost is prohibitively large, customers don't search, leading to revenue equivalence between the two pricing schemes.

We also study correlated product valuations and other operational strategies, such as mixed bundling and product returns. Our analysis generates novel insights different from those in the literature, as well as those derived in the base model without these considerations. We show that under correlated product valuations, the firm's revenue can be nonmonotone with respect to the search cost under both separate selling and bundling. Moreover, bundling does not always benefit from a negative correlation between product valuations. We also find that the economic benefits of mixed bundling, as often driven by a more profitable market segmentation, only carry through to our setting when customers' search cost is relatively small. In this case, mixed bundling leads to considerable revenue improvement in a market of one mature and one new product, but only tiny revenue improvement in a market of two new products. We also find that the optimal product-return program should offer positive refunds for returned products jointly with product bundling when customers' search cost is relatively small, in contrast to Su (2009), which rules out customer search as an option and recommends zero refunds accordingly.

We extend our model in various dimensions, including general valuation distributions, heterogeneous products, marginal cost, heterogeneous search costs, and simultaneous display of product information. We briefly describe the notable findings in these extensions and relegate the readers to Online Appendix A for details. For example, as far as marginal cost is concerned, there exists a region of search cost in a market of one mature and one new product, such that bundling dominates separate selling only when the marginal cost is intermediate, in contrast to the classic bundling literature, which claims the dominance of bundling under a small marginal cost. With heterogeneous products, customers always search the superior product first, and a strong product asymmetry can overturn the dominance of bundling in a market of two new products. Under simultaneous display of product information, which allows customers to search both products at the same time, bundling continues to outperform separate selling, but the revenues under simultaneous display of product information are no better than those when customers conduct sequential search under both pricing schemes.

2. Literature Review

Our paper is related to the vast literature on search theory, which studies the process of obtaining costly information to select the best from multiple alternatives; for example, see Stigler (1961), Weitzman (1979), and recent surveys by Armstrong (2017) and Chade et al. (2017). As aforementioned, the existing literature primarily focuses on single-product demands—for example, Bar-Isaac et al. (2012), Choi et al. (2018), Eeckhout and Kircher (2010), and Petrikaitė (2018)—and we depart from this literature by considering *multiproduct demands*. Closely related to our work is Zhou (2014), who proposes a framework to study customers' multiproduct search process among multiple firms, all offering the same set of products, and enjoys economies of scale in search with search cost incurred jointly for all products offered by a firm. The author shows that multiproduct search can make market prices decrease with search costs. Rhodes and Zhou (2019) incorporate downstream retailers in a two-product setting and examine how customer search shapes the retail structure, in the sense that some single-product retailers may choose to merge and form a multiproduct firm. Rhodes et al. (2021) generalize Rhodes and Zhou (2019) and go beyond the two-product setting to study issues other than mergers. Our work differs from Rhodes and Zhou (2019), Rhodes et al. (2021), and Zhou (2014) by allowing firms to manage customer search via product bundling for better revenues and profits.

The second departure of our work from the classic search theory is that we focus on nonobligatory search, wherein customers can purchase a product without having to search it first. Nonobligatory search is particularly relevant to our setting when products are sold in bundles because customers are under no obligation to search all products in the bundle in order to purchase that bundle. Although sound and intuitive, this feature has only been recently introduced by Doval (2018) in a single-product framework. Doval (2018) shows that with this simple twist, the celebrated Pandora's rule prescribed by Weitzman (1979) no longer applies. Following Doval (2018), Beyhaghi and Kleinberg (2019) propose heuristic policies that are computationally efficient and approximately optimal. In a similar spirit, Ke and Villas-Boas (2019) examine a two-box-binary-prize setting, in which the decision maker can obtain noisy signals through progressive inspection and can purchase a product without fully learning the contents. Relatedly, Wathieu and Bertini (2007) and Li et al. (2019) consider endogenous prices and point out the critical role of prices as a stimulus for nonobligatory search. We propose another instrument on top of prices to manage customer search—namely, *product bundling*—in a multiproduct setting.

Because we propose product bundling to manage customer search, our work is also related to the literature on product bundling. Stemming from Adams et al. (1976), this research stream identifies the main strength of bundling in reducing valuation dispersion when customers know their valuations; see also Bakos and Brynjolfsson (1999), Chen and Riordan (2013), Ibragimov and Walden (2010), McAfee et al. (1989), Wu et al. (2008), and Fang and Norman (2006). McAfee et al. (1989) and Schmalensee (1984) show that a negative correlation between product valuations can further contribute to the strength of bundling. Firms' bundling decisions in a competitive setting are studied by Armstrong and Vickers (2010) and Zhou (2017). None of these prior works considers an active search process undertaken by customers when they are uncertain about their valuations for a product. Nor do they demonstrate how this search behavior may affect a firm's bundling strategy.

A notable exception that indeed explores the interaction between customer search and product bundling is Zhou (2011). A key difference between our work and Zhou (2011) lies in customers' search behaviors. Zhou (2011) assumes that customers must search a product to discover its true valuation (e.g., by incurring a travel cost to visit a physical store) before they can purchase that product. So, nonobligatory search that entails customers having the option to purchase a product without search is trivially ruled out by Zhou (2011), whereas it is critical in our analysis and captures a major characteristic of many online environments. Furthermore, Zhou (2011) assumes *full market coverage* of each product, as is the convention of the literature on competitive firms. Unlike Zhou (2011), our model is featured by *endogenous* market coverage, which is well suited in numerous practical settings, such as CityPASS and lucky bags, that motivate this research. Being a critical driver of equilibrium outcomes, the market coverage in our model is highly dependent on the pricing scheme adopted. In addition, Zhou (2011) only considers markets of two new products, whereas we also consider markets of one mature and one new product, and, by doing so, we reveal the subtle, yet significant, effect of market structures on customers' search behavior and the firm's bundling strategy. Lastly, our analysis of product returns further differentiates our work from Zhou (2011) by exploring a unique operational perspective.

There is a rising literature that studies various operational aspects of product or service bundling. McCardle et al. (2007) study a firm's bundling decision under demand uncertainty. Cao et al. (2015) and Banciu et al. (2010) study the effectiveness of bundling under a supply constraint. Bhargava (2012) and Chakravarty et al. (2013) study a distribution channel where downstream retailers opt to sell multiple products to end customers in bundles or sell them separately. More recently, Wu and Yang (2018) study the bundling problem of multiple congested services with delay-sensitive customers.

Finally, because the goal of this paper is to provide practical implications and guidelines, we briefly review how search costs are estimated in the literature. Most empirical papers follow Weitzman (1979) to model customers' search behaviors and measure customers' utility and search-cost parameters via structural estimation (Kim et al. 2010, Honka and Chintagunta 2017). Recently, Chen and Yao (2017), De los Santos and Koulayev (2017), and Ursu (2018) present evidence that variations in filtering, recommendations, and rankings on e-commerce platforms can also affect customers' search costs and shape their search behaviors. These papers employ various econometric techniques, such as maximal likelihood estimation, to validate the consistency between the search theory and their empirical findings. We refer interested readers to Ursu (2018) and the references therein for more concrete plans of search-cost estimations.

3. The Model

We consider a monopoly firm (he) selling two different products. A unit mass of customers (she) enter the market: They are interested in both products and have positive valuations for each product. However, they are uncertain about their valuations for one product (or both) due to the nature of that product. For example, consider a product that is newly launched. With very limited product information, customers are unsure about how the new product fits into their needs and preferences.

3.1. Valuation Uncertainty

We assume that customers' (true) valuations V_i for each product $i \in \{1,2\}$ are independently, identically, and uniformly distributed over $[0,1]$.[4] Following the convention, we use the notation capital V to denote a random variable representing the valuations and small v to denote a realization of V. Our model distinguishes between two types of products, a *mature* product and a *new* product, differentiated by whether valuation uncertainty exists for that product. Specifically, customers observe their valuations for a *mature* product before search, but not a *new* product, so that valuation uncertainty exists for the latter, but not the former.

3.2. Costly Search

Customers can take a costly search to evaluate a target product and learn their true valuations. We denote the cost of search by c and assume that the search cost is incurred each time a new product is searched.[5] In general, the search cost of a new product is jointly determined by the inherent product characteristics (such as complexity of the product, communicability and observability of product benefits, and compatibility of the product with existing consumption), as well as sellers' manipulations of information (such as trialability, ranking, and sorting).

If customers decide not to search a new product, they only know the distribution of their valuations for that product, which we assume is consistent with the valuation distribution of the entire customer base; see Wathieu and Bertini (2007) and Li et al. (2019). In other words, customers do not overestimate or underestimate their valuations for a new product. The search process is nonobligatory, in the sense that customers reserve the right to purchase a product without having to search it first. This implies that when products are sold in a bundle, customers may strategically leave some products unsearched to save search costs when deciding whether to purchase the bundle. Nonobligatory search prevails in many practical settings—for example, a traveler is free to purchase a New York CityPASS after searching only a short list of attractions in the bundle.

3.3. Two Different Markets

We apply a nonobligatory search framework to study two different markets: (1) a market of one mature and one new product, in which valuation uncertainty exists for the new product only; and (2) a market of two new products, in which valuation uncertainty exists for both products. For now, we assume the marginal cost of each product is zero.[6]

3.4. Bundling vs. Separate Selling

We consider two strategies of selling the two products in the presence of valuation uncertainty and customer search: *bundling*, in which products are sold all together in a bundle, and purchasing the bundle grants access to both products; and *separate selling*, in which each product must be purchased at a separate price.[7] Our analysis reveals an intricate interplay between bundling, prices, and search and provides novel insights into managing customer search under multiproduct demands.[8]

4. Selling Products Separately

We first consider the strategy of separate selling, as the firm charges price p_i for product i, $i \in \{1, 2\}$. This analysis will help build intuition on how prices can serve as a stimulus for search, in the spirit of Wathieu and Bertini (2007). Because we assume that product valuations are independent, a customer's valuation for one product does not reveal additional information of her valuation for the other product. Hence, customers make *independent* search and purchase decisions for each product, and the firm sets a distinct price for each product based on the nature of that product. A *mature* product has no valuation uncertainty, and each customer purchases this product if her valuation is no less than the posted price p_i. Thus, the optimal price of a mature product is $p_i^* = 1/2$, generating a revenue $1/4$. In contrast, customers have an incentive to search a *new* product to guide better purchase decisions. If the decision is to search, then a searching customer purchases the product if she finds her valuation $v_i \geq p_i$. Thus, the expected payoff from search is $\mathbb{E}[V_i - p_i]^+ - c = (1 - p_i)^2/2 - c$, where $(\cdot)^+ = \max\{\cdot, 0\}$. If the decision is not to search, then each customer relies on her prior belief of the valuation to decide whether to make a purchase. Because all customers hold the same prior belief, they receive an expected payoff $(\mathbb{E}[V_i] - p)^+ = (1/2 - p_i)^+$ should they not search. Comparing the payoffs of these two options, customers follow the same strategy of search: either all of them search, or none of them does. The following lemma formalizes this intuition; see Li et al. (2019, lemma 1).

Lemma 1. *Customers' search and purchase decisions on a new product i are summarized as follows:*

i. *When $c > 1/8$, customers do not search; they purchase when $p_i \leq 1/2$.*

ii. *When $c \leq 1/8$,*

1. *If $p_i \leq \sqrt{2c}$, all customers purchase without search;*
2. *If $\sqrt{2c} < p_i \leq 1 - \sqrt{2c}$, all customers search; they purchase when they find their true valuations are no less than p_i;*
3. *If $p_i > 1 - \sqrt{2c}$, customers neither search nor purchase.*

Lemma 1 formally demonstrates prices as a stimulus for search. Part (i) of Lemma 1 shows that search is only possible when the search cost is not prohibitively large. To understand part (ii), note that customers will search a product only when doing so helps them make significantly better purchase decisions. In other words, customers will find search most valuable if postsearch purchase decisions have a high chance of deviating (in a positive way) from ex-search purchase decisions. If the price is sufficiently low, $p_i \leq \sqrt{2c}$, the intention of purchase tends to be high, whether customers search or not. Search creates less additional value (compared with the cost c), and customers make a no-search purchase to avoid the search cost. If the price is sufficiently high, $p_i > 1 - \sqrt{2c}$, customers neither search nor purchase: They cannot afford a no-search purchase after comparing the average valuation to the price; nor do they find search economically appealing because the excessive postsearch valuation over the price is insufficient to compensate for the search cost. However, intermediate prices can induce search. In this case, postsearch decisions are highly split: Customers purchase the product if they observe a valuation that is higher than the price and forgo purchase otherwise. There is a considerable chance of both scenarios, and customers can make significantly better decisions via search. In this way, the benefits of search can outweigh its cost.

Having derived customers' search and purchase outcomes under a fixed price, we next characterize the optimal price to sell a new product; see Li et al. (2019, proposition 1).

Proposition 1. *The optimal price of a new product is as follows*:

i. *If* $c > 1/8$, *the optimal price is* $p_i^* = 1/2$. *The sales is one, and the optimal revenue is* $1/2$.

ii. *If* $1/32 < c \leq 1/8$, *the optimal price is* $p_i^* = \sqrt{2c}$. *The sales is one, and the optimal revenue is* $\sqrt{2c}$.

iii. *If* $c \leq 1/32$, *the optimal price is* $p_i^* = 1/2$. *The sales is* $1/2$, *and the optimal revenue is* $1/4$.

In principle, the firm wishes to inhibit search and keep customers "in the dark," as this reduces customer heterogeneity and forces customers to rely on a common belief to make their purchase decisions. This allows the firm to charge a uniform price to capture the entire market. Now, when the search cost is sufficiently high, $c > 1/8$, no customers can afford the cost of search, and they will decide whether to purchase the new product based on their prior beliefs. This allows the firm to capture the entire market by setting price $p_i^* = 1/2$ and achieve a revenue as good as by practicing first-degree price discrimination. As the search cost decreases, $1/32 < c \leq 1/8$, the effect of search starts to factor in. However, from the firm's perspective, letting customers search will only create a threat: It will only add heterogeneity to the market without shifting the average valuations. In response to this threat, the firm lowers the price to eliminate customer search.[9] As the search cost further decreases and drops below a threshold, $c \leq 1/32$, the firm no longer finds it profitable to eliminate search by further decreasing the price. Instead, the firm chooses to tolerate search and sets a monopoly price identical to that absent valuation uncertainty.

Corollary 1. *Under separate selling, customers do not search a new product if* $c > 1/32$; *otherwise, all of them search.*

5. Selling Products in a Bundle

In this section, we consider the strategy of selling two products in a bundle, and we denote the price of the bundle by p_B. To understand how bundling affects nonobligatory search, we start by analyzing a market of one mature and one new product. The analysis of this market lays a foundation of analyzing a market of two new products.

When bundling is involved, customers' search processes will depend on the underlying market structure. Specifically, in a market of one mature and one new product (labeled as products 1 and 2, respectively), customers are differentiated by their valuations for the mature product, and the search decision is regarding the new product only. In a market of two new products (labeled as products 1 and 2, respectively), there are two dimensions of the search decisions: *whether* to search and *when* to stop search. Because the two products are symmetric ex ante, the search sequence does not affect a customer's payoff.[10] Without loss of generality, we assume that customers always search product 1 first, provided that they are willing to search. If customers decide to search, they become differentiated after searching product 1, upon which they further decide whether to search product 2. As a result, the "two-new product" market, once the first search takes place, reduces to a "one-mature-one-new product" market.

We analyze customers' search decisions via backward induction. We start by enumerating the search and purchase options of a customer who has already observed her valuation for product 1, but not for product 2.

5.1. Searching Product 2

Suppose a customer has observed her valuation v_1 for product 1. She then has the following search and purchase options:

1. The customer neither searches product 2 nor purchases the bundle, receiving a payoff of zero.

2. The customer purchases the bundle without searching product 2, receiving an expected payoff of $v_1 + \mathbb{E}_2[V_2] - p_B = v_1 + 1/2 - p_B$.

3. The customer searches product 2 and receives an expected payoff of $\mathbb{E}_2[v_1 + V_2 - p_B]^+ - c$, where the expectation operator $\mathbb{E}_2[\cdot]$ is calculated with respect to the distribution of V_2. To explain, note that a customer will purchase the bundle after searching product 2 if she finds that her valuation v_2 for product 2 satisfies $v_1 + v_2 \geq p_B$ and will forgo purchase otherwise.

Each customer selects the option that gives the highest payoff. Hence, the payoff of a customer with valuation v_1 is

$$U_2(v_1; p_B) = \max\{v_1 + 1/2 - p_B, \mathbb{E}_2[v_1 + V_2 - p_B]^+ - c, 0\}. \tag{1}$$

5.2. One Mature and One New Product

We first consider a market of one mature and one new product, in which each customer observes her valuation v_1 for the mature product. Note that the payoff function $U_2(v_1; p_B)$ in (1) is increasing in v_1 so that customers' search decisions are differentiated by their v_1. Customers with high v_1 purchase the bundle without search, and those with low v_1 neither search nor purchase. Customers with intermediate v_1 search the new product, learn their valuations, and then decide whether to purchase the bundle.

We next compute the volume of customers purchasing the bundle under price p_B. Two segments contribute to this demand.

1. $v_1 + 1/2 - p_B \geq \max\{\mathbb{E}_2[v_1 + V_2 - p_B]^+ - c, 0\}$: These customers will immediately purchase the bundle without searching product 2. The valuations v_1 of these customers should be high enough to justify no-search purchase. Searching product 2 only brings an additional, yet unnecessary, search cost.

2. $\mathbb{E}_2[v_1 + V_2 - p_B]^+ - c \geq \max\{v_1 + 1/2 - p_B, 0\}$ and $v_1 + v_2 \geq p_B$: These customers will search product 2 and then purchase the bundle after observing a high v_2. The valuations v_1 of these customers should be intermediate; otherwise, a high v_1 will induce a no-search purchase and a low v_1 will inhibit search or purchase.

Denote the demands from the two segments, respectively, as follows:

$$\begin{cases} \alpha(p_B) := \mathbb{P}\{v_1 : v_1 + 1/2 - p_B \\ \qquad \geq \max\{\mathbb{E}_2[v_1 + V_2 - p_B]^+ - c, 0\}\}, \\ \beta(p_B) := \mathbb{P}\{v_1, v_2 : \mathbb{E}_2[v_1 + V_2 - p_B]^+ - c \\ \qquad \geq \max\{v_1 + 1/2 - p_B, 0\},\ v_1 + v_2 \geq p_B\}. \end{cases}$$

Similar to Lemma 1 in the single-product setting, the firm can leverage prices to manage customer search in the multiproduct setting. However, if bundling is used, customers' search and purchase decisions are no longer homogeneous: They are now differentiated by their valuations for product 1 (recall that customers' search decisions are identical in the single-product setting). Depending on the bundle price, there can be a total of five scenarios differentiated by how these two segments contribute to the demand. We present a graphical illustration of the demands under different search cost c and bundle price p_B in Figure 1(a).

When $c > 1/8$, no customers can afford the cost of search. They make purchase decisions based on their valuations for product 1 and a common belief of the valuations for product 2. Hence, search can only exist when $c \leq 1/8$. When $p_B > 2 - \sqrt{2c}$, the bundle price is prohibitively high, so that even customers with the highest v_1 cannot afford the bundle with or without search. When the price is intermediately high, $1 + \sqrt{2c} < p_B < 2 - \sqrt{2c}$, the bundle starts to be appealing to certain customers. The price is still high though, so that customers must search product 2 in the hope that they will find a high v_2 to justify a purchase. When the price is medium, $1 - \sqrt{2c} < p_B < 1 + \sqrt{2c}$, customers with high v_1 purchase the bundle without search, and those with intermediate v_1 search product 2. Customers with extremely low v_1 are screened out: These customers neither search nor purchase. When the price is intermediately low, $\sqrt{2c} < p_B < 1 - \sqrt{2c}$, customers with high or intermediate v_1 retain their decisions, but the decisions of those with low v_1 will switch. This time, even those with the lowest $v_1 = 0$ will search product 2, thanks to the reduced price. When the price further decreases below $\sqrt{2c}$, the bundle is sufficiently attractive, even to customers with $v_1 = 0$: They choose to purchase the bundle without search. The argument above shows that bundling deepens the effect of prices on customer search in the multiproduct setting, which, jointly with the market heterogeneity, results in a wider variety of equilibrium outcomes.

Having derived customers' search and purchase decisions under a fixed bundle price, the firm selects the best price to optimize revenue:

$$\max_{p_B \geq 0} \quad \Pi(p_B) = p_B D(p_B), \tag{2}$$

where the demand $D(p_B) = \alpha(p_B) + \beta(p_B)$. We characterize the optimal bundle price in the next proposition.

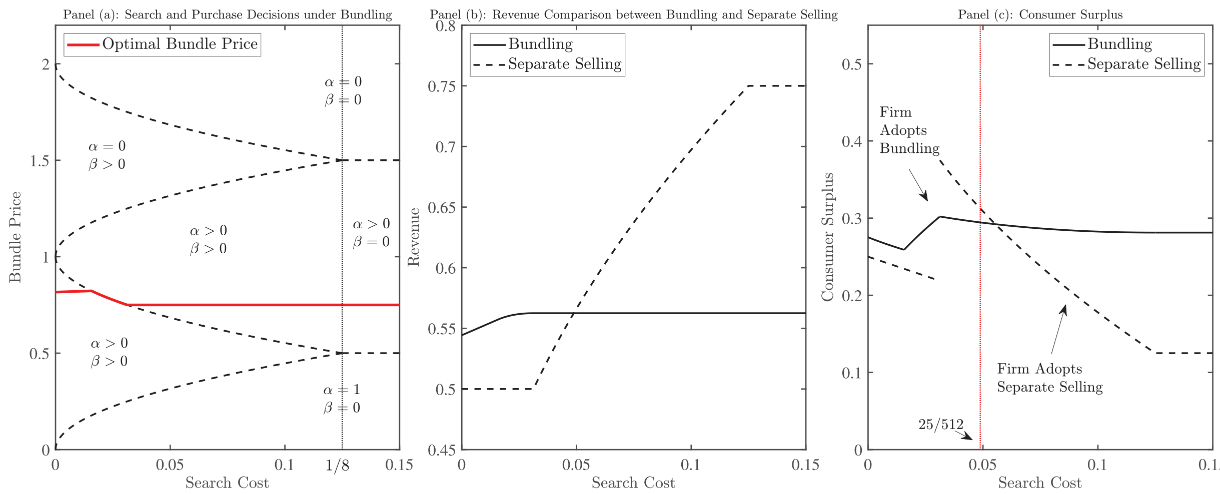
Proposition 2. *In a market of one mature and one new product, the firm's optimal bundle price and the resulting revenue are*

$$(p_B^*, \Pi(p_B^*)) = \begin{cases} \left(\sqrt{6(1+c)}/3, \frac{2}{9}(1+c)\sqrt{6(1+c)}\right), & \text{if } 0 \leq c \leq 2 - 3\sqrt{7}/4, \\ \left(1 - \sqrt{2c}, \frac{\sqrt{2c}}{2} - 2c + \frac{1}{2}\right), & \text{if } 2 - 3\sqrt{7}/4 < c \leq 1/32, \\ (3/4, 9/16), & \text{if } c > 1/32. \end{cases}$$

In particular, p_B^* is increasing in c for $c \leq 2 - 3\sqrt{7}/4$ and decreasing in c for $c > 2 - 3\sqrt{7}/4$.

We plot the firm's optimal bundle price in Figure 1(a). We find that when $c \leq 1/8$, the optimal bundle price lies between $\sqrt{2c}$ and $1 + \sqrt{2c}$, which implies that the demands from the two segments are both positive. Recall that α represents the demand from the upper segment with high v_1, who will purchase the bundle without search, and that β represents the demand from those with intermediate v_1, who will search and then purchase.

Figure 1. (Color online) Market of One Mature and One New Product



When the search cost is low, $c \le 2 - 3\sqrt{7}/4$, it is unlikely to keep all customers in the dark, especially those with low v_1, who have a strong incentive to search product 2. In this case, setting the bundle price sufficiently low to fully eliminate customer search is not profitable because doing so has to reduce the profit margin too much. As a result, the firm chooses to tolerate search among customers with low v_1. In this region of search cost, the existence of customers with high v_1 who tend to purchase without search allows the firm to charge a bundle price $\sqrt{6(1+c)}/3$, which is higher than the optimal price absent valuation uncertainty, $\sqrt{6}/3$. The optimal price increases with c in this region because the firm sees search as less of a threat as the search cost grows. As the search cost further grows, $2 - 3\sqrt{7}/4 < c < 1/32$, customers with intermediately high v_1 who used to search product 2 decide to drop search due to the increased search cost, and they switch to purchasing without search. Meanwhile, the increased search cost squeezes customers with $v_1 = 0$ out of the market. Hence, the effect of an increased search cost is twofold: It boosts the demand from those who purchase without search and, at the same time, forces customers with low v_1 out of the market. In response, the firm continues to adopt a *volume strategy* by lowering the price, so that customers with $v_1 = 0$ are now indifferent between searching product 2 and leaving the market without search. As the search cost continues to grow, $1/32 < c \le 1/8$, further lowering the price to keep these customers in the market is no longer profitable. Instead, the firm chooses to screen out these customers and induce a total demand $3/2 - p_B$, which solely depends on the price, but not search cost. To explain this demand, first note that α increases with c, as an increased search cost makes search less appealing as an option. Thus, the boundary v_1 that distinguishes searching customers from those who make a no-search purchase decreases with c, and so α expands. Now, those who search product 2 have a lower average v_1, and to purchase the bundle requires them to discover a higher realized v_2 than before. As a result, fewer customers end up purchasing the bundle after search, so that β decreases with c. Combined together, the effects of search cost on α and β cancel out and lead to a demand that is only price-dependent.

Proposition 2 shows that in a market of one mature and one new product, search exists under bundling when $c < 1/8$, in contrast to Corollary 1, which claims the existence of customer search under separate selling when $c < 1/32$. Hence, bundling enlarges the parameter space, where search takes place in a market of one mature and one new product. This result is driven by the distinctive ways in which the two pricing schemes interact with the market heterogeneity. Customers make identical search decisions on the new product under separate selling, whereas their search decisions are differentiated by their valuations for the mature product under bundling. Under separate selling, because distinct prices can be charged to each product, the firm chooses to charge a low price for the new product to inhibit customer search. As a result, search can only exist when the search cost is sufficiently small to discourage the firm from adopting an aggressively low price. In contrast, eliminating search is more difficult under bundling because there is already sufficient heterogeneity (for the mature product) in the market, which splits customers into an upper and a lower segment with distinct searching behaviors. Lowering the bundle price to inhibit customer search has the effect of expanding the upper segment, but, in the meantime, leaves a generous information rent to that segment. To balance these two effects, the firm charges a moderate bundle price to tolerate search among the lower segment, which allows the search region to expand.

Corollary 2. *In a market of one mature and one new product, search exists under bundling when* $c < 1/8$.

We next characterize the optimal strategy of selling the two products by comparing the revenues generated from bundling and separate selling. We present a numerical comparison in Figure 1(b).

Theorem 1. *In a market of one mature and one new product, bundling leads to higher revenue than selling separately if and only if* $0 \le c \le 25/512 \approx 0.049$.

Theorem 1 illustrates an intricate interplay between search, market heterogeneity, and prices. Without valuation uncertainty at play, it is well known that bundling can outperform separate selling for products with negligible marginal costs, thanks to the pooling effect of bundling in reducing valuation dispersion and demand elasticity. Indeed, even in the presence of valuation uncertainty, when search is costless (i.e., search cost close to zero), there is a dominant portion of customers who always search the new product, regardless of the pricing scheme adopted, and we restore the classic result on the dominance of bundling. As the search cost increases slightly, the revenue under separate selling remains unchanged because the increased search cost is insignificant to eliminate search. However, the firm can leverage bundling to induce the upper segment to purchase without search, and a slight increase in search cost helps increase the bundle revenue by boosting the bundle price and letting the upper segment expand. This implies that the revenue gap between bundling and separate selling increases with the search cost, a fact highlighting bundling as an effective instrument to exploit market heterogeneity.

However, as the search cost further increases, $c > 1/32$, it starts to favor separate selling. The firm charges $\sqrt{2c}$ for the new product to prevent search, and this price increases with the search cost. So does the revenue under separate selling. The revenue under bundling, however, remains unchanged, despite the increased search cost. As the search cost continues to grow to make search prohibitively expensive, $c > 1/8$, no customers will search under either pricing scheme. This time, separate selling can work well by allowing the firm to fully extract the consumer surplus for the new product. In contrast, the surplus extraction is only partial under bundling due to the existing heterogeneity in the market. Therefore, the heterogeneity underlying the mature product, which helps bundling outperform separate selling when the search cost is low, is exactly what defeats bundling when the search cost goes large.

Our results shed light on the practice of bundling new products with mature ones under small search costs, as alluded to by the increasing popularity of compilation albums (which are often a combination of newly released songs and several existing ones), such as Beyoncé's "More Only," Fall Out Boy's "Believers Never Die," and Taylor Swift's "Red." To sell these albums, many sellers offer previews to help interested customers understand their preferences. This suggests a small search cost and, according to Theorem 1, allows bundling to remain a profitable marketing strategy. Moreover, a slight increase in the search cost will strengthen the dominance of bundling over separate selling. This partially explains why most sellers choose not to display the full version of new releases in previews, but only a selected portion of them.

We next discuss how the firm's optimal pricing strategy affects consumer surplus. The consumer surplus under separate selling is $\int_{1/2}^{1}(v - 1/2)dv = 1/8$ for the mature product because the optimal price charged for that product is 1/2. The consumer surplus for the new product is $\max\{(1 - p_i^*)^2/2 - c, (1/2 - p_i^*)^+\}$, with p_i^* given by Proposition 1. This implies that the consumer surplus for the new product is $1/8 - c$ when $c \le 1/32$, is $1/2 - \sqrt{2c}$ when $1/32 \le c \le 1/8$, and is zero when $c > 1/8$. The consumer surplus under bundling is computed by $\int U_2(v_1; p_B^*)dF_1(v_1)$, where $U_2(v_1; p_B^*)$ defined in (1) denotes the payoff of a customer with valuation v_1 for the mature product under the optimal bundle price p_B^*. We plot the consumer surplus under the two pricing schemes in Figure 1(c). We find that bundling hurts the customers when the search cost $c \in [1/32, 0.055]$ and benefits the customers otherwise. Because bundling is the firm's dominant strategy for search cost $c < 0.049$, this implies that bundling creates Pareto gains for both the firm and customers when the search cost is sufficiently small. This outcome is driven by the fact that bundling is adopted by the firm as a volume strategy that aims at better market coverage, so that more customers can benefit from purchasing the products. For search cost $c \in [0.049, 0.055]$, separate selling creates a win-win situation for both the firm and customers. This happens when the firm inhibits customer search under separate selling, but the threat of search keeps the price low, which benefits the customers. The firm favors separate selling, too, for its strength in keeping customers in the dark for the new product. When the search cost is above 0.055, the firm continues to favor separate selling. But this time, the increased search cost allows the firm to charge higher prices for the new product; the surplus retained by customers starts to shrink relative to that under bundling.

5.3. Two New Products

We next study a market of two new products, in which valuation uncertainty exists for both products. Because customers hold the same belief of their valuations, their search decisions are identical at the initial stage. However, once they decide to search a product and discover their valuations, their subsequent decisions are differentiated by their valuations learned from the first search. Because the two products are symmetric ex ante, the search sequence does not affect a customer's payoff. Without loss of generality, we start by considering a customer's search and purchase options regarding product 1.

1. The customer does not search product 1 or purchases the bundle, receiving a payoff of zero.

2. The customer searches product 1, receiving an expected payoff of

$$U_1(p_B) = \mathbb{E}_1[U_2(V_1; p_B)] - c = \int U_2(v_1; p_B)dF_1(v_1) - c, \tag{3}$$

where $\mathbb{E}_1[\cdot]$ denotes the expectation with respect to the valuation distribution of product 1 and $U_2(v_1; p_B)$, defined in (1), denotes the payoff of a customer with realized valuation v_1 for product 1.

3. The customer purchases the bundle without searching product 1, receiving an expected payoff of $\mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B = 1 - p_B$.

Observe that the payoffs of the three options above involve arguments no more than the bundle price p_B and search cost c because customers hold a common belief of valuations before any search takes place. Customers select the option that yields the highest payoff, leading to three possible outcomes (when there is a positive demand for the bundle).

1. If $\mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B > U_1(p_B)$ and $\mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B \geq 0$, then all customers purchase the bundle without search. The sales is one and revenue p_B. To optimize revenue, the firm solves

Problem 1 (Purchase Without Search).

$$\max_{p_B} p_B$$
$$\text{s.t. } \mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B > U_1(p_B),\ \mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B \geq 0.$$

2. If $U_1(p_B) > \mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B$ and $U_1(p_B) \geq 0$, then all customers search product 1 and learn their v_1. The market after the first search becomes equivalent to a market of one mature and one new product. Thus, the demand of the bundle is the same as that characterized by (2). Then,

Problem 2 (Search and Then Purchase).

$$\max_{p_B} p_B D(p_B)$$
$$\text{s.t. } U_1(p_B) > \mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B,\ U_1(p_B) \geq 0.$$

3. If $U_1(p_B) = \mathbb{E}[V_1] + \mathbb{E}[V_2] - p_B \geq 0$, then customers play mixed strategies, as they are indifferent between purchasing without search and searching product 1. In this case, we select the equilibrium that is preferred by the firm, as prescribed by the optimal solution to Problem 1.[11]

By solving Problems 1 and 2 separately and selecting the solution that yields a higher objective value, we characterize the firm's optimal bundle price in the following proposition.

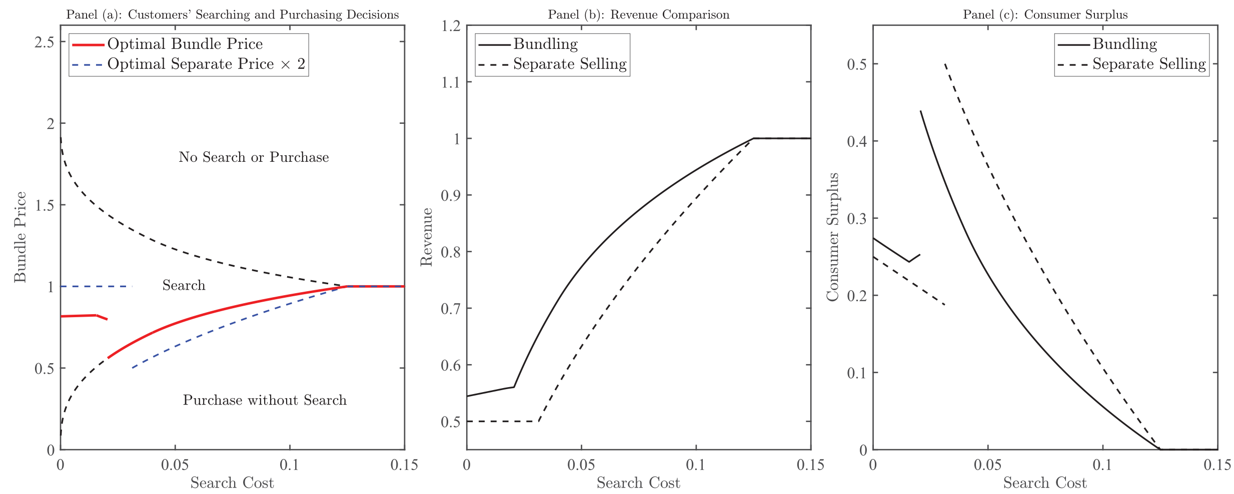
Proposition 3. *In a market of two new products, there exists $c_0 \approx 0.021$ and $c_1 \approx 0.040$ such that the firm's optimal bundle price p_B^* is as follows:*

$$p_B^* = \begin{cases} \sqrt{6(1+c)}/3, & \text{if } 0 \leq c \leq 2 - 3\sqrt{7}/4, \\ 1 - \sqrt{2c}, & \text{if } 2 - 3\sqrt{7}/4 < c \leq c_0, \\ \left(3c - 2c\sqrt{2c} + 3c\sqrt{1 - 4\sqrt{2c}/3}\right)^{1/3} & \\ \quad + 2c\left(3c - 2c\sqrt{2c} + 3c\sqrt{1 - 4\sqrt{2c}/3}\right)^{-1/3}, & \text{if } c_0 < c \leq c_1, \\ 1/2 + \sqrt{4c - 8c\sqrt{2c}/3 - 1/12}, & \text{if } c_1 < c \leq 1/8, \\ 1, & \text{if } c > 1/8. \end{cases}$$

In Figure 2(a), we plot the optimal bundle price derived in Proposition 3. Recall that customers' search decisions on product 1 are identical because they hold the same belief of valuations. For $c \leq c_0$, the small search cost allows customers to always search product 1, and the valuation uncertainty is effectively regarding product 2 only. The optimal bundle price in this market is identical to that in a market of one mature and one new product. We thus replicate the previous result that the optimal bundle price increases with c for $c \leq 2 - 3\sqrt{7}/4$. After searching product 1 to learn their valuations v_1, customers' subsequent search and purchase decisions are differentiated by their v_1 in a manner similar to Section 5.2: Those with high v_1 purchase the bundle without further searching product 2, and those with low v_1 continue to search. In the region $2 - 3\sqrt{7}/4 < c \leq c_0$, the bundle price decreases with c, as the firm lowers the price to keep customers with $v_1 = 0$ in the market and invite them to search product 2.

As c increases above c_0, $c_0 \leq c \leq 1/8$, further lowering the price to cover these customers is no longer profitable. Instead, the firm decides to eliminate customer search, even for product 1, and promotes no-search purchase among the entire market. The price is limited by the threat of search though, and the firm has to cut the price in a significant manner, leading to a downward jump in the price, with c_0 being the critical point where customers' search decisions

Figure 2. (Color online) Market of Two New Products



switch. The price then increases with the search cost, as the firm sees customer search as less of a threat. However, a precise prescription of the price is described by two different functions in intervals before and after $c = c_1$. To explain, note that to discourage customers from searching, the payoff of searching product 1 must be lower than that of no-search purchase. To calculate the former payoff $U_1(p_B)$, further note that the search cost is sunk after the first search and that the subsequent payoff is governed by the realized v_1. If a customer's realized v_1 is high, then she should purchase the bundle and stop search. If the realized v_1 is low, then her subsequent decision depends on the search cost. Those with extremely low v_1 continue to search for $c_0 < c < c_1$ and stop search for $c > c_1$. Hence, the payoff structure after the first search takes a switch at $c = c_1$, implying that the structure of $U_1(p_B)$ should also switch. As a result, the functional form of the bundle price should also switch to adjust the payoff of no-search purchase in order to inhibit customer search.

The following corollary follows immediately from Proposition 3.

Corollary 3. *In a market of two new products, search exists under bundling when* $c < c_0$.

Recall that under separate selling, customers search a new product when $c \leq 1/32$ and purchase a new product without search when $1/32 < c < 1/8$. This implies that when $c_0 < c < 1/32$, search exists under separate selling, but not under bundling. In other words, bundling inhibits search to a larger extent, in sharp contrast to our previous result in a market of one mature and one new product. This is because bundling reduces the appeal of search in a market of two new products by restricting the benefits it can bring to a customer.

To better understand this latter intuition, first note that the search decisions are independent under separate selling, but are sequential and path-dependent under bundling, in the sense that the second search depends on the realized valuation after the first search. Now, consider an intermediate search cost so that the search decisions must balance the benefits of search and search cost. Further, consider setting the bundle price $p_B = p_1 + p_2$ so that the *average price* of each product under bundling is the same as that under separate selling. Conducting the first search can lead a customer to three scenarios. (i) If the realized v_1 is very low, the customer tends to act differently depending on the pricing scheme used. Under bundling, she will exit the market without purchasing the bundle or searching product 2, receiving a zero payoff (assuming the cost of the first search is sunk). Nonetheless, she may still consider searching product 2 or purchasing product 2 without search under separate selling, both giving rise to a nonnegative utility. (ii) If the realized v_1 is medium, but not too high, the customer will further search product 2 under bundling to decide whether to purchase the bundle because the bundle is an "all-or-nothing" offer. If v_1 is less than p_1, then v_2 has to be sufficiently high to justify a purchase—that is, $v_2 > p_B - v_1 > p_B - p_1 = p_2$. In contrast, the requirement on v_2 is less stringent to justify purchasing product 2 under separate selling—that is, $v_2 \geq p_2$—provided that the customer searches it. Hence, the customer is more likely to receive a higher utility from purchase under separate selling than under bundling. (iii) If the realized v_1 is very high, the customer will purchase the bundle without searching product 2 under bundling and receive a payoff of $v_1 + \mathbb{E}[V_2] - p_B$. She can also purchase product 2 without searching it under separate selling and receive a utility $v_1 - p_1 + \mathbb{E}[V_2] - p_2 = v_1 + \mathbb{E}[V_2] - p_B$, which is no less than that achieved under bundling. Therefore, in all three scenarios, searching the first product can lead to a higher payoff to the customer under separate selling than under bundling.

We plot the total price of the two products under separate selling, namely, $2p_i^*$, in Figure 2(a) and compare it to the optimal bundle price. We find that the optimal bundle price falls below $2p_i^*$ for $c \le 1/32$, stays above $2p_i^*$ for $1/32 < c < 1/8$, and is equal to $2p_i^*$ for $c \ge 1/8$. This is because search exists under both bundling and separate selling for $c \le c_0$, and the optimal prices are only slightly affected by the valuation uncertainty. Consistent with the classic bundling literature, the firm utilizes bundling as a *volume strategy* to capture a large portion of customer crowd by charging a lower average price. For $c_0 < c \le 1/32$, search exists under separate selling, but not under bundling, and a firm adopting bundling has to lower the bundle price even further to inhibit customer search. For $1/32 < c < 1/8$, customers don't search under either pricing scheme, but the prices are still restricted by the threat of search though. This time, bundling allows the firm to charge a higher price because, as argued, bundling ties products together and makes search less appealing when the search cost is intermediate. For $c \ge 1/8$, search is prohibitively expensive, irrespective of the pricing scheme adopted, and the threat of search disappears. The average price of each product becomes identical under either pricing scheme in a way that fully extracts the consumer surplus.

We compare the revenues under the two pricing schemes in the next theorem and give a numerical comparison in Figure 2(b).

Theorem 2. *In a market of two new products, bundling generates strictly higher revenue than separate selling when* $c < 1/8$. *Bundling and separate selling generate equal revenue when* $c \ge 1/8$.

Theorem 2 shows that bundling (weakly) outperforms separate selling for any search cost and is strictly better for small to medium search cost, $c < 1/8$. To understand this result, we identify two distinct driving forces, each dominating under different search costs. First, when the search cost is sufficiently small, valuation uncertainty is insignificant, and customers always search. Bundling is favored for its well-established pooling effect in reducing customers' valuation dispersion. Second, as the search cost increases, the effect of valuation uncertainty starts to factor in, and, as discussed, bundling can restrict the benefits of search. Better at inhibiting search, bundling allows the firm to reduce customer heterogeneity by keeping them in the dark and contributes to a better revenue. Finally, for very large search costs that fully eliminate the threat of search, $c > 1/8$, bundling is revenue-equivalent to separate selling because consumer surplus is fully extracted under either pricing scheme. Observing that the bundle revenue increases with the search cost, our finding has implications for whether firms should foster or impede the sharing of purchase and consumption experience among users or leak product information on their websites.

We next compute the consumer surplus under both pricing schemes and plot it in Figure 2(c). The consumer surplus under separate selling is computed by using a similar argument to that in a market of one mature and one new product. The consumer surplus under bundling is the maximal payoff of the three options enumerated at the beginning of this section by plugging in the optimal bundle price given by Proposition 3. We find that bundling benefits the customers when the search cost $c < 1/32$—that is, when search exists under separate selling—and hurts the customers otherwise. To explain, recall that bundling, in general, is good at inhibiting customer search to enable a more efficient surplus extraction. A large search cost, $c > 1/32$, allows the firm to fully eliminate search under both pricing schemes, and the firm further experiments bundling to squeeze the surplus retained by customers. When $c_0 < c < 1/32$, search exists under separate selling only, and to inhibit customer search, the firm has to set the bundle price sufficiently low, which, in turn, benefits the customers. When the search cost is sufficiently small, $c < c_0$, search exists under both pricing schemes, and bundling benefits the customers again by selling the products to a larger customer crowd. Because bundling generates higher revenue than separate selling for all search costs, it follows that bundling can lead to Pareto gains for both the firm and customers when the search cost $c < 1/32$ in a market of two new products.

6. Correlated Valuations

In reality, customers often have correlated valuations for products with different functionalities. In the classic product-bundling setting, absent valuation uncertainty and customer search, McAfee et al. (1989) show that a negative correlation between product valuations can enhance the economic benefits of bundling. Schmalensee (1984) further shows that such a negative correlation is, in fact, not necessary to guarantee the success of bundling; bundling can also be a dominant strategy under a positive correlation. In this section, we explore how correlated valuations affect the efficacy of bundling in the presence of valuation uncertainty and customer search. The analysis of general correlations is often not tractable; see Wu et al. (2019) for a discussion on the analytical challenge of studying general correlations. Noting this analytic challenge, the existing research typically focuses on specific correlation structures for an insightful analysis—for example, Schmalensee (1984), Armstrong and Vickers (2010), and Ke and Lin (2020). We follow this convention and analyze a special class of correlations also considered by Armstrong and Vickers (2010).

6.1. Positive Correlation

We start by analyzing positive correlations. Following Armstrong and Vickers (2010), we specify the correlation structure as follows to develop contrast to our base model without correlations. The marginal distributions of customers' valuations for each product, V_1 and V_2, are uniform over $[0,1]$ (as they are in our base model without correlations). For $i \in \{1,2\}$, given a customer's valuation for product i, $V_i = t$, her valuation for the other product indexed by $-i$, $V_{-i} = t$ with probability κ, $0 \le \kappa \le 1$, and V_{-i} is uniformly distributed over $[0,1]$ independently of V_i with probability $1 - \kappa$. So, at the aggregate level, a κ faction of customers have the same valuations for both products, and the remaining $1 - \kappa$ fraction of customers have independent valuations for these two products. One can verify that the joint distribution of V_1 and V_2 under this correlation is well-defined and that V_1 and V_2 are symmetric. Moreover, κ represents the correlation coefficient between V_1 and V_2 and, thus, measures the strength of correlation.

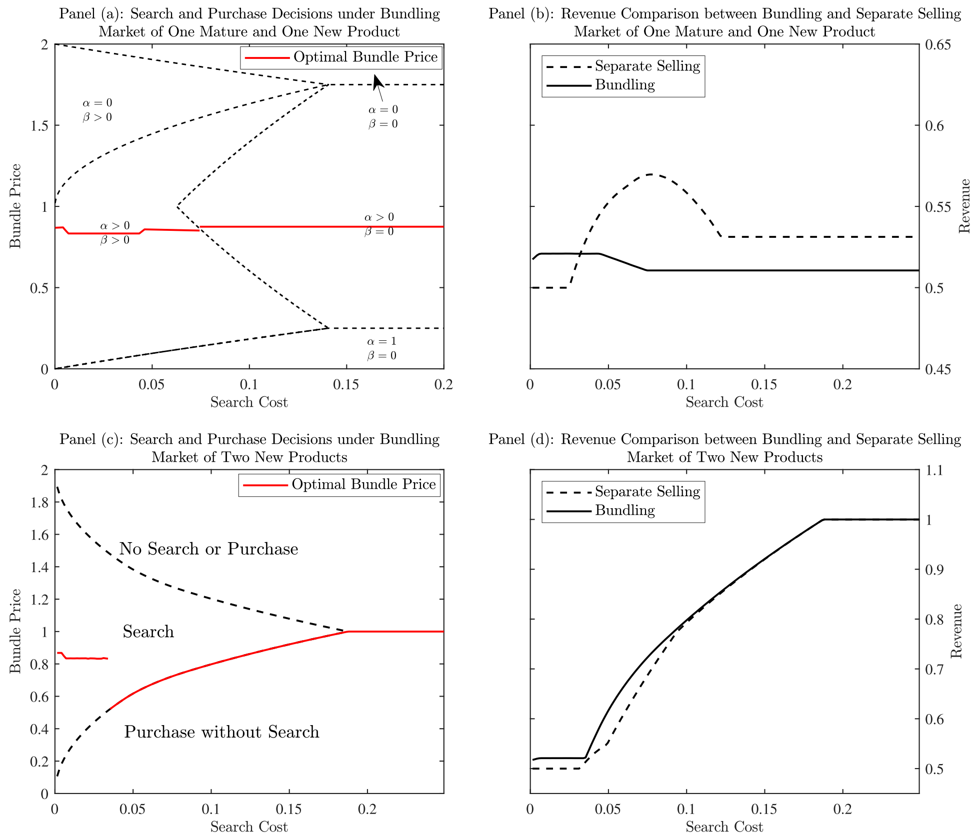
Similar to the base model, we assume that customers don't observe their true valuations for a new product if they don't search, but they know the distribution of their valuations for that product. To simplify analysis, we further assume that customers don't consider learning their valuations for a new product by purchasing and experiencing that product. This assumption fits into many online environments, where customers make search and purchase decisions in a short time period (e.g., hours), but product delivery required to experience a product takes significantly longer (e.g., days). In this case, customers may only consider resolving valuation uncertainty via a costly search. We leave a detailed analysis of this model with correlated valuations to Online Appendix B.1. We present the main results with correlation $\kappa = 0.5$ in Figure 3. We find that the main results derived from the base model with independent product valuations extend qualitatively to this new setting of positive correlations in a market of two new products, but not so in a market of one mature and one new product. Specifically, in this latter market, the firm's revenue is nonmonotone with respect to the search cost under both separate selling and bundling. To understand this new result, note that the presence of correlation conveys customers (partial) information of their valuations for one product if they already know the valuations for the other. Moreover, the presence of correlation creates diverging incentives of managing customer search differentiated by their valuations observed for the mature product v_1. Customers with high v_1 are likely to have high valuations for the new product, too. They tend to purchase the new product (the expected valuation for the new product tends to be high) if they choose not to search, but are likely to give up the new product if they choose to search, only to find low valuations. So, the firm prefers to inhibit search among these high-valuation customers. In contrast, customers with low v_1 will not purchase the new product if they don't search. Inviting these customers to search can create additional sales of the new product among those who find high valuations after search. The mixed effect of correlations drives the nonmonotonicity of the firm's revenue in the search cost. Despite this mixed effect, the revenue comparison between separate selling and bundling follows a similar structure as that in the base model: Bundling dominates when the search cost is small, and separate selling dominates otherwise.

6.2. Negative Correlation

In addition to positive correlations, we also consider negative correlations specified as follows. The marginal distributions of V_1 and V_2 are uniform over $[0,1]$. Given $V_i = t$, $V_{-i} = 1 - t$ with probability κ, $0 \le \kappa \le 1$, and V_{-i} is uniformly distributed over [0,1] independently of V_i with probability $1 - \kappa$. One can verify that the joint distribution of V_1 and V_2 under this correlation is well-defined and that V_1 and V_2 are symmetric. Moreover, $-\kappa$ represents the correlation coefficient between V_1 and V_2, and its value measures the strength of correlation.

We present the results of a negative correlation with $\kappa = 0.5$ in Figure 4. Similar to the case of a positive correlation, the firm's revenue under a negative correlation can be nonmonotone with respect to the search cost. This nonmonotonicity again follows from the diverging incentives of managing customer search differentiated by their valuations observed for one of the products. If a customer observes a high valuation for one product (which implies the expected valuation for the other product tends to be low if without search), the firm wishes to invite that customer to search the other product in the hope that postsearch valuations are discovered to be high. In contrast, customers who already observe low valuations for one product are advised not to continue searching. Doing so will hurt the sales of the new product, as customers who search and observe low valuations will give up the new product.

Figure 3. (Color online) Correlated Valuations: Positive Correlation, $\kappa = 0.5$



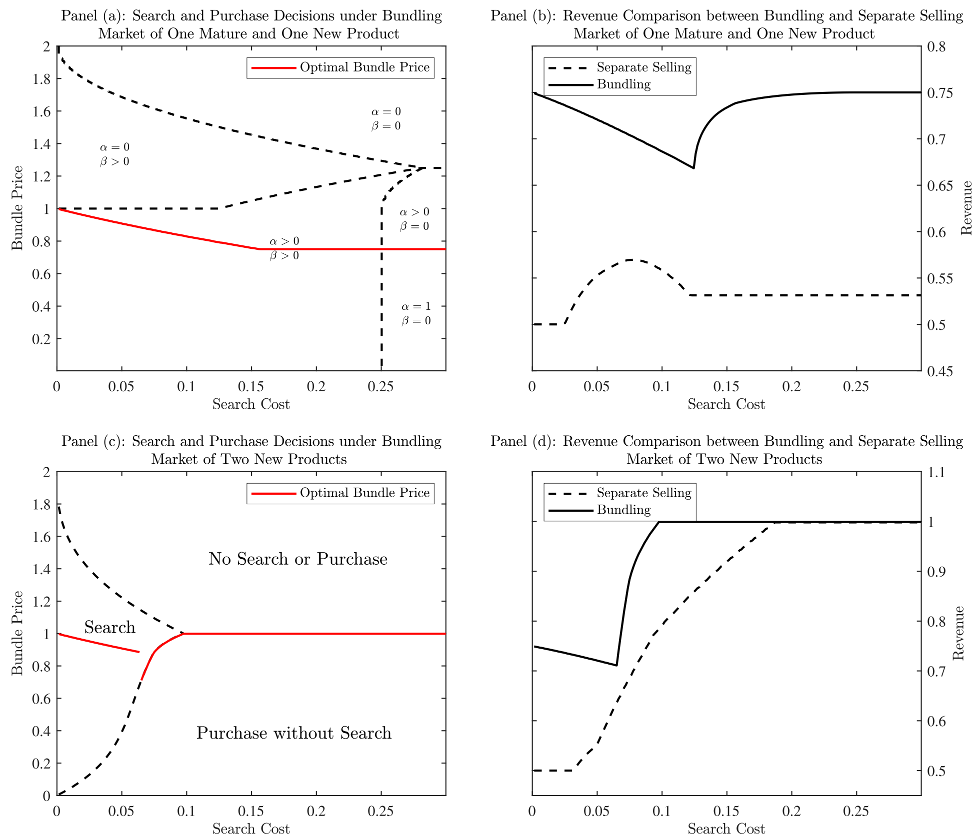
However, unlike a positive correlation, which is similar to no correlation in the way of inducing the revenue comparison between the two pricing schemes that depends on the search cost, a negative correlation always favors bundling as the dominant strategy in *both* markets, regardless of the search cost. In this sense, the role of a negative correlation in enhancing the economic benefits of bundling relative to separate selling extends to our setting featured by valuation uncertainty and customer search.

To further understand how different correlations affect the firm's revenue of bundling, we plot in Figure 5 the firm's revenues under different correlations. The existing wisdom in the classic bundling literature suggests that a negative correlation generally makes bundling more lucrative. We find that this is so in our setting when the search cost is sufficiently small, so that customers always search, effectively reducing our setting to the classic product-bundling problem without valuation uncertainty. However, as the search cost grows, the diverging incentives of managing customer search in distinct ways under correlated valuations start to factor in. A negative correlation can actually hurt the revenue of bundling (relative to no correlation) in a market of two new products under an intermediate search cost. Such a finding highlights valuation uncertainty and customer search as important drivers unique to our setting that fundamentally alter the performance of product bundling under correlated valuations.

7. Mixed Bundling

Thus far, we have considered separate selling and (pure) bundling. In this section, we consider *mixed bundling*, which involves offering products individually alongside the bundle. Endowed with more advanced flexibility in pricing, mixed bundling generally enables a more profitable market segmentation and better price discrimination and is known to outperform both separate selling and pure bundling in the classic product-bundling setting; see McAfee et al. (1989). (Contexts where mixed bundling fails to *strictly* outperform separate selling or pure bundling have been studied by Prasad et al. 2010 and Wu et al. 2020, with new features such as network externality and digital piracy.) Despite its economic appeal, mixed bundling is also known as being analytically intractable, even in the most simple settings; see Venkatesh and Kamakura (2003). Nonobligatory search in our setting further complicates the analysis by allowing more search and purchase options at the customer

Figure 4. (Color online) Correlated Valuations: Negative Correlation, $\kappa = 0.5$



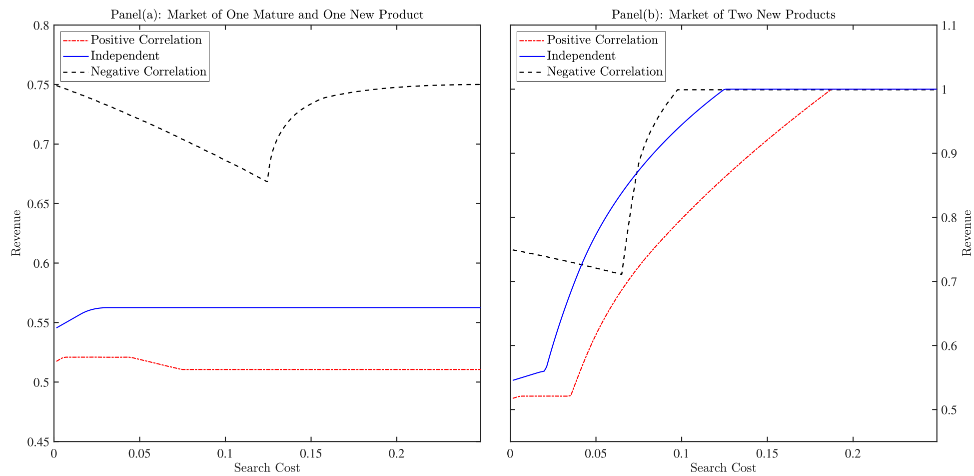
side. Thus, we can only numerically compute the optimal prices. For brevity, we leave a detailed analysis to Online Appendix B.2 and only present the main results in this section.

Figure 6 plots the optimal revenue under mixed bundling in comparison with separate selling and pure bundling. The dashed vertical lines in both panels (a) and (b) denote the threshold of search cost that differentiates whether search exists under mixed bundling. Naturally, mixed bundling should not perform worse than separate selling or pure bundling, despite valuation uncertainty and customer search, as it subsumes separate selling and pure bundling as special cases. However, whether it *strictly* outperforms separate selling and pure bundling is found to be highly dependent on the combination of market structure and search cost.

Specifically, in a market of one mature and one new product, mixed bundling can lead to significant revenue improvement when the search cost $c < 0.061$, so that search sustains. Recall that search exists when $c < 1/32 \approx 0.031$ under separate selling and when $c < 1/8 = 0.125$ under pure bundling. So, mixed bundling cultivates search relative to separate selling, but not so much as pure bundling. To understand this, recall also that customer heterogeneity in their valuations for the mature product is the key to the success of pure bundling when the search cost is small, but it will backfire when the search cost is large. Mixed bundling further exploits this market heterogeneity when the search cost is small by creating a more profitable market segmentation. When the customer heterogeneity starts to hurt pure bundling as the search cost grows (with $c > 25/512 \approx 0.049$), mixed bundling can still utilize price discrimination to achieve better revenues, as long as the search cost is not too large. However, as the search cost further grows, $c > 0.061$, letting customers search will only impede the surplus extraction for the new product, as it will create more customer heterogeneity than optimal. In this case, mixed bundling degenerates to separate selling.

In a market of two new products, mixed bundling can only yield a small revenue improvement when the search cost $c < c_0 \approx 0.021$ and will degenerate to pure bundling as the search cost grows above c_0. Recall that c_0 is the threshold of search cost that differentiates whether search exists under pure bundling. So, our results show that this threshold is actually identical under pure bundling and mixed bundling. This is because when the search cost is below this threshold, customers will search at least one product under pure bundling, and they become differentiated

Figure 5. (Color online) Revenue of Bundling Under Correlated Valuations: $\kappa = 0.5$ in Both Positive and Negative Correlations

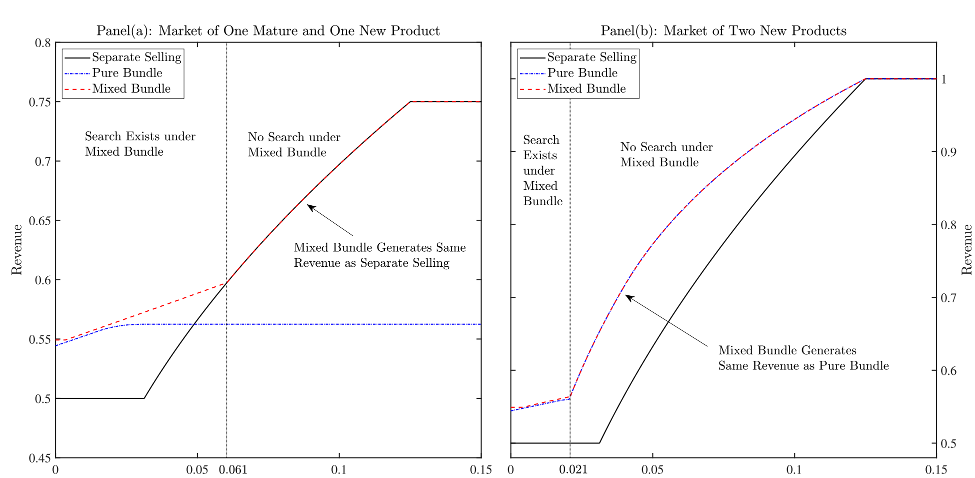


by their observed valuations after the first search. This creates an opportunity to leverage mixed bundling to better segment the market. When the search cost goes above c_0, customers stop search. Market heterogeneity induced by the first search vanishes, as customers hold the same expectation for each new product and make identical search and purchase decisions. No further market segmentation can be created, making mixed bundling effectively equivalent to pure bundling.

The results above are driven by the fact that mixed bundling can only work well when customers actively search, so that there is sufficient heterogeneity in the market. This requires the search cost to be sufficiently small. In a market of one mature and one new product, there is already some heterogeneity in the valuations for the mature product, so that mixed bundling can easily outperform separate selling and pure bundling for a wider range of search costs. In contrast, in a market of two new products, customers are ex ante homogeneous before search. So, the search cost must be even smaller to stimulate search and facilitate customer differentiation in their postsearch valuations.

Our results imply that mixed bundling can significantly outperform pure bundling and separate selling in a market of one mature and one new product under a moderate search cost,[12] but that there are only limited benefits of going for mixed bundling in a market of two new products. Our results have managerial implications for the practice of CityPASS. In practice, customers can purchase the bundle ticket or choose to go for individual sightseeing tours. Our results suggest that mixed bundling is particularly useful when the CityPASS has a signature attraction (such as the Statue of Liberty), for which customers can easily observe their valuations, even without a formal search. This creates ex ante heterogeneity in some bundle components

Figure 6. (Color online) Revenue Comparison: Mixed Bundle, Pure Bundle, and Separate Selling



and allows mixed bundling to have superior performance for a wider range of search costs.

8. Product Return

Product return has been a useful operational strategy commonly adopted by many physical and online retailers in order to stimulate advance purchase in the presence of valuation uncertainty—for example, Su (2009) and Altug and Aydinliyim (2016). A product-return program allows customers to purchase a product, experience that product, learn their valuations, and decide whether to return that product to receive a refund. This literature typically does not consider an active search process undertaken by customers to resolve uncertainty before they make a purchase. A notable exception is Nageswaran et al. (2020), who consider customers' strategic purchasing decisions when firms operate omnichannels. In their model, customers can visit a physical store to inspect a product or purchase online and return the product later. However, none of these existing papers considers customers' multiproduct demands, as well as the joint management of product return and product bundling. We explore this issue in this section.

8.1. Separate Selling

We start by analyzing separate selling. Note that a product-return program is only relevant to a new product for which valuation uncertainty exists, so we focus on analyzing the optimal pricing of a new product. We follow Su (2009) and assume that the firm charges p_i for a new product i and offers a refund r_i ($r_i \le p_i$) for each returned product i. With the additional option of product returns, a customer's expected payoff of no-search purchase becomes $\mathbb{E}[\max(V_i, r_i)] - p_i$, as the customer who finds her valuation $v_i \le r_i$ after purchase will return the product to get refund r_i. The expected payoff of search remains unchanged, as $\mathbb{E}[V_i - p_i]^+ - c$. We characterize the optimal price and refund for the product-return program in the next result.

Proposition 4. *For a new product i, the optimal product price, refund, and revenue under separate selling are*

$$(p_i^*, r_i^*, \Pi_i^*) = \begin{cases} (1/2, \sqrt{1/4 - 2c}, 1/4 + 2c), & \text{if } 0 \le c < 1/8, \\ (1/2, 0, 1/2), & \text{if } c \ge 1/8. \end{cases}$$

In particular, under the optimal product-return program, customers always make no-search purchase for all search costs c.

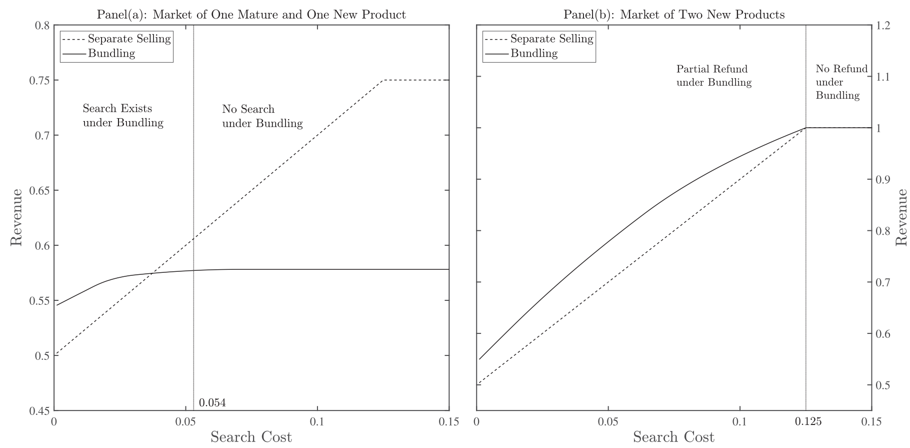
Unlike Su (2009, theorem 2), who asserts that the firm should offer no refunds for returned products with zero salvage value, Proposition 4 shows that a partial refund is actually desired when customers actively learn their valuations at a small search cost. To understand this result, note that on the one hand, the return program (with a positive refund) increases the payoff of no-search purchase because the post-purchase utility (assuming the cost of purchase is sunk) is guaranteed to be no less than the refund. Hence, a generous refund can inhibit customer search. On the other hand, no-search purchase does not translate to the firm's net revenue, as the firm must compensate those customers who find their valuations lower than the refund and return the product. How to induce a good level of no-search purchase without triggering a large amount of product return forms the crux of Proposition 4. Indeed, when the search cost is small, $c < 1/8$, the firm offers a positive refund and tailors it to eliminate customer search. When the search cost is large, $c \ge 1/8$, customers do not consider search as an option, and we recover the result of Su (2009) that predicts zero refunds.

8.2. Bundling

We next study the joint management of product bundling and product return. As is common in practice, we assume that customers must return the *entire bundle* to receive a refund. The firm charges p_B for the bundle and offers a refund r_B ($r_B \le p_B$) for each bundle returned. Because of the complexity of the problem, we can only numerically compute the optimal prices and refunds. We leave a detailed formulation of this problem to Online Appendix B.3 and only present the main results in Figure 7. The dashed vertical line in panel (a) denotes the threshold of search cost that differentiates whether search exists under the optimal product-return program when products are sold in bundles. A similar vertical line in panel (b) denotes the threshold of search cost that differentiates whether the firm should offer *positive* refunds to reward product returns.

Some observations are in order. First, similar to the case of separate selling, a product-return program jointly with the adoption of product bundling allows the firm to inhibit customer search to a higher level by increasing the payoff of no-search purchase. As a result, search is fully eliminated in a market of two new products for all search costs (recall the threshold of search cost to allow search to exist without product return is $c_0 \approx 0.021$) and exists in a market of one mature and one new product when the search cost is less than 0.054 (recall that the threshold of search cost without product return is $1/8 = 0.125$). Second, as discussed, to better inhibit customer search requires offering a positive refund. Indeed, the firm always offers a monetary refund in a market of one mature and one new product and does so in a market of two new products for search cost $c < 1/8$. This points to the critical role of market structures in the optimal design of a product-return program. Linking this result to

Figure 7. Revenue Comparison Under Product-Return Programs



practice, Snidel does not allow customers to return lucky bags that contain numerous latest designs of ladies' one-sized apparels (e.g., jackets, one-piece dresses, and skirts). No fitting is allowed, and opening the lucky bag before purchase is strictly prohibited. Thus, it is extremely challenging for customers to evaluate the fit of those items of apparel, thereby suggesting a substantially high search cost. As a result, Snidel does not accept any returned lucky bags, as is consistent with our prescription in panel (b). Third, introducing a product-return program does not qualitatively alter the revenue comparison between separate selling and bundling in both markets. This is because the product-return program is jointly considered with price optimization under both schemes, thus allowing prices to remain as an operational lever to manage customer search. Hence, the main insight of the base model that bundling cultivates search in one market and inhibits search in the other, together with the revenue implications, is unaffected by the introduction of the product-return program.

9. Conclusion

In this paper, we propose product bundling as an operational lever to manage customer search when customers demand multiple products and actively search to resolve valuation uncertainty. We apply a nonobligatory search framework to study two different markets, a market of one mature and one new product, as well as a market of two new products. Bundling cultivates search in the former market, exploits market heterogeneity, and leads to better revenue when the search cost is relatively small. In contrast, bundling inhibits customer search in the latter market by making the search decisions sequential and path-dependent and entails firms a better position to keep customers in the dark. We also examine pricing tactics and illustrate how they serve as a stimulus for nonobligatory search, taking effect jointly with product bundling.

Our study of mixed bundling shows that its economic benefits only carry through when the search cost is relatively small, in which case mixed bundling can lead to considerable revenue improvement in a market of one mature and one new product, but only tiny revenue improvement in a market of two new products. We also consider product returns and advocate that firms should always offer positive refunds for returned products jointly with product bundling when customers actively search at a relatively small cost. We conduct numerous extensions, including correlated product valuations, heterogeneous products, marginal cost, heterogeneous search costs, and simultaneous display of product information. These extensions generate more refined strategy recommendations for bundling, but, by and large, do not alter our main results. Finally, we acknowledge that there are other realistic factors not captured in our model, such as competition (Zhou 2014, Rhodes et al. 2021) and network externality (Prasad et al. 2010), and that the practice of bundling can also be affected by more nuanced features (e.g., menu costs) and historical reasons (e.g., business norms). We hope our paper will invite more investigations into this exciting strand of research.

Endnotes

[1] See https://www.kkday.com/en/product/60.

[2] See https://www.tripsavvy.com/buffet-of-buffets-caesars-palace-4135976.

[3] A lucky bag comprises numerous brand-new products (e.g., jackets, one-piece dresses, and skirts). See https://www.facebook.com/snidel.gelatopique/posts/2783134648447797/.

[4] We consider in Section 6 an extension to allow correlated valuations between two products and in Online Appendix A.1 an extension to allow nonuniform valuation distributions.

[5] We consider in Online Appendix A.4 an extension to allow heterogeneous search costs and in Online Appendix A.5 an extension to allow a single search to resolve uncertainties of both products.

[6] We consider in Online Appendix A.3 an extension of nonzero marginal cost.

[7] We consider in Section 7 an extension of mixed bundling, which involves offering products individually alongside the bundle.

[8] An implicit, yet important, assumption in our model, as well as in Wathieu and Bertini (2007) and Li et al. (2019), is that customers can observe the price of a product or bundle at a negligible cost. This is a reasonable assumption because the price information is often available across various channels and can be costless to obtain in many online environments. This is a common assumption widely adopted in the search literature; see, for example, Choi et al. (2018), Eeckhout and Kircher (2010), Petrikaitė (2018), and Ke and Lin (2020).

[9] As the firm sets $p = \sqrt{2c}$ for this range of search cost, customers are essentially indifferent between searching the new product and making a no-search purchase. So, at this price, it is possible that customers will play mixed strategy when choosing between these two options. We assume that all customers will make a no-search purchase with probability one, and, in doing so, we select the equilibrium that generates the highest revenue for the firm. From a practical point of view, this pure-strategy behavior of customers can also be induced by charging a price slightly less than $\sqrt{2c}$. In this way, customers *strictly* prefer a no-search purchase to search, and so all of them will purchase without search. The resulting revenue will be sufficiently close to the theoretic-optimal one prescribed by Proposition 1 and will not qualitatively affect our main results. The same logic applies to the case of bundling that we analyze later.

[10] We consider in Online Appendix A.2 an extension to allow asymmetric valuations between two products and characterize customers' optimal search sequence.

[11] If customers choose to purchase without search with probability one, the sales is one, and the revenue is p_B. Otherwise, if customers choose to search product 1 with a nonzero probability, then some of them will not purchase. This implies that the sales is strictly less than one, so that the revenue is strictly less than p_B. Therefore, the firm's preferred equilibrium is the one in which all customers purchase without search.

[12] A moderate search cost is plausible in practice. For example, in the hotel industry, De los Santos and Koulayev (2017) estimate that the search cost for hotels can range from \$8.35 to \$55.23, as opposed to the average hotel price of \$230. Search cost in the lower range of De los Santos and Koulayev's (2017) estimations will be considered moderate in our model.

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