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Bundling in advance sales: Theory and evidence from round-trip vs two one-way tickets

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Abstract

We develop a model to derive an optimal price for a bundle of two goods when buyers are risk averse and uncertain about the valuation of each good. In theory, the optimal bundle price depends not only on the probability of a positive valuation of each good, but also on the correlation between the two valuations. We analyze a unique airlines dataset in which we directly observe the prices of both bundled (round trip ticket) and unbundled items (two one-way tickets) for identical itineraries. We find that airlines offer bundle discounts, and that these discounts increase when the correlation between outbound and inbound demands is higher. Moreover, higher certainty about demand decreases bundling discounts. We also find that bundling discounts decrease with competition.

Keywords: Bundling, Advance purchases, Risk aversion, Monopoly, Airlines

JEL Classifications: D81, L12, L93

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1 Introduction

The offering of multiple goods in a bundle is common in a variety of industries. Fast food restaurants routinely offer combo meals (sandwich, fries, and drink), and communications companies offer discounts for bundling cable television, internet, and home phone services. In the travel industry, online travel agencies (Expedia, Orbitz, Travelocity) encourage consumers searching for airfares to purchase a travel package of both a flight and hotel room.[1] Online travel agencies provide consumers with incentives to purchase travel packages by offering significant monetary savings for consumers who purchase a hotel/airline ticket bundle with larger savings occurring at higher quality hotels (Kim et al., 2009).

Studying bundles empirically is challenging as researchers need to observe the prices of bundled and unbundled items simultaneously. Moreover, it is likely that costs to the seller vary significantly depending on whether the items are offered in a bundle or not. In this paper we take advantage of an interesting feature of online travel agencies. We simultaneously record the prices of the unbundled outbound and inbound flights—as if they were purchased separately—and the price of the round-trip bundle for the identical itinerary. The empirical strategy allows us to control for unobserved costs so that we can capture the bundling discount. Our unique dataset was collected using an automated spider that, in addition, has exogenous variation in variables that are aimed at capturing demand correlations between unbundled items, certainty about travel plans, and different levels of market competition.

Our theoretical model is set to explain bundling in advance purchases. We have risk-averse consumers who buy tickets in advance, and for them buying a round-trip bundle is riskier than buying the outbound and the inbound tickets separately. Travelers will be willing to take more risk from buying the round-trip bundle, however, if the bundle discount is large enough. The theory presents three main empirical implications. First, bundle discounts exists in advance sales. Second, the bundle discount increases as the correlation between the demands of the outbound and inbound flights increases. Third, bundle discounts decrease as travelers become more certain about their travel plans.

We find strong empirical support to these three empirical implications. First, we find

[1] Such bundles are likely to be more profitable than selling just an airline ticket given the commission from hotel bookings can be as large as 30% while airline ticket commissions are usually 2% (Salzman, 2013).

robust evidence that bundling discounts exist when buying a round-trip ticket rather than two one-way tickets separately. This is at odds with the large literature on airline pricing that uses data from the Bureau of Transportation and Statistics and simply assumes that one way prices are always half of round-trip prices (see, e.g., Brander and Zhang, 1990; Borenstein and Rose, 1994; and Gerardi and Shapiro, 2009). Second, our estimates show that bundling discounts are higher for tickets that include a Saturday-night stayover restriction, suggesting that bundling discounts increase when the correlation between demands is higher. Third, we find that bundling discounts decrease as the flight date nears, consistent with smaller discounts for consumers who have a higher probability of a positive demand. When considering the role of market structure, the results show that competition decreases bundling discounts.

In this paper we refer to a bundle as a round-trip ticket purchase in comparison to two one-way tickets which are considered unbundled. Airlines offer travelers a mixed bundle (Adams and Yellen, 1976) since consumers can purchase either a round-trip ticket or two one-way tickets of the same itinerary. However, anecdotal evidence supports the claim that selling a bundle could be more profitable for airlines since a bundled round-trip airline ticket is the default option in the largest US airlines websites for consumers searching for airline tickets. Evans and Salinger (2005) suggest that bundling offers efficiencies for firms due to marginal cost savings, quality improvements, and customer convenience. Marginal cost savings have been used to explain bundle discounts in both the production of physical goods (Hanson and Martin, 1990) and in the service industry (Guiltinan, 1987). Hence airlines may have lower marginal costs of issuing a round-trip ticket compared to issuing two separate one-way tickets. Others have also studied bundling in the airline industry as Gillen and Morrison (2003) examine the interaction between low cost carriers and full service carriers, where flights are a component of a larger bundle of goods that comprise air travel demand.

To the best of our knowledge, our analysis is the first to analyze demand uncertainty in bundling. While Alexandrov and Bedre-Defolie (2014) theoretically show the equivalence of bundling and advance sales, we model bundling in advance sales and show that mixed bundling is optimal when the correlation of valuations between the two goods is positive. Note that we do not contradict the the literature of bundling theory which find that mixed bundling is generally supported by a negative correlation between the valuations of the two goods, for example, Schmalensee (1984), Long (1984), Fang and Norman (2006), Chen and Riordan (2013), and Chen and Ni (2017). In those models, the correlation is calculated between buyers and derived from the seller's beliefs about each buyer's valuations since they are not observable by the seller. In contrast, the correlation in our model is calculated within a buyer and derived from the buyers' perspective since their valuations are random at the time of purchase.[2]

While this paper examines the bundle "discounts" from the purchase of a round-trip ticket compared to the unbundled price of purchasing two one-way tickets, an alternative view would label this "discount" as a penalty imposed on buyers who refuse to bundle. For example, Dillbary (2010) and Elhauge (2009) examine situations where bundle discounts can produce anticompetitive effects. The legal implications of bundle discounts are beyond the scope of this paper. The rest of the paper is structured as follows. Section 2 presents the theoretical model, including the optimal bundle scheme and the empirical implications. Section 3 presents the empirical analysis by first describing the bundling discounts, then setting the empirical model, and closing with the results. Section 4 concludes.

2 Theoretical Model

We propose a simple theoretical model that supports mixed bundling in a monopoly market. We assume that the seller produces and sells two goods, a and b, to three types of buyers, A, B, and AB. Type-A buyers consider buying only a, type-B buyers consider buying only b, and type-AB buyers consider buying both a and b. Unlike most bundling models that were built on Adams and Yellen (1976), we assume that the buyers make their purchase decisions in advance so they do not know their reservation prices with certainty. Since each advance-purchase decision involves risk, we use a random variable to represent each buyer's valuation of each good and assume that all players are risk averse. Thus, the ex-ante willingness to pay for both goods for type-AB buyers, depends not only on the distribution of each random variable, but also the correlation between the two random variables which

[2]Similar to the case of positive correlation, our claim that a bundle discount is not necessary when the correlation between the two valuations is zero does not contradict McAfee et al. (1989) who show that mixed bundling is an optimal strategy for a monopolist under the assumption on the reservation values being independently distributed.

is assumed to be nonnegative in our model.

We find that mixed bundling is optimal under the assumptions of positive correlation and risk-averse buyers. The intuition is as follows. Since a higher correlation implies a larger degree of combined risk, we find that the seller needs to offer a larger bundle discount for buyers with a larger correlation between the two valuations. Given an optimal price of a and b the seller sets for type-A and type-B buyers respectively, type-AB buyers will not buy both a and b without a large enough bundle discount because they face a larger risk than each of type-A or type-B buyers. If the bundle discount is not larger than the reservation price for a single good, the buyers who consider buying only one of the goods will not switch to buying a bundle and discard the good that they do not want. This is analogous to price discrimination via quantity discount. Given a zero marginal cost, mixed bundle pricing in our framework can increase both the firm's profit and social welfare.

2.1 Ex-ante willingness to pay for a bundle

Suppose that a monopolist sells two goods, a and b, in advance. The valuation of each good is not known at the time of purchase. We assume that, for $k = a, b$, the valuation of good k at the time of purchase is represented by random variable V_k which takes a strictly positive value of v with probability $\pi \in (0, 1)$ and zero with probability $1-\pi$. Even though V_a and V_b are identically distributed, they are not necessarily independent. The joint probabilities of the two variables are given in Table 1 where $\rho \in [0, 1]$ is Pearson's correlation coefficient.[3] Given the bivariate binomial distribution assumed in this paper, ρ represents how likely the valuation for a good is positive given the valuation for the other good is positive (or how likely the valuation for a good is zero given the valuation for the other good is zero). Specifically, the joint probabilities in Table 1 imply the following conditional probabilities:

$$Prob(V_k = v | V_l = v) = (1 - \rho)\pi + \rho \tag{1}$$

and

$$Prob(V_k = v | V_l = 0) = (1 - \rho)\pi \tag{2}$$

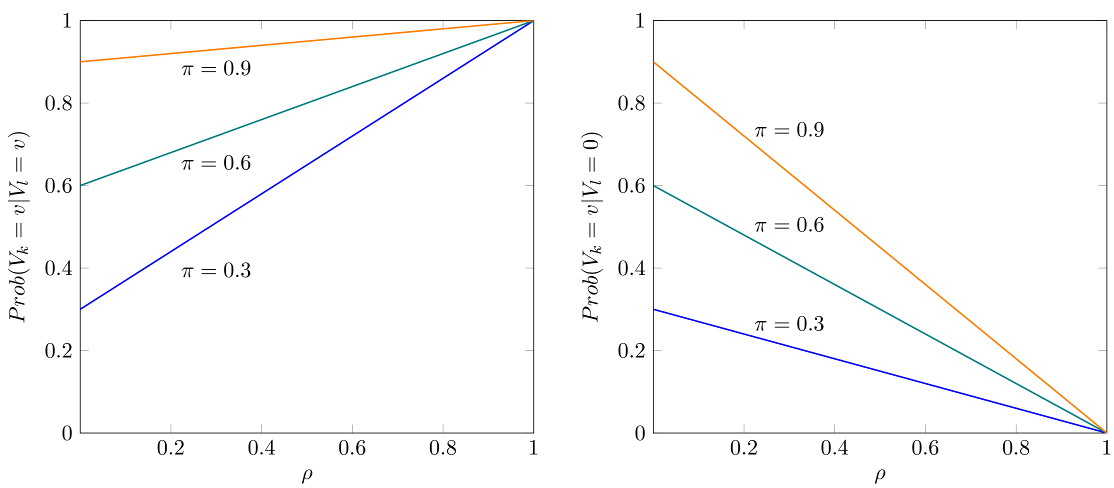
[3] See Biswas and Hwang (2002) for a more general class of bivariate binomial distributions where $Prob(V_a = v) \neq Prob(V_b = v)$ and $\rho < 0$.

where $k, l = a, b$ and $k \neq l$. Thus, the probability that $V_k = v$ given $V_l = v$ is a weighted average between π and 1 while the probability that $V_k = v$ given $V_l = 0$ is a weighted average between π and 0. These conditional probabilities are dependent on ρ as illustrated in Figure 1.

Table 1: Joint probabilities of V_a and V_b

	$V_b = v$	$V_b = 0$
$V_a = v$	$[(1-\rho)\pi + \rho]\pi$	$(1-\rho)(1-\pi)\pi$
$V_a = 0$	$(1-\rho)(1-\pi)\pi$	$[1-(1-\rho)\pi](1-\pi)$

Figure 1: Conditional probabilities given π and ρ



Suppose that the consumer has a utility function u and an initial wealth w_0. Given the joint probabilities in Table 1, we can derive his ex-ante willingness to pay for a bundle of goods a and b, denoted by x, under expected utility theory from

$$[(1-\rho)\pi + \rho]\pi u(w_0 + 2v - x) + 2(1-\rho)(1-\pi)\pi u(w_0 + v - x)$$
$$+ [1-(1-\rho)\pi](1-\pi)u(w_0 - x) = u(w_0). \tag{3}$$

We derive important properties of x in the following proposition.

Proposition 1. *Given an increasing utility function u, x is*

(i) increasing in π for any given ρ, and

(ii) decreasing (constant/increasing) in ρ for any given π if u is concave (linear/convex).

Proof. See Appendix A.1.

2.2 Optimal bundling scheme

Assume that the firm produces and sells goods a and b at zero marginal cost to consumers who are categorized as one of the three types: A, B, and AB. The consumers who consider buying both a and b, i.e., both $Prob(V_a = v)$ and $Prob(V_b = v)$ are strictly positive as analyzed above, are called type AB. Type-A consumers are those who consider buying only good a and type-B consumers are those who consider buying only good b. Specifically, we assume that $Prob(V_a = v)$ for type-A consumers and $Prob(V_b = v)$ for type-B consumers are equal to π, and $Prob(V_b = v)$ for type-A consumers and $Prob(V_a = v)$ for type-B consumers are zero. See Table 2.

Table 2: Three consumer types

	$Prob(V_a = v)$	$Prob(V_b = v)$
Type A	π	0
Type B	0	π
Type AB	π	π

Given a utility function u and the initial wealth w_0, a type-A consumer's willingness to pay for good a (and a type-B consumer's willingness to pay for good b) can be derived under expected utility theory as y such that

$$\pi u(w_0 + v - y) + (1 - \pi)u(w_0 - y) = u(w_0). \tag{4}$$

To obtain closed-form solutions for x in (3) and and y in (4), we assume the following utility function:

$$u(w) = 1 - e^{-rw} \tag{5}$$

where $r > 0$. This utility function is strictly concave and has a constant measure of absolute risk aversion r. It follows that

$$x = -\frac{1}{r} \ln\{[\pi(e^{-rv} - 1) + 1][(1 - \rho)\pi(e^{-rv} - 1) + 1] + \rho\pi e^{-rv}(e^{-rv} - 1)\}. \tag{6}$$

and

$$y = -\frac{1}{r} \ln[\pi(e^{-rv} - 1) + 1]. \tag{7}$$

To maximize profit, the firm chooses one of the three bundling schemes: components, pure bundling, and mixed bundling. In components sales, the firm sells the two goods separately at the price of p^a for good a and p^b for good b. In pure-bundling sales, the firm sells the two goods in a bundle (one unit of each good in each bundle) at the price of p^{ab}. In mixed-bundling sales, the firm offers the two goods separately, at p^a for good a and p^b for good b, and also in bundles, at p^{ab} per bundle.

We assume that all consumers will not purchase more than one unit of each good and that type-AB will either buy a unit of each good or nothing at all. In components selling, type-A consumers buy good a if and only if $p^a \leq y$. Type-B consumers buy good b if and only if $p^b \leq y$. Type-AB consumers buy both goods if and only if $p^a + p^b \leq x$. In pure-bundling sales, type-A and type-B consumers buy a bundle (and discard the undesired good) if and only if $p^{ab} \leq y$, while Type-AB consumers buy a bundle if and only if $p^{ab} \leq x$.

In mixed-bundling sales, type-A consumers buy good a if and only if $p^a \leq \min(y, p^{ab})$ and buy a bundle if and only if $p^{ab} < \min(y, p^a)$. Type-B consumers buy good b if and only if $p^b \leq \min(y, p^{ab})$ and buy a bundle if and only if $p^{ab} < \min(y, p^b)$. Type-AB consumers buy a bundle if and only if $p^{ab} \leq \min(x, p^a + p^b)$ and buy the two goods separately if and only if $p^a + p^b < \min(x, p^{ab})$.

Proposition 2. *Given the utility function in (5),*

(i) $x < (=)\ 2y$ *if and only if* $\rho > (=)\ 0$, *and*

(ii) mixed bundling with $p^{ab} = x$ *and* $p^a = p^b = y$ *strictly (weakly) dominates components selling and pure bundling if and only if* $\rho > (=)\ 0$.

Proof. See Appendix A.2.

If all consumers are risk neutral, (3) and (4) imply that $x = 2y$ and $y = \pi v$ for all ρ. Thus, a type-AB consumer is indifferent between buying each good separately at the unit price of πv and a bundle of the two goods at the bundle price of $2\pi v$, regardless of the correlation coefficient. The firm will be indifferent between component sales and mixed bundling for any value of ρ.

2.3 Optimal bundle discount

We define the discount value as

$$\gamma = p^a + p^b - p^{ab} \tag{8}$$

and the discount rate (in percentage) as

$$\delta = \frac{\gamma}{p^a + p^b} \times 100 = \left(1 - \frac{p^{ab}}{p^a + p^b}\right) \times 100. \tag{9}$$

Since mixed bundling is optimal, the firm sets $p^{ab} = x$ and $p^a = p^b = y$ where x and y are given by (6) and (7) respectively. We obtain the following properties of γ.

Proposition 3. *Assume the utility function in (5).*

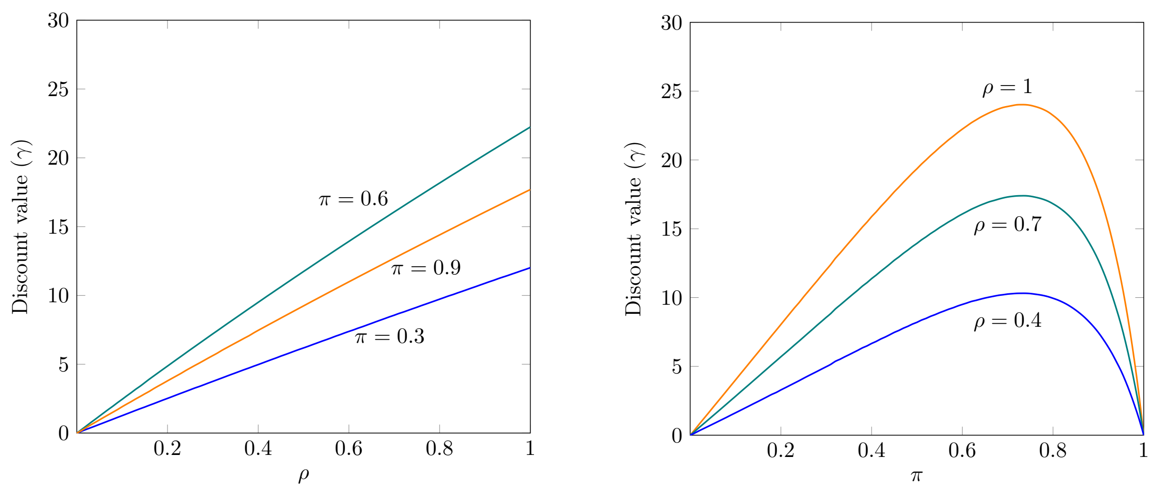
(i) γ *is strictly positive for all* $\rho \in (0, 1]$ *and* $\pi \in (0, 1)$.

(ii) γ *is strictly increasing in* ρ *for all* $\rho, \pi \in (0, 1)$, *and* $\gamma \downarrow 0$ *as* $\rho \downarrow 0$.

(iii) γ *is strictly decreasing (increasing) in* π *for all* $\pi > (<) \frac{1}{1+e^{-rv}}$ *and* $\rho \in (0, 1]$, *and* $\gamma \downarrow 0$ *as* $\pi \uparrow 1$ *or* $\pi \downarrow 0$.

Proof. See Appendix A.3.

Figure 2: Bundle discount values given $r = 0.01$ and $v = 100$



For example, given $r = 0.01$, $v = 100$, and $\pi \in \{0.3, 0.6.0.9\}$, we can plot the value of bundle discount, γ, as a function of ρ for a given value of π in the left panel of Figure 2.

It shows that, for any given π, a larger γ is needed for a type-AB consumer to buy a bundle for a larger ρ as proposed in Proposition 3 (ii). The effect of π on γ, however, is non-monotonic as illustrated in in the right panel of Figure 2. According to Proposition 3 (iii), γ decreases (increases) in π whenever π is larger (smaller) than $\frac{1}{1+e^{-rv}} = 0.7311$. Moreover, the magnitude of the effect from a change in π on γ is larger as ρ increases. This is consistent with the result in Proposition 3 (iv); $\frac{\partial\gamma}{\partial\pi}$ increases (decreases) as ρ increases when $\frac{\partial\gamma}{\partial\pi}$ is positive (negative), i.e., when π is smaller (larger) than 0.7311. This results is also illustrated in the right panel of Figure 2; $\frac{\partial\gamma}{\partial\rho}$ increases (decreases) as π increases whenever π is smaller (larger) than 0.7311.

Now we analyze the corresponding bundle discount rate (δ). Given $\delta = \frac{\gamma}{\Sigma} \times 100$ where $\Sigma = p^a + p^b$. It follows immediately that $\delta > 0$ for all $\pi \in (0,1)$. Since Σ does not depend on ρ, then $\frac{\partial\delta}{\partial\rho} = \frac{\partial\gamma}{\partial\pi} \times \frac{100}{\Sigma} > 0$ for all $\pi \in (0,1)$. Given $\frac{\partial\delta}{\partial\pi} = \left(\Sigma\frac{\partial\gamma}{\partial\pi} - \gamma\frac{\partial\Sigma}{\partial\pi}\right) \times \frac{100}{\Sigma^2}$, where $\frac{\partial\gamma}{\partial\pi} \lesseqqgtr 0$ if $\pi \gtreqqless \frac{1}{1+e^{-rv}}$ and $\frac{\partial\Sigma}{\partial\pi} > 0$ for all $\pi \in (0,1)$, then we know that there exists a threshold value $\bar{\pi} < \frac{1}{1+e^{-rv}}$ such that $\frac{\partial\delta}{\partial\pi} < 0$ for all $\pi \in (\bar{\pi}, 1)$. Thus, as π increases from zero to one, δ begins to fall and converge to zero before γ does. We summarize these results in the following Corollary.

Corollary 1. *Assume the utility function in (5).*

(i) δ *is strictly positive for all* $\rho \in (0,1]$ *and* $\pi \in (0,1)$.

(ii) δ *is strictly increasing in* ρ *for all* $\rho, \pi \in (0,1)$, *and* $\delta \downarrow 0$ *as* $\rho \downarrow 0$.

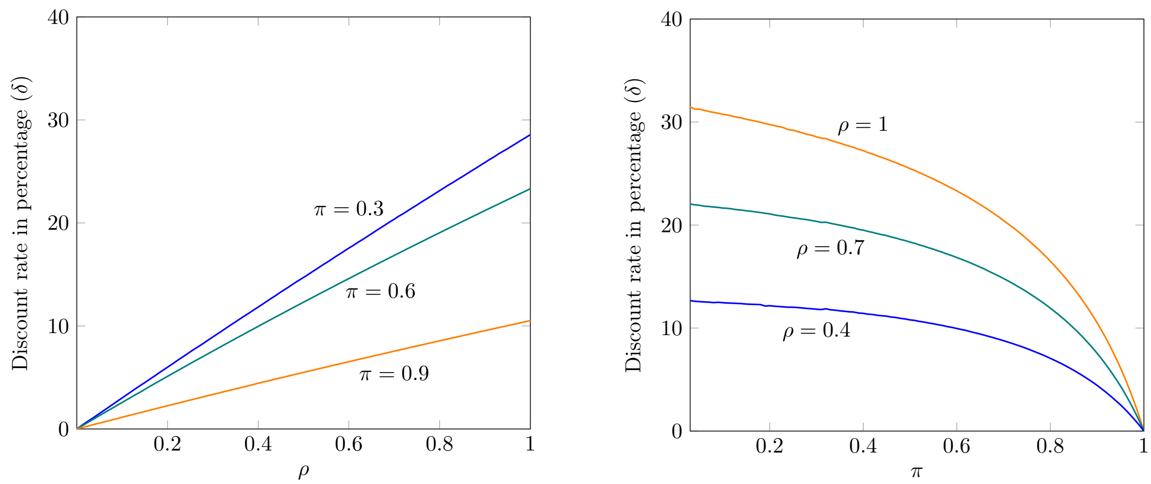
(iii) There exists $\hat{\pi} \in \left[0, \frac{1}{1+e^{-rv}}\right)$ *such that* δ *is strictly decreasing in* π *for all* $\pi \geq \hat{\pi}$ *and* $\rho \in (0,1]$, *and* $\delta \downarrow 0$ *as* $\pi \uparrow 1$.

Consider the same numerical example above. Given $r = 0.01$ and $v = 100$, we plot the corresponding bundle discount rate, δ, as a function of ρ for a given value of π and as a function of π for a given value of ρ in Figure 3. Note that for this set of parameters, $\hat{\pi} = 0$ so that δ is strictly decreasing in π for all $\pi \in (0,1)$.

2.4 Empirical implications

In this section we discuss the empirical implications of our theoretical model on airline ticket prices. Following our theoretical model, airline sellers provide outbound and inbound flights

Figure 3: Bundle discount rates given $r = 0.01$ and $v = 100$



between airport pairs and offer three different tickets: outbound (good a), inbound (good b), and round-trip (bundle ab) to three types of buyers: A, B, and AB. Since the correlation between the outbound and inbound flights is positive for type-AB buyers, Proposition 3 predicts that the seller should offer mixed bundling tickets. That is consistent with what we observe in airline markets as buyers can either buy the outbound and inbound separately or in a bundle.

Buyers arrive at the market before their departure date and purchase a ticket in advance if the fare is not greater than their ex-ante willingness to pay. Otherwise, they leave the market without buying. Our model can explain third-degree price discrimination by airlines. Airlines sell tickets in advance and the length of time between buyers arriving at the market and their departure date is negatively related to the probability that their valuation is positive. That is, as the departure date approaches, the probability of having a positive demand π increases as in Escobari and Jindapon (2014). Thus, (6) and (7) predict that outbound, inbound, and round-trip bundle prices will all increase as the departure date approaches, a feature that has been widely documented for airline prices (see, e.g., Escobari (2012) and Alderighi et al. (2015)). Proposition 2 part 3 predicts that the round-trip discount increases and then decreases as the departure date approaches.

A widely known screening device that airlines employ to separate between consumer types and second-degree price discrimination is the Saturday-night stayover restriction (Stavins, 2001). In this paper we also aim to assess the effect of the Saturday night-stay on the bundling discount. Business travelers are less likely to stay for the Saturday-night have a lower ρ (the demand correlation between a and b) as they are less likely to have definite plans. ρ is higher for tourists because once they already decided the date of the outbound, the date of the return is more certain. This suggests that the joint probability that both demands are positive is higher for tourists.

After understanding what π and ρ capture in airline markets, we obtain the following hypotheses from the theoretical predictions in Corollary 1.

Hypothesis 1. Bundle discount values and bundle discount rates are positive.

Hypothesis 2. Bundle discount values and bundle discount rates are larger for tickets with Saturday-night stay.

Hypothesis 3. Bundle discount values and bundle discount rates are smaller closer to departure.

3 Empirical analysis

3.1 Data and discounts

We used a spider to collect a unique panel dataset of posted fares from a U.S. online travel agency during the third quarter of 2017. The key advantage of our data construction is that we collected fare quotes simultaneously for the same seats for both roundtrip itineraries for the bundle ab and corresponding one-way fares for identical itineraries that capture the prices for the outbound a and the inbound b. Hence, we can use (8) to calculate the bundle discount value γ_{ijt} for flights i on route j at time t as:

$$\gamma_{ijt} = p^a_{ijt} + p^b_{ijt} - p^{ab}_{ijt}, \tag{10}$$

where p^a_{ijt} is the one-way outbound price, p^b_{ijt} is the one-way inbound price, and p^{ab}_{ijt} is the round-trip bundle from buying outbound and inbound together. By looking at the difference between $p^a_{ijt} + p^b_{ijt}$ and p^{ab}_{ijt} we are able to difference out any costs that change at the seat level, including capacity costs that arise due to aggregate demand uncertainty (see, e.g., Dana, 1999). Following (9), we are also interested in the discount rate δ_{ijt}, calculated as

$$\delta_{ijt} = \frac{\gamma_{ijt}}{p^a_{ijt} + p^b_{ijt}} \times 100 = \left(1 - \frac{p^{ab}_{ijt}}{p^a_{ijt} + p^b_{ijt}}\right) \times 100. \tag{11}$$

Our dataset incorporates three important features. First, we collected quotes at multiple times t prior to departure to be able to assess the role of the probability of having a positive demand π on discounts. Second, the sample contains two sets of roundtrip tickets, one that includes a Saturday-night stayover (outbound is Tuesday, October 3, and inbound is Tuesday, October 10) and one that does not (outbound is Tuesday, October 3 and inbound is Thursday October 5). This will allow us to assess the role of demand correlation ρ on the discount. Third, we examine the role of competition on bundle discounts since our sample includes a variety of market structures: 60 monopoly routes, 54 duopoly routes, 31 routes with three carriers, and 21 routes with four or more carriers.

Overall, the panel data includes 602,088 prices on 332 directional airport-pair routes (166 round-trip routes). Following Escobari and Jindapon (2014), we focus on single departure dates to help control for likely differences in prices and consumer heterogeneity across different day-of-the-week departures. The panel structure of our data is an improvement over Stavins (2001) as we can control for unobserved flight and route specific characteristics. As in Escobari (2012), all fares are non-refundable economy class to account for potential price differences associated with more complex itineraries and potential consumer heterogeneities (e.g., refundable tickets have a refundability premium). Each cross-sectional unit is a flight and we recorded prices every day for 51 days as the departure date approached. The carriers in the sample are Alaska, American, Delta, Frontier, Jet Blue, Southwest, Spirit, United, and Virgin, where the proportion of flights by carrier was selected to be close to the share of the carrier in the U.S. market.

Table 3 presents the summary statistics. Consistent with the existence of a bundle discount, the average of roundtrip fares p^{ab}_{ijt} (\$306.70) is less expensive than the sum of the average outbound p^a_{ijt} and inbound p^b_{ijt} prices (\$179.9+\$191.5=\$371.4). Moreover, the average inbound price is above the average of the outbound price. This can be explained by the fact that fares were recorded longer in advance for the inbound portion, and that fares typically increase as the departure date nears (see, e.g., Alderighi et al., 2015).

Table 3 shows that the average discount value is \$42.9 while the average discount rate

Table 3: Summary Statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
p^{ab}_{ijt} (Round-trip bundle price)	283,175	306.7	114.1	69.37	998.4
p^{a}_{ijt} (Outbound price)	319,224	179.9	112.4	45.20	915.2
p^{b}_{ijt} (Inbound price)	319,319	191.5	105.9	45.20	915.2
γ_{ijt} (Discount value)	283,175	42.90†	124.8	-363.0	1,467
δ_{ijt} (Discount rate)	283,175	8.674†	17.60	-147.8	85.47
$\tilde{\rho}_{ijt}$ (Saturday-night)	321,346	0.500	0.500	0	1
$\tilde{\pi}_{ijt}$ (Days)	321,346	25.52	14.86	1	52
HHI_{ij} (Concentration)	321,346	0.553	0.207	0.176	1
Alaska	321,346	0.0575	0.233	0	1
American	321,346	0.334	0.472	0	1
Delta	321,346	0.279	0.448	0	1
Frontier	321,346	0.00227	0.0476	0	1
Jet Blue	321,346	0.0138	0.117	0	1
Southwest	321,346	0.0227	0.149	0	1
Spirit	321,346	0.00741	0.0857	0	1
United	321,346	0.281	0.450	0	1
Virgin	321,346	0.00225	0.0474	0	1

Notes: † The null hypothesis that the mean is zero against the alternative that is positive has a p-value of 0.000.

is 8.67%. When testing the null hypothesis that the mean discount value and discount rate are equal to zero, we reject the null at the usual significance levels in both cases. We interpret this as strong empirical evidence supporting the first hypothesis from our theoretical model that the discount rate and discount value are positive. This result is important for the literature that uses airline prices from the popular DB1B data from the Bureau of Transportation Statistics as the standard assumption in this literature is that bundling discounts do not exist (i.e., $\gamma = \delta = 0$). For example, Borenstein and Rose (1994, pp. 677) explain that one-way fares are simply computed as one-half of the round-trip fare.[4] See also Borenstein (1989, pp. 349) and Gerardi and Shapiro (2009, pp. 5) for the same assumption.

3.2 Explaining the bundle discounts

Following hypotheses two and three, we are interested on how the discount value γ and the discount rate δ are affected by the demand correlation ρ and the probability of having a

[4]Earlier versions of these data are referred to as U.S. Department of Transportation's DB1A.

positive demand π. Hence, we estimate the following empirical specification:

$$\gamma_{ijt} = \beta_\rho \cdot \tilde{\rho}_{ij} + \beta_\pi \cdot \tilde{\pi}_{ijt} + \mu_{ij} + \varepsilon_{ijt}, \qquad (12)$$

where the dependent variable is the discount value γ_{ijt} (or the discount rate δ_{ijt}) on flights i, route j, and at time t.[5] $\tilde{\rho}_{ijt}$ is our empirical measure of ρ, and it is is an indicator variable equal to one if the itinerary includes a Saturday-night stay, zero otherwise. Moreover, $\tilde{\pi}_{ij}$ captures π and it is measured in number of days as the departure date nears. $\mu_{ij} + \varepsilon_{ijt}$ is the two-way error term.

Table 4: Monopoly estimates

VARIABLES	(1)	(2)	(3)	(4)
Panel A. Dependent Variable is the Discount Value γ				
$\tilde{\rho}$	127.0***		126.9***	149.3***
	(11.94)		(11.93)	(13.47)
$\tilde{\pi}$		-0.731***	-0.732***	-0.239***
		(0.0588)	(0.0587)	(0.0407)
$\tilde{\rho} \times \tilde{\pi}$				-0.904***
				(0.106)
Constant	75.94***	146.8***	-21.31	78.84***
	(22.40)	(1.481)	(23.29)	(22.11)
Observations	38,369	38,369	38,369	38,369
R-squared		0.072		
Panel B. Dependent Variable is the Discount Rate δ				
$\tilde{\rho}$	12.37***		12.36***	14.81***
	(1.036)		(1.035)	(1.210)
$\tilde{\pi}$		-0.106***	-0.106***	-0.0521***
		(0.00714)	(0.00714)	(0.00562)
$\tilde{\rho} \times \tilde{\pi}$				-0.0990***
				(0.0131)
Constant	9.664***	18.55***	12.50***	14.31***
	(2.497)	(0.180)	(2.491)	(2.996)
Observations	38,369	38,369	38,369	38,369
R-squared		0.094		

Notes: The dependent variable in Panel A is the discount value γ_{ijt} as defined in Equation (10), while in Panel B is the discount rate δ_{ijt} as defined in Equation (11). We omit the Virgin America dummy. *** significant at 1%, ** significant at 5%, and * significant at 10%. The figures in parentheses are robust standard errors, clustered by flights.

Table 4 presents the carrier fixed effects regression estimates of Equation (12), where the dependent variable is either the discount value (panel A) or the discount rate (panel B). The specifications in column 2 additionally include flights i fixed effects. We treat μ_{ij} as

[5] Note that the results would be equivalent if we define a premium for one-way tickets instead of a roundtrip discount.

random in the specifications that include $\tilde{\rho}_{ij}$ to be able to identify β_ρ as $\tilde{\rho}_{ij}$ does not change over time. The numbers in parentheses are robust standard errors, clustered by flights. All the specifications in this table focus on monopoly routes to better match our theoretical model.

The first column (panels A and B) presents strong empirical support that higher correlation between demands for goods a and b increases the discount when purchased together as a bundle ab. Consistent with the left panel of Figure 2, the highly statistically significant point estimate in panel A shows that the discount value γ is \$127 higher when the bundle ab includes a Saturday-night stay. In terms of the discount rate, consistent with the left panel of Figure 3, panel B in Table 4 indicates that a when the Saturday-night stayover is met, the discount rate for purchasing the bundle increases by 12.4 percentage points. Our theoretical model suggests a possible explanation for this result. The discount exists since risk averse travelers do not like combining two positively correlated risks of the outbound a and the inbound b portions of the trip. Hence, business travelers are willing to pay less for the round-trip bundle ab (they face a larger discount value and discount rate) as their correlation between a and b is lower.

The point estimates on the second column (panels A and B) provide strong empirical support to our third hypothesis. Increasing the probability of positive demand π lowers the discount value (panel A) and the discount rate (panel B), with both marginal effects being highly statistically significant. As $\tilde{\pi}$ is measured in days, the reported point estimates show that travelers who buy ten days closer to departure face a discount value that is \$7.31 (panel A) or 1.06 percentage points (panel B) lower. Our theoretical setup helps us understand this negative coefficient, as illustrated in the right panel of Figure 2, for relatively large values of π, and in the right panel of Figure 3. When π is large enough, getting closer to the departure date moves π towards certainty of flying. This means that there is less risk associated with buying tickets in advance and the bundle becomes more attractive. Consequently, airlines reduce the magnitude of the bundle discount as the departure date nears. The third column provides both sets of results, for $\tilde{\rho}$ and $\tilde{\pi}$, with the magnitudes of the point estimates being nearly the same as in the previous columns.

The last column on Table 4 additionally reports the coefficient on the interaction $\tilde{\rho} \times \tilde{\pi}$. Along with the point estimates on $\tilde{\rho}$ and $\tilde{\pi}$, the negative and statistically significant coefficient on the interaction term indicates that a larger demand correlation increases discounts and this effect is larger when the probability of positive demand is lower. This is illustrated in the left panel of Figure 3, where the marginal effect of ρ on δ is positive but decreasing for higher values of π. Likewise, a higher probability of positive demand decreases discounts, with the marginal effect being larger for a higher demand correlation as illustrated in the right panel of Figure 3 by steeper curves at high values of ρ.

Note that airlines use these same Saturday-night restriction and advance purchase requirements as screening devices to second-degree price discriminate. That is, these restrictions serve to separate consumers who have different valuations for a ticket so that airlines can charge higher prices to the group of consumers who have higher valuations. Our empirical specifications control for differences in valuations as the left-hand side variable in the regression is not the price, but the differences in prices as defined in (10). The structure is analogous to the first difference in a difference-in-differences specification.

Table 5: All markets estimates

VARIABLES	(1)	(2)	(3)	(4)
Panel A. Dependent Variable is the Discount Value γ				
$\tilde{\rho}$	47.33***		47.33***	50.30***
	(2.219)		(2.218)	(2.595)
$\tilde{\pi}$		-0.112***	-0.113***	-0.0541***
		(0.0152)	(0.0152)	(0.00877)
$\tilde{\rho} \times \tilde{\pi}$				-0.115***
				(0.0298)
Constant	-3.714	45.75***	-0.755	-2.275
	(6.210)	(0.387)	(6.201)	(6.211)
Observations	283,175	283,175	283,175	283,175
R-squared		0.002		
Panel B. Dependent Variable is the Discount Rate δ				
$\tilde{\rho}$	7.394***		7.395***	8.076***
	(0.343)		(0.342)	(0.375)
$\tilde{\pi}$		-0.0518***	-0.0520***	-0.0385***
		(0.00233)	(0.00232)	(0.00222)
$\tilde{\rho} \times \tilde{\pi}$				-0.0264***
				(0.00458)
Constant	1.073	9.993***	2.439***	2.090**
	(0.891)	(0.0593)	(0.891)	(0.891)
Observations	283,175	283,175	283,175	283,175
R-squared		0.010		

Notes: The dependent variable in Panel A is the discount value γ_{ijt} as defined in Equation (10), while in Panel B is the discount rate δ_{ijt} as defined in Equation (11). We omit the Virgin America dummy. *** significant at 1%, ** significant at 5%, and * significant at 10%. The figures in parentheses are robust standard errors, clustered by flights.

Table 5 reports the results for all the 166 round-trip routes in the sample, including non-monopoly routes. Both panels show that across all specifications the coefficient on $\tilde{\rho}$ is positive and statistically significant, and the coefficient on $\tilde{\pi}$ is negative and statistically significant. All signs are consistent with the ones reported for monopoly markets. Greater correlation across demands and lower probabilities of positive demand, both increase the bundle discounts. We interpret this as strong evidence that our results hold beyond monopoly markets. Appendix B presents an analysis on the role of market structure.

4 Conclusion

Studying bundling empirically has been challenging due to lack of data. This paper takes advantage of a unique dataset where we simultaneously observe the prices of goods offered separately and as bundles. This allows us to test if bundling discounts exist. Moreover, we are able to capture exogenous variation in two key characteristics, the correlation between demands and the probability of having a positive demand. Our theoretical model, set to understand bundling during advance sales, offers three main empirical predictions. First, that bundling discounts exists. Second, that discounts increase with higher correlation between demands, and third that discounts decrease with the probability of having positive demands. Our theory is also consistent with increasing prices as departure date nears, a feature widely observed in the industry.

The empirical results show strong support to our theory. Using data from airlines where tickets can be bought as round-trip bundle or two separate one way tickets, we find that the discount from buying the round-trip bundle rather than two separate one-way tickets is on average \$42.9. Measured as a rate, the discount is 8.67% of the sum of unbundled prices. Greater correlation across demands increases the discounts because risk averse travelers do not like two positively correlated risks. Moreover, as the probability of having a positive demand increases closer to the departure date, bundling discounts are lower. We argue that this is because the risk of buying tickets in advance decreases.

In addition to the contribution for bundling theory and empirics, the results are important for airlines as the previous empirical work assumed that round-trip prices are simply the sum of one-way fares. When assessing the role of market structure we found that concentration increases discounts and also increases the effects of demand correlation and positive demand on bundling discounts. We interpret this as evidence that previous work that aimed at obtained the role of concentration on price dispersion is biased.

A Proofs

A.1 Proof of Proposition 1

Denote the left-hand side of (3) by $U(x;\pi,\rho)$. Define $\Delta_1 = u(w+v-x) - u(w-x)$ and $\Delta_2 = u(w+2v-x) - u(w+v-x)$. Given $u' > 0$, then $\frac{\partial U}{\partial x} < 0$, $\Delta_1 > 0$ and $\Delta_2 > 0$.

(i) We find $\frac{\partial U}{\partial \pi} = [2(1-\rho)\pi + \rho]\Delta_2 + [2(1-\rho)(1-\pi) + \rho]\Delta_1 > 0$. Therefore, $\frac{dx}{d\pi} = -\frac{\partial U/\partial \pi}{\partial U/\partial x} > 0$.

(ii) We find $\frac{\partial U}{\partial \rho} = (1-\pi)\pi(\Delta_2 - \Delta_1)$. Since $\Delta_2 \lesseqqgtr \Delta_1$ whenever $u'' \lesseqqgtr 0$, then $\frac{dx}{d\rho} = -\frac{\partial U/\partial \rho}{\partial U/\partial x} \lesseqqgtr 0$ whenever $u'' \lesseqqgtr 0$.

A.2 Proof of Proposition 2

(i) Given $\rho = 0$, then (6) can be written as

$$x = -\frac{1}{r}\ln\left\{[\pi(e^{-rv} - 1) + 1]^2\right\} \tag{13}$$

which is equal to $2y$ where y is derived in (7). Proposition 1 suggests that, given a concave u, x is decreasing in ρ. Since y does not depend on ρ, it follows immediately that $x < 2y$ if and only of $\rho > 0$.

(ii) Let n_τ be the number of type-τ buyers where $\tau = A, B, AB$. Let R_C, R_P, and R_M be the firm's revenue from components, pure-bundling, and mixed-bundling sales, respectively. Consider two possible cases.

Case 1: $\rho = 0$ (i.e. $x = 2y$). Under components selling, the firm sets $p^a = p^b = y$ so $R_C = (n_A + n_B + 2n_{AB})y$. Under pure bundling, the firm sets $p^{ab} = x$ so $R_P = n_{AB}x$, or $p^{ab} = y$ so $R_P = (n_A + n_B + n_{AB})y$. Under mixed bundling, the firm sets $p^{ab} = x$ and $p^a = p^b = y$. Thus, $R_M = n_{AB}x + (n_A + n_B)y$. Since $x = 2y$, then $R_M = R_C > R_P$.

Case 2: $\rho > 0$ (i.e., $y < x < 2y$). Under components selling, the firm's optimal price menu is one of the following: (1) $p^a = p^b = y$ so $R_C = (n_A + n_B)y$, (2) $p^a = y$ and $p^b = x - y$ so $R_C = n_A y + n_B(x - y) + n_{AB}x$, or (3) $p^a = x - y$ and $p^b = y$ so $R_C = n_A(x - y) + n_B y + n_{AB}x$. Under pure bundling, the firm sets $p^{ab} = x$ so $R_P = n_{AB}x$, or $p^{ab} = y$ so $R_P = (n_A + n_B + n_{AB})y$. Under mixed bundling, the firm sets $p^{ab} = x$ and $p^a = p^b = y$ so that $R_M = n_{AB}x + (n_A + n_B)y$. Since $x < 2y$, then $R_M > \max(R_C, R_P)$.

A.3 Proof of Proposition 3

The firm sets $p^{ab} = x$ and $p^a = p^b = y$ where x and y are given by (6) and (7), respectively.

(i) Given the utility function in (5), Proposition 2 (i) implies $\gamma > 0$ for all $\pi \in (0, 1)$.

(ii) Given the utility function in (5), Proposition 1 (ii) implies γ is strictly increasing in ρ. Thus, Proposition 1 (ii) and Proposition 2 (i) together imply $\gamma \downarrow 0$ as $\rho \downarrow 0$.

(iii) Given x in (6) and y in (7), we can write

$$\gamma = \frac{1}{r} \ln \left\{ \frac{\phi}{[\pi(e^{-rv} - 1) + 1]^2} \right\}. \tag{14}$$

where

$$\phi = [\pi(e^{-rv} - 1) + 1][(1 - \rho)\pi(e^{-rv} - 1) + 1] + \rho\pi e^{-rv}(e^{-rv} - 1) > 0. \tag{15}$$

We find that

$$\frac{\partial \Delta}{\partial \pi} = \frac{\rho(e^{-rv} - 1)^2 \psi}{r[\pi(e^{-rv} - 1) + 1]^2 \phi} \tag{16}$$

where

$$\psi = (1 - e^{-2rv})\pi^2 - 2\pi + 1. \tag{17}$$

Thus, the sign of $\frac{\partial \Delta}{\partial \pi}$ is the same as the sign of ψ which is a quadratic function of π. It follows that $\psi < 0$ if and only if $\frac{1}{1+e^{-rv}} < \pi < \frac{1}{1-e^{-rv}}$. Given $0 < \frac{1}{1+e^{-rv}} < 1 < \frac{1}{1-e^{-rv}}$ for all r and v, we find that $\frac{\partial \Delta}{\partial \pi} < (>)\ 0$ if $\pi > (<)\ \frac{1}{1+e^{-rv}}$ for all $\pi \in (0, 1)$. Given $\pi = 1$, (3) and (4) imply $x = 2v = 2y$ and, as a result, $\Delta = 0$. Therefore, $\Delta \downarrow 0$ as

$\pi \uparrow 1$. Given $\pi = 0$, (3) and (4) imply $x = y = 0$ and, as a result, $\Delta = 0$. Therefore, $\Delta \downarrow 0$ as $\pi \downarrow 0$.

B The role of market structure

Formally extending our theoretical model to include competition is challenging because we would need to have an equilibrium concept, in addition to showing its existence and uniqueness. Moreover, a model that includes competition would probably need assumptions on the structure of competition, e.g., to model if competition is on prices or on quantities. It is possibly that because of these complications, most papers on optimal bundling focus on monopoly markets (see, e.g., Adams and Yellen, 1976; Guiltinan, 1987; Hanson and Martin, 1990).[6] With our theoretical model as the starting point, it is reasonable to argue that competition is likely to decrease bundling discounts. In a perfectly competitive market, prices are set to be equal to the marginal cost. Then, because marginal costs of providing a and b is the same as marginal costs of ab, there should be no price markup over marginal costs; hence, no bundling discounts.

Table B1 presents the regression results where we interact $\tilde{\rho}$ and $\tilde{\pi}$ with the Herfindahl-Hirschman Index (HHI) on each route. We use the number of direct flights on each route to capture each of the carriers' shares, and then use these shares to obtain the HHI. HHI captures the level of competition in a route, where higher values indicate more concentrated markets. We assume that HHI is exogenous in our bundling discount equation. This is consistent with Stavins (2001), who assumes that the HHI is exogenous in her pricing equation. We believe our assumption is milder as bundling discounts are less likely to trigger changes in scheduled flights. Moreover, we note the sequential nature of airline operational decisions—they schedule flights and assign aircraft capacity many months in advance of departure and then they sell tickets. This sequence of decisions is consistent with HHI not responding to prices. We are aware that some airline pricing papers instrument for HHI (e.g., Borenstein and Rose, 1994), but in these papers the data spans over various months or years, giving airlines sufficient time to adjust their scheduled flights in response to prices from previous flights. In our two-month sample period HHI is constant as we did not observe

[6] One exception is Zhou (2021) who examines mixed bundling in oligopoly markets.

any changes in the number of flights for any of our routes.

Table B1: Role of market structure on bundling discounts

Dependent Variable:	Discount value γ			Discount rate δ		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$\tilde{\rho}\times$ HHI	172.0***		172.0***	12.18***		12.18***
	(18.95)		(18.96)	(1.869)		(1.871)
$\tilde{\pi}\times$ HHI		-1.276***	-1.276***		-0.138***	-0.138***
		(0.0980)	(0.0980)		(0.0123)	(0.0123)
HHI	67.45***	193.9***	100.6***	9.079***	19.27***	12.67***
	(5.632)	(14.61)	(7.018)	(0.730)	(1.319)	(0.850)
$\tilde{\rho}$	-46.27***	45.84***	-46.29***	0.718	7.246***	0.715
	(9.117)	(2.083)	(9.125)	(1.069)	(0.336)	(1.070)
$\tilde{\pi}$	-0.112***	0.611***	0.611***	-0.0519***	0.0265***	0.0265***
	(0.0152)	(0.0553)	(0.0553)	(0.00232)	(0.00708)	(0.00708)
Constant	13.21***	-54.64***	-5.811	2.499***	-3.023***	0.438
	(4.895)	(8.346)	(4.890)	(0.636)	(0.990)	(0.651)
Observations	283,175	283,175	283,175	283,175	283,175	283,175

Notes: The dependent variable in columns 1 through 3 is the discount value γ_{ijt} as defined in Equation (10), while in columns 4 through 6 is the discount rate δ_{ijt} as defined in Equation (11). We omit the Virgin America dummy. We omit the American Airlines dummy. *** significant at 1%, ** significant at 5%, and * significant at 10%. The figures in parentheses are robust standard errors, clustered by flights.

Across all columns of Table B1, HHI has a positive and statistically significant effect on the discount value and the discount rate. For example, column 1 shows that for the average $\tilde{\rho}$, the marginal effect of a one-point increase in HHI on the discount value is about \$153.45 (\$67.45+0.5×\$172.0). Consider the most extreme cases in our sample where HHI goes from a minimum of 0.176 to a maximum of 1. We estimate that the most concentrated routes, based on the HHI, have discount values approximately \$126.44 (\$153.45×(1-0.176)) higher than in the most competitive routes. Calculating the impact of the same extreme change in HHI on discount rates using column 4 estimates reveals that the most competitive routes in our sample have discount values that are about 13.78 percentage points lower than monopoly routes. The marginal effects are consistent across all columns, showing robust evidence that market concentration increases bundle discounts.

When assessing how demand correlation between the inbound and the outbound, and the probability of having a positive demand change with market structure, both marginal effects show intuitive results. We previously found that higher correlated risks associated with the consumption of two positively correlated goods will increase the discount. The point estimate of 172 on the interaction $\tilde{\rho}\times$HHI reported in column 1 suggests that this effect is greater in more concentrated markets. Moreover, columns 2 and 5 support the theoretical prediction that as uncertainty about consuming the bundle disappears the bundle discount decreases. This effect is larger in more concentrated markets.

Our results that bundling discounts decrease with competition is in line with Gerardi and Shapiro (2009), who find that competition has a negative effect on price dispersion. However, because their data does not allow to measure bundling discounts, they are likely to be underestimating the effect of competition on price dispersion. Moreover, our results additionally suggest that the estimates on the role of competition on price dispersion in Borenstein and Rose (1994), who also assume bundling discounts are zero, are likely to be biased.

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