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Bidding for Bidders? How the Format for Soliciting Supplier Participation in NYOP Auctions Impacts Channel Profit

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In a name-your-own-price (NYOP) auction, consumers bid for a product or service. If a bid exceeds the concealed threshold price, the consumer receives the product at her bid price. This paper examines how to optimize the interactions between the NYOP retailer and service providers, while, at the same time, managing the bid acceptance rates in order to induce the desired consumer bidding behavior. Channel profit is impacted by how the retailer decides whether or not a given consumer bid will be accepted and, if so, which service provider is chosen to supply a unit of the product to the consumer. We devise a mechanism, the modified second-price auction, which maximizes channel profit.

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1. Introduction

The name-your-own-price (NYOP) mechanism is a customer-driven pricing strategy invented by Priceline.com to sell travel reservations on the Internet. Under NYOP, consumers bid for a product or service. If a bid exceeds the concealed threshold price, the consumer receives the product at her bid price. Other retailers use the NYOP system to sell both travel services (e.g., Germanwings) and nontravel services (e.g., Chiching.com, which offers restaurant meals and beauty/fitness services; eBay sellers who employ eBay's "Best Offer" feature; the Gap's usage of its "Gap My Price" promotion) (Spann et al. 2010, Conlan 2011).

Many current NYOP retailers (e.g., Priceline.com, Chiching.com, Prisminister.dk) are intermediaries that rely on service providers (such as airlines, hotels, and car rental companies) to provide the service offerings. An NYOP intermediary has to make two interrelated decisions: First, he must set the hidden threshold price policy that will determine which consumer bids will be accepted. The acceptance threshold policy influences how much consumers bid.[1] Second, he must determine which service provider is selected to fulfill the demand from each consumer. These two decisions are interrelated because the threshold prices typically depend on the wholesale costs the intermediary is facing, which are in turn driven by the mechanism used to select suppliers. While prior work in the literature has addressed the first decision, i.e., how to set the threshold (e.g., Fay 2009, Shapiro and Zillante 2009, Wang et al. 2009, Zeithammer 2015), this is the first paper, to our knowledge, to endogenize the second decision, i.e., how to procure the good. Thus, we provide the first complete model of a two-sided NYOP market.

We identify how to structure the NYOP channel in order to maximize total channel profit. At first glance, an NYOP retailer's role in an NYOP auction seems deceptively simple: the NYOP retailer creates a marketplace, facilitating the communication of a consumer bid to sellers and letting the sellers decide whether or not to accept a bid. We show, however, that such a passive approach (which we term "demand collection") results in suboptimal profit because it induces relatively low bids from potential customers. Instead, to maximize channel profit, we show that the NYOP

[1] Although NYOP sellers do not reveal the threshold price that is in effect at any given moment, they often communicate a bid-acceptance schedule to help consumers make more informed bid decisions. For example, Lufthansa accepts bids for upgrades under their "myOffer" program and shows a "strength meter" to indicate how "strong" the amount of the offer is. Similarly, Greentoe.com, MeanBuy.com, and ScoreBig.com use a "PriceMeter," "Chance" sliding scale, and color-coded "bid success potential," respectively, to convey the approximate probability that a bid will be accepted.

retailer must actively manage the acceptance rate associated with any particular bid submitted by a consumer while at the same time soliciting bids from potential service providers in a way that their true costs can be uncovered. We identify one such mechanism that uncovers supplier costs while procuring their services only when there is an acceptable buyer; we call it the modified second-price (MSP) auction. In the MSP auction, service providers bid in a reverse second-price, sealed-bid auction for the right to supply the product. Our mechanism "modifies" the standard second-price, sealed-bid auction by making the reservation price depend on the level of the consumer's bid in a particular way that maximizes overall channel profit. The chosen procurer is thus the service provider who submits the lowest bid, and the price this winning supplier receives is the lesser of the next lowest bid submitted by a rival supplier and the reservation price. The reserve price is calibrated to replicate the optimal bid-acceptance strategy derived in Zeithammer (2015), and MSP generates the optimal channel profit because it both achieves the optimal number of trades and ensures that the low-cost supplier is awarded the sale. If side payments between the NYOP retailer and the service providers are feasible (e.g., participation fees charged to suppliers who wish to be affiliates in the NYOP system), then each supplier and the NYOP retailer prefer the MSP mechanism over any alternative.

Alternative systems, such as one in which the NYOP retailer specifies a margin for each transaction, would suppress competition since suppliers are chosen randomly rather than on the basis of who submitted the lowest bid.[2] Our results suggest that such a lack of competition does not necessarily benefit service providers, however. In fact, service providers are more profitable if the NYOP retailer establishes a system in which service providers bid against each other for customers, provided that the NYOP retailer also takes an active role in managing the acceptance rates of consumers' bids.

The remainder of the paper is organized as follows: Section 2 reviews the related literature and discusses the study's contributions. We present the formal analytical model in Section 3. Section 4 derives the optimal channel profit and constructs a mechanism (MSP) that can reach this optimum. In Section 5, we consider several alternative NYOP mechanisms. Section 6 considers the allocation of profit across channel members. In Section 7, we offer concluding remarks, including managerial implications and areas for future research.

[2] For instance, the conventional wisdom is expressed in Anderson (2009): Priceline's mechanism "favors the property because . . . the random nature of property selection does not require the properties to compete with each other on price; they only compete with the customer because a firm's price relative to that of another firm does not impact its probability of being selected" (pp. 308–309).

2. Literature Review

A stream of literature on NYOP channels is emerging. The extant literature can be divided into studies that focus predominantly on (1) how consumers respond to the NYOP format and (2) how firms can utilize this format. This paper's main contribution is to the second stream of study. On the consumer-centric side, previous work has used bidding data to estimate consumers' bidding costs and/or their values for the underlying product (e.g., Hann and Terwiesch 2003, Spann et al. 2004) and highlights the importance of the bid-elicitation format (Chernev 2003, 2006; Spann et al. 2012). Researchers have documented that consumer bidding behavior depends systematically on the information about the threshold price distribution (Hinz and Spann 2008, Wolk and Spann 2008, Wang et al. 2010), the expectations that the (hidden) threshold price may change over time (Fay and Laran 2009), risk aversion (Abbas and Hann 2010), and the emotional components (such as potential frustration or excitement) involved in bidding (Ding et al. 2005). In this study, we model consumers as being strategic risk-neutral agents who adopt bidding strategies to maximize expected consumer surplus, taking into account the expected probability a given bid will be accepted. For tractability reasons, we utilize a static model in which the consumer places at most one bid (as is done in many other analytical studies; see, e.g., Wilson and Zhang 2008, Fay 2009, Shapiro and Zillante 2009, Wang et al. 2009, Spann et al. 2010). This assumption is also consistent with the business model utilized by Priceline, the most prominent NYOP practitioner, which restricts consumers to a single bid for a given product (where subsequent bids can only be placed after a specified number of days have passed). Our model closely follows Zeithammer (2015) by taking into account that consumers have the choice of whether to utilize the NYOP channel or to buy the item through a traditional posted-price channel.

The second strand of research on NYOP markets focuses on how firms can better utilize the NYOP format. Note that the consumer-centric research discussed above often examines the NYOP format in an environment where consumers can place multiple bids for a certain product. Thus, an often-asked research question in the firm-focused literature is how a firm is impacted if it allows consumers to rebid, rather than restricting them to a single bid (Fay 2004, Terwiesch et al. 2005, Cai et al. 2009). An intuitive finding is that the opportunity to rebid leads consumers to place lower initial bids. Other research questions addressed in the literature include how a firm might optimally set the threshold price (Terwiesch et al. 2005, Wilson and Zhang 2008) and whether or not charging consumers for the opportunity to bid might increase profit (Spann et al. 2010).

A key issue that arises in the extant literature is interaction *across* channels. In particular, a service provider must determine how to utilize an NYOP channel in conjunction with a posted-price channel (Cai et al. 2009, Shapiro and Zillante 2009, Wang et al. 2009). By contrast, the current study focuses on how service providers interact with the NYOP retailer *within* the NYOP channel. Several common assumptions that appear in the literature include having a single service provider (Wang et al. 2009), taking the wholesale price offered to the NYOP retailer as being given exogenously (Wilson and Zhang 2008, Terwiesch et al. 2005, Cai et al. 2009, Spann et al. 2010, Zeithammer 2015), and having service providers offer their own NYOP products without the use of an intermediary (Fay 2009). Our study enriches the extant literature by developing a model that includes multiple service providers and an NYOP retailer. This model enables us to provide unique insights into NYOP markets by studying the interactions of service providers both with each other (as they compete to be the supplier of the good) and with the NYOP retailer. These are important considerations because, as noted in the introduction, the most prominent NYOP channels employ an intermediary that is not itself a producer of the core service but instead relies on multiple suppliers to provide the services to its customers. Thus, how service providers are selected for each particular transaction and how payments to them are determined critically impact the profitability of the NYOP channel (both as a whole and for each channel member separately).

Our study also relates to the vast literature on auction design. It is well known that a second-price auction induces competing agents to truthfully reveal their private valuations (Vickrey 1961). For the NYOP channel, however, setting threshold prices through such an auction among service providers will not, in general, maximize total channel profit because the NYOP channel also involves bidding by consumers and using a second-price auction for procurement (without a reserve) will not generate the maximum revenue from consumers. In particular, setting the threshold price equal to the second-lowest cost realization induces consumers to place relatively low bids (to take advantage of the low threshold prices that occur when multiple service providers have low costs).

The literature on two-sided auctions (e.g., McAfee 1992, Friedman and Rust 1993) is more closely related to this study. Models of traditional two-sided auctions typically involve multiple buyers, assuming that all of them have submitted their bids prior to any allocation decisions being made (e.g., Myerson and Satterthwaite 1983, Wilson 1985). By contrast, the NYOP retailer has to decide whether or not to accept a given bid prior to observing bids from other potential customers. The literature on continuous double auctions, which allow for transactions to be completed prior to all bids being submitted, is relatively scant, and it primarily consists of studies involving field and laboratory experiments (Friedman and Rust 1993). Theoretical analyses, such as Wilson (1987), rely on incomplete information approaches, which are heavily dependent on strong assumptions regarding common knowledge. Such models assume that consumers collect an enormous amount of information and that they possess unrealistic computational abilities (Friedman and Rust 1993). By contrast, in an NYOP market, consumers do not need to know the history of past bids or have a rational expectation of future bids. Instead, knowledge of the bid-acceptance probabilities is sufficient for a consumer to determine her optimal bidding strategy. However, the NYOP retailer needs to play an active role both in setting and in publicizing the acceptance rules for consumer bids.

3. The Model

3.1. Supply-Side Assumptions

We posit two service providers (also interchangeably termed "suppliers"). It is straightforward to extend the analysis to allow for additional service providers, but this complicates the notation without qualitatively altering our results. We assume each service provider has access to the traditional retail channel, which offers a unit of either product at a posted price R.[3] We do not formally model how R is determined, which would presumably be an outcome of competition in the traditional retail channel. Instead, as is commonly assumed in the extant literature, and in line with the empirical observation that NYOP sales tend to account for a relatively small portion of each service provider's total sales, we assume the posted price is given exogenously and does not depend upon the bid-acceptance policy of the NYOP retailer. A critical assumption of our model is that neither service provider is guaranteed the ability to sell all of its capacity at the posted price R. Instead, the probability of exhausting inventory is θ_1 and θ_2 for service providers 1 and 2, respectively. The two probabilities differ because the two suppliers experience idiosyncratic demand shocks (e.g., how many conventions and wedding parties have already booked rooms for a certain hotel

[3] One way to justify the assumption that both suppliers sell at identical posted prices in the traditional channel is if the two firms are not vertically differentiated and the products appear undifferentiated to the NYOP consumers, who are placing NYOP bids without specifying a particular supplier (i.e., the NYOP product is "opaque" in the nomenclature of Fay and Xie 2008).

on a specific weekend). This reflects the reality that fixed capacity and demand uncertainty result in the potential to have unutilized capacity in most service industries.

Let $\omega_i = \theta_i \times R$ represent the opportunity cost of a unit of service to service provider i, $i = \{1, 2\}$, which will, by construction, be less than or equal to R. This metric is analogous to the "shadow price" of capacity because selling through the NYOP channel is advantageous to service provider i only if its payment from the NYOP retailer exceeds ω_i. Thus, when participating in an NYOP channel, a service provider chooses between selling a unit to the NYOP customer (at a price that will depend on the exact NYOP mechanism that is being utilized) or retaining this unit for potential sale through the posted-price channel (which would yield an expected profit of ω_i). These opportunity costs are assumed to be private information to each service provider, i.e., unobserved by the NYOP retailer, the rival service provider, or the consumer. We assume ω_1 and ω_2 are drawn independently from a continuous distribution G with support on $[\underline{\omega}, R]$ (where the density function is denoted g).[4] The study's key results hold for general G. However, to illustrate the key results and to derive additional insights, we also report an analysis that assumes opportunity costs follow a uniform distribution. To reduce notation, we normalize the lower limit of the cost distribution to zero; i.e., $\underline{\omega} = 0$.

An intermediary operates the NYOP channel. The NYOP retailer is selling an opaque good since it does not specify to consumers which supplier the product will be procured from (if the bid is, in fact, accepted) and customers cannot make their bids contingent upon which service provider is utilized. This NYOP retailer faces a key decision: whether or not to accept a given consumer's bid, b. The NYOP retailer must also decide which service provider to use whenever a bid is accepted.

3.2. Demand-Side Assumptions

We assume a risk-neutral consumer has a private value V for a unit of the service (the value is private in that neither the NYOP retailer nor the service providers can observe V). The consumer visits the NYOP website and places a bid, b, of her choosing. If the bid is accepted, the consumer obtains a unit of the product and pays b, thus receiving a utility of $V - b$. If the bid is rejected, the consumer has the option to purchase a unit at the posted price R. The valuation V is drawn from a continuous distribution $F(V)$ with density $f(v)$ and support on $[\underline{V}, \bar{V}]$, where $\bar{V} \geq R$. We assume the *virtual value* $\Psi(V) \equiv V - (1 - F(V))/f(V)$ is increasing; i.e., the distribution F is regular in the sense of Myerson (1981). The virtual value function is a central concept in the theory of mechanism design, and it represents the marginal revenue a seller can extract from a consumer of type V in a direct revelation mechanism (see Krishna 2002 for more details).

3.3. Timing of the Game

Figure 1 illustrates the timing of the game. First, the NYOP retailer announces its bid-acceptance schedule, $A(b)$. We assume that this announcement is credible; i.e., the announced bid-acceptance function reports the true probability that a bid of size b will be accepted.[5] Whether or not there is a formal announcement, we assume that the consumer knows the bid-acceptance function before deciding on her bid (perhaps learning it through experience or Internet word of mouth).[6] The assumption that the bid-acceptance function is known to consumers is commonly made in the literature (e.g., Fay and Laran 2009, Almadoss and Jain 2008, Wilson and Zhang 2008, Fay 2004, Shapiro 2011, Zeithammer 2015).

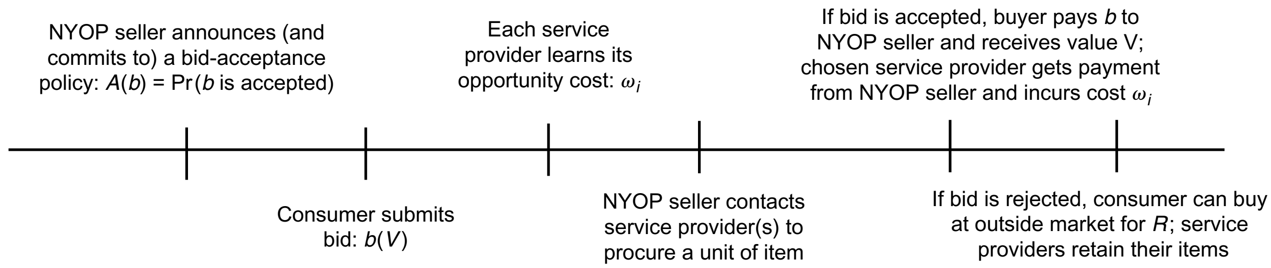
Next, the consumer submits a bid, with the bid level chosen to maximize her expected net utility (taking into account that she will have an opportunity to purchase at the posted price R if this bid is rejected). Then, the service providers observe their opportunity costs of selling a unit through the NYOP channel (i.e., they get a signal of their θ_i). The NYOP retailer contacts the service providers to determine whether or not to accept the bid and, if so, which supplier to use. Thus, whether a bid is accepted depends on both the NYOP retailer's procurement policy and the service providers' cost realizations. In subsequent sections, we discuss various ways to structure the procurement mechanism, i.e., the interaction between the NYOP retailer and the service providers. In equilibrium (with credible commitment), the bid-acceptance schedule announced to consumers must equal the expected probability a particular bid will result in a transaction, where expectations are based on the supplier cost distribution and the procurement mechanism.

[4] The core results of the study continue to hold if costs are correlated. However, the importance of our study, i.e., examining how NYOP mechanisms determine which supplier to use to fulfill demand, hinges upon there being potential differences in suppliers' costs. If costs are identical in every instance, the choice between suppliers becomes irrelevant.

[5] As indicated previously, real-world NYOP sellers such as Lufthansa, Greentoe.com, Meanbuy.com, and Scorebig.com actively communicate their bid-acceptance schedules. Through repeated interactions (and observation of these interactions, for example, via posted user comments, chat rooms, and web forums), customers can observe whether the posted schedules are being (approximately) followed, thus providing NYOP sellers with the opportunity to develop a reputation for making credible announcements.

[6] For instance, to learn the probability associated with bids on Priceline, consumers could consult third-party sites (such as FlyerTalk.com, BetterBidding.com, and BiddingForTravel.com) on which users post their winning and losing bids.

Figure 1 Timing of the NYOP Model



4. Analysis

4.1. Optimal Channel Profit

In this subsection, we use a result of Zeithammer (2015) to derive the maximum channel profit that can be generated from the NYOP channel. The established theory of mechanism design (Riley and Zeckhauser 1983) implies that the maximum profit that would be obtainable in the channel, given our assumptions about demand and costs, is the profit that can be obtained by a monopolist who can first (somehow) obtain the service for $\min(\omega_1, \omega_2)$ and then set the optimal take-it-or-leave-it monopoly price. Zeithammer (2015) takes the retailer's procurement cost as exogenously given and proves that an NYOP selling strategy can reach this theoretical maximum. He constructs the optimal cost-contingent bid-acceptance policy, Pr(*accept* $b \mid$ *cost*), the expectation of which then implies the consumer faces the bid acceptance function $A^*(b) = E_{cost}[\Pr(accept\ b \mid cost)]$.

To apply Zeithammer's (2015) analysis to our model, let $M(\omega)$ be the cumulative distribution function of the order statistic $\omega = \min(\omega_1, \omega_2)$, and let $m(\omega)$ be the associated density function. Consider a hypothetical NYOP seller who faces $M(\omega)$ as his cost distribution. One way to describe the motivation of this seller is to imagine that our retailer and both service providers are all integrated into a single firm. Such a firm faces a procurement cost drawn from $M(\omega)$ and collects the entire channel profit by construction. The following lemma characterizes the cost-contingent bid-acceptance policy that maximizes channel profit, where this policy consists of an optimal bid acceptance function, $A^*(b)$, which takes into account the consumer's best response, $\beta(V)$, to this acceptance function.

Lemma 1. *Let $\beta_R^- = \lim_{V\to R-}\beta(V)$. The total channel profit is maximized by the cost-contingent bid-acceptance policy of accepting bids below β_R^- whenever $b > \beta(\Psi^{-1}(\omega))$ and accepting bids at or above $\beta(R)$ with certainty.*

The implied ex ante optimal bid-acceptance function is

$$A^*(b) = \begin{cases} 0 & \text{if } b < \beta(\psi^{-1}(0)), \\ M(\psi(\beta^{-1}(b))) & \text{if } \beta(\psi^{-1}(0)) \le b < \beta_R^-, \\ \text{less than } \int_{\psi^{-1}(0)}^{R} \dfrac{M(\psi(z))}{R-b}\,dz & \\ & \text{if } \beta_R^- \le b < \beta(R), \\ 1 & \text{if } b \ge \beta(R), \end{cases}$$

where

$$\beta(V) = \begin{cases} \displaystyle\int_{\omega=0}^{\psi(V)} \psi^{-1}(\omega)\frac{m(\omega)}{M(\psi(V))}\,d\omega & \text{if } \psi^{-1}(0) < V < R, \\ \displaystyle R - \int_{\psi^{-1}(0)}^{R} M(\psi(z))\,dz & \text{if } V \ge R, \end{cases}$$

is the bidding function that best responds to A^*.

Lemma 1 is Proposition 2 of Zeithammer (2015) with $M(\cdot)$ corresponding to the distribution of costs the retailer faces. The appendix contains a sketch of the proof of Lemma 1; see the proof of Proposition 2 of Zeithammer (2015) for more detail. To gain intuition for Lemma 1, suppose that the outside posted price were irrelevant to all consumers. (Note that this situation corresponds to $\bar{V} = R$ under our notation and assumptions.) Then, $\Psi^{-1}(\omega)$ is the optimal monopoly posted price given a marginal cost of ω, and thus $b > \beta(\Psi^{-1}(\omega))$ is equivalent to accepting bids from consumers who would have been able to afford the optimal monopoly price. Lemma 1 effectively generalizes this intuition to the case when $\bar{V} \ge R$, and thus the optimal monopoly price is $\min(\Psi^{-1}(\omega), R)$. We postpone further discussion of the structure of the A^* and β functions until the full solution (i.e., both the demand and supply sides) has been presented (i.e., until after Proposition 1).

4.2. Procurement Auction for Maximizing Channel Profit

In the previous section, we identified the demand-side conditions that optimize total channel profit. Namely, Lemma 1 specifies the bid-acceptance function that enables the NYOP channel to reach the maximum profit possible when consumer valuations are privately observed. The analysis in the previous section assumed away any procurement issues by effectively considering service providers that are fully vertically integrated with the NYOP retailer. However, the NYOP retailer we model must procure the service from two independently managed service providers. Thus, to maximize channel profit following Lemma 1, the NYOP retailer must implement the cost-contingent bid-acceptance policy specified in Lemma 1 even though he does not actually face the cost $\omega = \min(\omega_1, \omega_2) \sim M()$ as his cost of procurement from the duopolistic, independent suppliers.

Suppose the retailer simply invites the suppliers to bid in a second-price sealed-bid reverse auction,[7] forcing them to reveal their opportunity costs ω_i (because of that auction's well-known dominant truth-revealing strategy, first shown by Vickrey 1961). Such an auction results in the NYOP retailer paying $\max(\omega_1, \omega_2)$ to the winning supplier. Setting a bid-acceptance rule of accepting a bid only if $b > \max(\omega_1, \omega_2)$ will not induce the allocation decision implied by Lemma 1. For example, if $\max(\omega_1, \omega_2) > b > \beta(\Psi^{-1}(\omega))$, this acceptance rule would lead to a rejected bid, even though such a bid must be accepted to achieve optimality. On the other hand, if $\beta(\Psi^{-1}(\omega)) > b > \max(\omega_1, \omega_2)$, this acceptance rule would lead to an accepted bid, even though such a bid must be rejected to achieve optimality. To achieve Lemma 1's allocation through competitive procurement, the NYOP retailer must use the consumer's bid to appropriately set the reserve threshold of the reverse auction. Specifically, to achieve exactly the optimal cost-contingent allocation, the reserve price needs to be $\Psi(\beta^{-1}(b))$, because $b > \beta(\Psi^{-1}(\omega))$, if and only if $\omega < \Psi(\beta^{-1}(b))$.

We call the resulting mechanism (a second-price, sealed-bid reverse auction with the channel-optimal reserve price) the MSP auction. Under this mechanism, each supplier, after observing her own ω_i, submits a bid of p_i to the NYOP retailer. The following definition describes how the MSP mechanism we propose uses the suppliers' bids to determine which (if any) supplier is selected and the transfer price paid by the NYOP retailer to the selected supplier.

[7] In a "reverse" auction, the supplier with the lowest bid wins, and the buyer pays him the second-lowest bid for supplying the good.

Definition (The MSP Auction). Let $p_1 < p_2$ denote the supplier bid prices. Let

$$\omega^*(b) = \begin{cases} 0 & \text{if } b < \beta(\psi^{-1}(0)), \\ \psi(\beta^-(b)) & \text{if } \beta(\psi^{-1}(0)) \le b < \beta_R^-, \\ \text{less than } M^{-1}\left(\displaystyle\int_{\psi^{-1}(0)}^{R} \frac{M(\psi(z))}{R-b}\,dz\right) & \\ & \text{if } \beta_R^- \le b < \beta(R), \\ R & \text{if } b \ge \beta(R). \end{cases}$$

After a consumer bids, the NYOP retailer compares the cost threshold $\omega^*(b)$ to the service providers' prices in the following fashion to determine whether a transaction will occur and at what transfer price:

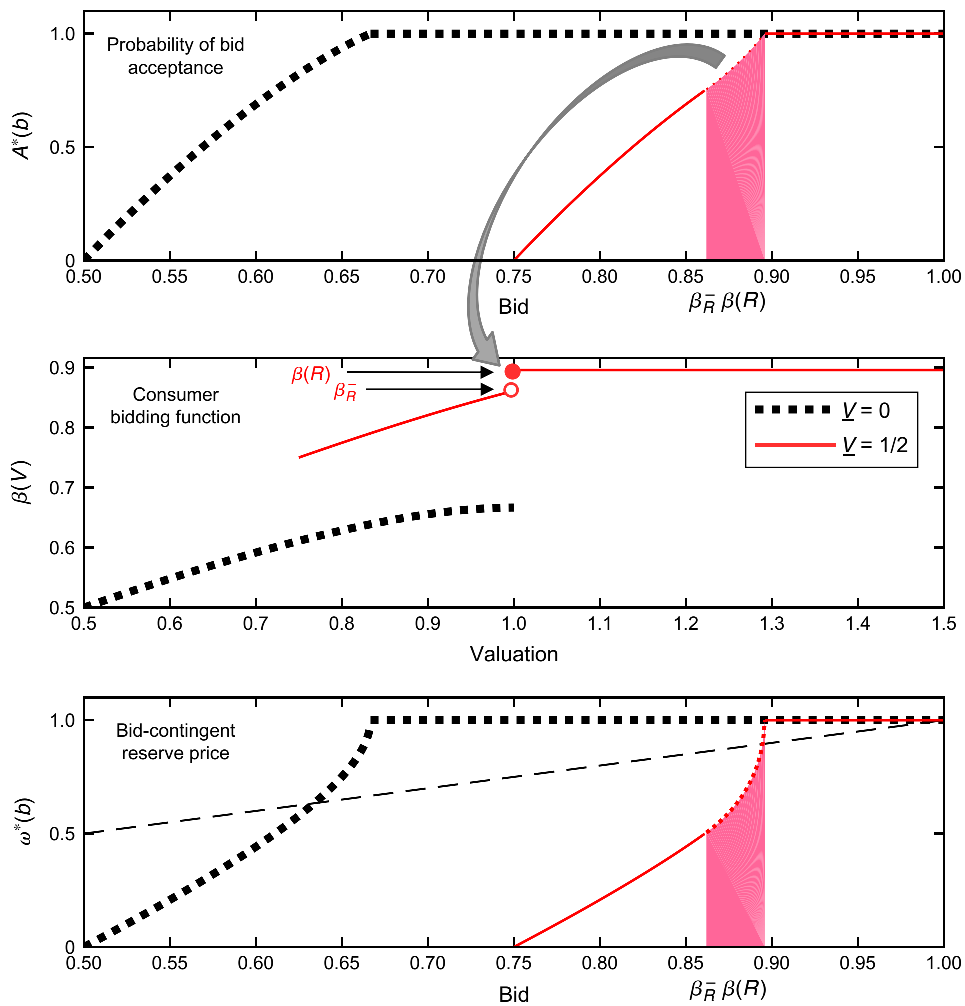
1. If $p_2 \le \omega^*(b)$, the consumer pays b to the NYOP retailer, and the NYOP retailer pays p_2 to the lowest-priced supplier in return for providing a unit of the good to the consumer.
2. If $p_2 > \omega^*(b) \ge p_1$, the consumer pays b to the NYOP retailer, and the NYOP retailer pays $\omega^*(b)$ to the lowest-priced supplier in return for providing a unit of the good to the consumer.
3. If $p_1 > \omega^*(b)$, no transaction occurs.

The "medium-bid" case, $\beta_R^- \le b < \beta(R)$, specifies the channel-optimal reserve threshold only as an upper bound because of the analogous indeterminacy of $A^*(b)$ in Lemma 1. Thus, a continuum of (sufficiently low) reserve prices in this bid region will satisfy the condition implied by Lemma 1. One value that keeps the formula for $\omega^*(b)$ parsimonious and elegant is to let $\omega^*(b) = \Psi(R)$ across this entire bid interval. We illustrate the indeterminacy issue in more detail in Example 2 and provide a formal remark to show why profit maximization implies only a bound on the reserve price for medium bids. Proposition 1 reports the key properties of MSP.

Proposition 1 (Optimality of MSP). *The modified second-price auction, described in the MSP definition, induces service providers to truthfully reveal their costs to the NYOP retailer and also achieves the optimal channel profit by generating the bid-acceptance function outlined in Lemma 1.*

As explained previously, simply running an unconstrained second-price sealed-bid procurement auction will not enable the NYOP channel to reach its optimal profit because the consumer's probability of winning would be different from that established in Lemma 1. Proposition 1 shows that one modification of a simple second-price auction that does optimize channel profit is the addition of a reserve $\omega^*(b)$, where the reserve price depends on the consumer's bid level. This reserve is calibrated to induce the bid-acceptance probability given in Lemma 1.

Figure 2 (Color online) Examples of the Strategies Within MSP When F and G Are Uniform



Notes. The thicker dotted (black) lines correspond to Example 1 ($\underline{V} = 0$). The thinner solid (red) lines correspond to Example 2 ($\underline{V} = 1/2$). The shaded (pink) areas indicate indeterminacy of A^* and ω^* over the bid interval $[\beta_R^-, \beta(R))$ in Example 2. The arrow indicates how the acceptance strategy in this indeterminate bid interval implies that no bids are submitted inside this interval (a jump discontinuity in the bidding function). The dashed line in the bottom panel indicates the 45-degree line.

Example 1 (F and G Uniform; Outside Price R Not Affordable to Any Consumers). To illustrate the main features of MSP, we begin with an example in which no consumer can afford the outside posted-price option. Let the consumer valuations and the provider costs both be uniformly distributed on the interval $[0, 1]$, and assume that $R = 1$. The implied distribution of ω is $M(\omega) = \omega(2 - \omega)$. The virtual value function is $\Psi(V) \equiv V - (1 - F(V))/f(V) = 2V - 1$. Using Lemma 1, we find the optimal acceptance strategy A^* and the consumer bidding function β that best responds to it:

$$A^*(b) = \begin{cases} \dfrac{z(4-z)}{4} & \text{if } b < \dfrac{2}{3}, \\ 1 & \text{if } b \geq \dfrac{2}{3}, \end{cases}$$

$$\text{where } z = \max[3b - \sqrt{3(2-b)(2-3b)}, 0], \quad (1)$$

$$\beta(V) = \int_0^{2V-1} \frac{\omega + 1}{2} \frac{m(\omega)}{M(2V-1)} \, d\omega = \frac{2 + 4V(1-V)}{3(3-2V)}. \quad (2)$$

The reserve price under MSP that induces this optimal acceptance strategy, as specified in the MSP definition, is

$$\omega^*(b) = \begin{cases} \dfrac{z}{2} & \text{if } b < \dfrac{2}{3}, \\ 1 & \text{if } b \geq \dfrac{2}{3}, \end{cases} \quad \text{where } z \text{ is defined in (1).} \quad (3)$$

These functions for bid acceptance, consumer bidding, and reserve price are illustrated by the thick dotted (black) lines in the three respective subplots of Figure 2. Lemma 1 indicates that the optimal bid-acceptance function involves a minimum bid threshold, $\beta(\Psi^{-1}(0))$, such that any bid below this threshold will always be rejected. The minimum bid threshold equals 1/2 in this particular example. Therefore, Figure 2 considers only bids above 1/2, with the understanding that $A^* = \omega^* = 0$ for all bids below that level. As a result, consumers with $V \leq 1/2$ will not be able to obtain the good at any bid at or below their valuations. Rather than submitting a bid that will never be accepted, such low-valuation consumers could (and probably would) simply refrain from bidding.

At the other extreme, any bid of $\beta(R)$ or more must be accepted with certainty. In this example, $\beta(1) = 2/3$. Thus, in the top panel of Figure 2, we see that the bid-acceptance probability will be 1 if $b \geq 2/3$. To guarantee procurement of a unit of service, the NYOP retailer must set the reserve price ($\omega^*(b)$) to 1 (as illustrated in the bottom panel of Figure 2 by the fact that $\omega^*(b) = 1$ for any $b \geq 2/3$). For consumer bids that lie between these two extremes, a bid will be accepted with a positive probability that is increasing in the bid level (and the reserve price is increasing in b in order to achieve an increasing rate of bid acceptance).

An interesting characteristic of this channel-optimal solution is that some transactions that would generate ex post positive channel profit are foregone, while some transactions that generate ex post negative channel profit take place. This can easily be observed in the bottom panel of Figure 2 by comparing the reserve price, $\omega^*(b)$, to the 45-degree line for which $b = \omega$ (as indicated by the dashed line). Notice that, for low bid levels, the 45-degree line is above $\omega^*(b)$, which indicates that cost realizations can occur such that $b > \omega > \omega^*(b)$. Here, no transaction would occur (since $\omega > \omega^*(b)$), even though the consumer bids more than that it would cost a supplier to provide the product (since $b > \omega$). Now consider higher bid levels for which the 45-degree line is below $\omega^*(b)$, which indicates that cost realizations can occur such that $\omega^*(b) > \omega > b$. Here, a transaction would occur (since $\omega < \omega^*(b)$), even though the consumer pays less than that it costs a supplier to provide the product (since $b < \omega$).

This apparent inefficiency is analogous to the deadweight losses that arise for a posted-price monopoly that has an incentive to price above marginal cost in order to maximize profit. In the case of the NYOP market, the NYOP retailer does not set the reserve price equal to marginal cost but instead configures the reserve price function to generate a bid acceptance function that motivates consumers to bid higher than they otherwise would.

Now consider how the MSP mechanism allocates revenue from the NYOP market across channel members. Note that the NYOP retailer does not retain all of the channel profit because he has to compensate the winning supplier in the procurement auction that the MSP Definition characterizes. Whenever a consumer's bid is accepted, the NYOP retailer pays either $\max(\omega_1, \omega_2)$ or $\omega^*(b)$ to the low-cost service provider. This payment can be quite sizeable and may even result in the NYOP retailer experiencing a negative realized profit from a given transaction; i.e., when the payment to the winning supplier exceeds the revenue, the NYOP retailer receives from the consumer. For the numerical example, we have $\beta(1) = 2/3$ and $\omega^*(2/3) = 1$. Thus, the NYOP retailer receives a payment of 2/3 from the consumer but will make a payment to the service provider that can be as high as 1. Despite the potential of a negative realized profit, the NYOP retailer earns a positive profit in expectation. In Example 1, the optimal channel profit is 1/8.[8] Under the MSP mechanism, this profit is split evenly across the channel members; i.e., each service provider earns an expected profit of 1/24, and the NYOP retailer also earns an expected profit of 1/24.[9]

It is important to note that the MSP mechanism is designed to maximize total channel profit. An NYOP retailer who is optimizing his own profit given his actual procurement cost would likely choose a different reserve and, as a result, would generate a lower total channel profit than that achieved under Lemma 1. In other words, the MSP mechanism avoids double marginalization problems that would arise if the retailer set his reserve price to maximize his own profit given each bid level. In the next section, we discuss alternative NYOP mechanisms that an NYOP retailer may consider as a way to boost his profit.

As an extension to the base model, we consider a market setting in which side payments between the channel members are feasible. If transfer payments can be made such that each channel member's share of the profit is constant across procurement mechanisms, then the retailer prefers the MSP mechanism to all other alternatives. For instance, an NYOP retailer

[8] A simple way to calculate total profit is to note that Zeithammer (2015) proves that the optimal channel profit is the same as the expected profit (over cost realizations) of a monopolist who first learns his cost and then sets the optimal posted price contingent on it. For a given ω, a posted-price monopolist would set a price of $(1+\omega)/2$. Thus, the expected profit is $\Pi^{\text{MSP}}_{\text{Total}} = \Pi^{\text{Optimal}}_{\text{Total}} = \int_{\omega=0}^{1}((1+\omega)/2 - \omega)(1-(1+\omega)/2)2(1-\omega)\,d\omega = 1/8$.

[9] The expected surplus earned by the service providers is $\Pi^{\text{MSP}}_{\text{suppliers}} = \int_{V=1/2}^{1}\int_{\omega=0}^{2V-1}\left[\int_{h=\omega}^{2V-1}(h-\omega/1-\omega)\,dh + (2-2V/1-\omega)(2V-1-\omega)\right]\cdot 2(1-\omega)\,d\omega\,dV$, where $h = \max(\omega_1, \omega_2)$, and the distribution of h conditional on ω is clearly uniform $[\omega, 1]$ because there are exactly two suppliers. The first term in the bracket captures the situation when $h < \omega^*(x)$, and the second term captures the situation when the reserve is binding. Thus, the bracketed term gives the expected surplus of the winning supplier given V and ω. The outer two integrals merely average over the valuations and lowest costs whenever there is a trade according to the underlying direct revelation mechanism. Evaluating this double integral, we find $\Pi^{\text{MSP}}_{\text{suppliers}} = 1/12$. Since each service provider is equally likely to be the low-cost supplier, each firm earns an expected profit of 1/24, and the remainder of the channel profit is retained by the NYOP retailer: $\Pi^{\text{MSP}}_{\text{retailer}} = \Pi^{\text{MSP}}_{\text{Total}} - \Pi^{\text{MSP}}_{\text{suppliers}} = 1/8 - 1/12 = 1/24$.

who uses two-part tariffs and makes take-it-or-leave-it offers to the service providers could capture all channel profit by utilizing MSP to set the marginal transfer prices and using fixed fees to extract the service providers' entire surplus.

Although the formulas in Lemma 1 and the MSP definition are rather complex, implementation of the MSP mechanism is relatively simple. Using the preceding numerical example, the NYOP retailer should never accept a consumer bid that is less than or equal to 1/2. This could be incorporated into the bid interface for consumers by specifying that only bids in excess of 1/2 are allowable or by automatically generating a bid rejection message (before searching for supplier availability) for bids that are "too low." Furthermore, the MSP mechanism specifies that any bid that is 2/3 or larger should be accepted with a probability of 1. This could be incorporated into the bid interface by using a "buy-it-now price." Thus, the bid interface would allow consumers to bid between 1/2 and 2/3. A table or figure could be displayed indicating to consumers how likely it is for a given bid to be accepted in this intermediate region (see Figure 5 for an example of such a display from Greentoe.com). On the supply side, the NYOP retailer would set a reserve price according to $\omega*(b)$ after receiving a consumer bid of b. The service providers would submit their price bids (or have them held in a database that could be updated as frequently as desired). These price bids would depend on the cost realizations, and the price bids (in conjunction with the reserve price) would determine whether or not a given bid is accepted. While such a mechanism is clearly logistically feasible, issues of credibility could be very important. In particular, a consumer may worry that the NYOP retailer will deviate from these posted acceptance rates. Indeed, this potential lack of commitment is a main rationale for why we consider alternative NYOP mechanisms in the next section. We discuss the issue of credibility in more detail in the concluding section of the paper.

Example 2 (F and G Uniform, and Outside Price R Affordable to Some Consumers). Before turning to alternative NYOP mechanisms, we must examine one aspect of the MSP mechanism left out of the previous example. Example 1 assumes that no consumer would be willing to buy at the posted price. This example helps one understand the central driving factors of the MSP mechanism and captures market environments in which the NYOP channel fully segments consumers, i.e., enables service providers to reach only the customers who would not purchase through traditional channels. However, in practice, segmentation may not be perfect, and some consumers who use the NYOP channel may be willing to purchase through the traditional channel. To explore such market situations, we keep the assumptions about the supply side the same as in Example 1, but we shift the distribution of valuations up by $\underline{V}$ to become $V \sim \mathrm{U}[\underline{V}, \underline{V}+1]$, where $\underline{V} \in [0,1]$ (so Example 1 is a special case with $\underline{V}=0$).[10] Under these assumptions, $F(V) = V - \underline{V}$, so the virtual value function becomes $\Psi(V) = 2V - \underline{V} - 1$. The consumer's bidding function under MSP, as given in Lemma 1, is thus

$$\beta(V) = \begin{cases} \dfrac{1}{6}\left(2+4V+\underline{V}-\dfrac{2}{3-2V+\underline{V}}\right) & \text{if } V<1, \\[2ex] \dfrac{4-\underline{V}^3+3\underline{V}}{6} & \text{if } V \geq 1, \end{cases} \tag{4}$$

with an inverse of

$$\beta^{-1}(b) = \frac{4+6b+\underline{V}-\sqrt{3(4+\underline{V}-2b)(4+3\underline{V}-6b)}}{8}$$
$$\text{for } b < \beta_1^- = \lim_{V\to R-} \beta(V) = 1+\frac{\underline{V}}{6}-\frac{1}{3(1+\underline{V})}.$$

The corresponding bid-acceptance policy is

$$A^*(b) = \begin{cases} 0 \quad \text{if } b < (1+\underline{V})/2, \\ (2\beta^{-1}(b)-\underline{V}-1)(3-2\beta^{-1}(b)+\underline{V}) \\ \quad \text{if } (1+\underline{V})/2 \leq b < \beta_1^-, \\ \text{less than } \dfrac{2-3\underline{V}+\underline{V}^3}{6(1-b)} \\ \quad \text{if } \beta_1^{-1} \leq b < (4-\underline{V}^3+3V)/6, \\ 1 \quad \text{if } b \geq (4\underline{V}^3+3\underline{V})/6. \end{cases} \tag{5}$$

The optimal reserve is

$$\omega^*(b) = \begin{cases} 0 \quad \text{if } b<(1+\underline{V})/2, \\ 2(\beta^{-1}(b))-1-\underline{V} \\ \quad \text{if } (1+\underline{V})/2 \leq b < \beta_1^-, \\ \text{less than } 1-\sqrt{1-\dfrac{2-3\underline{V}+\underline{V}^3}{6(1-b)}} \\ \quad \text{if } \beta_1^{-1} \leq v < (4-\underline{V}^3+3V)/6, \\ 1 \quad \text{if } b \geq (4-\underline{V}^3+3\underline{V})/6. \end{cases} \tag{6}$$

Figure 2 illustrates this example for $\underline{V}=1/2$, using the thinner solid (red) lines. The graphs for Example 2 share many of the same characteristics as those for Example 1. In particular, a lower threshold of bid level exists, below which all bids are rejected and a higher threshold exists, above which all bids will be accepted. Because of the higher valuations, these thresholds are higher than in Example 1 (increasing from 1/2 to 3/4 for the lower threshold and from 2/3 to $43/48 \approx 0.896$ for the higher threshold). A notable difference from

[10] Under these assumptions, the expected channel profit is $\Pi_{\text{Total}}^{\text{MSP}} = (3-\underline{V})(1+\underline{V})^3/24$.

Example 1 is that all consumers whose valuations exceed the posted price in the non-NYOP channel (i.e., $V \geq R = 1$) bid the same amount, effectively mimicking the consumer with $V = R$, because they have a real option to buy in the outside market should their NYOP bid be rejected. The NYOP retailer wants to induce higher bids from this high-value segment as its size increases, but to do so, it must reduce the probability of accepting low bids (sacrificing sales from low-value customers to generate more revenue from high-value ones).

The top and bottom panels of Figure 2 contain a shaded region, which corresponds to the third line of the equation for $A^*(b)$ in Lemma 1, for which optimality implies only an upper bound when bids are within the $[\beta_R^-, \beta(R))$. interval. Thus, any value in the shaded region is equally profitable. The reason for the indeterminacy is that for all the possible values of $A^*(b)$ in the shaded region, no consumer has an incentive to submit a bid in the $[\beta_R^-, \beta(R))$. interval; this jump discontinuity is indicated by the arrow pointing from the top panel to the middle panel of Figure 2. We formalize this result in the following remark in regard to the reserve price.

Remark. The bid-contingent reserve price $\omega^*(b)$ that obtains the optimal channel profit is not unique.

While this remark indicates the presence of multiple equilibria, it is important to recognize that all equilibria induce the same bidding behavior and allocation decisions, and thus result in the same total channel profit.

5. Other Common or Hypothesized Pricing Mechanisms

Adoption of the MSP mechanism hinges upon the retailer and the supplier firms' ability to coordinate on an NYOP contract structure that maximizes total channel profit. A necessary component of the optimal selling strategy is the retailer's credibility in establishing the optimal bid-acceptance function. Because such conditions may be challenging to achieve in practice, we draw both on practice and on the existing literature to identify three alternative ways one could structure NYOP pricing mechanisms, and we analyze how these alternative mechanisms perform relative to the optimal profit available in the NYOP channel. This analysis provides insight into factors that can undermine the profitability of the NYOP channel.

5.1. Demand Collection

At its core, an NYOP mechanism collects offers to buy from individual customers and communicates this demand directly to participating sellers. We begin our analysis of alternative NYOP mechanisms by considering an NYOP channel that operates merely as a collection platform to facilitate the transference of consumer bids to potential suppliers. Consider the following model of such an interaction, in which a consumer's bid is presented to suppliers in a sequential fashion:

1. A consumer bids b for a unit of the product.
2. The NYOP retailer randomly selects a service provider and queries it to see whether it is willing to sell a unit of its product at the price b. If it agrees, then the bid is accepted, and the service provider receives a payment of b.
3. If the first supplier rejects the bid, the NYOP retailer queries the other service provider to see whether it is willing to sell at the price b.

We refer to this NYOP mechanism as demand collection (DC) since the NYOP retailer does not receive a payment for each transaction. This is consistent with a market structure in which the service providers pay a fixed fee to have access to the consumers, or if the NYOP channel is jointly owned by the suppliers (similar to the way in which Orbitz.com developed as a partnership of several airline companies in the non-NYOP hospitality market).

We analyze the above three-stage game via backward induction. In the third stage (if it occurs), service provider j has two choices: accept the bid (and thus receive a net payoff of $b - \omega_j$) or reject the bid (and receive a payoff of zero). Clearly, the service provider should accept the bid only if $\omega_j \leq b$. Similarly, in the second stage, provider i can accept the bid (for a payoff of $b - \omega_i$) or reject the bid (for payoff of zero). Thus, service provider i will accept the bid only if $\omega_i \leq b$. Now turn to the first stage. Anticipating the responses by the service provider, the consumer knows her bid will be accepted (by one of two service providers) if and only if $b > \omega = \min(\omega_1, \omega_2)$ Recall that we denote $M(\omega)$ as the cumulative distribution function of the order statistic ω. Thus, the consumer will choose b to maximize $CS = (V - b)M(b)$ if $V < R$ or $CS = (R - b)M(b)$ if $V \geq R$.[11] Let $b^{DC}(V)$ be the bid level that maximizes the surplus for a consumer with valuation V. For example, suppose $R = 1$ and $\omega_i \sim \mathrm{U}[0, 1]$ as in Example 1. For these parameters, $M(\omega) = \omega(2 - \omega)$, and the resulting consumer's optimal bid function is

$$b^{DC}(V) = \begin{cases} \dfrac{2+V-\sqrt{V^2 - 2V + 4}}{3} & \text{if } V < 1, \\[2ex] \dfrac{3-\sqrt{3}}{3} \approx 0.42265 & \text{if } V \geq 1. \end{cases} \tag{7}$$

[11] The high-valuation consumers with $V \geq R$ mimic the consumer with $V = R$ as in the main model. The outside option price R generates the expected surplus $M(b)(V - b) + [1 - M(b)](V - R) = (V - R) + (R - b)M(b)$.

The expected profit to supplier 1 (who is symmetric with supplier 2) is

$$\begin{aligned}\Pi_{S1}^{DC} = F(R)E_{V<R}\bigg[&\bigg(1-\frac{G(b^{DC}(V))}{2}\bigg)G(b^{DC}(V))\\&\cdot E_{\omega_1|\omega_1<b^{DC}(V)}(b^{DC}(V)-\omega_1)\bigg]\\&+[1-F(R)]\bigg(1-\frac{G(b^{DC}(R))}{2}\bigg)G(b^{DC}(R))\\&\cdot E_{\omega_1|\omega_1<b^{DC}(R)}(b^{DC}(R)-\omega_1).\end{aligned}\tag{8}$$

The first term of Equation (8) gives the profit when the consumer's valuation is below R, and either only supplier 1 is willing to sell for the consumer's bid (probability $(1-G(b))G(b)$) or both suppliers' costs are below R, and the mechanism thus splits their profits in half, resulting in supplier 1 winning with probability $G^2(b)/2$. The second term of Equation (8) then analogously captures the profit when the consumer's valuation is above R. The total profit created under DC is $\Pi_{\text{Total}}^{DC}=2\Pi_{S1}^{DC}$, since each service provider earns an expected profit of Π_{S1}^{DC} and the NYOP retailer earns zero profit.

Let $\tilde{V}=\min(V,R)$ be the effective consumer valuation the NYOP retailer faces. Total channel profit is

$$\Pi^{DC}=E_{\tilde{V}}[M(b^{DC}(\tilde{V}))E_{\omega_1|\omega_1<b^{DC}(\tilde{V})}(b^{DC}(\tilde{V})-\omega_1)].\tag{9}$$

In other words, a consumer with effective valuation $\tilde{V}$ will have his bid accepted with the probability of $M(b^{DC}(\tilde{V}))$ and delivers a profit equal to an expected difference between his bid and all possible costs of a *single* supplier that fall below the bid.

5.2. Percentage Margin Commission

In contrast to DC's essentially benevolent NYOP retailer who does not distort the communication between the consumer and the suppliers, the NYOP retailer could seek to capture profit from each transaction. A simple way to do so would be to transfer only a portion, rather than all, of the consumer's bid to the selected service provider. Here, we assume the NYOP retailer specifies its required margin (or commission) in percentage terms. Specifically, under the percentage margin (PM) mechanism, the NYOP retailer retains a fraction γ of the bid value for itself. Thus, a sale occurs only if a service provider is willing to provide the good to the consumer for $(1-\gamma)$ times the bid value. An example of a percentage margin used in the NYOP channel is described by Malhotra and Desira (2002), who assert that Priceline seeks to find a hotel that allows it to receive a 7% margin by using a randomizer program to choose among the hotels that are willing to accept this offer. Furthermore, Elkind (1999) reports that Priceline's negotiation with Delta Airlines specified that the latter retained "any gross profits over 12% on the Delta seats." This PM setup is also consistent with the NYOP model utilized by Chiching.com, in which the NYOP retailer solicits bids from consumers, passes them along to participating merchants, and collects a 15% commission only when a merchant accepts an offer.

Let γ be the percentage commission retained by the retailer. Under PM, having received a bid of b, the NYOP retailer randomly selects a service provider and queries it to see whether it is willing to sell a unit of its product at the price $(1-\gamma)b$. If it agrees, then the bid is accepted, and the NYOP retailer makes a payment of $(1-\gamma)b$ to that service provider. If it does not agree, the NYOP retailer queries the other service provider to see whether it is willing to sell at the price $(1-\gamma)b$. Service provider i is willing to accept the NYOP retailer's offer as long as $\omega_i\le(1-\gamma)b$. Note that the previously considered demand collection system is a special case of the percentage margin mechanism in which $\gamma=0$.

Observing the structure of the game, the consumer anticipates that her bid will be accepted if and only if $\omega\le(1-\gamma)b$. We assume that the NYOP retailer chooses γ to maximize its own profit, and since γ is publicly announced, the consumer knows its value when she decides on her bid. Thus, the consumer will choose b to maximize $CS=(V-b)M((1-\gamma)b)$ if $V<R$ or $CS=(R-b)M((1-\gamma)b)$ if $V\ge R$. Let $b^{PM}(V,\gamma)$ be the bid level that maximizes the surplus of a consumer with valuation V, when the commission rate is γ. For example, the consumer's optimal bid function under uniform G and $R=1$ is

$$b^{PM}(V,\gamma)=\begin{cases}\dfrac{2+(1-\gamma)V-\sqrt{4-V(1-\gamma)(2-V(1-\gamma))}}{3(1-\gamma)} & \text{if } V<1,\\[2ex] \dfrac{3-\gamma-\sqrt{4-(1-\gamma)(3-\gamma)}}{3(1-\gamma)} & \text{if } V\ge 1.\end{cases}\tag{10}$$

The NYOP retailer recognizes that its choice of γ will impact the consumer's optimal bid. Thus, the NYOP retailer chooses γ to maximize ("I" stands for "intermediary"):

$$\begin{aligned}\Pi_I^{PM}&=\int_{y=\underline{V}}^{R}\int_{x=0}^{(1-\gamma)b^{PM}(y,\gamma)}\gamma b^{PM}(y,\gamma)m(x)f(y)\,dx\,dy\\&\quad+\int_{y=R}^{\overline{V}}\int_{x=0}^{(1-\gamma)b^{PM}(R,\gamma)}\gamma b^{PM}(R,\gamma)m(x)f(y)\,dx\,dy.\end{aligned}\tag{11}$$

Let γ^* be the value of γ that maximizes the profit given in (11).[12] For instance, numerical calculations for

[12] One could envision market settings in which γ chosen to maximize an objective function other than the NYOP retailer's profit. However, all the analytical results that follow depend only on γ being positive.

the example with uniform distributions show that γ^* ranges from 0.54 to 0.58 as $\underline{V}$ goes from 0 to 1.

Let $\tilde{V}=\min(V,R)$ be the effective consumer valuation the NYOP retailer faces. The expected profit to service provider 1 (who is symmetric with supplier 2) is

$$\Pi_S^{PM}=E_{\tilde{V}}[M(\tilde{b}(\tilde{V},\gamma^*))E_{\omega_1\mid\omega_1<\tilde{b}(\tilde{V},\gamma^*)}(\tilde{b}(\tilde{V},\gamma^*)-\omega_1)], \quad (12)$$

where $\tilde{b}(V,\gamma^*)=(1-\gamma^*)b^{PM}(V,\gamma^*)$ is the effective bid received by the suppliers. Note that Equation (12) is derived from Equation (8) by replacing $b^{DC}(\tilde{V})$ with $\tilde{b}(\tilde{V},\gamma^*)$.

5.3. First-Price, Sealed-Bid Supplier Auction

Another way the NYOP retailer could extract profit from the NYOP channel would be to keep the spread between the consumer's and the seller's bid for itself. Indeed, this is how Ding et al. (2005) describe Priceline's system: "Priceline takes a bid from a consumer and then…searches its price database, which contains the lowest acceptable prices by various airlines partners at that time. If the bid price is higher than the lowest fare available to Priceline, it will accept the bid and retain the spread (bid − lowest fare) as its profit" (p. 352). Similar descriptions of Priceline's business model are provided in Terwiesch et al. (2005), Hann and Terwiesch (2003), Wang et al. (2009), and Wang et al. (2010). In such a system, service providers are encouraged to compete for the opportunity to be the chosen supplier for a given consumer. We assume the service providers' bids are kept secret from each other and refer to this mechanism as a first-price, sealed-bid (SB) mechanism.

Consider the following game setup:

I. Having experienced a privately observed, realized cost of ω_i, each service provider simultaneously submits a bid price P_j, $j=\{1,2\}$. These prices are not observed by the consumer.

II. The consumer submits a bid b.

III. The NYOP retailer compares b to the lowest submitted price by the suppliers. If $b\geq\min[P_1,P_2]$, the consumer pays b to the NYOP retailer, and the NYOP retailer pays $\min[P_1,P_2]$ to the supplier with the lowest bid in return for providing a unit to the consumer. If $b<\min[P_1,P_2]$, no transaction occurs.

A supplier's optimal bid price will depend on its own realized cost, the expected bid price of the rival service provider, and the expected bid level of the consumer. In particular, service provider 1 observes ω_1, conjectures that service provider 2 follows a bidding rule $P_2(\omega_2)$, and anticipates that the consumer bid is drawn from the distribution $D(x)$ with support on the interval $[\underline{b},\bar{b}]$. Let $\hat{\omega}(P)$ be the inverse function of $P_2(w_2)$. For a given ω_1, supplier 1's expected profit is

$$\Pi_{S1}^{SB}(P_1)=\int_{\omega_2=\hat{\omega}(P_1)}^{R}\int_{b=P_1}^{\bar{b}}(P_1-\omega_1)d(b)g(\omega_2)\,db\,d\omega_2. \quad (13)$$

Supplier 1 chooses P_1 to maximize (13). In equilibrium, a supplier's expectation of the other's bidding rule coincides with the actual bidding rule the other follows, and as a result of symmetry, the suppliers have the same bidding function, which we denote as $P^{SB}(\omega_i)$. Thus, the lower-cost supplier will win the auction.

Now consider the consumer's optimal bid (which will determine $D(x)$). The consumer knows a bid of b will be accepted only if $P^{SB}(\min[\omega_1,\omega_2])\leq b$. Thus, the consumer chooses b to maximize $CS=(\min[V,R]-b)\text{Prob}[b\geq P^{SB}(\min[\omega_1,\omega_2])]$. Let $b^{SB}(V)$ be the bid level that maximizes the consumer surplus of a consumer with valuation V.

A Nash equilibrium, characterized by the ordered pair $(b^{SB}(V),P^{SB}(\omega))$, exists when the consumer is best responding to the service providers' bid price function, $P^{SB}(\omega)$, and the service providers are best responding to each other, with the consumer's bid drawn from $D(x)$, where $D(x)$ is cumulative distribution that results when the consumer uses the bidding rule $b^{SB}(V)$. In this equilibrium, the NYOP retailer earns an expected profit of $\Pi_I^{SB}=\int_{\omega=0}^{R}\int_{b=P^{SB}(\omega)}^{\bar{b}}(b-P^{SB}(\omega))d(b)m(\omega)\,db\,d\omega$, and the total profit for the NYOP channel is $\Pi_{\text{Total}}^{SB}=\int_{\omega=0}^{R}\int_{b=P^{SB}(\omega)}^{\bar{b}}(b-\omega)d(b)m(\omega)\,db\,d\omega$. Figure 3 illustrates this profit for the example of $R=1$, $\omega_i\sim\text{U}[0,1]$ and $V\sim\text{U}[\underline{V},\underline{V}+1]$, where $0\leq\underline{V}\leq1$. The equilibrium is calculated numerically via repeated iterations until the bid function of consumers and the service providers converge to a stable solution in which all agents are best responding to each other.

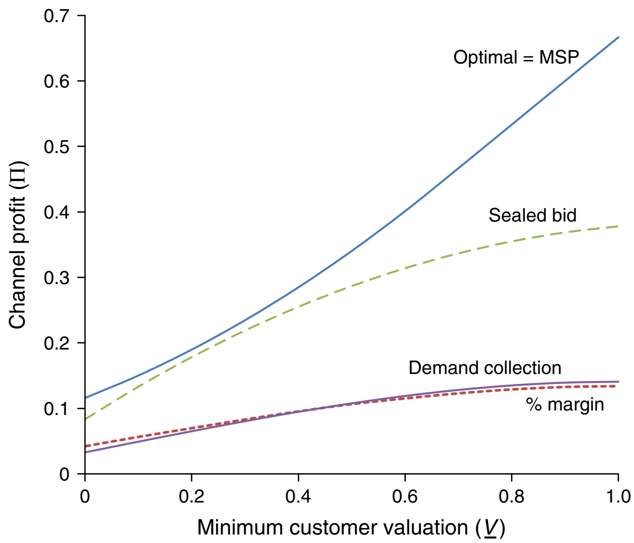
5.4. Suboptimality of Alternative Selling Mechanisms

Proposition 2 compares the profit under the three alternative NYOP mechanisms to the optimal channel profit.

Proposition 2 (Suboptimality of Common Pricing Mechanisms). *The NYOP pricing mechanisms demand collection, percentage margin, and sealed bid yield strictly less total channel profit than the optimal channel profit,* $\Pi_{\text{Total}}^{\text{Optimal}}$.

Proposition 2 shows that none of the three alternative mechanisms achieves the maximum channel profit. The logic behind this result is straightforward: none of these alternative procurement mechanisms will generate the optimal bid-acceptance function. One easy way to see this is to note from Lemma 1 that, to reach the optimal NYOP channel profit, one necessary condition is that all consumers with $V\geq R$ must receive a unit of the product regardless of the cost realization. However, under DC, PM, and SB, the bid submitted by such a high-value consumer will be strictly less than R; i.e., each consumer will shade her bid downward in order to maximize her expected surplus. Under each of these three mechanisms, such a bid will be accepted

Figure 3 (Color online) Profit Comparisons of the NYOP Mechanisms



with a probability of less than 1 (since it is possible for $\omega_1 = \omega_2 = R$).

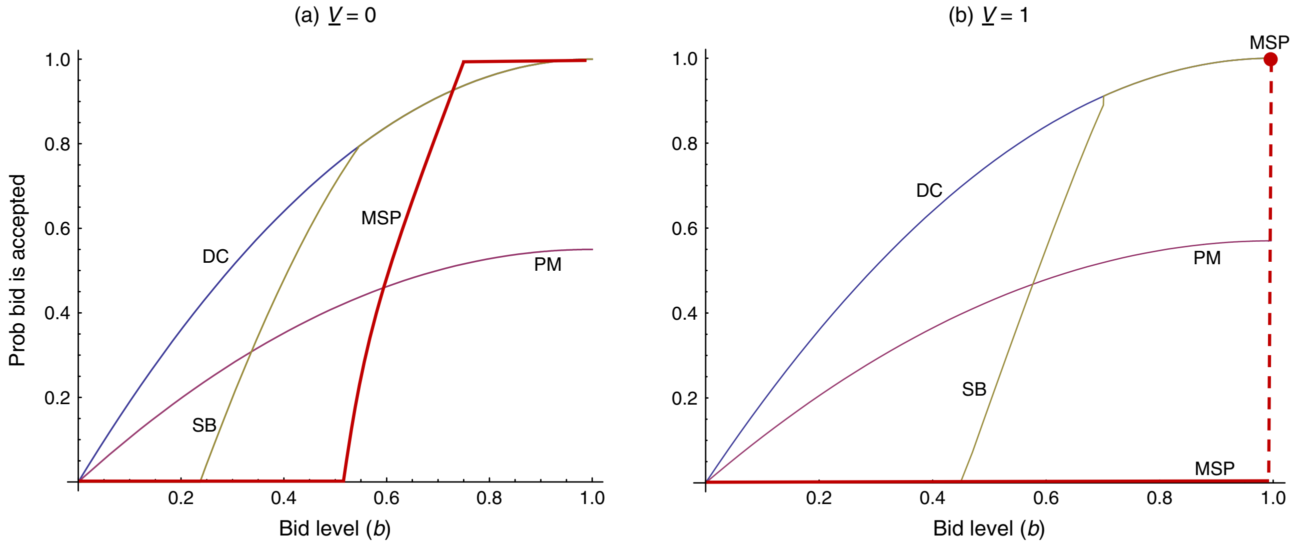
While it may not be surprising that (unlike MSP) DC, PM, and SB do not reach the optimal NYOP channel profit, it is more interesting to examine the magnitude of these shortfalls. For instance, intuition drawn from the preceding paragraph might suggest the shortfall is small (or even trivial) since the identified "lost" transactions (that occur when both service providers have high cost realizations) would yield relatively small returns (or even be negative). It is obvious that the exact magnitude of the shortfall in channel profits will depend on the underlying parameters and the cost/value distributions. However, to provide insight regarding the relative performance of these various NYOP mechanisms, we present results using numerical examples. In particular, Figure 3 illustrates the channel profit for these mechanisms as $\underline{V}$ varies from 0 to 1, under the assumptions that $R = 1$, $\omega_i \sim \text{U}[0, 1]$, and $V \sim \text{U}[\underline{V}, \underline{V}+1]$. Examples 1 and 2 are special cases of this family of assumptions.

Figure 3 demonstrates that the optimal NYOP channel profit that can be reached via MSP is substantially larger than that under the other NYOP mechanisms. At $\underline{V} = 0$, DC obtains only 28.4% of the profit possible under MSP. For PM and SB, the percentages of optimal profit obtained are 33.8% and 82.2%, respectively. For $\underline{V} = 1$, the sacrificed profit is even more significant, with PM, DC, and SB obtaining only 20.1%, 21.1%, and 56.5% of the optimal profit, respectively. Note that the profit under SB is substantially larger than that under PM and DC. This advantage of the sealed-bid format arises from the increased efficiency of the SB mechanism: unlike PM and DC, SB always selects the lowest-cost supplier by forcing them to compete for the bidder.

A key factor that explains the large magnitude of the profit shortfalls relative to MSP is that consumers bid much lower when they face the PM, DC, or SB versions of the NYOP mechanism. Lower bids occur because PM, DC, and SB lead to higher bid-acceptance rates for low bid levels (relative to MSP). Figure 4 shows the bid-acceptance probabilities across the various mechanisms for two cases, $\underline{V} = 0$ and $\underline{V} = 1$. First, consider the case of $\underline{V} = 1$. With this distribution of consumer valuations, any consumer is willing to purchase in the posted-price market if her bid at the NYOP channel is rejected. As a result, the optimal bid level does not depend on the value realization. To maximize NYOP channel profit through the MSP mechanism, the NYOP seller would establish an acceptance rule that any bid at or above 1 will be accepted, while any bid below this threshold will be rejected. In response, a consumer will bid 1. By contrast, under DC, the consumer knows her bid will be accepted whenever $b \geq \min[\omega_1, \omega_2]$ (a value that is very likely to be significantly less than 1). Taking into account the distribution of $\min[\omega_1, \omega_2]$ (as shown in Figure 4(b)), the consumer maximizes her expected surplus by bidding 0.423 (i.e., less than half of what she would have bid under MSP). Instituting a commission fee via PM makes low bids less likely to be accepted, as shown in Figure 4. Such a downward shift in the acceptance rate schedule slightly increases the bid a consumer would place (to 0.47). But PM also leads to other demand-side inefficiencies because it creates a situation in which transactions occur only if there is a substantial gap between a consumer's bid and the procurement cost, thus eliminating all transactions that would generate only moderate or small profit margins. Thus, as Figure 3 shows, both DC and PM generate much less channel profit than the optimal NYOP mechanism. The SB mechanism creates an incentive for service providers to shade their bid prices upward (since, under this first-price auction, payment will equal the submitted bid price). This shading behavior has an especially large effect when a service provider realizes a very low cost (and thus anticipates that the other supplier is likely to have significantly higher costs). Taking into account this shift in bid prices, the consumer will bid at 0.701, which is significantly higher than under PM or DC, but still much lower than under MSP.

Now consider the case of $\underline{V} = 0$, where the bid acceptance function for this example is given in Figure 4(a). Under MSP, the NYOP retailer rejects all bids below 1/2 and any bid at or above 2/3 will be accepted for sure. As a result, a consumer with $V < 1/2$ will not bid, and consumers with valuations between 1/2 and 1 will place a bid between 1/2 and 2/3, with higher valuations leading to higher bids. By contrast, the largest bid induced under PM, SB, and DC is 0.469, 0.61, and 0.423, respectively. Furthermore, whereas MSP would induce a consumer with $V = 1/2$ to bid her true valuation (namely, 1/2), a consumer with $V = 1/2$ will

Figure 4 (Color online) Probability of Bid Acceptance



only bid 0.243, 0.404, and 0.232 under PM, SB, and DC, respectively.

These examples help illustrate the potential shortcomings of various NYOP mechanisms. Specifically, the analysis suggests that the format used to solicit service providers' participation in the NYOP channel can significantly impact consumer bidding behavior. If a consumer anticipates a substantial possibility that a low bid will be accepted, she will significantly shade her bid downward. This bid-shading effect is especially large when the NYOP retailer simply collects demand and transfers the bids, in full, to the participating suppliers. To counteract such bid shading by consumers, the NYOP retailer can take an active role in trying to reduce the probability that low bids will be accepted. There are several means of doing so, including implementing minimum margins that must be achieved on each transaction, setting minimum levels at which consumers must bid to use the NYOP system, and having the service providers bid to be the chosen supplier (since they will have an incentive to place bids in excess of their true costs). However, such shifts in the acceptance rate under these alternative mechanisms cannot replicate the optimal bid-acceptance function and thus fall short of maximizing channel profit. To achieve the optimal bidder incentives, the NYOP retailer must actively manage the acceptance rate, which will involve strategically accepting some bids that are below realized costs and rejecting some bids that are above them. Our identified MSP mechanism is capable of generating this optimum bid-acceptance function.

Furthermore, one must carefully consider whether or not a mechanism achieves supply-side efficiency. The NYOP retailer must ensure that the mechanism is providing an incentive for service providers to truthfully reveal their costs and that this cost information is being used to fulfill demand in the most cost-efficient manner possible. Margin-based strategies, such as PM, do not always identify the lower-cost service provider, e.g., when both service providers can provide the product at the requested margin. In such cases, the higher-cost service provider may be the chosen supplier, thus leading to a smaller total channel profit.

6. Allocation of Profit Across Channel Members

In this section, we discuss the allocation of channel profit among channel members. This is an important topic since channel members are primarily concerned with their own profit.

Let $\Pi_{Si}^{M}(T)$, $\Pi_{I}^{M}(T)$, and Π_{Total}^{M} be, respectively, the expected profit for each supplier, for the NYOP retailer (i.e., "Intermediary"), and for the entire channel under selling mechanism M, where $\Pi_{\text{Total}}^{M} = 2\Pi_{Si}^{M} + \Pi_{I}^{M}$ and T is a lump-sum transfer payment from a supplier to the retailer. Specifically, the NYOP retailer charges each service provider a fixed fee (T) for the right to be a participating supplier. Note that T can be negative, in which case the NYOP retailer pays the suppliers to join the NYOP channel. Suppose that channel profit is allocated so that each service provider receives a share S_S of the total channel profit; i.e., $\Pi_{Si}^{M}(T) = S_S \times \Pi_{\text{Total}}^{M}$ and $\Pi_{I}^{M}(T) = (1 - 2S_S) \times \Pi_{\text{Total}}^{M}$. For instance, S_S could reflect the outcome of a Nash bargaining solution, which is a common way of modeling noncooperative negotiation (Binmore et al. 1986). For example, Draganska et al. (2010) model a setting with multiple retailers and manufacturers by analyzing one manufacturer–retailer dyad at a time. Dukes and Gal-Or (2003) find that the

Nash bargaining solution involves each pair splitting the gain from the market evenly. For the setting in the current study, bargaining power, represented by S_S, determines what level of T results from the negotiations between channel members. Note that the critical assumption is that S_S is not a function of the selling mechanism M. For example, this assumption holds if the channel members are engaged in Nash bargaining and the value of the outside options are zero. In our model, it is reasonable to assume that the outside options (also known as disagreement payoffs should negotiations fail) are zero, since the NYOP retailer will have no products to sell if the suppliers do not participate in the NYOP channel, and the opportunity costs to the suppliers of selling a good through the NYOP channel are subsumed into the costs ω_i.

The choice of selling mechanism is modeled as a three-stage game. In the first stage, the NYOP retailer chooses M, where M equals MSP, DC, SB, or PM. In the second stage, the fixed fee T is determined, e.g., via bilateral negotiations. In the third stage, a consumer arrives at the NYOP channel and places a bid. Contingent on the chosen mechanism, the analysis from Sections 4 and 5 gives the consumer's optimal bid, whether or not this bid is accepted, and the size of the payment made to each respective channel member. Allowing a service provider to choose M in the first stage would not alter the results that follow. Furthermore, allowing for additional mechanisms will not impact the equilibrium profit, since Proposition 1 shows that no mechanism can yield more channel profit than MSP. Proposition 3 summarizes the results of this game.

Proposition 3 (Channel Member Profit). *In equilibrium, the NYOP retailer chooses the modified second-price auction. Each supplier earns an expected profit of* $S_S \times \Pi_{\text{Total}}^{\text{Optimal}}$, *and the NYOP retailer earns an expected profit of* $(1-2S_S)\times\Pi_{\text{Total}}^{\text{Optimal}}$. *A supplier participation fee is set at* $T=\Pi_{S1}^{\text{MSP}}-S_S\Pi_{\text{Total}}^{\text{Optimal}}$.

Since the channel members will share channel profit according to a predetermined percentage, they have an incentive to utilize the mechanism that generates the highest total channel profit. MSP is a mechanism that achieves this optimal level. Transfer payments are used to ensure that each channel member receives its appropriate share of the surplus.

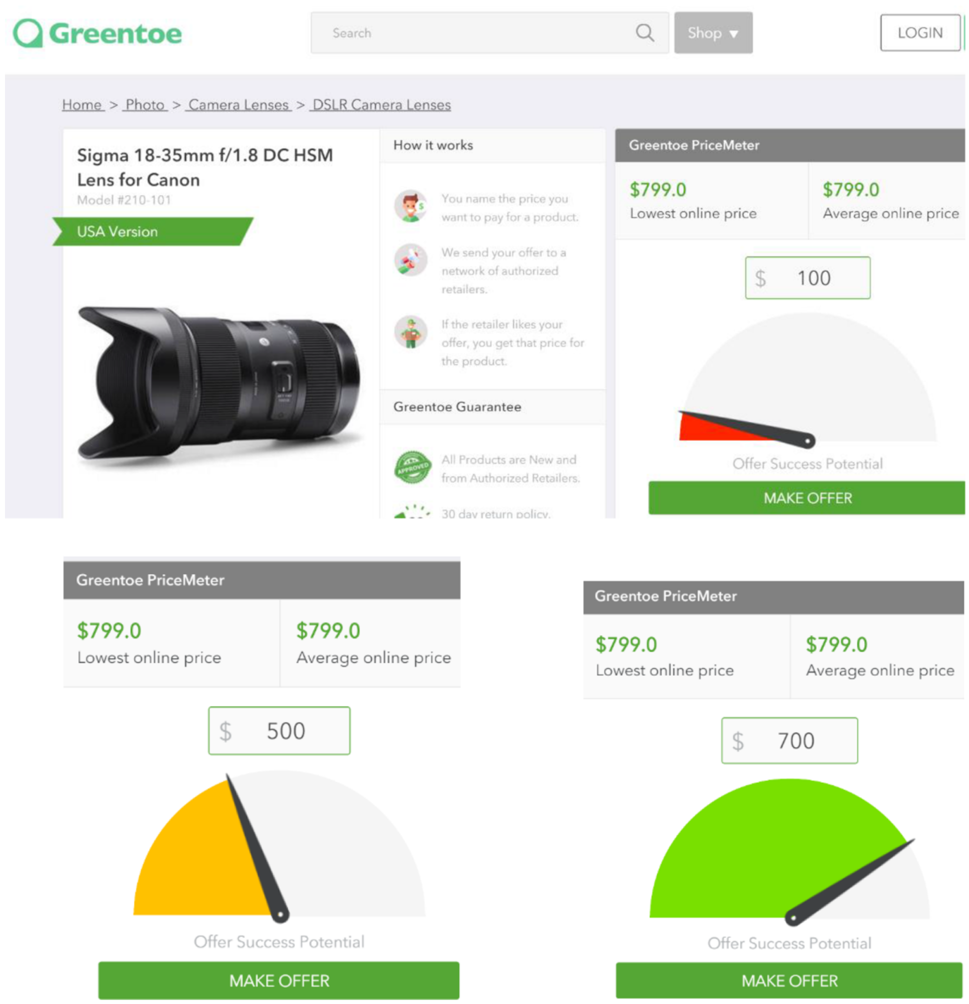
An important implication of Proposition 3 is that, when fixed transfer payments between channel members are feasible, switching to MSP from another currently used NYOP procurement mechanism can be structured in a way to generate a win-win-win outcome. To illustrate this result, consider an NYOP channel that currently yields an expected profit of Π_I for the NYOP retailer and Π_S for each of the two service providers. Define $\Pi_{\text{Total}}=\Pi_I+2\Pi_S$ and $S_S=\Pi_S/\Pi_{\text{Total}}$. Now, suppose the firms switch to the MSP mechanism and agree to transfer payments from each service provider to the NYOP retailer such that $T=\Pi_{S1}^{\text{MSP}}-S_S\times\Pi_{\text{Total}}^{\text{MSP}}$. Under this new system, each service provider earns a net profit of $S_S\times\Pi_{\text{Total}}^{\text{MSP}}$, whereas each earned a profit of $S_S\times\Pi_{\text{Total}}$ under the previous format. The retailer now earns a net profit of $(1-2S_S)\times\Pi_{\text{Total}}^{\text{MSP}}$, whereas it previously earned a profit of $(1-2S_S)\times\Pi_{\text{Total}}$. Define $\Delta=\Pi_{\text{Total}}^{\text{MSP}}-\Pi_{\text{Total}}$. From Proposition 3, we know $\Delta\geq 0$. Thus, this switch to MSP would increase each service provider's expected profit by $S_S\times\Delta$ and would increase the NYOP retailer's expected profit by $(1-2S_S)\times\Delta$. In other words, each channel member benefits, independently, from switching to MSP, with the magnitude of each member's benefit depending on their bargaining power.

7. Concluding Comments

The results of this study show that the specific mechanism used by an NYOP retailer to identify a supplier to meet consumer demand can significantly impact how much profit is generated by the NYOP channel. Different mechanisms influence the channel profit both directly by selecting different suppliers and indirectly by affecting consumer bidding strategies. We construct a mechanism we call the *modified second-price auction* that maximizes channel profit by simultaneously identifying the lowest-cost supplier and inducing consumers to bid at the maximum level possible given that a consumer's valuation is private information.

Our second main finding is that several NYOP mechanisms used in the industry and commonly discussed in the extant literature do not maximize channel profit. However, before wholeheartedly advocating that NYOP firms adopt MSP, it is important to consider potential impediments that might be encountered during implementation. For an NYOP retailer to implement the optimal NYOP strategy, consumers have to believe that the acceptance probability associated with a particular bid is given by the bid acceptance function the retailer announces. Similar issues of credible commitment arise for other marketing strategies, such as advance selling, i.e., committing to a future posted price (Xie and Shugan 2001) and committing not to haggle with customers (Desai and Purohit 2004). However, in these cases, a breach (e.g., a posted price that differs from what was promised or a price concession from haggling) is verifiable. In our setting, the NYOP seller must commit to a bid-acceptance policy, where the bid-acceptance probability is not verifiable unless consumers can observe a large sample of bid outcomes. Thus, the credibility issue our NYOP retailer faces is more similar to the commitment problems that arise for stochastic auditing, where a tax collector commits to an auditing probability (Border and Sobel 1987) and

Figure 5 (Color online) Bid-Acceptance Information at Greentoe.com



Source. https://www.greentoe.com/product/Sigma_18-35mm_f-1-8_DC_HSM_Lens_for_Canon_210-101?keyword=Sigma+18-35. Used with permission from Greentoe.

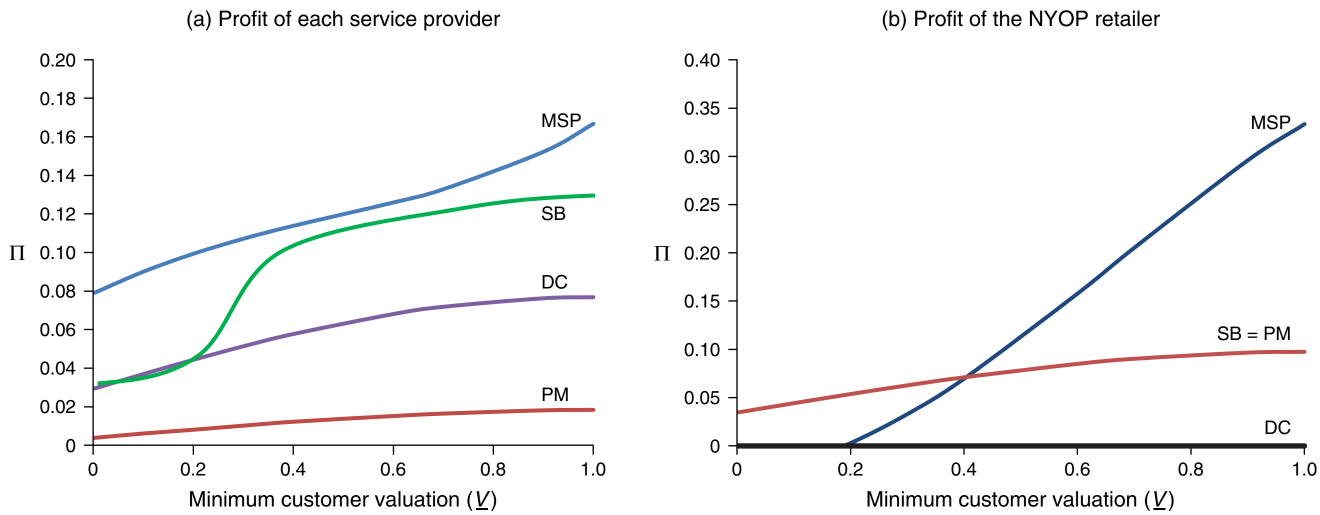
probabilistic selling, i.e., committing to random product assignments (Fay and Xie 2008).

As discussed in Section 4.2, lower and upper bounds for the bid-acceptance function can be established via simple modifications to the bidding interface, e.g., by only allowing consumers to enter bids within a certain range. While it may be more difficult to establish the probability of acceptance for intermediate bid values (Zeithammer 2015), as mentioned in the introduction, several online retailers already convey the approximate probability that a bid will be accepted. For example, Figure 5 presents several screenshots from Greentoe.com.[13] These screenshots indicate that a very low bid ($100 on a lens that has an online price of $799) has a very low success rate. By contrast, a bid of $500 has a moderate chance of success, and a bid of $700 is very likely to be accepted. It would be straightforward for an NYOP seller to modify these graphs to convey the probability of acceptance that occurs under MSP.

The more challenging issue for the seller is how to induce customers to believe these acceptance rates reflect the actual bid acceptance policy. It may be possible for a seller to obtain such credibility via reputation building, e.g., through transparent observation of previous responses to consumers' bids. The seller can establish such a reputation if consumers are able to observe prior acceptance/rejection decisions. The Internet has facilitated the spread of word of mouth, thus enabling users to learn more easily about other users' experience with NYOP retailers. For instance, BiddingForTravel.com, which has experienced over 100 million visits, is a forum in which Priceline users report which bids have been either accepted or rejected (Fay and Xie 2008). By

[13] Note that a customer is not restricted to the three particular bid levels shown in Figure 5. By adjusting one's proposed bid, a customer can explore the entire spectrum of possible bids and determine the corresponding acceptance rate of each.

Figure 6 (Color online) Channel Member Profit in the Absence of Transfer Payments



viewing the listings that are most closely related to one's current purchase decision, a consumer can estimate the probability of winning with a particular bid. Or, if an NYOP retailer were to announce a certain bid-acceptance function, a consumer could determine whether or not actual bid acceptance rates differ significantly from the announced rates. Such observations could facilitate development of a reputation for truthful announcements. Sellers could accelerate this process by financially backing the development and promotion of such consumer forums. Furthermore, an NYOP retailer might introduce an automated reporting system in which the bid rejections and acceptances are verified by a third party and automatically posted to that third party's website. Such an automated procedure would increase both the amount and the accuracy of information available to potential buyers.

It is important to note that developing a reputation for following the announced bid acceptance policy requires consumers or a third-party auditor to be able to observe a large sample of bid outcomes. Thus, implementation of MSP would be very difficult, if not impossible, in thin markets in which transactions occur infrequently. However, repeated transactions of the same product are not required since the reputation concerns the relationship between the stated and actual probability of acceptance by the same retailer, not necessarily for the same product (Zeithammer 2015). Since reputations take time to build, this NYOP mechanism would only be applicable for sellers who are sufficiently focused on long-run profits rather than short-term gains.

An NYOP retailer's lack of necessary information can also impede implementation of the optimal NYOP selling mechanism. In particular, to establish the optimal acceptance-rate schedule, the NYOP retailer must know the distributions of customer valuations and of the suppliers' opportunity costs. Absence of such information would also impede the ability to set appropriate transfer payments between the NYOP retailer and its service providers. Without such transfer payments, each channel participant's profit may not be maximized by utilizing the MSP selling mechanism. In Figure 6, we show the expected profit of the service providers and the NYOP retailer, respectively, under the assumption of a uniform cost distribution on $[0,1]$ and a uniform value distribution on $[\underline{V}, \underline{V}+1]$. Notice from Figure 6(a), in the absence of any participation fees, a service provider's expected profit is higher under our proposed MSP mechanism than under any of the other alternative NYOP mechanisms discussed in the paper (with the percentage margin strategy yielding the lowest profit for the service providers). However, from Figure 6(b), we see that MSP yields the highest profit for the NYOP retailer only if consumer valuations are sufficiently high. Otherwise, the sealed-bid mechanism and percentage margin strategies are more profitable for the NYOP retailer. Thus, if the NYOP retailer is unable to charge fixed fees to the service providers and very few customers value the product in excess of the posted price, he will not have an incentive to adopt the MSP mechanism. However, notice that the service providers still would prefer the MSP mechanism over other ones. Thus, they may be willing to pay the NYOP retailer to switch to MSP.

This study suggests that participation fees may be a useful means for allocating profit across channel members and thus ensuring an incentive to adopt the mechanism that maximizes total channel profit. This result complements the finding in Spann et al. (2010) that it can be beneficial for an NYOP retailer to charge a fee to consumers for the right to bid. Here, we show that an NYOP retailer may also benefit from charging its suppliers for the right to sell to these consumers.

One limitation of the current study is that suppliers' costs are assumed to be uncorrelated, while in practice, they can be correlated. In the appendix, we consider an extension to our model in which costs are perfectly correlated and find that all of the core results of the study continue to hold in this case. Specifically, while the choice between suppliers becomes irrelevant when costs are perfectly correlated, the procurement mechanism still has a large impact on the bid-acceptance function, which, in turn, affects customer bidding decisions. The MSP auction still obtains the maximum channel profit, while the alternative NYOP mechanisms fall short of this optimum. These results suggest that (imperfect) correlation of costs would reduce the potential inefficiency losses from choosing the wrong supplier but would increase the relative importance of designing the procurement mechanism so as to manage consumer bidding behavior appropriately.

Several important areas remain for future research to address. One potential extension would be to model how bargaining power is obtained. Cross-channel effects could be important since service providers with more profitable non-NYOP channels would have greater outside options and thus higher bargaining power. It would also be of interest to consider the impact of having more than two service providers. One would expect that greater competition among suppliers would shift profit from service providers to the NYOP retailer. Furthermore, adding more service providers to the NYOP channel could significantly impact the total channel profit obtained under the various selling mechanisms. Although all the core results of the study should continue to hold qualitatively when additional suppliers are added, one would expect more competitive bidding under auction formats, such as the SB mechanism, and that the NYOP retailer would set higher margins under margin-based strategies such as the PM mechanism. Another potential area for future research is to consider issues that arise in a dynamic setting. For instance, suppliers might be concerned if repeated interactions through the NYOP channel reveal private information about their costs to their rivals. Thus, they may prefer NYOP mechanisms that allow their costs to remain opaque. In addition, past interactions in the NYOP channel may impact how service providers are treated by the NYOP retailer in the future; e.g., Priceline rewards suppliers who have made successful offers in the past by directing a greater share of future demand to such suppliers (Anderson 2009). Furthermore, in a dynamic setting, consumers face the decision of when to bid. Bid timing could have important implications for capacity allocation both within and across channels.

Acknowledgments

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Appendix

Sketch of a Proof of Lemma 1

Lemma 1 is equivalent to Proposition 2 of Zeithammer (2015), using slightly different notation. We provide only a sketch of the proof here. See Zeithammer (2015) for further details.

The retailer is effectively a monopolist facing buyers with private valuations drawn from F censored above at R (consumers with $V > R$ all mimic the consumer with $V = R$). When such a monopolist learns his production cost ω before having to accept a consumer's bid, the optimal direct revelation mechanism (DRM) allocates the object to the consumer whenever a posted-price monopolist facing the same demand would. Specifically, the optimal DRM allocates the good to the consumer whenever $V < R$ and $\omega < \psi(V)$ per standard monopoly pricing, and when $V \geq R$ because the production cost is below R by construction.

The main contribution of Zeithammer (2015) is showing how this allocation rule can be implemented in NYOP selling when consumers shade their bids below their valuations (in other words, NYOP is not a DRM). The constructive proof uses revenue equivalence, i.e., the fact that all mechanisms that allocate the good with the same probability $q(V)$ for every V generate the same revenue. The optimal DRM rule implies a unique $q(V) = \Pr(\omega < \psi(V)) = M(\psi(V))$ for every $V < R$ and $q(R) = 1$. Moreover, the DRM also determines the expected utility of every consumer type $V < R$ to be $U(V) = \int_{\psi^{-1}(0)}^{V} M(\psi(z))\,dz$. Under the NYOP mechanism, the expected utility to a consumer of type $V < R$ is $U(V) = q(V)(V - \beta(V))$. Thus, the optimal NYOP mechanism must deliver the same expected utility as the optimal DRM. By setting these two utilities equal, one can solve for the unique bidding function $\beta(V)$ for $V < R$. To ensure that $q(R) = 1$, the bid of the high bidders $\beta(R)$ must be strictly above $\lim_{V \to R-} \beta(V)$ to prohibit low-value bidders bidding slightly more and securing certain acceptance. Since the bidding function has a step discontinuity (as long as $\bar{V} > R$), the optimal bid-acceptance function must involve an interval of intermediate bid levels $(\lim_{V \to R-} \beta(V), \beta(R))$ for which the acceptance probability (A) of those bid levels is low enough that nobody submits them. Lemma 1 gives the upper bound on A on that interval such that no consumer submits a bid in that interval.

Proof of Proposition 1

We begin by showing that each service provider's optimal strategy is to submit a price equal to its true cost, i.e., $p_i = \omega_i$. Note that the size of the payment made by the NYOP retailer to the winning supplier does not depend on the price submitted by that service provider; the payment either equals the price submitted by the rival service provider (under condition 1) or is a function of the consumer's bid, i.e., $\omega^*(b)$

(under condition 2). Thus, the bid price of a service provider will only impact whether or not its bid will be accepted. Assume service provider 2 has bid its true cost ($p_2 = \omega_2$), and suppose service provider 1 considers placing a bid higher than its true cost, i.e., $\hat{p}_1 > \omega_1$. Compared with bidding its true cost, the service provider will lose sales in the following two cases: (1) if $\omega^*(b) \geq p_2$ and $\hat{p}_1 > p_2 > \omega_1$ or (2) if $\omega^*(b) < p_2$ and $\omega_1 \leq \omega^*(b) < \hat{p}_1$.[14] Sales under both of these scenarios would be profitable for service provider 1, either yielding a net profit of $p_2 - \omega_1 > 0$ in the first case or a net profit of $\omega^*(b) - \omega_1 \geq 0$ in the second case. Thus, bidding above cost lowers one's profit. Now consider the effect of bidding lower than one's true cost, i.e., $\tilde{p}_1 < \omega_1$. Compared with bidding at one's true cost, the service provider will gain sales in the following two cases: (1) if $\omega^*(b) \geq p_2$ and $\tilde{p}_1 < p_2 < \omega_1$ or (2) if $\omega^*(b) < p_2$ and $\omega_1 > \omega^*(b) \geq \tilde{p}_1$. Sales under both of these cases would yield negative profit for service provider 1 (either $p_2 - \omega_1 < 0$ in the first case or $\omega^*(b) - \omega_1 < 0$ in the second case). Thus, bidding less than one's opportunity cost lowers one's profit. Therefore, service provider 1's optimal strategy is to submit a bid price equal to its true realized opportunity cost. The same line of reasoning verifies that service provider 2's optimal strategy is to bid truthfully.

We now show that the MSP generates the optimal allocation, as identified in Lemma 1. Given that both service providers are submitting bid prices equal to their true costs (as shown in the preceding paragraph), the MSP mechanism explicitly specifies that the lower-cost supplier be chosen and that a transaction will occur only if $\min[\omega_1, \omega_2] \leq \omega^*(b)$. Note that, directly by the definition of $\omega^*(b)$, this condition reaches the same allocation as the cost-contingent bid-acceptance policy of Lemma 1.

Proof of Remark

Note from the definition of MSP, the third line includes the condition "less than," thus indicating that the optimal cost threshold is not unique; i.e., a continuum of thresholds in this particular interval would yield the same profit. From Lemma 1, channel profits are maximized such that no consumer would find it optimal to place a bid in the interval $(\beta_R^-, \beta(R))$. By definition, at the upper bound of MSP given in the third line, a consumer with a valuation of R would be indifferent between bidding $\beta(R)$ and placing a bid in the interior of this interval. Thus, setting a cost threshold at any level below this lower bound will make it suboptimal to place a bid in the interval $(\beta_R^-, \beta(R))$. (Such a bid now has a lower probability of acceptance and the same payoff if the bid is accepted, thus decreasing the expected payoff of placing a bid in this interval. A cost threshold decrease in this interval does not change the expected payoff of bidding $\beta(R)$. Therefore, placing a bid of $\beta(R)$ is now a strictly superior option to bidding in the interval $(\beta_R^-, \beta(R))$).

Proof of Proposition 2

To prove that the alternative mechanisms yield channel profit strictly below the optimum, we demonstrate that each alternative violates a necessary condition that defines the optimal solution. In particular, as we note in our proof of Lemma 1, Zeithammer (2015) proves that, to obtain the optimal channel profit, a mechanism must allocate the object to the consumer whenever a posted-price monopolist facing the same demand would do so. One characteristic of the optimal allocation is that all consumers with valuations at or above R receive the good with probability one. Thus, to prove that DC, PM, and SB yield suboptimal profit, it is sufficient to simply demonstrate that, for each of these NYOP mechanisms, high-value consumers receive the product with a probability of less than 1; i.e., $A(b(R)) < 1$.

First, we show that under any NYOP mechanism, including MSP, a bid of a consumer whose true valuation is R must be strictly less than R. Such a consumer earns an expected surplus of $CS = (R-b)A(b)$ and chooses b to maximize CS. Any bid such that $b > R$ yields a negative expected surplus. A bid of $b = R$ yields zero surplus regardless of the acceptance-rate function. As long as $A(b) > 0$ for at least some $b < R$, then the consumer can earn a strictly positive expected surplus by placing some bid less than R. To prove that the optimal consumer bid, $b(R)$, is strictly less than R, we only need to show that the acceptance rate of a bid $R - \varepsilon$ is strictly greater than zero (for each of the three alternative mechanisms), where ε is arbitrarily small but strictly greater than zero. Under DC, $A(b) = M(b)$. Since ω_i is continuously distributed from $[0, R]$, we have $M(R-\varepsilon) > 0$; thus, $A(R-\varepsilon) > 0$. Similarly, under PM, the acceptance rate is $A(b) = M[(1-\gamma)b]$. Since ω_i is continuously distributed from $[0, R]$ and $0 < \gamma < 1$ (which we will show in the next paragraph), we have $A(R-\varepsilon) = M[(1-\gamma)(R-\varepsilon)] > 0$. Finally, for SB, consider a service provider who realizes a cost of 0. Let $P^{SB}(0)$ be the price bid of such a firm in equilibrium. We should note that it must be the case that $P^{SB}(0) < R$. If $P^{SB}(0) > R$, the service provider will earn zero profit from the NYOP channel since no consumer will ever bid in excess of R. If $P^{SB}(0) = R$, there are two cases to consider: (a) if the rival submits a price bid less than R, then the focal service provider will earn zero profit since the product will be procured from his rival; or (b) the rival submits a price bid equal to R, then, if the consumer's bid is also R, the focal service provider will make a sale half of the time. Clearly, one could earn a higher profit by submitting a price bid of less than R. In the first case, profit will remain at zero if he does not win the auction and be positive if he does win. In the second case, a price bid of $R - \varepsilon$ would double the probability of making a sale and have only an infinitely small impact (ε) on his margin. Thus, under SB, $P^{SB}(0) < R$, and thus $A(R-\varepsilon) > 0$.

Second, to complete the proof, we show that, under each of these three mechanisms, $A(R-\varepsilon) < 1$. Under DC, $A(b) = M(b)$. Since ω_i is continuously distributed from $[0, R]$, we have $A(R-\varepsilon) = M(R-\varepsilon) < 1$. Under PM, the NYOP retailer chooses γ to maximize its own profit. If $\gamma < 0$, the retailer's expected profit is negative (since all sales produce negative margins. If $\gamma = 0$, the NYOP retailer earns zero profit regardless of whether or not a sale occurs. If $\gamma \geq 1$, the NYOP retailer also earns zero profit, since there is no cost realization for which a service provider would be willing to accept the price offer. Thus, any optimal γ must satisfy the condition $0 < \gamma < 1$; i.e., any successful transaction generates positive profit for both the NYOP retailer and the chosen service provider. Since the acceptance rate under PM is $A(b) =$

[14] Under all other situations, bidding $\hat{p}_1$ yields the same outcome for service provider 1 as bidding ω_1.

$M[(1-\gamma)b]$, where $0<\gamma<1$, and ω_i is continuously distributed from $[0,R]$, we have $A(R-\varepsilon)=M[(1-\gamma)(R-\varepsilon)]<1$. Finally, for SB (which is a first-price auction), each service provider submits an offer price of $P_i>\omega_i$. (If $P_i=\omega_i$, the service provider would earn zero profit regardless of whether or not his bid is accepted; if $P_i<\omega_i$, the service provider would earn zero profit if his bid is rejected and negative profit if his bid is accepted). Since it is possible for $\omega_1=\omega_2=1$, we have $A(R-\varepsilon)<1$.

In summary, we have shown that consumers have an incentive to shade their bids—namely, that one's surplus-maximizing bid, $b(R)$, is strictly less than R. Furthermore, under each of the alternative mechanisms, the bidding threshold can be as high as the upper bound of the cost realizations, i.e., equal to R. Thus, DC, PM, and SB will be characterized by an equilibrium bid acceptance rate of $A(b(R))<1$. Since the optimal allocation requires $A(b(R))=1$, none of these alternative mechanisms is able to reach the optimal channel profit.

Proof of Proposition 3

We solve the three-stage game using backward induction. In stage 3, each mechanism (M) yields the allocation outcome and total profit (Π^M_{Total}) given in Sections 4 and 5. (Note that the value of T will not impact any of the pricing or bid acceptance decisions in the third stage since it is a fixed cost/benefit.) In stage 2, bilateral negotiations determine the value of T. Specifically, for each selling mechanism, M, T is set so that $\Pi^M_{Si}(T)=\Pi^M_{S1}-T\equiv S_S\times\Pi^M_{\text{Total}}\Rightarrow T=\Pi^M_{S1}-S_S\times\Pi^M_{\text{Total}}$, where $\Pi^M_{\text{Total}}=2\Pi^M_{Si}+\Pi^M_I$.

We now turn to the first stage of the game. The NYOP retailer chooses the M that yields the highest profit for itself: $\operatorname{argmax}_{M=\{MSP,DC,SB,PM\}}\Pi^M_I=(1-2S_S)\times\Pi^M_{\text{Total}}$. Since S_S is constant across M, the NYOP retailer's profit is maximized by choosing the M with the highest Π^M_{Total}. Propositions 1 and 2 establish that MSP is the mechanism that yields the highest total channel profit and that no other mechanism can do strictly better.

Perfectly Correlated Costs

In the base model, we assumed ω_1 and ω_2 were drawn independently from a continuous distribution G with support on $[\underline{\omega},R]$. If costs are perfectly correlated, we have $\omega_1=\omega_2\equiv\omega$, where ω is drawn from G. The derivation of Lemma 1 proceeds exactly the same as in the original model, except the minimum cost realization is distributed according to G rather than according to M. Thus, Lemma 1 becomes the following.

Lemma 1(a). *The total channel profit is maximized by the following bid-acceptance function*:

$$A^*(b)=\begin{cases}0 & \textit{if } b<\beta(\Psi^{-1}(0)),\\ G(\Psi(\beta^{-1}(b))) & \textit{if } \beta(\Psi^{-1}(0))\le b<\lim_{V\to R-}\beta(V),\\ \textit{less than } \int_{\Psi^{-1}(0)}^{R}\dfrac{G(\Psi(z))}{R-b}\,dz & \\ & \textit{if } \lim_{V\to R-}\beta(V)\le b<\beta(R),\\ 1 & \textit{if } b\ge\beta(R),\end{cases}$$

where $\beta(V)$ is the bidding function that best responds to A^*:

$$\beta(V)=\begin{cases}\displaystyle\int_{\omega=0}^{\Psi(V)}\Psi^{-1}(\omega)\frac{g(\omega)}{G(\Psi(V))}\,d\omega & \textit{if } \Psi^{-1}(0)<V<R,\\ \displaystyle R-\int_{\Psi^{-1}(0)}^{R}G(\Psi(z))\,dz & \textit{if } V\ge R.\end{cases}$$

All three of the propositions are unaffected by this modeling change. Thus, allowing for correlated costs does not alter the fact that MSP can reach the optimal channel profit or that the alternative NYOP mechanisms fall short of this optimal.

However, allowing for correlated costs will impact the exact profit earned under each NYOP mechanism. To see this, return to the numerical example in which $R=1$, $\omega_i\sim U[0,1]$, and $V\sim U[\underline{V},\underline{V}+1]$. Figure 3 shows the profit (when costs are independent) for the four NYOP mechanisms considered in this paper, as $\underline{V}$ varies from zero to one. Now, let us suppose that the costs are perfectly correlated; i.e., each firm realizes the same cost. Substituting the fact that $G(x)=x$ and $g(x)=1$, the consumer's bidding function under MSP, as given in Lemma 1(a), is

$$\beta(V)=\begin{cases}\displaystyle\int_{\omega=0}^{2V-\underline{V}-1}\frac{1+\omega+\underline{V}}{2}\frac{1}{(2V-\underline{V}-1)}\,d\omega\\ \displaystyle\qquad=\frac{1}{4}(1+2V+\underline{V}) \quad \text{if } V<1,\\ \displaystyle 1-\int_{z=(1+\underline{V})/2}^{1}(2z-\underline{V}-1)\,dz=\frac{(3-\underline{V})(1+\underline{V})}{4}\\ \qquad \text{if } V\ge 1.\end{cases}\tag{14}$$

The corresponding optimal acceptance function is

$$A^*(b)=\begin{cases}0 & \text{if } b<\dfrac{1+\underline{V}}{2},\\ 2(2b-\underline{V}-1) & \text{if } \dfrac{1+\underline{V}}{2}\le b<\dfrac{3+\underline{V}}{4},\\ \text{less than } \dfrac{(1-\underline{V})^2}{4(1-b)} & \\ & \text{if } \dfrac{3+\underline{V}}{4}\le b<\dfrac{(3-\underline{V})(1+\underline{V})}{4},\\ 1 & \text{if } b\ge\dfrac{(3-\underline{V})(1+\underline{V})}{4}.\end{cases}\tag{15}$$

To induce this acceptance rate, the following threshold under MSP is needed:

$$\omega^*(b)=\begin{cases}0 & \text{if } b<\dfrac{1+\underline{V}}{2},\\ 2(2b-\underline{V}-1) & \text{if } \dfrac{1+\underline{V}}{2}\le b<\dfrac{3+\underline{V}}{4},\\ \text{less than } \dfrac{(1-\underline{V})^2}{4(1-b)} & \\ & \text{if } \dfrac{3+\underline{V}}{4}\le b<\dfrac{(3-\underline{V})(1+\underline{V})}{4},\\ 1 & \text{if } b\ge\dfrac{(3-\underline{V})(1+\underline{V})}{4}.\end{cases}\tag{16}$$

The resulting profit is

$$\Pi^{\text{MSP}}_{\text{Total}}=\frac{1+3\underline{V}(1+\underline{V})}{12}.\tag{17}$$

Under the demand collection mechanism, the consumer knows her bid will be accepted (by one of two service providers) if and only if $\min[\omega_1, \omega_2] \le b$. For correlated costs, $\min[\omega_1, \omega_2]$ is distributed according to $G(x) = x$. Thus, the consumer will choose b to maximize $CS = (V-b)G(b)$ if $V < R$ or $CS = (R-b)G(b)$ if $V \ge R$:

$$b^{DC}(V) = \begin{cases} \dfrac{V}{2} & \text{if } V < 1 \\ \dfrac{1}{2} & \text{if } V \ge 1. \end{cases} \tag{18}$$

The expected profit to service provider 1 (who is symmetric with supplier 2) is

$$\Pi_{S1}^{DC} = F(R) E_{V<R}\left[\frac{G(b^{DC}(V))}{2} E_{\omega_1 \mid \omega_1 < b^{DC}(V)}(b^{DC}(V) - \omega_1)\right] + [1-F(R)]\frac{G(b^{DC}(V))}{2} E_{\omega_1 \mid \omega_1 < b^{DC}(R)}(b^{DC}(R) - \omega_1). \tag{19}$$

Note that Equation (19) is simpler than Equation (8) because, with identical realized costs, either both firms are willing to sell at the consumer's bid price or neither firm is willing to do so.

The total profit created under DC is $\Pi_{\text{Total}}^{DC} = 2\Pi_{S1}^{DC} = (1 + 3\underline{V} - \underline{V}^3)/24$ (since each service provider earns an expected profit of Π_{S1}^{DC} and the NYOP retailer earns zero profit).

Under the percentage margin mechanism, the consumer anticipates her bid will be accepted if and only if $\omega \le (1-\gamma)b$. Taking γ as given, the consumer chooses b to maximize $CS = (V-b)G((1-\gamma)b)$ if $V < R$, or $CS = (R-b)G((1-\gamma)b)$ if $V \ge R$:

$$b^{PM}(V) = \begin{cases} \dfrac{V}{2} & \text{if } V < 1, \\ \dfrac{1}{2} & \text{if } V \ge 1. \end{cases} \tag{20}$$

The NYOP retailer chooses γ to maximize its profit:

$$\Pi_I^{PM} = \int_{y=\underline{V}}^{1} \int_{x=0}^{(1-\gamma)y/2} \gamma \frac{y}{2} g(x) f(y)\, dx\, dy + \int_{y=1}^{\underline{V}+1} \int_{x=0}^{(1-\gamma)\frac{1}{2}} \gamma \frac{1}{2} g(x) f(y)\, dx\, dy. \tag{21}$$

Taking the derivative of (22) with respect to γ, we find that the NYOP retailer maximizes its profit with $\gamma = 1/2$, which yields a profit of $\Pi_I^{PM} = (1 + 3\underline{V} - \underline{V}^3)/48$. The expected profit to each service provider is

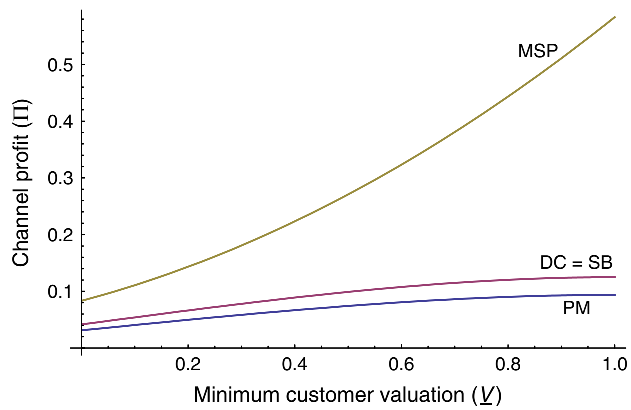
$$\Pi_{S1}^{PM} = \frac{1}{2} \int_{y=\underline{V}}^{1} \int_{\omega=0}^{y/4} \left[\frac{y}{4} - \omega\right] f(y) g(\omega)\, d\omega\, dy + \frac{1}{2} \int_{y=1}^{1/4} \int_{\omega=0}^{y/4} \left[\frac{1}{4} - \omega\right] f(y) g(\omega)\, d\omega\, dy = \frac{1 + 3\underline{V} - \underline{V}^3}{192}. \tag{22}$$

The total channel profit is $\Pi_{\text{Total}}^{PM} = \Pi_I^{PM} + 2\Pi_{S1}^{PM} = (1 + 3\underline{V} - \underline{V}^3)/32$.

Finally, we consider the sealed-bid mechanism. With identical costs, each service provider knows the other firm's cost, which results in Bertrand competition: $P_1 = P_2 = \omega$. Thus, the consumer knows her bid will be accepted if and only if $\omega \le b$. Since this is the same decision choice one would face under DC, the optimal bid strategy is given by (18). With consumer bids being the same as under DC, transactions occurring under exactly the same conditions as DC, and the service providers earning zero profit, total channel profit must be the same as DC: $\Pi_{\text{Total}}^{SB} = (1 + 3\underline{V} - \underline{V}^3)/24$, where all the profit is retained by the NYOP retailer.

In sum, profits are lowest under PM. DC and SB yield the same profit, which is strictly less than MSP. The profits of these NYOP mechanisms are given in Figure A.1.

Figure A.1 (Color online) Profit Comparisons of the NYOP Mechanisms (Perfectly Correlated Costs)



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