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Abstract

Should a peer-to-peer platform set prices for the products on the platform, or should it let sellers set their own prices while providing price recommendations?

Centralized prices allow a platform to use demand information it observes, while price recommendations allow for competition in which sellers set prices based on their private information. On sharing economy platforms, for example, we observe a myriad of such pricing regimes.

We investigate the implications of each pricing regime for the profits of platforms, buyers and sellers. When a platform recommends prices, it effectively plays the role of a sender in a multi-receiver cheap-talk game.

platforms are not always better off by centralizing pricing. When the variance of aggregate demand is large, price recommendations can be sustained in equilibrium and are often more profitable for the platform. Otherwise, a price recommendation is not credible. High (low) quality sellers have a stronger (weaker) preference for centralized pricing than the platform. Buyers, in contrast, receive lower surplus when the platform provides price recommendations, and prefer centralized pricing or competition without price recommendations.

The results provide tools for platform designers and policy makers to assess the impact of different pricing regimes in markets with platforms. Although price recommendations might seem to encourage lower prices among sellers through increased competition, this is not always the case.

Keywords: two-sided markets, peer-to-peer platforms, sharing economy, price recommendations, cheap talk.

1 Introduction

Platforms that operate peer-to-peer (P2P) markets can influence the interaction between sellers and buyers through their platform design. Among many examples, Lyft controls pricing to facilitate rides between riders (buyers) and drivers (sellers), Airbnb controls search results and recommends pricing to influence matching between hosts (sellers) who rent their houses to guests (buyers), and LendingClub assigns a credit worthiness score to borrowers (sellers) who are asking for a loan from investors (buyers).

Since the P2P structure is prevalent in many industries, it is not surprising that there is no single “one size fits all” market design of a P2P market. Platforms differ in many aspects including how search results are presented to buyers, their fee structure, how much choice buyers and sellers have and whether sellers can promote their offerings for an additional fee. Many of these differences arise from the choices platforms make when using information about consumer demand and seller competition to maximize their profits.

In many P2P markets, sellers often find it difficult to select prices for their products because of uncertainty about demand and competition. Equilibrium price levels, however, have a dramatic impact on the profits of the platform. Higher prices will lead to less transactions but with a higher margin, while low prices may increase the number of purchases but erode profit. For example, when Airbnb initially launched their platform, sellers were setting high prices that lowered the number of transactions, user satisfaction and platform revenue. Consequently Airbnb introduced a price recommendation tool for hosts in 2013 which they later improved in 2015 (Hill 2015). Because sellers set their prices based on beliefs they have about buyer demand, the platform can influence competition and price levels through supplying information to sellers or through coordinating prices directly.

A second factor that impacts the long-term profitability of the platform is the quality of matches achieved in realized transactions. Low-quality matches will lead to long-term churn of buyers who switch to competing options. The platform can use its information about buyer preferences and seller differentiation to influence the quality of matches offered to buyers, alongside the prices achieved in these transactions. In this paper we analyze how the information design of the platform can maximize its profits through manipulating the realized price levels, levels of competition and match quality.

Researchers recently devoted substantial attention to analyzing selling mechanisms on P2P platforms, with particular focus on using auctions vs. posted prices (Hammond 2010; 2013, Bauner 2015, Einav et al. 2015; 2018, Waisman 2017). Another stream of research looks at dynamic pricing as a tool to influence the supply of sellers in the market (Guda and Subramanian 2019).

Less attention was given to which party sets the prices on the platform. While Lyft’s algorithm sets the price for each ride (centralized pricing), Airbnb hosts and eBay sellers are free to set their own prices (competitive pricing). However, even in competitive markets, platforms sometimes participate by providing a price recommendation to sellers/hosts. Following its introduction of “price tips” in 2015, for example, Airbnb developed the recommendation tools further by introducing “smart pricing” in 2017, which lets the host set the maximum and the minimum price of a stay and the platform adjusts the price of the listing in response to predicted changes in demand.

When choosing whether to centralize pricing or let sellers compete, the platform has to consider two key factors. First is the amount of demand information the platform possesses relative to the information sellers have. In the case of Airbnb, for example, how good is the algorithm at predicting demand compared to the hosts themselves? If the platform decides to centralize pricing, the prices will not reflect the private information that sellers have. But if the platform chooses to let sellers compete without providing them with information, the sellers cannot use demand-related data available to the platform to assist in their pricing decisions. Recommending prices may alleviate this trade-off partially; it lets the platform share some of its information with the sellers, while maintaining the flexibility of sellers to compete. As we will show, these choices may alter the level of competition in the market, influencing the equilibrium price levels and match quality. The second factor the platform needs to consider is that in a competitive market sellers will set relatively low prices, while centralized pricing allows the platform to extract more of the consumer surplus. A possible solution to this tradeoff is to let sellers compete while providing them with price recommendations that align with the platform’s goals. However, as we will show, price recommendations constitute cheap talk by the platform, posing a challenge to the usefulness of this strategy if the recommendations are not credible and ignored by the sellers.

Our goal in this paper is to describe when a platform would prefer to centralize or decentralize pricing and the implications of this decision for the platform, sellers and buyers. Our results can help platform designers make informed decisions regarding pricing regimes and information design.

Because we also consider the effects of these choices on consumer surplus, our results can also guide policymakers and regulators considering the regulation and impact of P2P markets.

To study these questions, we construct a theoretical model of segmented competition between two differentiated sellers who sell imperfect substitutes on a platform to buyers. Buyers choose whether to buy a product in the market or pick an outside option. The platform can design a search technology that limits the buyers ability to buying from only one seller, or two. The platform also chooses whether to set prices for the sellers or to let the sellers compete with or without a price recommendation. If the sellers are allowed to compete, they can set prices for their product while taking the recommendation of the platform into account.

There are two sources of uncertainty in our model. First, each seller has private information about the quality of her product, which affects the utility buyers receive from the product. Second, there is an aggregate market-level shock to willingness to pay (e.g., how many visitors to a certain city are budget-conscious tourists and how many are business travelers with expense accounts). This shock is observed by the platform, but not by the sellers.

Like most real-life platforms, we assume that the platform receives a fixed-percentage fee of the sellers' revenues. This means that while the platform wants to maximize the joint revenue of the sellers, each seller seeks to maximize their own profit and does not internalize the sales they take away from their competitor by lowering their price. Because of this misalignment of incentives between the sellers and the platform, the sellers will not follow a price recommendation by the platform blindly. The sellers will form rational expectations of the platform's strategy, i.e., in which state of the world the platform will choose to recommend each price. This messaging game where the platform recommends prices and the sellers have misaligned incentives is an instance of classic cheap talk (Crawford and Sobel 1982). However, unlike Crawford and Sobel (1982) and most of the cheap talk literature, our model has multiple receivers (sellers) that interact with each other (i.e., compete) and the outcome of this interaction determines the payoff of the sender. In a standard cheap talk game, the misalignment in incentives between the sender and the receiver is exogenous, while in our model it is endogenous and stems from the difference in market power between the platform and the sellers, as well as the level of competition among the sellers. Both of these are influenced by the price recommendations of the platform.

We find that the platform should choose to centralize pricing if there is little uncertainty about

the quality of sellers' products. On the other hand, if this uncertainty is large and the variance of the aggregate demand shock observed by the platform is large, the platform should recommend a price. If the variance of the aggregate shock is small, price recommendations cannot be credible in equilibrium and the platform should let the sellers set their own prices. The intuition is that the agents that possess the more valuable demand information should set the prices that reflect that information.

To provide an example of such a setting, consider an Airbnb market in a particular city. The willingness to pay of buyers depends on how many business travelers are looking to book in this market, which the platform can observe. The private information each seller (host) has is the (unobserved by the platform) quality of apartment offered. For example the quality of the view or location is often hard for platforms to assess. If both sources of uncertainty are small, e.g., it is either a place where people only come for business that has no good views at all or a place where all views are great and that attracts primarily tourists, the platform should centralize pricing to leverage its position as a monopolist. If both sources of uncertainty are large, e.g., there are different kinds of travelers in this market and some apartments can have extremely nice views while others are facing a brick wall, the platform should recommend a price and allow sellers to use both sources of information for pricing.

When focusing on the benefit of pricing regimes for sellers, we find surprising results. High quality sellers surprisingly exhibit a stronger preference for centralized pricing, while low quality sellers have a stronger preference for recommendation and competition. These differences stem from how competition affects the levels of demand and prices when a high quality seller faces a low quality seller.

We also find that buyer surplus is almost always maximized under competitive pricing by the sellers. Unlike sellers, buyers do not benefit when prices adjust with the state of the demand. If the price is too high, buyers can always take an outside option with a limited downside. But if the price is low when demand is high, they will enjoy a large surplus. Therefore, buyers are better off when prices respond the least to changing demand. In most cases, this happens under competitive pricing, as the sellers only take into account the information about their own quality. Price recommendations always hurt buyers compared to the fully competitive case, as it increases price variance without lowering the average price. Under centralized pricing, the average price is

higher, but in extreme cases when the variance of the aggregate shock is small (all visitors are tourists), but the range of possible qualities is large (the views are superb or terrible), then the buyers prefer centralized pricing.

One emerging result from our analysis shows that platforms are generally better off (in terms of profit) with centralized pricing and search technology that gives customers many options to choose from. However, if platforms also want to take their growth into account, price recommendations provide a better avenue to achieve both growth and profit, because centralized pricing excludes consumers from the market. A second emerging result is that unlike much of the previous research, we find that centralizing prices through a platform is not always profit maximizing for both the platforms and sellers. Moreover, there are cases where price recommendations from a platform may not be credible, and the platform might be better off not offering them at all.

Following a review of the literature, we present our game theoretic model. We then follow with an analysis of a benchmark case with a platform that can choose between centralized pricing and competition. This analysis serves as a stepping stone to analyze the cheap-talk game where platforms recommend prices. We conclude with an analysis of the market implications for different stakeholders. All proofs are relegated to Appendix A.

2 Contribution to Literature

Our work contributes to three streams of literature. First, our paper adds to the growing literature on P2P platforms (see, e.g., Narasimhan et al. (2018) and Eckhardt et al. (2019) for surveys on related research in marketing). The substantial research on platform design and impact (e.g. Einav et al. 2016, Horton and Zeckhauser 2016, Jiang and Tian 2016, Zervas et al. 2017, Ke et al. 2017, Fradkin 2017, Fradkin et al. 2018, Guda and Subramanian 2019) has focused on measuring the impact of collaborative consumption on the market, as well as explored how different features of platform design affect market outcomes. Within this literature, the research on platform pricing has mostly considered auctions vs. posted prices, or the impact of dynamic pricing on matching buyers and sellers. Auctions, however, are not a natural choice for many platforms, while dynamic pricing requires exerting pricing controls and having dynamic information that many platforms might not possess. For this reason we focus on two common general mechanisms - centralized pricing where the platform sets pricing for all sellers vs. competitive pricing where the platform allows sellers to

set their own prices, with or without a price recommendation.

Second, we add to the theoretical work on strategic communication (Milgrom 1981; 2008, Crawford and Sobel 1982, Sobel 2013), which has recently been applied in marketing contexts on persuasive communication (Gardete 2013, Chakraborty and Harbaugh 2014). Interestingly, cheap talk has rarely been applied to the analysis of a market with many competing receivers. The work of Kim and Kircher (2015), for example, has many senders who send cheap-talk messages, while our work looks at a sender trying to coordinate a market using cheap talk. We prove that the results of Crawford and Sobel (1982) are robust to introducing competition in our model: we find that all possible equilibria have “coarse” communication, i.e., the platform recommends a range of prices instead of a single price and the platform (the sender) and the sellers (receivers) benefit when more fine-grained communication is possible.

Finally, our paper is related to the literature on oligopolistic competition under uncertainty (Klemperer and Meyer 1986; 1989, Gardete 2016). While in these works the level of competition is determined by exogenous uncertainty competitors face, our research extends these works to a scenario in which a market designer can control the level of uncertainty facing competitors and thus influence the level of the competition to her benefit using cheap talk.

3 Model and Pricing Benchmark

There are three types of players who interact in a one-shot game: buyers, sellers and a platform. The mass of $2M$ buyers are distributed uniformly on the real line in the range $[-M, M]$ when M is large. The buyers visit a P2P platform to buy a product from two potential sellers. Seller 1 is positioned at -1 and seller 2 is positioned at 1 .¹ A buyer located at $x \in [-M, M]$ has demand for up to one product. If they choose to buy a product from seller i , their utility is:

$$u_i(x) = v + q_i - p_i - d_i(x) \tag{1}$$

Where p_i is the price of product i , $d_i(x)$ is the distance between seller and buyer and q_i is the quality of the product which equals $-q$ or q with $q > 0$. Because sellers 1 and 2 are located at 1 and -1 respectively, the distances equal $d_1(x) = |x + 1|$ and $d_2(x) = |x - 1|$.

¹The symmetry around 0 simplifies the exposition vs. a standard Hotelling model with locations 0 and 1

The buyer’s willingness to pay v is drawn from an a-priori uniform distribution $U[\underline{v}, \bar{v}]$ with $\underline{v} > 0$. We assume that the platform has more information about the realization of v than the sellers. If buyers are business travelers, for example, their willingness to pay might be higher than budget conscious tourists. A platform will be able to observe if searches for listings in a specific city, for example, come mostly from business travelers. Buyers will also know their realization of v before buying the product. Sellers, in contrast, are not exposed to the search process on the platform, and hence will have less information about v . For simplicity, we assume that the platform observes the realization of v and the sellers do not.

The value of q_i is private information of each seller. It is drawn independently with equal a-priori probability of being q or $-q$. We assume that buyers can observe q_i before purchasing the product, but the platform cannot. Although we abstract away from the details of such a setup, this is consistent with a signaling game where buyers can learn the quality from observed prices before making their purchase decisions, but the platform cannot learn these qualities before making its own decisions. Section B provides a detailed model in which this is the outcome.

Finally, we assume that the outside option is the same for all buyers and is normalized to 0. The outside option can capture the utility from going to a competitor (taxi, public transit or Uber instead of Lyft) or from not making any purchase.

Before visiting the platform, buyers are not aware of the sellers and hence cannot buy from them. Once consumers visit the platform, buyers use search tools to find their preferred product. We assume a simple search technology: a share $\alpha < 1/2$ of buyers discover seller 1 only, another group of size α discover seller 2 only, and the remaining mass of $1 - 2\alpha$ buyers discovers both sellers. We call the first two groups “captives” as they can only buy from one seller or pick the outside option. We call the buyers who are aware of both sellers “comparison shoppers” (or shoppers). If only one seller is active on the platform, all buyers see this seller when they search and are effectively captive. Once consumers visit the platform, they see the prices, distances and qualities of each seller. The consumers pick the option that gives them the highest utility among the sellers or the outside option. Initially, we assume that α is exogenous. Later, we compare the choices of different values of α in Section 6.

The platform receives a fixed share ϕ of the sellers’ revenues that is set exogenously. This revenue-sharing arrangement mimics many of the contracts in the P2P universe. Hence seller i ’s

expected profit is:

$$\pi_i = \mathbb{E}_v[(1 - \phi)p_i D_i(p_1, p_2)] \quad (2)$$

while the platform's expected payoff is:

$$\pi_P = \mathbb{E}_{q_1, q_2}[\phi(p_1 D_1(p_1, p_2) + p_2 D_2(p_1, p_2))] \quad (3)$$

where $D_i(p_1, p_2)$ is the realized demand, being the total mass of consumers buying from seller i .

From the profit functions it is evident that the sellers and the platform have misaligned incentives. The platform would like to maximize the joint revenue of the sellers, while each seller would like to maximize its own profit. Moreover, the competition might affect the pricing incentives of the sellers, while the platform does not care which seller sells the product as long as a transaction is made. Hence the incentives of the platform and the sellers are not perfectly aligned with respect to setting prices.

A second factor that affects the profit of the sellers and the platform is information asymmetry. If the platform sets the prices, it cannot use the information that the sellers have about q_i . If the sellers set prices, they are uncertain about the willingness to pay v unless they receive information from the platform.

Our main goal is to analyze the usage of price recommendations by the platform to manipulate the equilibrium profits, price levels and matching quality in the market. To achieve this goal, we initially analyze two benchmark pricing strategies to gain insights about the model and serve as a stepping stone for the analysis of the price recommendation strategy. We will analyze the equilibria of the following three cases in terms of platform and seller profits, consumer surplus, and quality of matching:

1. Centralized Pricing (CP) - The platform sets prices for both sellers.
2. Competition (C) - The platform lets the sellers set their own prices without providing them information.
3. Recommendation (R) - The platform recommends a non-binding price to the sellers, and each seller sets their own price.

As we discuss in detail later, any recommendation message the platform sends to sellers is effectively

a signal about the value of v , because v is the only payoff-relevant private information that the platform has. In other words, all price recommendations that the platform can provide in our model are functions of v and are therefore isomorphic to a “direct” message communicating the value of v .

The three cases above cover the full range of actions the platform can take to influence the sellers in our model. To finalize the model, the timing of the game is as follows:

1. The platform selects a pricing and recommendation strategy.
2. Nature draws v (observed by the platform and buyers), q_1 (observed by seller 1) and q_2 (observed by seller 2).
3. The platform gives a price recommendation to the sellers if it decided to do so.
4. Prices are set by the platform or by the sellers.
5. Buyers visit the platform. They learn d_i , p_i and q_i for one or two sellers.
6. Buyers make their purchase decisions and payoffs are realized.

At step 3, if the platform elects to not recommend a price, we can assume that it is giving an uninformative recommendation (e.g., recommends a random price independent of the state of the world v or the same price in every state of the world).

3.1 Centralized Pricing vs. Competition

To analyze the benchmark cases of centralized pricing and competitive pricing, we first derive the demand experienced by each seller when the prices are p_1 and p_2 .

For captive consumers, each buyer chooses between seller i and the outside option. There are two buyers who are indifferent between buying and not buying, equidistant to the left and to the right of -1 (seller 1) or 1 (seller 2). The demand from captives is then the mass of buyers between these two points:

$$D_i^{cap}(p_i) = 2(v + q_i - p_i) \tag{4}$$

To find the demand from comparison shoppers, we first make an assumption that facilitates tractability of the analysis:

Assumption A1. (i) $\underline{v} > 2q + 3 - 2\alpha$ and (ii) $q < 1$.

The first part of Assumption A1 is a standard full coverage assumption for shoppers in the $[-1, 1]$ interval, and makes sure these shoppers buy from either firm 1 or 2. The second part implies that the difference in quality between sellers is not so high that comparison shoppers always buy only from one seller. Effectively, it guarantees that if the prices set by the sellers are equal, each seller will receive some demand from comparison shoppers even if qualities are different. Relaxing these assumptions will not change the results qualitatively, but will make the analysis less tractable.

Using assumption A1, the demand of shoppers is:

$$D_i^s(p_i, p_{-i}) = \frac{q_i - q_{-i} - p_i + p_{-i}}{2} + v + 1 + q_i - p_i \quad (5)$$

Combining the demands from both segments the total demand for seller i can be written to yield a linear and differentiated Bertrand model (Klemperer and Meyer 1986; 1989):

$$D_i(p_i, p_{-i}) = \frac{2v + (3 - 2\alpha)q_i - (1 - 2\alpha)q_{-i} + 2(1 - 2\alpha)}{2} - \frac{3 - 2\alpha}{2}p_i + \frac{1 - 2\alpha}{2}p_{-i} \quad (6)$$

The differentiation in the model stems from the difference in price sensitivities of consumers buying from a specific firm. Because each firm's own price influences also the captive segment, the demand each firm sees is more elastic with respect to changes in its own price compared to changes in the competitor's price.

Solving for the profit-maximizing price results in the following:

Proposition 1. *When using centralized pricing:*

- The unique profit-maximizing price is: $p_1^* = p_2^* = p^*(v) = \frac{v+1-2\alpha}{2}$.

The optimal centralized price increases with v , but decreases with α .

- The maximum centralized profit is: $\pi_P^{CP} = \phi \frac{(v+1-2\alpha)^2}{2}$.

The optimal centralized profit increases in v and decreases with α .

- The maximum expected centralized profit is:

$$\mathbb{E}(\pi_P^{CP}) = \phi \frac{(\bar{v} + 1 - 2\alpha)^3 - (\underline{v} + 1 - 2\alpha)^3}{6(\bar{v} - \underline{v})}$$

The expected centralized profit increases in $\bar{v}$ and $\underline{v}$, and decreases with α .

- The ex ante expected profit of high and low type sellers is:

$$\begin{aligned}\mathbb{E}(\pi_H^{CP}) &= (1 - \phi) \left(\frac{\mathbb{E}(\pi_P^{CP})}{2\phi} + \frac{q(3 - 2\alpha)(\bar{v} + \underline{v} + 2(1 - 2\alpha))}{8} \right) \\ \mathbb{E}(\pi_L^{CP}) &= (1 - \phi) \left(\frac{\mathbb{E}(\pi_P^{CP})}{2\phi} - \frac{q(3 - 2\alpha)(\bar{v} + \underline{v} + 2(1 - 2\alpha))}{8} \right)\end{aligned}$$

Proposition 1 shows that prices and profits increase, as expected, with the average willingness to pay v . A surprising result is that the profit decreases with α , as intuition might suggest that the platform could gain the most by exposing each buyer to only one product, and use monopoly pricing for each product. This intuition breaks when the platform has uncertainty over q_i . When the sellers differ in quality, if most buyers are captives (high α), those aware of the low quality seller will only buy if the price is low. The platform, however, is constrained to setting the same price for both products. If these buyers are made aware about the other seller, however, they may be willing to make a purchase at a higher price from a high quality seller. Hence, it is in the interest of the platform to make more buyers informed and decrease α .

Turning the attention of analysis to competition, seller i with type τ will set a price $p_{i\tau}$ to maximize their expected profit. We look for a symmetric subgame perfect equilibrium, and hence can denote the equilibrium strategy of sellers as p_τ^C for type $\tau \in \{H, L\}$ and drop the subscript i . The profit of a seller of type τ who sets a price p_τ (not necessarily equal to p_τ^C) is:

$$\mathbb{E}(\pi_\tau) = \frac{1}{2}(1 - \phi)p_\tau \mathbb{E}_v(D_\tau(p_\tau, p_H^C) + D_\tau(p_\tau, p_L^C)) \quad (7)$$

where D_τ denotes the demand of a seller with type τ .

Solving for the equilibrium results in the following:

Proposition 2. *Under price competition between the sellers:*

- Equilibrium prices are:

$$p_H^C = \frac{q}{2} + \frac{2\mathbb{E}(v) + 2(1 - 2\alpha)}{(5 - 2\alpha)} \quad (8)$$

$$p_L^C = -\frac{q}{2} + \frac{2\mathbb{E}(v) + 2(1 - 2\alpha)}{(5 - 2\alpha)} \quad (9)$$

The price p_H^C increases with q and p_L^C decreases with q . Both prices increase in α if $\bar{v} + \underline{v} > 8$ and decrease in α otherwise.

- The platform's profits are:

$$\pi_P^C = \phi \frac{q^2(3-2\alpha)}{4} - \phi \frac{16(\mathbb{E}(v) + 1 - 2\alpha)(2\mathbb{E}(v) - (5-2\alpha)v - 3 + 8\alpha - 4\alpha^2)}{4(5-2\alpha)^2}$$

- The platform's ex ante profits are:

$$\mathbb{E}(\pi_P^C) = \frac{\phi(3-2\alpha)(4(\bar{v} + \underline{v} + 2(1-2\alpha))^2 + q^2(5-2\alpha)^2)}{4(5-2\alpha)^2}$$

- The sellers' ex ante profits are:

$$\begin{aligned} \mathbb{E}(\pi_H^C) &= \frac{(1-\phi)(3-2\alpha)(2(\bar{v} + \underline{v} + 2(1-2\alpha)) + (5-2\alpha)q)^2}{8(5-2\alpha)^2} \\ \mathbb{E}(\pi_L^C) &= \frac{(1-\phi)(3-2\alpha)(2(\bar{v} + \underline{v} + 2(1-2\alpha)) - (5-2\alpha)q)^2}{8(5-2\alpha)^2} \end{aligned}$$

Proposition 2 shows that prices are linear in the beliefs of the sellers about the expectation of v . When we analyze price recommendation using cheap talk in the next section, this feature will come into play as the platform will want to influence the resulting equilibrium prices through influencing the beliefs of sellers. Specifically, the platform's profit is quadratic in the beliefs of the sellers, first increasing and then decreasing.

When we compare the equilibrium prices and profits between centralized pricing and competition, we find the following:

Corollary 1.

- The prices p_L^C and p_H^C are higher than the centralized price when $\bar{v}$ is high enough and v is low enough.
- The profits of the platform are higher than under centralized pricing when

$$q > \sqrt{\frac{2}{3-2\alpha}} \left(v + \frac{(1-2\alpha)^2 - 2(\bar{v} + \underline{v})}{5-2\alpha} \right)$$

- *There is a $\tilde{q}$ such that the platform makes a higher ex-ante profit without a price recommendation compared to centralized pricing if and only if $q > \tilde{q}$.*
- *There is a $\tilde{q}_H$ ($\tilde{q}_L$) such that a high (low) quality seller makes a higher ex-ante profit without a price recommendation compared to centralized pricing if and only if $q > \tilde{q}_H$ ($q > \tilde{q}_L$).*

Corollary 1 has two interesting findings. First, prices under competition may be higher than prices set by a centralized planner. When $\bar{v}$ is high, and the realization of v is low, sellers will set too high prices because they expect higher demand than what is realized, and as a result will lower the platform's profit. If the platform could affect the beliefs of sellers about v , it might be able to better influence this competition to its benefit.

The second interesting finding is that in scenarios where q is high, and there is substantial uncertainty about the difference in seller quality, it is more beneficial for the platform to let sellers compete than to set prices for them. This is in contrast to the previous literature that found that coordinating centralized prices is beneficial for a platform as it softens competition among sellers and increases sale prices. In a world where there is sufficient uncertainty about the quality of sellers on a platform, the platform should relinquish the pricing power to the players that hold the most uncertain information.

Having established the considerations for picking among the two basic pricing models, in the next section we turn to analyze price recommendations. These recommendations allow the platform to influence the beliefs of sellers about v , and thus manipulate the benefits of competition for the platform.

4 Price Manipulation with Cheap Talk

When sellers set their own prices they integrate over their beliefs about v to maximize their expected profits (Equation (6)). The platform can try to influence the sellers' decision by providing them with a price recommendation that the sellers will incorporate into their decisions. Providing a price recommendation and providing information about the value of v are equivalent because setting prices is the only action sellers can take, and v is the only missing piece of information sellers need from the platform. If the platform chooses to provide (possibly inaccurate) information about v , the sellers can back-out the real value of v consistent with an equilibrium strategy of the platform,

and make a pricing decision. Similarly, if the platform provides a price recommendation (and not a direct message about the value of v), the sellers will infer the values of v which are consistent (in equilibrium) with the platform's recommendation.

We therefore assume that the platform's strategy is a (possibly non-deterministic) mapping from the interval of possible realizations of $v \in [\underline{v}, \bar{v}]$ to a message space on the same interval. In other words, the platform observes the realization of v and reports to the sellers some plausible value $m(v) \in [\underline{v}, \bar{v}]$, which may or may not coincide with the actual realization.

An important feature of the model is that the message $m(v)$ is costless for the platform (the Sender) to send, and that the platform's incentives are misaligned with the sellers (the Receivers). Sellers have an incentive to lower prices to respond to competition and maximize their own profits, while the platform would like sellers to maximize their joint profit, which often means increasing their prices from a competitive level. This is an instance of a cheap-talk game (Crawford and Sobel 1982), but unlike the extant cheap-talk literature, our model features multiple receivers who interact strategically with each other. Our analysis also tries to answer whether cheap talk can be both a credible and a profitable equilibrium strategy with competing receivers.

A second interesting insight is that a "babbling equilibrium", which always exists in cheap talk games, coincides in our model with the competition scenario we analyzed in the previous section. In such an equilibrium, the message sent by the platform is uninformative, i.e., it is statistically independent from the realization of v . Examples of such strategies would be to always recommend the same price, or to report a random value of v to senders. The sellers will then ignore the message and rely on their prior beliefs over v when setting prices.

To understand what actions the platform should take, we first analyze the response of sellers to a message m in the pricing subgame. When receiving a recommendation m , sellers will update their beliefs (using Bayesian updating) about the distribution of v . When updating their beliefs sellers will take into account the equilibrium strategy $m(v)$ used by the platform to narrow the possible values of v to those consistent with the message m . The resulting equilibrium prices depend only on the updated expected value of v , $E(v|m)$ as shown in the following Lemma:

Lemma 1. *Given a platform's messaging strategy $m(v)$ and after receiving a message m , the unique*

equilibrium prices that sellers set are:

$$p_H^R = \frac{q}{2} + \frac{2\mathbb{E}(v|m) + 2(1 - 2\alpha)}{(5 - 2\alpha)} \quad (10)$$

$$p_L^R = -\frac{q}{2} + \frac{2\mathbb{E}(v|m) + 2(1 - 2\alpha)}{(5 - 2\alpha)} \quad (11)$$

where $\mathbb{E}(v|m) = \frac{\int_{v:m(v)=m} v dv}{\int_{v:m(v)=m} dv}$.

When we compare to the results of proposition 2, it is notable that the recommendation of the platform affects the prices through the expectation linearly, and that if both types of sellers believe the expected value of v is higher, they will set higher prices.

Because the platform influences the decision of the sellers by communicating a value for v , we can calculate the the profit of the platform as a function of the true state v and the seller's expectations induced by m :

$$\pi_P^R(v, m) = \frac{q^2(3 - 2\alpha)}{4} - \frac{16(\mathbb{E}(v|m) + 1 - 2\alpha) (2\mathbb{E}(v|m) - (5 - 2\alpha)v - 3 + 8\alpha - 4\alpha^2)}{4(5 - 2\alpha)^2}$$

$\pi_P^R(v, m)$ is quadratic in $\mathbb{E}(v|m)$ and linear in v . Consequently every state v has a value $\mathbb{E}^*(v)$ that maximizes the payoff of the platform:

$$\mathbb{E}^*(v) = \frac{v(5 - 2\alpha) + (1 - 2\alpha)^2}{4} \quad (12)$$

This expectation does not equal to v itself and is in fact always larger than v , hence the platform would like to inflate the sellers' expectations of v through the recommendation. However, as sellers are rational and anticipate this strategy of the platform, that is impossible.

Given this limitation, we show in the next Lemma (based on Crawford and Sobel (1982)'s Lemma 1) that only a finite set of beliefs can be induced in equilibrium, which implies that the true value of v cannot be communicated, and only an indication of ranges of values of v can be sent as a message:

Lemma 2. *If for every message m the values $v \neq \mathbb{E}^*(v|m)$, then there exists an $\varepsilon > 0$, such that for any two equilibrium messages m_1 and m_2 that induce different beliefs $\mathbb{E}(v|m_1)$ and $\mathbb{E}(v|m_2)$, the difference is at least ε , i.e., $|\mathbb{E}(v|m_1) - \mathbb{E}(v|m_2)| > \varepsilon$. Moreover, the set of expectations that can be*

induced in equilibrium is finite.

Lemma 2 shows that whenever two messages induce different equilibrium beliefs, those beliefs will have at least some minimal distance between them. In other words, the platform cannot induce a continuous set of beliefs and will have “jumps” between them. The intuition behind this result is that because the platform’s incentives and the seller incentives differ, the platform will want to deviate from revealing the value of v and send a message that induces an expectation closer to $\mathbb{E}^*(v)$. To induce these higher beliefs, the platform needs a large enough jump from the true value. Because the message space is bounded and because there are jumps between beliefs, this means that there is a finite number of induced expectation values possible in equilibrium. The consequence of Lemma 2 is that the true value of v cannot be communicated in equilibrium, i.e., there cannot be full revelation of v in equilibrium.

Given that there is no full revelation, we construct an equilibrium in which the state space is partitioned into n subintervals $[\underline{v}, v_1], [v_1, v_2], \dots, [v_{n-1}, \bar{v}]$ and the platform reveals to the sellers in which interval the realization of v lies. Suppose that the realized state is $v \in [v_k, v_{k+1}]$. Let m_k denote the message sent by communicating a random value drawn from $U[v_k, v_{k+1}]$. Hence, the message m_k can be any value from the interval it represents, which rules out possible out-of-equilibrium beliefs.²

Using Lemma 1, the equilibrium belief that determines the prices will be $\mathbb{E}(v|m_k) = \frac{v_{k-1} + v_k}{2}$. To find the boundaries v_k between the subintervals of the message space, we notice that if the true value is $v = v_k$, the platform should be indifferent between sending the messages m_{k-1} and m_k . We can write this indifference condition as:

$$\pi^R(v_k, m_{k-1}) = \pi^R(v_k, m_k), \quad k = 1, \dots, n-1 \quad (13)$$

which can be rewritten as the following difference equation:

$$v_k = \frac{v_{k+1} + v_{k-1} - (1 - 2\alpha)^2}{3 - 2\alpha} \quad (14)$$

with boundary conditions $v_0 = \underline{v}$ and $v_n = \bar{v}$.

²It is sufficient to focus on uniform distributions for the mixing strategies within intervals because for any other set of mixing distributions, the outcomes will be equal.

The unique solution of equation (14) is:

$$v_k = C_1 \lambda_1^k + C_2 \lambda_2^k + v^* \quad (15)$$

where

$$\begin{aligned} v^* &= 2\alpha - 1 \\ \lambda_{1,2} &= \frac{3 - 2\alpha \pm \sqrt{(3 - 2\alpha)^2 - 4}}{2} \\ C_1 &= \frac{\bar{v} - v^* - \lambda_2^n(\underline{v} - v^*)}{\lambda_1^n - \lambda_2^n} \\ C_2 &= \frac{\lambda_1^n(\underline{v} - v^*) - (\bar{v} - v^*)}{\lambda_1^n - \lambda_2^n} \end{aligned}$$

This unique solution determines the interval boundaries v_k for messages sent by the platform to reveal information about the value v and recommend a price.

Once we know how to find the boundaries that determine messages, a second value that determines the equilibrium is the number of intervals n . How large can n be? As n becomes larger, we approach full revelation, which was ruled out by Lemma 2. The fact that v_{k+1} has to be greater than v_k for every k allows us to write a condition that determines the maximum n possible:

$$\frac{\bar{v} - v^*}{\underline{v} - v^*}(\lambda_1 - \lambda_2) > \lambda_1^n(1 - \lambda_2) + \lambda_2^n(\lambda_1 - 1) \quad (16)$$

These results are summarized in the following proposition.

Proposition 3. *When there is a natural number $n^* > 1$ such that condition (16) holds, then there is a price recommendation equilibrium. In this equilibrium $[\underline{v}, \bar{v}]$ is divided into n^* subintervals $[\underline{v}, v_1]$, $[v_1, v_2]$, ..., $[v_{n^*-1}, \bar{v}]$, where v_k is defined by equation (15). When $v \in [v_{k-1}, v_k]$, the platform draws a value from $U[v_{k-1}, v_k]$ and sends that value as a message to the sellers.*

In the price recommendation equilibrium:

- *Equilibrium prices with a message from the subinterval $[v_{k-1}, v_k]$ are:*

$$p_H^R|k = \frac{q}{2} + \frac{v_k + v_{k-1} + 2(1 - 2\alpha)}{(5 - 2\alpha)} \quad (17)$$

$$p_L^R|k = -\frac{q}{2} + \frac{v_k + v_{k-1} + 2(1 - 2\alpha)}{(5 - 2\alpha)} \quad (18)$$

- *The ex ante expected equilibrium profits are:*

$$\mathbb{E}(\pi_P^R(v)) = \phi \sum_{k=1}^{n^*} \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{(3 - 2\alpha)(4(v_k + v_{k-1} + 2(1 - 2\alpha))^2 + q^2(5 - 2\alpha)^2)}{4(5 - 2\alpha)^2} \quad (19)$$

$$\mathbb{E}(\pi_H^R) = (1 - \phi) \sum_{k=1}^{n^*} \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{(3 - 2\alpha)(2(v_k + v_{k-1} + 2(1 - 2\alpha)) + (5 - 2\alpha)q)^2}{8(5 - 2\alpha)^2} \quad (20)$$

$$\mathbb{E}(\pi_L^R) = (1 - \phi) \sum_{k=1}^{n^*} \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{(3 - 2\alpha)(2(v_k + v_{k-1} + 2(1 - 2\alpha)) - (5 - 2\alpha)q)^2}{8(5 - 2\alpha)^2} \quad (21)$$

- *When $n^* \geq 2$, the platform and the sellers prefer price recommendation to no recommendation (competition). There exists a $\hat{q}$, such that the platform is better off under price recommendation compared to centralized pricing if and only if $q > \hat{q}$. There also exists $\hat{q}_H$ ($\hat{q}_L$) such that a high (low) type seller is better off under recommendation than under centralized pricing if and only if $q > \hat{q}_H$ ($q > \hat{q}_L$).*

Proposition 3, which is a major result of the paper, shows that whenever there is a natural number larger than 1 for which the inequality in (16) holds, it is more profitable for the platform to give recommendations in equilibrium compared to letting sellers compete without a recommendation. Moreover, when the uncertainty q is high enough, recommendations are more profitable to the platform (and the sellers) compared to centralized pricing. The intuition is that as n increases, the profit of the platform also increases, which makes recommendations preferable. When q is high enough, similarly to the competition case, profits might also increase above the centralized pricing case.

Along with the bubbling (competition) equilibrium, when $n^* \geq 3$ there are multiple price recommendation equilibria. These equilibria differ by how coarse the partition of values of v is. Theorems 3 and 5 of Crawford and Sobel (1982) establish that in a cheap talk game, both the sender and receiver are ex ante better off in an equilibrium with a larger n . Since the conditions of

these theorems hold in our model, the profit of the platform and the sellers increases with n^* .

To understand which one of the multiple cheap-talk equilibria might be reasonably played, we apply the no incentive to separate (NITS) criterion of Chen et al. (2008). NITS states that a sender with the lowest type (i.e., a platform that observes $v = \underline{v}$) always prefers the cheap-talk equilibrium payoffs than having the receiver (i.e., the sellers) observe the sender's true type (i.e., the sellers knowing that $v = \underline{v}$). Using this criterion, we can prove the following:

Corollary 2. *The unique equilibrium that satisfies NITS is the equilibrium with the most refined partition, i.e., with n^* intervals. Consequently, the platform will provide price recommendations rather than choose competition when cheap talk is possible.*

To summarize, we have found conditions under which a platforms might prefer to let consumers compete with or without price recommendations. These cases are applicable when the uncertainty in the market about seller quality is high enough. An interesting additional finding is that price recommendations are not always beneficial. In many cases they are not credible and will be ignored by the sellers.

After establishing the conditions for which a platform would prefer to provide price recommendations, we deepen the analysis in the following section to understand the impact on sellers, buyers and the market.

5 Market Implications

In this section we compare the benefits for sellers and consumers, as well as the equilibrium demand in the different pricing regimes. We start with illustrating the regions of parameters for which the platform or the sellers are better off in the different pricing regimes. Because the inequalities for these conditions have higher order polynomials, we are only able to provide numerical analysis.

Figure 1 shows the regimes in which each player achieves maximum profit, as a function of q and $\bar{v}$ when $\alpha=0.45$ and $\underline{v} = 5$. We can see a common pattern emerge: when $\bar{v}$ is high and q is low, all players prefer centralized pricing (top left); when $\bar{v}$ is low and q is high, all players prefer competition (bottom right); when both q and $\bar{v}$ are large, recommendation leaves all players better off. The intuition is that $\bar{v}$ captures the amount of information the platform has while q captures the amount of information the sellers have. If $\bar{v}$ is small, i.e., close to $\underline{v}$, there is little variation

in the aggregate demand level and demand is consistent. Consequently there is little value to the platform's information. Because, in addition, low values of $\bar{v}$ cannot sustain the recommendation equilibrium, all players are better off if the sellers are allowed to price based on the information they possess. In contrast, if $\bar{v}$ is high and q is low, there is little value to the sellers' private information and the platform can safely ignore it and centralize pricing. Finally, if both sources of uncertainty are relatively strong, the platform should recommend a price, so that the sellers can combine their private information with the platform's information.

The second surprising feature to observe are in the differences between the three figures. High type sellers prefer centralized pricing more strongly than low types and even more than the platform. This result is formally stated in the following proposition:

Proposition 4. *For $\tilde{q}_H$, $\tilde{q}_L$ and $\tilde{q}$ as defined in Proposition 2, and $\hat{q}_H$, $\hat{q}_L$ and $\hat{q}$ as defined in Proposition 3:*

- $\tilde{q}_H > \tilde{q} > \tilde{q}_L$
- $\hat{q}_H > \hat{q} > \hat{q}_L$

The proposition shows the counter-intuitive result that high types prefer to relinquish pricing control to the platform, although they have pricing power in competition against low types. The intuition is that when pricing is centralized, prices are equal across types. If one of the sellers is a high type and the other is low, the high type will obtain a large market share and a substantially larger profit than the low type. When the pricing is decentralized, the high type's advantage is mitigated by the fact that the low type can lower their price to attract more buyers. The centralized pricing can be exploited by the high type to soften competition from price cutters. If one considers the dynamics of pricing on platforms, this implies that the more platforms centralize pricing, the more we might see higher quality players on the platform.

Next, we consider the expected total size of the market, i.e., the expected mass of buyers served in equilibrium. Total demand is equal to

$$TD(p_1, p_2) = 2(1 - 2\alpha) + 2v + q_1 + q_2 - p_1 - p_2$$

(a) Platform

(b) Low type

(c) High type

Figure 1: Pricing regimes that the platform and the sellers prefer depending on the values of q and $\bar{v}$. Other parameters: $\alpha = 0.45$, $\underline{v} = 5$.

Using symmetry and integrating over q and v , the expected total demand is:

$$\mathbb{E}(TD(p_1, p_2)) = 2(1 - 2\alpha) + \bar{v} + \underline{v} - 2\mathbb{E}(p)$$

Using the fact that the expected total market coverage turns out to depend only on expected prices, we can prove the following result:

Proposition 5.

- $\mathbb{E}(TD^R) = \mathbb{E}(TD^C) > \mathbb{E}(TD^{CP})$.
- *The expected distance between a buyer and the seller they purchase from is $\mathbb{E}(\frac{TD}{4})$.*

Proposition 5 shows that total demand is higher when sellers compete on prices. It does not change if recommendations are feasible or not. This is because the only differences between prices under recommendation and competition is that under recommendation the expectation over v is conditional on the message from the platform. As the sellers have rational expectations and the prices are linear in those expectations, summing over all possible messages and weighting by the message probability yields the same ex ante expectation and hence the same expected price. Under centralized pricing, the prices are higher on average, as the platform internalizes the substitution patterns between the two sellers and therefore faces less elastic overall demand than each seller individually.

One of the important implications of proposition 5 is that when cheap talk (or competition) are more profitable to a platform than centralized pricing, the effect is not coupled with decreased demand, but rather with an increase in market size. As we discuss later, for many young platforms, growth often comes at the expense of profits, but as our results show, these two goals do not necessarily contradict.

Now we consider the consumer surplus (expected utility) of buyers, which we illustrate in Figure 2. Because buyers have an outside option, they are shielded from some of the risk of experiencing a low realization of v or receiving $-q$. In other words, the downside of participating in the market is limited. In this case, from an ex ante perspective, buyers prefer a payoff that varies more, as they can capture more of the upside. The more prices reflect the realizations of v and q , the less variation there is in the buyers' payoff. Therefore, buyers prefer those pricing regimes that attenuate the

Figure 2: Pricing regimes that the buyers prefer depending on the values of q and $\bar{v}$ when $\alpha = 0.45$ and $\underline{v} = 5$.

uncertainty the most when translating from realizations of v and quality to prices. Buyers always prefer no recommendation to recommendation, since then prices do not vary with v . They also prefer centralized pricing when $\bar{v}$ is small and therefore v matters little, while q is large.

The intuition is formalized in the following result:

Proposition 6. *When comparing the consumer surplus of buyers under the three pricing regimes:*

- $CS^C > CS^R$.
- *There exists a q' such that $CS^{CP} > CS^C$ if and only if $q > q'$.*

The first item of Proposition 6 emphasizes the contradicting preferences of the platform and the sellers with those of buyers. Similarly, buyers prefer centralized pricing only when q is large, which is exactly when the platform and the sellers prefer competition. This result underscores the potential trade-offs between the two sides of the market that platform designers have to consider.

6 Impact of Search Technology α

An interesting feature of our model is the search technology α that determines what share of consumers see more or less options when visiting the platform. If the platform could influence α by designing a different search algorithm, what would be the platform's preferred choice?

Performing a complete analysis of how α impacts the equilibria results is non-tractable because of the complexity of the model. To further the analysis, we therefore use numerical analysis as well as compare the cases of $\alpha = 0$ and $\alpha = 1/2$.

Figure 3 shows the effect of α on the possible number of intervals in cheap-talk equilibria for representative values of $\underline{v}$ and $\bar{v}$. As α increases, more consumers see only one seller, and the platform and the sellers have more aligned incentives. This results in the platform having an incentive to reveal the true value of v more accurately as α increases, up to a point (when $\alpha = 1/2$) in which the platform would reveal the true value of v and the sellers will price without any uncertainty about v . A second insight is that when $\bar{v}$ increases, a cheap-talk equilibrium is

Figure 3: Number of possible cheap-talk intervals (n^*) as a function of α and $\bar{v}$ when $\underline{v} = 5$.

possible for lower values of α , and in such cases, it is more profitable for the platform to select recommendations vs. pure competition.

Finally, we analyze the platform's preferred choices in the extreme cases of $\alpha = 0$ and $\alpha = 1/2$:

Proposition 7. *If the platform can set α to be either 0 or $\frac{1}{2}$ before committing to a pricing regime, it will choose*

- *Centralized pricing if $\alpha = 0$*
- *Recommendation if $\alpha = \frac{1}{2}$*
- *The platform always chooses to set $\alpha = 0$ and centralize pricing.*

The results show that although the platform would generally prefer price recommendations coupled with limiting choice by consumers, it gains the most when consumers have more choice but the platform chooses prices for sellers. Because the analysis only focuses on the extreme values of α , we are unable to tell whether there is an intermediate value of α in which cheap talk recommendations are preferable to centralized pricing. Research looking at the interaction of search technology and platform pricing is a promising avenue for future research.

7 Conclusion

In our analysis, we considered three pricing regimes: (i) competitive pricing by sellers; (ii) centralized pricing by the platform; (iii) recommending prices to sellers. We find that from the platform's and the seller's perspective, the optimal choice of the pricing regime depends on the type of uncertainty prevalent in the market. If the aggregate demand uncertainty is more important than the uncertainty about the sellers' quality, the platform should set prices in a centralized fashion. If the quality uncertainty is larger than the aggregate uncertainty, the platform should let the sellers set their own prices.

A major advantage that the platform can utilize in markets when both types of uncertainties are high are price recommendations. In this case, providing sellers with some information, but not fully revealing it, may increase the profits of the platform above the centralized and the no recommendation case. This increase in profits is not always feasible, as there are cases when price recommendations will not be credible in equilibrium, and sellers will ignore them. Another interesting finding is about which sellers prefer centralized pricing. We found that sellers with high qualities prefer centralized pricing, although intuition would suggest that they would have stronger

pricing power and would prefer pricing autonomy. From the perspective of buyers, competitive decentralized pricing is almost always the best regime. Only when the aggregate uncertainty is small and the quality uncertainty is large, do buyers prefer centralized pricing.

Our analysis uncovers a tradeoff between maximizing the platform profit and consumer surplus which may inform platform designers and managers. Even though we do not model entry of buyers and sellers explicitly, often higher expected consumer surplus will lead to more buyers using the platform and a higher expected seller profit will encourage more sellers to join. Consequently, a growth-stage platform that is willing to sacrifice some profits for larger market share should let sellers set their own prices. A mature platform, in contrast, should use the profit-maximizing pricing regime. In fact, we might interpret the changes in Airbnb’s pricing strategy as following this rule. At first, while the company was growing, Airbnb let the hosts set their own prices. Later they introduced Price Tips, which is a price recommendation service. The introduction of smart pricing takes Airbnb even closer to a centralized pricing system.

The results are of course not without limitations. In order to achieve a tractable solution, we assumed a specific simple demand form. Although we believe the results would hold in more generalized cases, this is still an open question. A second limitation of our model, which would be interesting to explore in future work is the amount of information buyers have, compared to the platform and the sellers. In our model buyers have full knowledge of all relevant model parameters, and relaxing this assumption may be important. Finally, in our game we did not consider entry or exit of the sellers, which is one of the important features that determines platform profits in dynamic platforms such as ride sharing.

In terms of future work, there are two interesting questions that arise naturally from our model and we are considering to focus on. The first is further analysis of the a platform that can design the search technology and pick α to maximize its profit. Platforms often change the amount of search results they display to customers strategically. The second is the impact of the share of revenue the platform takes from sellers on seller behavior. In our model, because sellers do not enter or exit, this share has no consequence, and extending the model to capture this effect can be an important next step.

For policymakers, our paper suggests that price recommendation systems may soften competition and potentially harm buyers, compared to not recommending prices. A critical part of many

online platforms’ business model is the status of sellers or service providers as independent contractors, rather than employees. This allows the platforms to avoid, e.g., labor regulation. One criterion for determining the status of an employee vs. a contractor is their ability to set their own price. Our paper shows that platforms do not always have to centralize pricing to achieve profits that are above competitive. Price recommendations allow platforms to extract large profits while avoiding the need to set prices for sellers. Regulators should therefore consider the impact of price recommendations and its influence on equilibrium outcomes when they consider the employment status of individuals.

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A Proofs

Proof of Proposition 1.

Because the profits of sellers 1 and 2 are ex-ante symmetric from the viewpoint of the platform, the optimal prices will have $p_1^* = p_2^*$. The solutions to the first order conditions on price yield the expressions in the proposition. When setting $p = p_1 = p_2$, the expected profit is concave in price, hence the solution is a unique equilibrium.

The comparative statics analysis of prices follow from the linearity of optimal prices in all parameters.

For α , $\frac{\partial \pi_P^{CP}}{\partial \alpha} = -2(v + 1 - 2\alpha) < 0$ because $\alpha < 1/2$. Integrating over v and using Leibniz’s integral rule also proves that $\frac{\partial \mathbb{E}(\pi_P^{CP})}{\partial \alpha} < 0$. □

Proof of Proposition 2.

To find the equilibrium prices, the FOC of a seller of type τ is:

$$\frac{2\mathbb{E}(v) + q(3 - 2\alpha) + 2 - 4\alpha}{2} - p_\tau^C(2\alpha - 3) + (p_L^C + p_H^C)\frac{1 - 2\alpha}{4} = 0 \quad (22)$$

Imposing $p_\tau^* = p_\tau^C$ results in the equilibrium prices as the solution. Comparative statics with respect to q follow from the linearity in q .

For α , $\frac{\partial p_\tau^C}{\alpha} = \frac{4(\mathbb{E}(v) - 4)}{(5 - 2\alpha)^2} > 0$ when $\mathbb{E}(v) > 4$.

The other items result from plugging-in the prices into the profit functions and integrating over values where necessary. $\square$

Proof of Corollary 1.

Comparing p_L^C to p^* , we find that $p_L^C > p^*$ when

$$v < -q + \frac{2(\bar{v} + \underline{v}) - (1 - 2\alpha)^2}{5 - 2\alpha}$$

and

$$\bar{v} > \frac{1}{2} (q(5 - 2\alpha) + (1 - 2\alpha)^2 + (3 - 2\alpha)\underline{v})$$

For the second item, the platform's profit π_P^C is compared to π_P^{CP} . Because π_P^C is quadratic and increasing in q , and because π_P^{CP} does not depend on q , finding the q for which $\pi_P^C = \pi_P^{CP}$ gives the solution in the proposition. Finally, because $\pi_P^C|_{q=0} \leq \pi_P^{CP}$, there is a crossover of profits as described in the proposition.

For the third item, we follow a similar approach to the second item. $\mathbb{E}(\pi_P^C)$ is increasing and quadratic in q and $\mathbb{E}(\pi_P^{CP})$ is a constant, therefore, to show the existence of a crossing point, we only need to show that there is a point such that $\mathbb{E}(\pi_P^C) < \mathbb{E}(\pi_P^{CP})$ for some q . We take the lowest possible value, $q = 0$. Then the inequality can be reduced to the following:

$$\frac{4(3 - 2\alpha)(\mathbb{E}(v) + 1 - 2\alpha)^2}{(5 - 2\alpha)^2} < \mathbb{E}\left(\frac{(v + 1 - 2\alpha)^2}{2}\right)$$

Note that (i) $\frac{4(3 - 2\alpha)}{(5 - 2\alpha)^2} < \frac{1}{2}$ and (ii) $(\mathbb{E}(v) + 1 - 2\alpha)^2 < \mathbb{E}((v + 1 - 2\alpha)^2)$ by Jensen's inequality.

For the fourth term, first observe that $\mathbb{E}(\pi_H^{CP})$ is a linear increasing function of q and $\mathbb{E}(\pi_H^C)$ is a quadratic increasing function of q . Moreover, if $q = 0$, $\mathbb{E}(\pi_H^{CP}) = (1 - \phi)\frac{\mathbb{E}(\pi_P^{CP})}{2\phi} > \frac{\mathbb{E}(\pi_P^C)}{2\phi} = \mathbb{E}(\pi_H^C)$. Second, we can rewrite $\mathbb{E}(\pi_L^C) = (1 - \phi)\left(\frac{\mathbb{E}(\pi_P^C)}{2\phi} - \frac{(\bar{v} + \underline{v} + 2(1 - 2\alpha)q)}{2(5 - 2\alpha)}\right)$. As $\frac{3 - 2\alpha}{4} > \frac{1}{5 - 2\alpha}$, $\mathbb{E}(\pi_L^{CP})$ is

decreasing in q faster than $\mathbb{E}(\pi_L^C)$. At $q = 0$ the profits are again proportional to the platform's expected profit and therefore there is a crossing point. $\square$

Proof of Lemma 1.

Using the expressions for prices p_L^C and p_H^C , they depend on v solely through the belief sellers have about $\mathbb{E}(v)$. Hence, given any equilibrium strategy $m(v)$ and corresponding m , the unique equilibrium prices are as specified in the text. $\square$

Proof of Lemma 2.

We follow the steps from Lemma 1 in Crawford and Sobel (1982). Assume w.l.o.g. that $\mathbb{E}(v|m_1) < \mathbb{E}(v|m_2)$. First, there exists a state $\tilde{v}$, such that $\pi^P(\tilde{v}, m_1) = \pi^P(\tilde{v}, m_2)$. This state is

$$\tilde{v} = \frac{2(\mathbb{E}(v|m_1) + \mathbb{E}(v|m_2)) - (1 - 2\alpha)^2}{5 - 2\alpha} \quad (23)$$

and the optimal induced expectation in that state for the platform is $\mathbb{E}^*(\tilde{v}) = \frac{\mathbb{E}(v|m_1) + \mathbb{E}(v|m_2)}{2} \in (\mathbb{E}(v|m_1), \mathbb{E}(v|m_2))$.

Second, it follows that $\mathbb{E}(v|m_1)$ is not induced in equilibrium in any state $v > \tilde{v}$, as it is more profitable to induce $\mathbb{E}(v|m_2)$ and vice versa, $\mathbb{E}(v|m_2)$ is not induced in any state $v < \tilde{v}$.

Third, since $\mathbb{E}(v|m_1)$ is a rational expectation over which states the platform would choose to induce such expectation, $\mathbb{E}(v|m_1) \leq \tilde{v}$ and similarly $\mathbb{E}(v|m_2) \geq \tilde{v}$.

Fourth, we know that $\mathbb{E}^*(v) \neq v \forall v$, then $\left| \tilde{v} - \frac{\mathbb{E}(v|m_1) + \mathbb{E}(v|m_2)}{2} \right| > \epsilon$, which means that $\mathbb{E}(v|m_2) + \mathbb{E}(v|m_1) > \epsilon$. Since the state space is bounded, this means that there can only be a finite number of induced expectations. $\square$

Proof of Proposition 3.

First, we prove that price recommendation always gives a higher payoff than competition to both the platform and the sellers. Given that $\sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{v_k + v_{k-1}}{2} = \mathbb{E}(v)$, the condition $\mathbb{E}(\pi_i^R) > \mathbb{E}(\pi_i^C)$ for $t \in \{P, H, L\}$ can be reduced to

$$\sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \left(\frac{v_k + v_{k-1}}{2} \right)^2 > \left(\frac{\bar{v} + \underline{v}}{2} \right)^2$$

which is true by convexity of the function $f(x) = x^2$.

Second, we prove that when $q = 0$, $\mathbb{E}(\pi_P^R) < \mathbb{E}(\pi_P^{CP})$. This inequality reduces to

$$\sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{4(3-2\alpha)((v_k + v_{k-1})/2 + t(1-2\alpha))^2}{(5-2\alpha)^2} < \mathbb{E}\left(\frac{(v + t(1-2\alpha))^2}{2}\right) \iff$$

$$\sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{4(3-2\alpha)(\mathbb{E}(v|k) + t(1-2\alpha))^2}{(5-2\alpha)^2} < \sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \mathbb{E}\left(\frac{(v + t(1-2\alpha))^2}{2} | k\right)$$

Note that (i) $\frac{4(3-2\alpha)}{(5-2\alpha)^2} < \frac{1}{2}$ and (ii) $(\mathbb{E}(v|k) + t(1-2\alpha))^2 < \mathbb{E}((v + t(1-2\alpha))^2 | k)$ by Jensen's inequality. Then the inequality holds. The rest of the proof follows the same steps as the proof of Corollary 1. $\square$

Proof of Corollary 2.

We first prove that the cheap talk equilibria satisfy the monotonicity criterion that for every two cheap talk equilibria characterized by vectors of interval boundaries $\hat{v} = (\hat{v}_0, \hat{v}_1, \dots)$ and $\tilde{v} = (\tilde{v}_0, \tilde{v}_1, \dots)$ with $\hat{v}_0 = \tilde{v}_0$ and $\hat{v}_1 > \tilde{v}_1$ then $\hat{v}_i > \tilde{v}_i$ for every $i \geq 2$.

Let $\hat{v}$ and $\tilde{v}$ be solutions for the interval boundaries in Equation (15). By definition, $\hat{v}_0 = \tilde{v}_0 = \underline{v}$. Suppose $\hat{v}_1 > \tilde{v}_1$ then $\hat{v}_1 - \tilde{v}_1 = \frac{\hat{v}_2 - \tilde{v}_2}{3-2\alpha} > 0$ which results in $\hat{v}_2 > \tilde{v}_2$. Now assume that monotonicity applies for every $i < m$. Then: $\hat{v}_{m-1} - \tilde{v}_{m-1} = \frac{\hat{v}_m - \tilde{v}_m}{3-2\alpha} > 0$ and by the same logic from above, this proves that monotonicity holds by induction.

Using Proposition 3 from Chen et al. (2008), because the equilibria in the game are monotonic, only the unique equilibrium partition with the maximum number of induced actions satisfies NITS. $\square$

Proof of Proposition 4.

First consider the high type. Note that $\mathbb{E}(\pi_H^R) = (1 - \phi)\left(\frac{\mathbb{E}(\pi_P^R)}{2\phi} + \frac{(\mathbb{E}(v)+1-2\alpha)q}{5-2\alpha}\right)$. If $q = \hat{q}$, $\mathbb{E}(\pi_H^R) < \mathbb{E}(\pi_H^{CP})$ as the first summands are equal, but the second linear part is larger for $\mathbb{E}(\pi_H^{CP})$. As the profit in case of recommendation is quadratic and increasing, the crossing point has to be further to the right than $\hat{q}$. Then $\hat{q}_H > \hat{q}$.

Second, consider the low type. Again we can write it as a combination of quadratic increasing function of q and a linear decreasing function of q . $\mathbb{E}(\pi_L^R) = (1 - \phi)\left(\frac{\mathbb{E}(\pi_P^R)}{2\phi} - \frac{(\mathbb{E}(v)+1-2\alpha)q}{5-2\alpha}\right)$. By the same logic as before, we get that at $q = \tilde{q}$, $\mathbb{E}(\pi_L^R) > \mathbb{E}(\pi_L^{CP})$. We also know that at $q = 0$ $\mathbb{E}(\pi_L^R) < \mathbb{E}(\pi_L^{CP})$. Both functions are monotonic, so it has to be the case that $\hat{q}_L < \hat{q}$.

The proof for the competition regime follows the same steps. $\square$

Proof of Proposition 5.

As established in the text, the relationship between the expected total demands is determined by the expected prices. They are the following:

$$\begin{aligned}\mathbb{E}(p^{CP}(v)) &= \frac{\bar{v} + \underline{v} + 2(1 - 2\alpha)}{4} \\ \mathbb{E}(p^C) &= \frac{p_H^C + p_L^C}{2} = \frac{\bar{v} + \underline{v} + 2(1 - 2\alpha)}{5 - 2\alpha} \\ \mathbb{E}(p^R) &= \sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \frac{v_k + v_{k-1} + 2(1 - 2\alpha)}{5 - 2\alpha} = \frac{\bar{v} + \underline{v} + 2(1 - 2\alpha)}{5 - 2\alpha}\end{aligned}$$

Higher expected prices result in lower expected demand. Because $5 - 2\alpha > 4$, the expected demand is ordered as specified in the text. $\square$

Proof of Proposition 6.

First we need to derive the expressions for expected consumer surplus. For captives, they purchase from the seller that they are aware of if and only if their distance from that seller is below $v - p_i + q_i$. The maximum utility a captive buyer can achieve is $v - p_i + q_i$. The utility of captive buyers decreases linearly with distance. Then the total surplus of captive consumers is an area under a triangle with base $2(v - p_i + q_i)$ and height $v - p_i + q_i$. Then $CS^{cap} = (v - p_i + q_i)^2$.

For shoppers, those located at $(-\infty, -1) \cup (1, +\infty)$ act as captives (by Assumption A1). Then their surplus is $\frac{(v - p_i + q_i)^2}{2}$. The shoppers in the interval $[-1, 1]$ choose between the two sellers. Denote by $\tilde{x} = \frac{q_1 - q_2 - p_1 + p_2}{2}$ the location of the shopper indifferent between the two sellers. Then the consumer surplus of the buyers in $[-1, \tilde{x}]$ is a trapezoid with area $(\tilde{x} + 1) \frac{2(v + q_1 - p_1) + (\tilde{x} + 1)}{2}$ and for the buyers in $[\tilde{x}, 1]$ it is $(1 - \tilde{x}) \frac{2(v + q_2 - p_2) + (1 - \tilde{x})}{2}$. Combining everything together, we get the following expression for consumer surplus:

$$\begin{aligned}CS(p_1, p_2) &= (v + q_1 - p_1)^2 + (v + q_2 - p_2)^2 + \\ &+ (1 - 2\alpha) \left(\frac{2(v + q_1 - p_1)(\tilde{x} + 1) + 2(\tilde{x}^2 + 1) + 2(v + q_2 - p_2)(1 - \tilde{x})}{2} \right)\end{aligned}$$

Using equilibrium prices, the expected consumer surplus under centralized pricing is:

$$\mathbb{E}(CS^{CP}) = \frac{\mathbb{E}(v^2) + q^2(5 - 2\alpha) - 3 + 8\alpha - 4\alpha^2}{2} \quad (24)$$

The expected consumer surplus under competition is

$$\mathbb{E}(CS^C) = \frac{q^2(5-2\alpha)}{8} + \frac{1}{(5-2\alpha)^2} (2\mathbb{E}((2\mathbb{E}(v) - v(5-2\alpha))^2) + (1-2\alpha)^2(3-2\alpha)\mathbb{E}(v) - 37 + 126\alpha - 124\alpha^2 + 40\alpha^3)$$

And the expected consumer surplus under recommendation regime is

$$\mathbb{E}(CS^R) = \frac{q^2(5-2\alpha)}{8} + \frac{1}{(5-2\alpha)^2} \left(2 \sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \mathbb{E}((2\mathbb{E}(v|k) - v(5-2\alpha))^2|k) + 2(1-2\alpha)^2(3-2\alpha)\mathbb{E}(v) - 37 + 126\alpha - 124\alpha^2 + 40\alpha^3 \right)$$

Second, we need to show that $\mathbb{E}(CS^C) > \mathbb{E}(CS^R)$. This reduces to

$$\begin{aligned} \mathbb{E}((2\mathbb{E}(v) - v(5-2\alpha))^2) &> \sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \mathbb{E}((2\mathbb{E}(v|k) - v(5-2\alpha))^2|k) \iff \\ &-8(2-\alpha)(\mathbb{E}(v))^2 > -8(2-\alpha) \sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} (\mathbb{E}(v|k))^2 \iff \\ -8(2-\alpha) \left(\sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} \mathbb{E}(v|k) \right)^2 &> -8(2-\alpha) \sum_{k=1}^n \frac{v_k - v_{k-1}}{\bar{v} - \underline{v}} (\mathbb{E}(v|k))^2 \end{aligned}$$

which is true by concavity of $f(x) = -8(2-\alpha)x^2$.

Finally, we need to show that there exist a q' such that $\mathbb{E}(CS^C) > \mathbb{E}(CS^{CP})$ if and only if $q < q'$. Both are quadratic and increasing in q , but $\mathbb{E}(CS^{CP})$ is increasing faster. Therefore, when q is large enough, $\mathbb{E}(CS^{CP}) > \mathbb{E}(CS^C)$. Then we need to show that if $q = 0$, $\mathbb{E}(CS^C) > \mathbb{E}(CS^{CP})$. The difference between the two expressions is

$$\begin{aligned} \mathbb{E}(CS^C) - \mathbb{E}(CS^{CP}) &= \\ &= \frac{(1-2\alpha)^4 + 2(3-2\alpha)(1-2\alpha)^2(\bar{v} + \underline{v}) + (3-2\alpha)^2\bar{v}^2 + (4\alpha^2 - \alpha - 7)\bar{v}\underline{v} + (3-2\alpha)^2\underline{v}^2}{2(5-2\alpha)^2} > 0 \end{aligned}$$

which completes the proof. $\square$

Proof of Proposition 7.

For this proof, we introduce the expected full revelation revenue, i.e. the revenue the platform

would get under competition if v was observable by the sellers:

$$\mathbb{E}(\pi_P^{FR}) = \frac{(3 - 2\alpha)\phi(3(5 - 2\alpha)^2 q^2 + 16(12\alpha^2 + \bar{v}^2 - 6\alpha(\bar{v} + \underline{v} + 2) + \bar{v}\underline{v} + 3\bar{v} + \underline{v}^2 + 3\underline{v} + 3))}{12(5 - 2\alpha)^2} \quad (25)$$

It follows from Jensen's inequality that $\mathbb{E}(\pi_P^{FR}) \geq \mathbb{E}(\pi_P^R) \geq \mathbb{E}(\pi_P^C)$.

First, consider the case $\alpha = 0$. It is possible to show that $\mathbb{E}(\pi_P^{CP})|_{\alpha=0} > \mathbb{E}(\pi_P^{FR})|_{\alpha=0}$ given the parameter restrictions given by Assumption A1. Then if $\alpha = 0$ centralized pricing is the most profitable regime for the platform.

Second, consider the case $\alpha = \frac{1}{2}$. In this case under recommendation n^* goes to infinity. Note that now since in this case both sellers are effectively monopolists over their segments of the market, there is no misalignment of incentives between the platform and the sellers. Therefore, when $\alpha = \frac{1}{2}$, the platform will communicate the realization of v to the sellers perfectly. In other words, $\mathbb{E}(\pi_P^R)|_{\alpha=\frac{1}{2}} = \mathbb{E}(\pi_P^{FR})|_{\alpha=\frac{1}{2}}$. It is possible to show that $\mathbb{E}(\pi_P^R)|_{\alpha=\frac{1}{2}} > \mathbb{E}(\pi_P^{CP})|_{\alpha=\frac{1}{2}}$ given Assumption A1. Then when $\alpha = \frac{1}{2}$ the most profitable regime for the platform is price recommendation.

Finally, one can show that $\mathbb{E}(\pi_P^{CP})|_{\alpha=0} > \mathbb{E}(\pi_P^R)|_{\alpha=\frac{1}{2}}$ given Assumption A1. This means that in the first stage of the game, the platform will choose $\alpha = 0$ and then it will choose to centralize pricing. $\square$

B Signaling Model of Buyer Demand

In this section we provide an example of a model that would generate behavior similar to the one presented in the paper without the assumption that the buyers observe the sellers' qualities q_1 and q_2 . The key insight is that under competition and recommendation, the sellers can use prices to signal their quality while under centralized pricing they cannot.

The setup of the model is the same as before, except for two changes. First, the buyers do not observe q_1 and q_2 before making purchase decisions. Instead, they form expectations of quality given the information they observe (i.e., the prices). Second, we assume that some buyers can become disgruntled when their expectations are not met and ask for (and receive) a refund with probability $\gamma(\mathbb{E}(q_i|p_i) - q_i)$. The probability of refund is a function of the difference between the expected and realized quality. We assume that $\gamma(x) = 0$ if $x < 0$, i.e., no refunds happen after positive surprises. Note that this means that since q is the highest possible quality level, the high

quality type never has to pay out a refund.

If $x > 0$, i.e., if the surprise is negative, we assume that $\gamma(x) = \frac{x}{2q}$. Then the probability of refund is linear and increasing in the size of the negative surprise. Because $\gamma(2q) = 1$, if buyers believe the seller to be of high quality, but it turns out to be low quality, they will always get a refund. Suppose buyers believe that a seller setting price p is of high type with probability $\beta(p)$. Then $\mathbb{E}(q_i|p) = (2\beta(p) - 1)q$ and if $q_i = -q$, $\gamma = \beta(p)$. This can be interpreted as whenever a buyer is fooled into buying from a low quality seller, they will ask for a refund.

Given this setup, we can find the following:

Proposition 8. *Under competition and recommendation there is a separating equilibrium in which all players' strategies and payoffs are identical to the ones described in Propositions 2 and 3. This equilibrium survives the intuitive criterion refinement.*

Under centralized pricing, in the unique equilibrium all players' strategies and high type sellers' payoffs are identical to Proposition 1 and the low type sellers' payoffs are divided by 2 and the platform's expected revenue multiplied by $\frac{3}{4}$.

Proof. We start with competition. Since the strategies are the same as in Proposition 2, we only need to describe the buyers' beliefs to characterize this equilibrium. The beliefs are the following: $\beta(p_H^C) = 1$ and $\beta(p) = 0 \forall p \neq p_H^C$.

First, we verify that there are no deviations. Suppose the high type deviates. Then it is believed to be low type with probability 1. In this case and given that the other seller is playing the equilibrium prices, the best possible deviation is to p_L^C yielding $\mathbb{E}(\pi_L^C)$, which is less than $\mathbb{E}(\pi_H^C)$, therefore, there are no profitable deviations for the high type.

Now suppose the low type deviates. If they deviate to p_H^C , they will earn 0 because of the buyers' refunds. If they deviate to any other price, they do not shift the buyers' beliefs and we already know by revealed preference that the optimal price under the belief that the player is low type is p_L^C , so there are no profitable deviations for low type. This means that this is in fact an equilibrium.

Second, we show that this equilibrium survives the Intuitive criterion refinement (Cho and Kreps 1987). This refinement says (in terms of our model) that if for a certain price p , $\beta(p) > 0$ ($\beta(p) < 1$), then it has to be the case that this price is not equilibrium-dominated for high (low type). A price is said to be equilibrium-dominated for type τ if $\max_{\tilde{\beta}} \mathbb{E}(\pi_\tau^{dev}(p, \tilde{\beta})) \leq \mathbb{E}(\pi_\tau^C)$. In other words, if a

price p is believed to be set with a positive probability by a type τ seller, it has to be rationalizable in the sense that there exists a belief $\tilde{\beta}(p)$, for which this price would be a profitable deviation. Since the original Intuitive Criterion is formulated for a single sender environment, we have to adjust our refinement to assume that for all conditions the other sender's equilibrium actions are taken as given. This is perhaps the most restrictive version of the refinement.

For a high type seller, for any price, the belief that maximizes their expected profit is $\tilde{\beta}(p) = 1$. The best price under this belief is p_H^C . Therefore, for the high type seller, every $p \neq p_H^C$ is equilibrium-dominated. The out-of-equilibrium beliefs we described above satisfy that.

For a low type seller, if there exists a price that is equilibrium-dominated, then it is equilibrium-dominated for both types and (i) the Intuitive Criterion does not restrict beliefs about these prices (ii) these prices are irrelevant to whether an equilibrium exists or not, since they are not feasible deviations. This means that the out-of-equilibrium beliefs described above satisfy the Intuitive Criterion.

Finally, under centralized pricing, since the platform sets the prices without observing q_1 and q_2 and the sellers take no action, there is no opportunity for signalling. The beliefs are $\beta(p) = \frac{1}{2} \forall p$, since the buyers know that the platform does not know anything about the sellers' qualities. This implies that for the low type seller $\gamma = \frac{1}{2}$, i.e., half of the sales are refunded. For the platform, $\frac{3}{4}$ of all sales are refunded. As a multiplier, this adjustment does not change the optimal pricing of the platform.

Following this model, the results of the paper might change for specific parameter values, but will not change qualitatively. $\square$