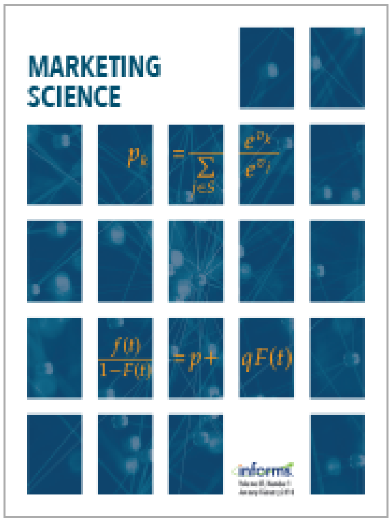

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Price Fairness and Strategic Obfuscation

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Abstract. Firms are increasingly using technology to enable targeted, or "personalized," pricing strategies. In settings where prices are transparent to all consumers, however, there is the potential for interpersonal price differences to be perceived as inherently unfair. In response, firms may strategically obfuscate their prices so that direct interpersonal comparisons are more difficult. The feasibility of such a pricing strategy is not well understood. In this paper, we investigate the conditions under which it is profitable for firms to engage in price obfuscation, given the potential fairness concerns of consumers. We study how price obfuscation affects consumer fairness concerns, consumer demand, and equilibrium pricing strategies. The findings suggest that if obfuscation mitigates fairness concerns, it can arise as an equilibrium outcome, even if consumers are aware of the seller's strategic behavior and are able to update their beliefs and expectations about the prices offered to their peers accordingly. To test the theoretical predictions, an experiment is conducted in which price obfuscation is varied both exogenously and endogenously. The results confirm that buyers have intrinsic distributional (based on the seller's margins) and peer-induced fairness (due to others being charged different prices) concerns when prices are transparent. In particular, disadvantaged peer-induced fairness concerns enter utility as an intrinsic cost that the seller has to compensate for through lower prices. Obfuscation effectively reduces peer-induced fairness concerns and increases sellers' pricing power. However, this pricing power is constrained by distributive inequity becoming more salient when prices are obfuscated.

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Keywords: personalized pricing • fairness • inequity aversion • price discrimination • retail pricing

1. Introduction

Retailers are increasingly turning to price personalization as a way to move consumers away from nontargeted mass discounts in order to improve their profit margins. In a recent survey, 64% of U.S. retailers agreed that "it will become important to deliver personalized prices to shoppers in the next three years,"(Retail Systems Research 2017, p. 14), a significant increase from the prior year. However, many retailers realize that implementing a personalized pricing strategy can result in blowback if consumers find out about different prices being offered to other consumers. This was highlighted in an incident when users discovered that Amazon.com charged some customers more than others for the same products. Faced with furious responses from consumers and the press, Amazon halted the practice and apologized for the 'unfair' treatment (Weiss 2000). Peer-induced fairness (PIF) concerns, that is, consumers disliking paying a different price than their peers for the same good, are at the core of retailer fears and a major constraint in successful implementation of such personalized pricing strategies (e.g., Darke and Dahl 2003, Xia et al. 2004, Ho and Su 2009, Li and Jain 2015).

Aware of these fairness concerns, many large retailers are exploring different ways to obfuscate (i.e., make less transparent) the practice of personalized pricing. In this paper, we define price obfuscation as a purposeful action taken by a price-discriminating seller to prevent buyers from observing prices offered to other buyers for the same good. For example, Sam's Club introduced checkout apps that deliver individual prices without other customers noticing. In addition, Kroger is piloting a project called "digital shelf edge," which uses in-store sensors and analytics to provide product recommendations and custom pricing discreetly through mobile devices. Similarly, Amazon is engaged in highly sophisticated personalized pricing through individualized coupons and price fluctuations across time designed to get as close as possible to first-degree price discrimination without consumers noticing that final prices shown to them might be different from those shown to others. These examples illustrate the tension that retailers face between optimizing their price personalization strategies and consumer fairness concerns.

The feasibility of such a pricing system rests on the successful obfuscation of prices across customers in order to make their interpersonal price comparisons difficult. In other words, retailers are expending great effort not only to offer a consumer the optimal personalized price, but also to obfuscate the prices offered to other consumers. In this paper, we investigate how the strategic obfuscation of prices across buyers affects consumer fairness concerns, consumer demand, and equilibrium pricing strategies. The goal of this paper is to answer the following four research questions:

1. When consumers are uncertain about the valuations/prices offered to their peers, under what conditions are firm profits higher when prices are obfuscated versus when they are transparent?
2. How do optimal prices vary when pricing is obfuscated versus when it is transparent? Moreover, what happens to the corresponding consumer surplus?
3. Can price obfuscation be sustained as an equilibrium outcome if consumers are aware that the seller is strategically (endogenously) choosing to obfuscate prices and are able to update their beliefs and expectations about the prices offered to other buyers accordingly?
4. Is price obfuscation effective at mitigating consumer fairness concerns?

To answer these questions, we develop a game theoretic model of a seller facing two buyers who exhibit both distributive fairness (DF) and PIF concerns. The former captures a consumer's intrinsic concern about excessive retail margins; the later captures concerns about paying a different price than other buyers. The two buyers have different valuations/willingness to pay (WTP) for the seller's good and are capable of forming rational expectations regarding the optimal pricing strategy. The seller observes both buyers' WTP and can offer different prices accordingly, that is, price discriminate. We analyze three games: (1) an exogenous transparency game, where each buyer always observes both prices; (2) an exogenous obfuscation game, where each buyer observes only his own price but not that of the other buyer; and (3) an endogenous obfuscation game, where the seller sets the prices and decides whether they will be transparent or obfuscated, that is, the seller decides whether each buyer can or cannot observe the price offered to the other buyer. In the endogenous obfuscation case, the buyers are aware of the sellers' transparency or obfuscation decision and rationally update their beliefs accordingly.

The theoretical model predicts that the seller's profit and equilibrium prices under exogenous obfuscation will be higher than under exogenous transparency when differences in buyers' WTP are high. If PIF concerns are equally strong under obfuscation and transparency, then obfuscation cannot be sustained in equilibrium in the endogenous obfuscation game. When consumers are aware that the seller strategically chose obfuscation, they will expect the highest level of price discrimination possible, which ends up making it optimal for the seller to choose transparency. This means that although obfuscation can be more profitable than transparency when imposed exogenously, it can fail to materialize in equilibrium once consumers consider that the seller is engaging in it strategically.

Notably, the theoretical model suggests that if obfuscation mitigates PIF concerns, it can arise as an equilibrium outcome, even if consumers are aware of the sellers' strategic behavior. The seller will still find obfuscation more profitable than transparency when the difference in WTP is sufficiently high, even though consumers can use this information to update their beliefs about the prices offered to their peers and the seller's price-discrimination strategy. Finally, if obfuscation completely eliminates the PIF concerns but increases DF concerns by attention shifting, the same predictions hold.

We test the predictions of the theoretical model of strategic obfuscation through a two-sided experiment in which subjects play the role of either a price-discriminating seller or a utility-maximizing buyer. A controlled experiment provides the ability to separate consumer fairness from other confounding factors (reciprocity, betrayal, altruism, etc.) present in transactional data. In particular, in our experiment, buyers decide whether to accept the price offered by the seller, while the level of interpersonal price transparency is varied both exogenously and endogenously. We impose exogenous price obfuscation by allowing subjects to have two theoretical extremes in price transparency: complete knowledge of what others were offered or no peer price information at all. Endogenous price obfuscation is examined by allowing the seller to pay to obscure prices between buyers, so both the level of obfuscation and prices are endogenously determined. We use an incentive-compatible design so that the participants' actual monetary payments are directly proportional to the surplus they accumulate during the experiment.

Next, we use the experimental data to test the theoretical predictions using either simple mean comparisons or reduced form regressions. Notably, the results suggest strong statistical support for nine theoretical results related to equilibrium prices, consumer surplus, profits, and obfuscation/transparency decisions. In other words, we find strong model-free support that the observed pricing strategies as well as the endogenous obfuscation/transparency decisions are consistent with our theoretical equilibrium predictions. Because we have a two-sided game and strategic behavior on both sides, we use an econometric model to account for the buyer and seller decisions simultaneously. This allows us to estimate the magnitude and direction of the inequity aversion parameters and further test our theory.

We find that peer-induced fairness concerns are an important obstacle to charging personalized prices, but obfuscation can help sellers mitigate buyers' aversion to inequity. This result holds even when they are aware that the seller is doing so. The results also suggest that when prices are obfuscated, the buyer's attention shifts to how the total surplus is divided between the seller and the buyer (i.e., distributional inequity concerns), which adds a constraint for effective price discrimination even when peer prices are effectively concealed.

This study contributes to both the theoretical and empirical literature on price fairness by explaining how strategic obfuscation can be sustained as an equilibrium strategy by a price-discriminating seller to ameliorate buyers' peer-induced concerns even when buyers know that the seller is practicing price discrimination. To this point, the literature on interpersonal perceptions of price fairness has taken price transparency/obfuscation as exogenously given. However, sellers are able to invest in technologies that ensure prices are targeted to individual buyers and make interpersonal price comparisons more difficult. Our theoretical and empirical model explicitly considers the effect of these seller decisions on equilibrium prices. Furthermore, whereas the mechanisms that underlie perceptions of price fairness are by now relatively well understood (Xia et al. 2004), there is little research on how these perceptions manifest in purchase decisions, or the optimal seller response. However, there is evidence that equilibrium prices are likely to be different if rational sellers take into account the fact that inequity-averse buyers may not purchase if they think they are being taken advantage of (Anderson and Simester 2008, Rotemberg 2011). Our findings on the decision to obfuscate add another level of realism to the theoretical fairness literature and its practical importance. Finally, this study provides empirical evidence that obfuscation can mitigate PIF concerns by making prices paid by other consumers less salient.

2. Related Literature

Perhaps because of its fundamental importance to the viability of any pricing system, price fairness has assumed a prominent place in marketing, psychology, and economics research (Xia et al. 2004, Cui et al. 2007, Rotemberg 2011, Goldfarb et. al. 2012, Li and Jain 2015). Although this may pose a threat to a successful personalized pricing strategy, our paper shows that obfuscation can lead to higher equilibrium prices compared with a transparent setting. This study is unique, as it links two distinct streams of literature on fairness concerns and strategic obfuscation, which we summarize in this section.

2.1. Fairness

Although there are many ways consumers form perceptions of price fairness, we primarily focus on interpersonal comparisons, as our objective is to study the viability of price-discrimination regimes that rely on interpersonal differences in prices. There is a wealth of empirical evidence that interpersonal comparisons are particularly important in forming perceptions of price fairness. In particular, Darke and Dahl (2003) sought to explain why consumers seem to place unusual value in obtaining a bargain. Framing their analysis in terms of equity theory (Adams 1965, Bagozzi 1975, Oliver and Swan 1989) and transaction utility theory (Thaler 1985), they found that learning another customer received a better deal had a much larger impact on satisfaction than the direct effects of the bargain participants received themselves. Haws and Bearden (2006) compared the effects of different modes of price comparison on perceptions of fairness and found that interpersonal price differences resulted in the greatest perceptions of unfairness. Similarly, when the only comparisons were between the buyer's own past price and another buyer's price, Xia and Monroe's (2010) results suggested that the price paid by someone else had a much stronger influence on the perception of unfairness. More recently, Ashworth and McShane (2012) conducted two studies in the laboratory to investigate whether interpersonal differences in price led to feelings of "disrespect" from the seller and whether those feelings were associated with comparisons with others buying from the same store or at a regular or discounted price. Perhaps not surprisingly, their results show that buyers consider themselves disrespected if they are charged a higher price compared with another consumer. This effect is exacerbated if the comparison is made within store, and for the same type of item. In our paper, the concept of interpersonal price differences takes center stage. As we explain in our theoretical model and the empirical application of the model below, these interpersonal price differences and the anticipations of fairness concerns drive sellers' pricing decisions and determine the sellers' incentives to invest in making the prices less transparent.

It is important that PIF is considered separately from DF, which deals with how total transaction surplus is distributed between buyers and sellers. The distinction is important because concerns regarding both types of fairness stem from different behavioral mechanisms. In the case of DF, the dual entitlement theory of Kahneman et al. (1986a, b) implies that, in their relationships with sellers, buyers are motivated by a sense that both sides of the transaction are entitled to at least some of the transaction surplus. Their theory maintains that buyers' perceptions of price fairness are governed by the notion that firms are expected to earn a reference level of profit, and buyers expect to pay a reference price. If buyers believe that a price increase is driven by a higher demand—a snowstorm raising the demand for shovels—then the price is more likely to be viewed as unfair compared with an increase in the cost of manufacturing the shovels, for example. Our theoretical model assumes that one can measure the DF, and our experiment is designed to isolate the effects of the DF mechanism from PIF on the consumer's choice. Our paper also shows the interdependence between the peer-induced fairness and the DF and how both of them are affected by peer price obfuscation; namely, we show that when prices are obfuscated, buyers shift their attention from caring about the PIF to caring relatively more about DF.

Several studies investigate how distributional and/or PIF concerns influence economic outcomes in a supply chain (Cui et al. 2007, Ho et al. 2014, Cui and Mallucci 2016). Two studies, by Ho and Su (2009) and Ho et al. (2014), analyze a setting where both types of fairness concerns, PIF and DF, are present. They focus on a leader (e.g., manufacturer) who makes ultimatum offers sequentially to identical followers (e.g., retailers or employees). Their work empirically disentangles PIF and DF concerns, highlights how PIF concerns limit price discrimination, and shows that PIF concerns cause the second follower to get a better offer than the first. There are two important differences between their studies and ours. First, their sequential framework applies primarily to business-to-business transactions or negotiations. In contrast, our simultaneous framework is better suited to study business-to-consumer transactions. Second, they treat the level of obfuscation as exogenously given and do not investigate the interaction between strategic (endogenous) obfuscations and PIF concerns. To our knowledge, no previous study focuses on how a seller's strategic obfuscation decision affects buyers' perceptions of price fairness and their subsequent purchase behavior.

2.2. Obfuscation

Ignorance as a source of market power has been well understood since Scitovsky (1950). If firms are able to make price comparisons difficult or costly, they will be more likely to sell to buyers unwilling, or unable, to form expectations of what constitutes a reasonable price. In other words, if price transparency does indeed represent a significant barrier to a firm's ability to price discriminate, then obfuscating prices represents a potential source of market power and should yield higher equilibrium prices.

The term obfuscation has been used previously in the literature to refer to a variety of purposeful actions taken by sellers to prevent consumers from comparing prices of similar products, whether across sellers, across products from the same seller, or across buyers. By whatever means, the intent of strategic obfuscation is to raise search costs, thereby creating opportunities for margin expansion (Stigler 1961). Strategic obfuscation takes many forms, from creating slightly different versions of the same product (e.g., Ellison 2005, Gabaix and Laibson 2006, Ellison and Ellison 2009) to creating confusion in how prices are reported to consumers (e.g., Carlin 2009, Wilson 2010, Wilson and Price 2010, Chioveanu and Zhou 2013, Muir et al. 2013), or to the personalized pricing examples discussed above. In this paper, we focus on a particular type of strategic obfuscation, namely, the purposeful action taken by a price-discriminating seller to prevent buyers from observing prices offered to other buyers for the same good. The purpose of this kind of obfuscation is to reduce their ability to compare prices across different buyers accurately. In our model, sellers can either choose between transparency or obfuscation of prices. The former (latter) corresponds to making buyers' search costs infinite (zero).

There is some empirical evidence that strategic obfuscation can be profit enhancing under the right circumstances. In the context of online shopping, Ellison and Ellison (2009) show that price obfuscation strategies, such as not showing the retail price in the search results, can yield higher equilibrium profits because they give more monopoly power to firms by increasing search frictions and making consumers less informed. Similarly, Blake et al. (2017) document that obfuscation of shipping and handling fees led to a revenue boost for StubHub.com. They show that part of this effect is due to higher search costs making comparisons across substitute products more difficult. In this paper, on the other hand, we allow firms to obfuscate interpersonal price comparisons while buyers are fully aware of the transparency versus obfuscation decision. That way, we can test whether obfuscation is effective at alleviating PIF concerns and raising equilibrium profits. Therefore, in our theoretical model as well as the empirical application, we capture not only perceptions of fairness and how they affect demand, but also how sellers anticipate buyers' responses in setting equilibrium prices and deciding whether to pay to obfuscate peer price offers.

3. Theoretical Model

There are two buyers, a and b, who each have a unique willingness to pay for a good. The buyers' WTPs are independent and identically distributed (i.i.d.) draws from a uniform distribution on $[\underline{w},\overline{w}]$ whose cumulative distribution function (CDF) is given by $F(w_i) = \frac{w_i-\underline{w}}{\overline{w}-\underline{w}}$. A seller produces the good at a constant marginal cost, $c \in [0, \underline{w}]$, which is common knowledge to all players.[1] The seller observes both buyers' WTP. Each buyer, however, knows only his own WTP, and not that of the other buyer. The seller makes a take-it-or-leave-it offer (price) to each buyer, who accepts if the offer leaves him with at least the same utility as his outside option. Without loss of generality, we normalize the utility of the buyers' outside option to zero. Let p_i denote the price the seller offers buyer i, with information set Ω_i, who obtains the following utility by accepting the offer:

$$U_i(w_i, p_i; \Omega_i) = \underbrace{\alpha(w_i - p_i)}_{\text{obj. surplus}} - \underbrace{\delta(p_i - c)}_{\text{DF effect}} - \underbrace{\rho_d \Pr(P_j < p_i \mid \Omega_i)(p_i - \mathbb{E}[P_j \mid P_j < p_i; \Omega_i])}_{\text{Negative PIF effect}}, \quad (1)$$

where $i, j \in \{a, b\}$, $i \neq j$. We follow standard notation and capitalize P_j to reflect that it is a random variable from the perspective of buyer i. The first term in the equation captures the buyer's objective (obj.) surplus weighted by a parameter $\alpha > 0$. The second term captures his DF concerns (i.e., how much he cares about the surplus the seller keeps for herself) weighted by $\delta > 0$. The third term captures his PIF concerns (i.e., the negative utility from another buyer getting a lower price) weighted by $\rho_d > 0$.[2]

We analyze three games: (1) an exogenous transparency game, where both prices are exogenously revealed to both buyers; (2) an exogenous obfuscation game, where each buyer only observes his own price but not that offered to the other buyer; and (3) an endogenous obfuscation game, where the seller first observes both WTPs, then endogenously decides whether to reveal or obfuscate prices. Without loss of generality, we simplify the exposition of the theoretical analysis by normalizing the constant marginal cost of producing the good, c, to zero. Throughout the analysis, we will make use of the following two definitions.

Definition 1. Let $p^{\max}(w_i) \equiv \dfrac{\alpha w_i}{\alpha + \delta}$ denote the maximum price a buyer with WTP $w_i \in [\underline{w}, \overline{w}]$ would pay in the absence of PIF concerns (i.e., if $\Pr(P_j < p_i \mid \Omega_i) = 0$ and/or $\rho_d = 0$).

Definition 2. Let l and h, respectively, denote the buyer with the lower and higher WTP such that $w_l \equiv \min\{w_a, w_b\}$ and $w_h \equiv \max\{w_a, w_b\}$.

3.1. Exogenous Transparency

In this game, each buyer observes both prices offered by the seller. Because buyer i observes both prices, then he knows with certainty whether $p_j < p_i$, and his utility in Equation (1) reduces to

$$U_i^{trp}(w_i, p_i, p_j) = \alpha(w_i - p_i) - \delta p_i - \rho_d \max\{0, p_i - p_j\}, \forall i, j \in \{a, b\},\ i \neq j. \quad (2)$$

Because the seller always observes both WTPs, her objective profit function is given by

$$\max_{p_a, p_b} \pi^{trp} = p_a + p_b \quad \text{s.t. } U_i^{trp}(w_i, p_i, p_j) \geq 0,\ \forall i, j \in \{a, b\},\ i \neq j. \quad (3)$$

Lemma 1. *The unique equilibrium of the exogenous transparency game is characterized by the following:*

i. *The seller charges buyer l her maximum price, but charges buyer h a discounted price below her maximum price.*

ii. *Buyer h's discount (price) decreases (increases) in buyer l's WTP; such that the discount is highest as $w_l \to \underline{w}$, and it is zero as $w_l \to w_h$.*

iii. *Equilibrium prices are given in Equation (4), and the seller's profit is $\pi^{trp*}(w_h, w_l) = p_h^{trp*} + p_l^{trp*}$;*

$$p_l^{trp*}(w_l) = p^{\max}(w_l) \text{ and}$$
$$p_h^{trp*}(w_h, w_l) = p^{\max}(w_h) - \underbrace{\frac{\rho_d(p^{\max}(w_h) - p^{\max}(w_l))}{\alpha + \delta + \rho_d}}_{t_h^{trp*}(w_h, w_l) = \text{discount below } p^{\max}(w_h)}. \quad (4)$$

When prices are transparent, the low WTP buyer knows with certainty he is receiving the lower price. Hence, PIF concerns are absent for him, and the seller is able to charge the maximum price. Conversely, the high WTP buyer suffers a disutility due to PIF concerns because he observes that his price is higher than that of the other buyer. Thus, the seller must compensate him with a discounted price below his maximum price. The magnitude of a discount depends on the price offered to the low WTP buyer. Specifically, the lower the price (and WTP) of buyer l, the higher the discount needed for buyer h to accept the offer.

For a given w_h, Figure 1(a) graphically illustrates the relationship between prices and w_l (see the dashed lines representing transparent prices).

3.2. Exogenous Obfuscation

In this game, buyer i does not observe the price offered to buyer j (nor w_j). We assume that each buyer is capable of forming a rational expectation about the seller's pricing strategy. Therefore, the utility of a buyer will depend on her expectation about the price offered to the other buyer (see Equation (1)). Because a buyer does not observe the other's price, the seller's optimal price for him will depend only on his WTP and not on that of the other buyer. In other words, the seller's optimal price for buyer i will be a function of w_i only and not w_j.

Buyers capable of forming rational expectations should *only* expect the seller to price according to a strictly increasing function, say $\hat{p}(w)$.[3] Because $\hat{p}$ is monotone, then its inverse, $\hat{p}^{-1}$, must exist, and $\Pr(\hat{p}(W_j) \le p_i) = \Pr(W_j \le \hat{p}^{-1}(p_i))$. The buyer's utility from Equation (1) can now be written as

$$U_i^{obf}(w_i, p_i; \hat{p}(\cdot)) = \alpha(w_i - p_i) - \delta p_i - \rho_d \Pr\left(W_j \le \hat{p}^{-1}(p_i)\right) \times \left(p_i - \mathbb{E}\left[\hat{p}(W_j) \mid W_j \le \hat{p}^{-1}(p_i)\right]\right). \tag{5}$$

Let $p^{obf*}(w_i)$ denote the seller's equilibrium pricing strategy. Then, the following two conditions must be satisfied. First, $p^{obf*}(w_i) = \arg\max p_i$, subject to $U_i^{obf}(w_i, p_i; \hat{p}(\cdot)) \ge 0$, for all $i \in [a, b]_i^{p_i}$, which ensures price optimality. Second, $\hat{p}(\cdot) = p^{obf*}(\cdot)$, which ensures rationality of buyers' expectations.[4] Taken together, the utility in Equation (2), and these two conditions yield the following equation

$$p^{obf*}(w_i) = p^{\max}(w_i) - \underbrace{\frac{\rho_d \Pr(W_j \le w_i)\left(p^{\max}(w_i) - \mathbb{E}[p^{obf*}(W_j) \mid W_j \le w_i]\right)}{\alpha + \delta + \rho_d \Pr(W_j \le w_i)}}_{t^{trp*}(w_i) = \text{ discount below } p^{\max}(w_i)}, \tag{6}$$

where $\Pr(W_j \le w_i) = F(w_i) = (w_i - \underline{w})/(\overline{w} - \underline{w})$, and $\mathbb{E}[p^{obf*}(W_j) \mid W_j \le w_i] = \int_{\underline{w}}^{w_i} \frac{p^{obf*}(w_j)}{w_i - \underline{w}} \mathrm{d}w_j$.

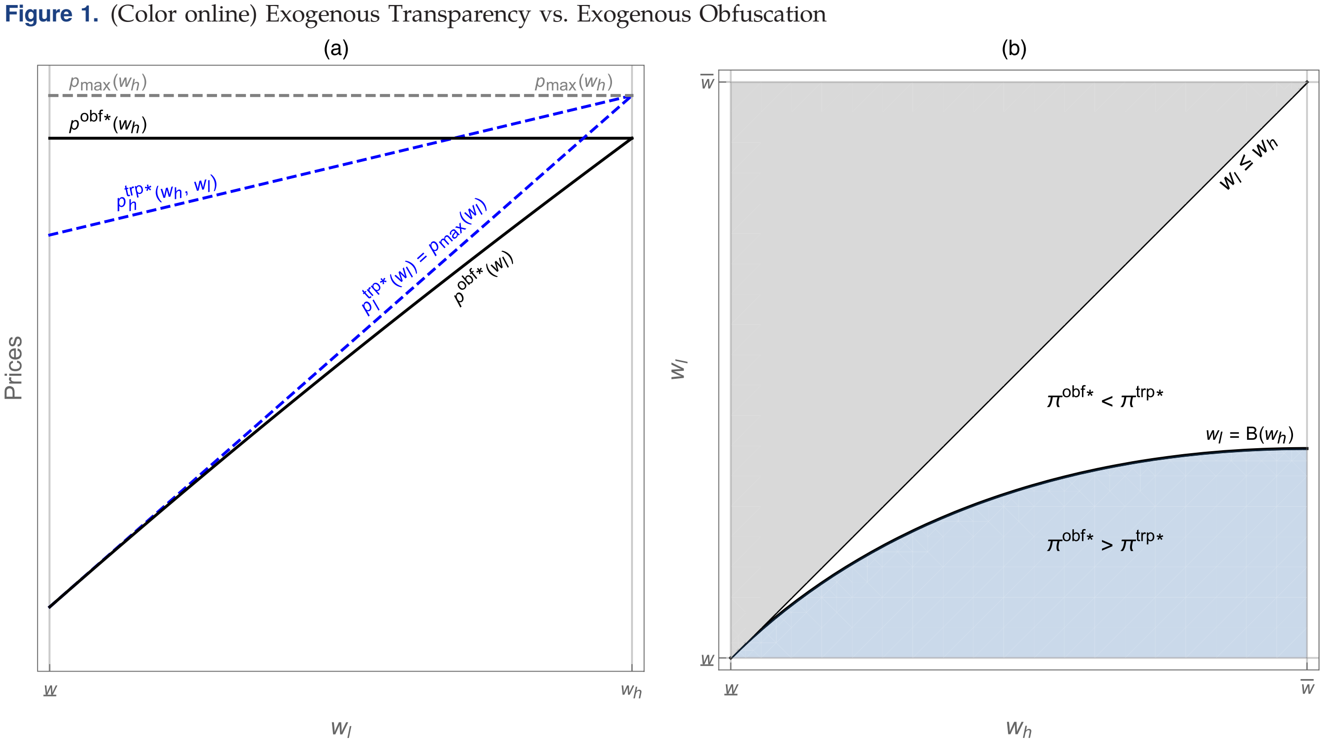
Lemma 2. *The unique equilibrium of the exogenous obfuscation game is characterized by the following:*

i. *The seller's equilibrium pricing strategy that satisfies Equation (6) is increasing in WTP and can be expressed in explicit form as*

$$p^{obf*}(w_i) = p^{\max}(\underline{w}) + \frac{\alpha(\overline{w} - \underline{w})}{\rho_d} \log_e\left(1 + \frac{\rho_d(w_i - \underline{w})}{(\alpha + \delta)(\overline{w} - \underline{w})}\right), \text{ and} \tag{7a}$$

$$\pi^{obf*}(w_h, w_l) = p^{obf*}(w_h) + p^{obf*}(w_l). \tag{7b}$$

Figure 1. (Color online) Exogenous Transparency vs. Exogenous Obfuscation



Prices for a given w_h

Profit Regions

ii. *The seller offers the lowest WTP buyer his maximum price (i.e., $p^{obf*}(\underline{w}) = p^{\max}(\underline{w})$), but she charges any other buyer a discounted price below his maximum price (i.e., $p^{obf*}(w_i) < p^{\max}(w_i)$, for all $w_i \in (\underline{w}, \overline{w}]$).*

iii. *The discount increases in WTP such that the higher a buyer's WTP, the higher the objective surplus he receives.*

When buyer i faces exogenous obfuscation, he cannot be certain that he received the higher or lower price. His PIF utility loss depends on two things: (1) the probability that the other buyer's WTP is below his, $F(w_i) \equiv \Pr(W_j < w_i)$, and (2) his expectation of the price the other buyer received conditional on $W_j < w_i$ (see Equation (5)). In turn, the discount he receives depends on the two same things (see Equation (6)). Because the lowest WTP buyer ($w_i = \underline{w}$) is certain that the other buyer's price is not lower than his, there is no discount for PIF concerns. As the buyer's WTP increases, both the probability that the other price is below his and the conditional expected price the other buyer receives increase. Therefore, the higher a buyer's WTP, the higher the discount he receives. Because buyers observe neither each other's price nor each other's WTP, the price/discount a buyer receives depends only on his own WTP, and not the other's WTP.

3.3. Comparing Exogenous Obfuscation vs. Exogenous Transparency

It is now useful to reiterate the following observations based on the previous results:

1. Under exogenous transparency, the low WTP buyer receives no discount, regardless of his WTP, because he knows with certainty that the other buyer received a higher price. In contrast, under exogenous obfuscation, the low WTP buyer receives a positive discount (for any $w_l \in (\underline{w}, \overline{w}]$) that increases in his own WTP.

2. Under exogenous transparency, if the WTP of the low buyer decreases, the high WTP buyer will observe a bigger gap in prices; hence, his discount will increase. In contrast, under exogenous obfuscation, if the WTP of the low buyer decreases, the high WTP buyer's expectations do not change; hence, his discount does not change.

3. Under exogenous transparency, if both buyers have equal WTPs, the seller gives neither of them a discount because they both observe that there is no price gap. In contrast, under exogenous obfuscation, the seller offers them both a discount.

Proposition 1. *The difference between the seller's profits under exogenous obfuscation and exogenous transparency depends on the difference between the buyers' WTPs as follows:*

i. *If the low buyer's WTP is sufficiently far from that of the high WTP buyer, the seller prefers exogenous obfuscation to exogenous transparency. Formally, $w_l < B(w_h) \Rightarrow \pi^{obf*} > \pi^{trp*}$.*

ii. *If the low buyer's WTP is sufficiently close to that of the high WTP buyer, the seller prefers exogenous transparency to exogenous obfuscation. Formally, $w_l > B(w_h) \Rightarrow \pi^{trp*} > \pi^{obf*}$.*

iii. *The cutoff function $B(w_i)$ is increasing, such that $B(\underline{w}) = \underline{w}$, $B'(\underline{w}) = 1$, $0 < B'(w_i) < 1$ for all $w_i \in (\underline{w}, \overline{w})$, $B'(\overline{w}) = 0$, and $\underline{w} < B(w_i) < w_i$ for all $w_i \in (\underline{w}, \overline{w}]$.*

A good way to grasp the intuition behind the proposition above is to fix the high WTP, w_h, and consider the seller's pricing strategies as the low WTP moves from the low extreme case ($w_l \to \underline{w}$) to the high extreme case ($w_l \to w_h$). If $w_l \to \underline{w}$, the seller charges the low buyer his maximum price under both exogenous transparency and exogenous obfuscation. Under exogenous transparency, however, she will have to give the high WTP buyer the highest possible discount because he observes that buyer l received the lowest possible price (see part ii of Lemma 1). In contrast, under obfuscation, the high WTP buyer does not know for sure whether the other buyer is getting a lower price. Thus, the seller offers him a smaller discount because his PIF disutility will depend on the probability that he is the high buyer and the conditional expected price of the other buyer is below his. This is illustrated graphically in Figure 1(a), where $p^{obf*}(\underline{w}) = p_l^{trp*}(\underline{w})$ and $p^{obf*}(w_h) > p_h^{trp*}(w_h, \underline{w})$, both of which imply that as $w_l \to \underline{w}$, profit from obfuscation is higher than that from transparency.

Now, consider the opposite scenario, where $w_l \to w_h$. When both buyers share the same WTP, the seller charges them both their maximum prices under exogenous transparency. The buyers will observe that they both received the same price, and the PIF disutility will no longer be a concern. In contrast, under obfuscation, neither buyer knows with certainty whether the other buyer is getting a lower, a higher, or the same price, and the seller has to offer them both a discount. This is illustrated graphically in Figure 1(a), where $p^{obf*}(w_h) < p^{\max}(w_h)$ and $p_h^{trp*}(w_h, w_h) = p^{\max}(w_h)$, both of which imply that as $w_l \to w_h$, transparency profit is higher than obfuscation profit. Figure 1(b) shows the cutoff function $B(w_h)$ that determines the critical value of w_l for a given w_h. If w_l is sufficiently low (below $B(w_h)$), exogenous obfuscation profits dominate transparency profits, and vice versa.

3.4. Endogenous Obfuscation

In this section, we analyze the case where the seller, after observing the two buyers' WTPs, w_a and w_b, endogenously chooses either price obfuscation or transparency and sets the prices. As a result, buyer $i \in \{a, b\}$ observes the seller's obfuscation/transparency decision, and because this decision is endogenous, he uses it to update his beliefs about the other buyer's WTP and price. Let I_{obf} be a binary variable that takes the value 1 or 0, respectively, if the seller chooses obfuscation or transparency. Buyer i's utility of accepting a price p_i conditional on the seller's obfuscation decision is given by

$$U_i^{end}(w_i, p_i \mid I_{obf}) = \begin{cases} \alpha(w_i - p_i) - \delta p_i - \rho_d \max\{0, p_i - p_j\} & \text{if } I_{obf} = 0, \\ \alpha(w_i - p_i) - \delta p_i \\ \quad - \lambda\rho_d \Pr(P_j \le p_i \mid I_{obf} = 1) \\ \quad \times (p_i - \mathbb{E}[P_j \mid P_j \le p_i, I_{obf} = 1]) & \text{if } I_{obf} = 1. \end{cases} \tag{8}$$

Note that in the obfuscation prong, ρ_d is multiplied by a parameter λ, which captures the degree to which the price obfuscation mitigates PIF concerns relative to price transparency. We conjecture that PIF concerns will be weaker under obfuscation versus transparency (i.e., $0 < \lambda < 1$). There are two main reasons for this conjecture. First, when consumers are given less information about certain attributes, those attributes become less salient to them (Reutskaja et al. 2011, Orquin and Loose 2013). In other words, if consumers do not directly observe the prices offered to others, PIF concerns become less salient, and the corresponding utility weight gets diminished compared with when consumers directly observe peer prices. Second, when prices are obfuscated, buyers need to form expectations about peer prices. In this case, a buyer's own price becomes the only anchor, and the buyer will not adjust far enough from it when forming his expectations.[5]

The following stages formally summarize the game:

Stage 0. Nature draws w_a and w_b. The seller observes both and calculates $w_h \equiv \max\{w_a, w_b\}$ and $w_l \equiv \min\{w_a, w_b\}$. Buyer i observes w_i but not w_j, for all $i, j \in \{a, b\}$, $i \ne j$.

Stage 1. Seller chooses either price obfuscation or transparency (i.e., $I_{obf} \in \{0, 1\}$) and sets respective prices, p_i and p_j.

Stage 2. If the seller chose transparency ($I_{obf} = 0$), both buyers observe both prices. If the seller chose obfuscation ($I_{obf} = 1$), buyer i observes only p_i and not p_j, and updates his beliefs to calculate the posterior distribution $\mu_i^*(W_j)$. This, in turn, allows him to calculate $\Pr(P_j \le p_i \mid I_{obf} = 1)$ and $\mathbb{E}[P_j \mid P_j \le p_i, I_{obf} = 1]$ for all $i, j \in \{a, b\}$, $i \ne j$. If $U_i^{end} \ge 0$, buyer i accepts the transaction and purchases; otherwise, he does not.

In this game, the seller is informed of both buyers' WTP, but buyers are uninformed about each other's WTP. Because the seller endogenously chooses whether to obfuscate, the uniformed buyers can use this information to update their beliefs about each other's WTP. We look for a perfect Bayesian equilibrium (PBE) for this game (see Fudenberg and Tirole 1991). A PBE requires that players' strategies are optimal given beliefs, and that beliefs of uninformed players are consistent with Bayesian updating. For this game, the two requirements can be summarized as follows:

1. *Optimality*: Given buyers' beliefs, the seller's equilibrium strategies must be optimal (sequentially rational).

2. *Bayesian consistency*: Buyers' beliefs are determined by Bayes' rule and the seller's equilibrium strategies.

The quintuplet $(I_{obf}^*, p_a^{end*}, p_b^{end*}, \mu_a^*(w_b), \mu_b^*(w_b))$ characterizes the PBE in this game. The first term specifies the seller's equilibrium obfuscation/transparency decision, the second and the third terms specify equilibrium prices, and the forth and fifth specify buyers' equilibrium posterior beliefs after observing $I_{obf} = 1$. We will present the unique PBE for this game by (i) specifying the seller's optimal obfuscation strategy regardless of buyers' beliefs, (ii) deriving the buyers' beliefs that satisfy the Bayesian consistency requirement, (iii) showing that the optimal obfuscation strategy from step (i) constitutes a unique PBE given buyers' Bayesian consistent beliefs, and (vi) listing the sufficient off-equilibrium beliefs that guarantee that the seller does not have an incentive to deviate off the equilibrium path.

First, suppose the seller chooses transparency and buyers observe both prices. Then, the utility in Equation (8) converges to the one in (1), in which case, the game converges to the exogenous transparency game with equilibrium prices, $p_h^{trp*}(w_h, w_l)$ and $p_l^{trp*}(w_l) = p^{\max}(w_l)$, as specified by Equation (4). From observing each other's price, buyers will be able to perfectly infer each other's WTP. Next, suppose the seller chooses obfuscation. Buyer i will update his beliefs about buyer j's WTP (and, in turn, the price offered). For any arbitrary set of posterior beliefs, the seller's optimal pricing strategy, $p^{eobf}(w_i)$,[6] will be an increasing function that satisfies $U_i^{end}(w_i, p^{eobf}(w_i)) = 0$ (see Lemma A.4 in Appendix A), such that

$$p^{eobf}(w_i) = p^{\max}(w_i) - \underbrace{\frac{\lambda\rho_d \Pr(W_j \le w_i \mid I_{obf} = 1)(p^{\max}(w_i) - \mathbb{E}[p^{eobf}(W_j) \mid W_j \le w_i, I_{obf} = 1])}{\alpha + \delta + \lambda\rho_d \Pr(W_j \le w_i \mid I_{obf} = 1)}}_{t^{eobf}(w_i) = \text{discount below } p^{\max}(w_i)}. \tag{9}$$

Unlike in the exogenous obfuscation case, when buyers observe endogenous obfuscation, they will update their beliefs regarding the other buyers' WTP and price. This is reflected in the difference between the optimal prices under endogenous versus exogenous obfuscation (Equation (6) versus Equation (9)).

Lemma 3. *The condition* $\lambda \le \frac{\alpha+\delta}{\alpha+\delta+\rho_d}$ *is sufficient (but not necessary) to ensure that, regardless of buyers' posterior beliefs, the seller will always find it optimal to choose obfuscation (transparency) if the low buyer's WTP is sufficiently far from (close to) the high buyer's WTP. Formally, the equilibrium obfuscation decision must satisfy*

$$I^*_{obf}(w_l, w_h) = \begin{cases} 1 & \text{if } \underline{w} \le w_l < A(w_h), \\ 0 & \text{if } A(w_h) \le w_l \le w_h, \end{cases} \tag{10}$$

where $A : [\underline{w}, \overline{w}] \to [\underline{w}, A(\overline{w})]$ *is a continuous, strictly increasing function, with* $A(\underline{w}) = \underline{w}$ *and* $A(w) < w$*, for all* $w \in (\underline{w}, \overline{w}]$*. Its inverse is denoted by* A^{-1}*.*

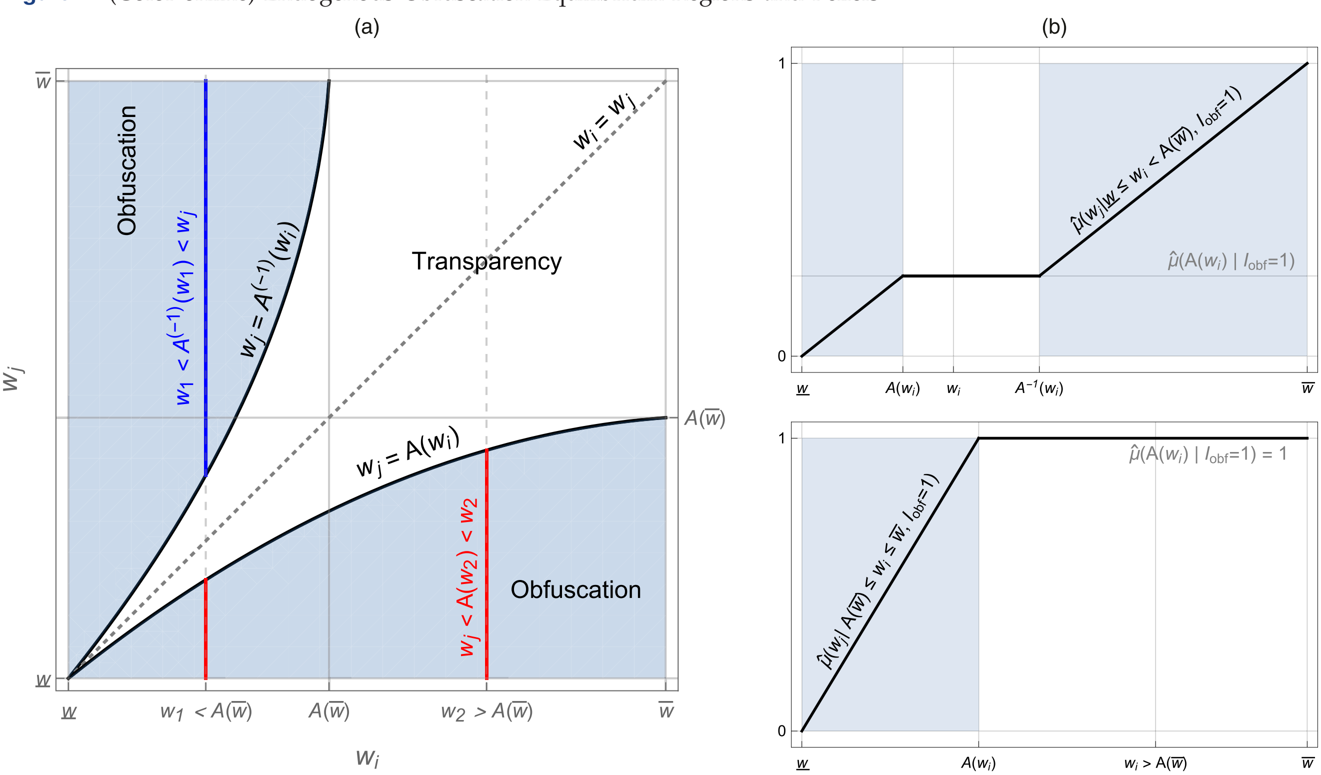
The intuition is similar to that presented in Section 3.3. Whenever the difference between the WTPs of both buyers is small (large), the seller will find it optimal to choose transparency (obfuscation). The condition on λ in Lemma 3 is sufficient but not necessary to ensure that the equilibrium characterized is unique. It is important to note that the equilibrium holds regardless of this condition; however, the condition allows us to analytically prove its uniqueness as well.[7] The function A defines the regions in which obfuscation is more profitable than transparency (shaded areas in Figure 2(a)) and those in which transparency is more profitable (white area in Figure 2(a)).

Next, suppose the seller chooses to obfuscate prices and buyer i does not observe p_j. Buyer i's prior on W_j is given by the uniform distribution, $F(w_j) = \frac{w_j - \underline{w}}{\overline{w} - \underline{w}}$. Because buyer i understands that the seller's obfuscation decision follows (10), he updates his beliefs about w_j using Bayes' rule as follows:

Lemma 4. *If the seller chooses obfuscation, then buyer i's equilibrium posterior beliefs about buyer j's WTP are given by the posterior CDF in Equation (11) such that*

i. *if* $w_i < A(\overline{w})$*, then* $W_j < A(w_i) < w_i$ *with probability* $\mu^*(w_i) = \frac{A(w_i) - \underline{w}}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} < 1$ *and is drawn from a uniform distribution on* $[\underline{w}, A(w_i)]$*, and* $W_j > A^{-1}(w_i) > w_i$ *with*

Figure 2. (Color online) Endogenous Obfuscation Equilibrium Regions and Beliefs



Regions Posterior CDF

probability $1 - \mu^*(w_i)$ *and is drawn from a uniform distribution on* $[A^{-1}(w_i), \overline{w}]$;

ii. *if* $w_i \geq A(\overline{w})$, *then* $W_j < A(w_i) < w_i$ *with probability* $\mu^*(w_i) = 1$ *and is drawn from a uniform distribution on* $[\underline{w}, A(w_i)]$. *The posterior CDF,* $\mu^*(w_j) \equiv \Pr(W_j < w_j \mid I_{obf} = 1)$, *is given by*

$$\mu^*(w_j) = \begin{cases} \dfrac{w_j - \underline{w}}{A(w_i) - \underline{w} + \max\{\overline{w} - A^{-1}(w_i), 0\}} & \text{if } \underline{w} \leq w_j \leq A(w_i), \\ \dfrac{A(w_i) - \underline{w}}{A(w_i) - \underline{w} + \max\{\overline{w} - A^{-1}(w_i), 0\}}, & \text{if } A(w_i) < w_j \leq \min\{A^{-1}(w_i), \overline{w}\}, \\ \dfrac{A(w_i) - \underline{w}}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} + \dfrac{w_j - A^{-1}(w_i)}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} & \text{if } A^{-1}(w_i) < w_j \leq \overline{w}. \end{cases} \tag{11}$$

Figure 2 depicts the obfuscation/transparency regions as well as buyer i's posterior beliefs (CDF) about w_j. Suppose buyer i has a relatively low WTP, as represented by the vertical line at $w_i = w_1 < A(\overline{w})$ in Figure 2(a). When he observes obfuscation, he infers that the other buyer's WTP cannot be close to his own, that is, he is certain that $w_j \notin [A(w_i), A^{-1}(w_i)]$, otherwise, the seller would have chosen transparency. Hence, w_j must be sufficiently far from his own WTP, which can occur in either of the following two ways: (i) with some probability below 1, the other buyer's WTP is below his, such that $w_j < A(w_i) < w_i$ (see the bottom segment of the $w_i = w_1$ line), and (ii) with the complimentary probability, the other buyer's WTP is above his, such that $w_j > A^{-1}(w_i) > w_i$ (see the top segment of the $w_i = w_1$ line). The posterior CDF in this case is illustrated by the top panel of Figure 2(b). In contrast, suppose buyer i has a relatively high WTP, as represented by the vertical line at $w_i = w_2 > A(\overline{w})$ in Figure 2(a). He will know that even if the other buyer draws the highest possible WTP, $\overline{w}$, it will still be close enough for the seller to choose transparency. Therefore, when such a buyer observes obfuscation, he will know that the other buyer's WTP is certainly below his such that $w_j < A(w_i) < w_i$ (see the bottom segment of the $w_i = w_2$ line). The posterior CDF is illustrated by the bottom panel of Figure 2(b). In both cases, if the other buyer's WTP is below ($w_j < w_i$), then it will be distributed uniformly on $[\underline{w}, A(w_i)]$.

Proposition 2. *If obfuscation does not mitigate buyers' PIF concerns* ($\lambda \longrightarrow 1$), *then obfuscation is not sustainable in a perfect Bayesian equilibrium, and the seller will always choose transparency in equilibrium. If obfuscation mitigates PIF concerns* ($0 < \lambda < 1$), *the PBE is characterized by the following:*

i. *The seller will choose obfuscation (transparency) if* w_l *is sufficiently far from (close to)* w_h, *as formally given by Equation (10).*

ii. *If buyer i observes obfuscation, he updates his beliefs according to Lemma 4.*

iii. *If the seller chooses transparency, equilibrium prices are the same as those in the exogenous transparency game in Equation (4).*

iv. *If the seller chooses obfuscation, the equilibrium prices are given by* $p^{end*}(w_i) = p^{\max}(w_i) - t^{end*}(w_i)$, *where*

$$t^{end*}(w_i) = \frac{\lambda\, \rho_d\, \mu^*(w_i)\left(p^{\max}(w_i) - \int_{\underline{w}}^{A(w_i)} p^{end*}(w_j)\, d\mu^*(w_j)\right)}{\alpha + \delta + \lambda\, \rho_d\, \mu^*(w_i)}.$$

v. *The function* $A(w_h)$ *is the unique solution to* $t_h^{trp*}(w_h, A(w_h)) = t^{end*}(w_h) + t^{end*}(A(w_h))$.

vi. *The condition* $\lambda \leq \frac{\alpha+\delta}{\alpha+\delta+\rho_d}$ *is sufficient (but not necessary) to guarantee the uniqueness of this equilibrium.*

If PIF concerns are as strong under obfuscation as they are under transparency, then obfuscation cannot be sustained in equilibrium. This means that although obfuscation can be more profitable to the seller when exogenously imposed,[8] it can no longer be sustained in equilibrium when buyers know that she is making this decision strategically. To see why, suppose buyer i draws a high WTP: $w_i = w_2 > A(\overline{w})$, and his posterior CDF for w_j is illustrated by the bottom panel of Figure 2(b). If buyer i observes obfuscation, he will know that buyer j is certainly getting a lower price and will form his expectations based on the belief that $w_j \sim U[\underline{w}, A(w_i)]$. Now, suppose buyer j draws $w_j = A(w_i)$; thus, the seller should be indifferent between obfuscation and transparency for the equilibrium to hold. However, under obfuscation, she needs to offer a discount to buyer j (lower WTP), whereas under transparency, she does not. Moreover, she has to offer a higher discount to buyer i under obfuscation (versus transparency) because w_j, in this case, is higher than the posterior expectations. In other words, whenever the buyer believes that obfuscation is optimal in some region, the seller will end up finding transparency to be optimal within some parts of that region, which violates the sequential rationality requirement of seller's strategy. Thus, there does not exist a region where obfuscation is sustained in equilibrium if PIF concerns are as strong under obfuscation as they are under transparency. In equilibrium, any buyer observing obfuscation will believe (rationally) that the other buyer has the lowest possible WTP, that is, will assume that her price disadvantage is as high as it can get.

In contrast, if obfuscation mitigates PIF concerns, then it can be sustained in equilibrium. There will exist a nonempty region for which buyers will hold the equilibrium belief that the seller will endogenously choose obfuscation (as per Equation (10) and Figure 2(a)). Given that belief, it is sequentially rational for the seller to indeed obfuscate in this region because the mitigation of PIF concerns makes it optimal to do so everywhere within the obfuscation region. Thus, in the PBE, the seller endogenously chooses obfuscation when the difference in WTP is sufficiently high (low), as the same dynamics of Proposition 1 apply. When the difference in WTP is high, transparency requires that the seller provide a very high discount to the high WTP buyer. In which case, obfuscation is more profitable because it reduces that discount. In contrast, when the difference in WTP is low, transparency is more profitable because it requires only a small discount to the high WTP buyer.

We now turn attention to off-equilibrium beliefs. Suppose that the WTP draws imply a transparency equilibrium strategy ($w_l > A(w_h)$), but the seller chooses obfuscation instead. It is sufficient to assume that the buyers will still believe that the seller is acting optimally and update their posterior believing that $w_l < A(w_h)$. This simply ensures that there is no signaling value for the seller from acting suboptimally.[9] Also, suppose a buyer receives a price that is different from the equilibrium price for his WTP; it is sufficient to assume that the buyer will still believe that the seller is offering the optimal equilibrium price to the other buyer. In sum, buyers believing that unobserved seller decisions are optimal is sufficient to rule out any off-equilibrium deviations by the seller.

Finally, we consider the case when obfuscation completely eliminates PIF concerns but inflates DF concerns through attention shifting (Reutskaja et al. 2011, Orquin and Loose 2013). The parameter $\psi > 1$ in the utility function below captures the degree to which obfuscation inflates DF concerns versus transparency:

$$U_i^{end}(w_i, p_i \mid I_{obf}) = \begin{cases} \alpha(w_i - p_i) - \delta p_i - \rho_d \max\{0, p_i - p_j\} & \text{if } I_{obf} = 0, \\ \alpha(w_i - p_i) - \psi\delta p_i & \text{if } I_{obf} = 1. \end{cases} \tag{12}$$

Proposition 3. *If obfuscation completely eliminates buyers' PIF concerns ($\lambda = 0$) and inflates DF concerns ($\psi > 1$), then the seller will choose obfuscation (transparency) in equilibrium if w_l is sufficiently far from (close to) w_h, as formally given by*

$$I_{obf}^{*} = \begin{cases} 1 & \text{if } \underline{w} \le w_l < \frac{(\alpha+\delta)(\rho_d - \delta(\psi-1))w_h}{\rho_d(\alpha+\delta\psi)+\delta(\psi-1)(\alpha+\rho_d+\delta)}, \\ 0 & \text{if } \frac{(\alpha+\delta)(\rho_d - \delta(\psi-1))w_h}{\rho_d(\alpha+\delta\psi)+\delta(\psi-1)(\alpha+\rho_d+\delta)} \le w_l \le w_h. \end{cases}$$

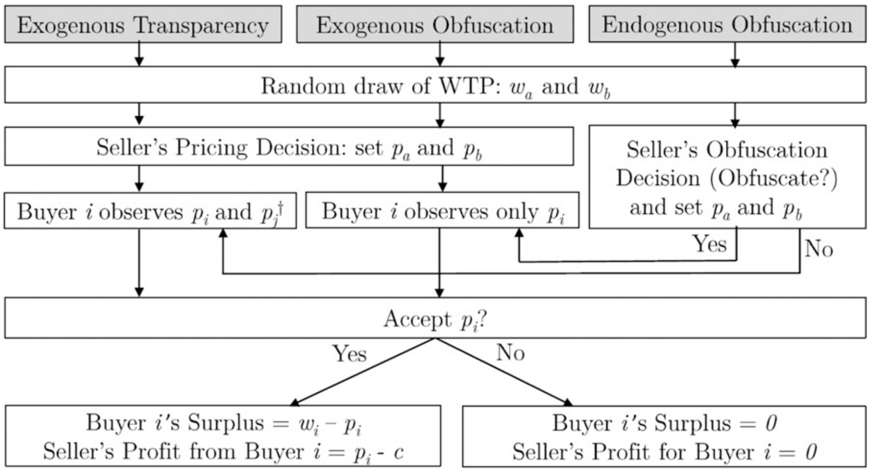
Proposition 3 suggests that if there is a trade-off between the PIF and DF concerns, the same result arises: if the difference in WTP is low (high), the seller will choose transparency (obfuscation). The intuition is the same as in Propositions 1 and 2. When the difference in WTP is high, transparency requires that the seller provide a very high discount to the high WTP buyer. In this case, obfuscation is more profitable because it reduces that discount. In contrast, when the difference in WTP is low, transparency is more profitable because it requires only a small discount to the high WTP buyer.

4. Experiment Design and Procedure

The three games described in the theoretical section were implemented in a two-sided, incentive-compatible laboratory experiment with three treatments. Each subject was randomly assigned to play the role of either a buyer or a seller throughout the entire experiment. In each round, a single seller was randomly and anonymously matched with two different buyers using networked computers.[10] The random matching allowed different buyer–seller combinations to occur every period. Furthermore, anonymity was imposed so participants were not aware who they were matched with in any period. This anonymous matching was used to eliminate collusion, reciprocity, reputation effects, and other dynamic strategic behavior (Amaldoss and Rapoport 2005, Lim and Ho 2007, Yuan et al. 2013, Ho et al. 2014). Each period, therefore, represented a one-shot game with the decisions made in a single period independent from all the others.

The experiment included two exogenous treatments where price transparency/obfuscation was endogenously imposed, and one endogenous treatment that let sellers endogenously decide whether to obfuscate prices. Figure 3 summarizes the three treatments. Under the exogenous transparency treatment, each buyer always observed his and his peer's prices. Under the exogenous obfuscation treatment, a buyer observed only his own price. Finally, in the endogenous obfuscation treatment, the seller had an opportunity to pay a fee, τ, to obfuscate prices after observing both buyers' WTP. If she chose to obfuscate

Figure 3. Summary of Experiment Process and Design



Note. For w_i, w_j, p_i and p_j, $i, j \in \{a, b\}$, $i \neq j$.

prices, then each buyer would see only his own price. If she chose not to obfuscate, then full price transparency set in. Depending on their experimental conditions, buyers were fully aware whether obfuscation/transparency was endogenously imposed or endogenously chosen by the seller. Together, the treatments were designed to elicit information on sellers' surplus allocation and to provide observations of buying behavior under different price obfuscation scenarios. This allowed us to disentangle buyer's DF and PIF concerns as well as observe whether buyers' reactions differed based on their treatment conditions.

We recruited 138 subjects (~ 46 for each treatment) from a large eastern university in the United States. The majority of the subjects were students in the undergraduate business school of that university. Each of the three treatments were conducted in two sessions with, on average, 23 periods per session for a total of 2,118 observed transactions. After the instructions were given, we conducted two practice rounds in order to give participants the opportunity to learn how the experiment worked. All participants were then asked privately (i.e., on their computer screens) whether they understood the nature of the decisions they were being asked to make and were encouraged to ask questions. Once the experiment began, subjects traded for as many periods as possible over a 60-minute time frame. In order to avoid end-game behaviors (Zwick and Chen 1999, Yuan et al. 2013), subjects were informed that the experiment would last for approximately 60 minutes, but did not know which period was the last until it was over. This approach is preferable to a known fixed number of periods because it allows for the maximum number of rounds possible within the 60-minute time frame and does not require that the last period be discarded.

In each treatment, as illustrated in Figure 3, in each period, a seller set two separate prices based on two different, random WTP draws from a uniform distribution on $[EC50, EC150]$, where EC denotes experimental dollars. Both sellers and buyers knew that seller's marginal cost was always c = EC50. If the offer was rejected, both the buyer and the seller earned nothing. If the offer was accepted, the buyer obtained the difference between his WTP and the price (consumer surplus), whereas the seller kept an amount equal to the price minus the marginal cost of EC50 (producer surplus). Once all buyers made their decisions, a surplus/profit screen showed the amount each subject earned in a given round and the accumulated earnings in the game up to a given round. In order to motivate the participants to make thoughtful, realistic decisions during the experiment, an incentive-compatible design was used. Prior to starting the experiment, we explained that subjects could earn an additional \$0–\$10 in compensation based on their total profit/surplus at the end of the experiment.[11]

5. Descriptive Statistics and Model-Free Evidence

Table 1 provides the descriptive statistics from the experiment across the three treatments. In this section, we discuss how these summary observations along with the model-free data patterns are consistent with our theoretical model predictions.

We summarize these results with the following list:

1. Recall from Section 3.3 that under transparency, the low WTP buyer does not get a discount, regardless of his WTP, because he knows for sure that he is receiving a lower price. Under obfuscation, however,

Table 1. Summary Statistics of the Treatments

	Exogenous transparency		Exogenous obfuscation		Endogenous obfuscation			
					Yes		No	
w_h (high WTP)	116.55	(22.99)	115.9	(23.01)	122.96	(15.61)	108.34	(26.08)
w_l (low WTP)	85.25	(23.38)	83.50	(22.91)	79.99	(23.14)	86.68	(26.17)
p_h (high price)	89.53	(18.06)	92.29	(17.08)	101.61	(14.48)	88.24	(20.08)
p_l (low price)	74.64	(18.00)	70.41	(16.04)	70.04	(18.83)	75.55	(19.43)
$w_h - w_l$	31.30	(23.23)	32.40	(21.45)	42.97	(21.80)	21.66	(18.78)
$p_h - p_l$	14.89	(16.34)	21.88	(15.41)	31.57	(16.20)	12.69	(14.86)
Pr[Accept]—high	0.803		0.818		0.803		0.8182	
Pr[Accept]—low	0.853		0.861		0.853		0.8611	
Pr[Obfuscation]	—		—		0.551			
Seller's profit								
$PS_h = w_h - c$	37.89	(17.51)	40.50	(16.76)	50.96	(14.48)	34.14	(18.63)
$PS_l = w_l - c$	26.16	(17.91)	19.58	(15.66)	20.88	(19.44)	26.41	(18.50)
Buyer's surplus								
$CS_h = w_h - p_h$	26.30	(14.64)	24.71	(10.49)	22.15	(8.58)	20.39	(12.38)
$CS_l = w_l - p_l$	15.19	(12.48)	13.81	(9.21)	10.71	(6.93)	15.78	(12.60)
τ (obf. cost)	—		—		10.18	(2.66)		
# of transactions	432		357		270			

Notes. This table reports means (standard deviations) of variables for the three experimental treatments. The buyer WTP is randomly drawn from a uniform distribution [EC50, EC150]. Seller profit and buyer surplus are from accepted offers only. obf., Obfuscation.

he gets a discount because there is a positive probability that he is receiving a higher price. Thus, our theoretical model predicts that the average price offered to the low WTP buyer under the exogenous obfuscation treatment will be lower than that under the exogenous transparency treatment. This prediction is supported by the experiment data: $p_l^{obf} = 70.41 < p_l^{trp} = 74.64$ ($p = 0.000$, $t. = 3.450$).

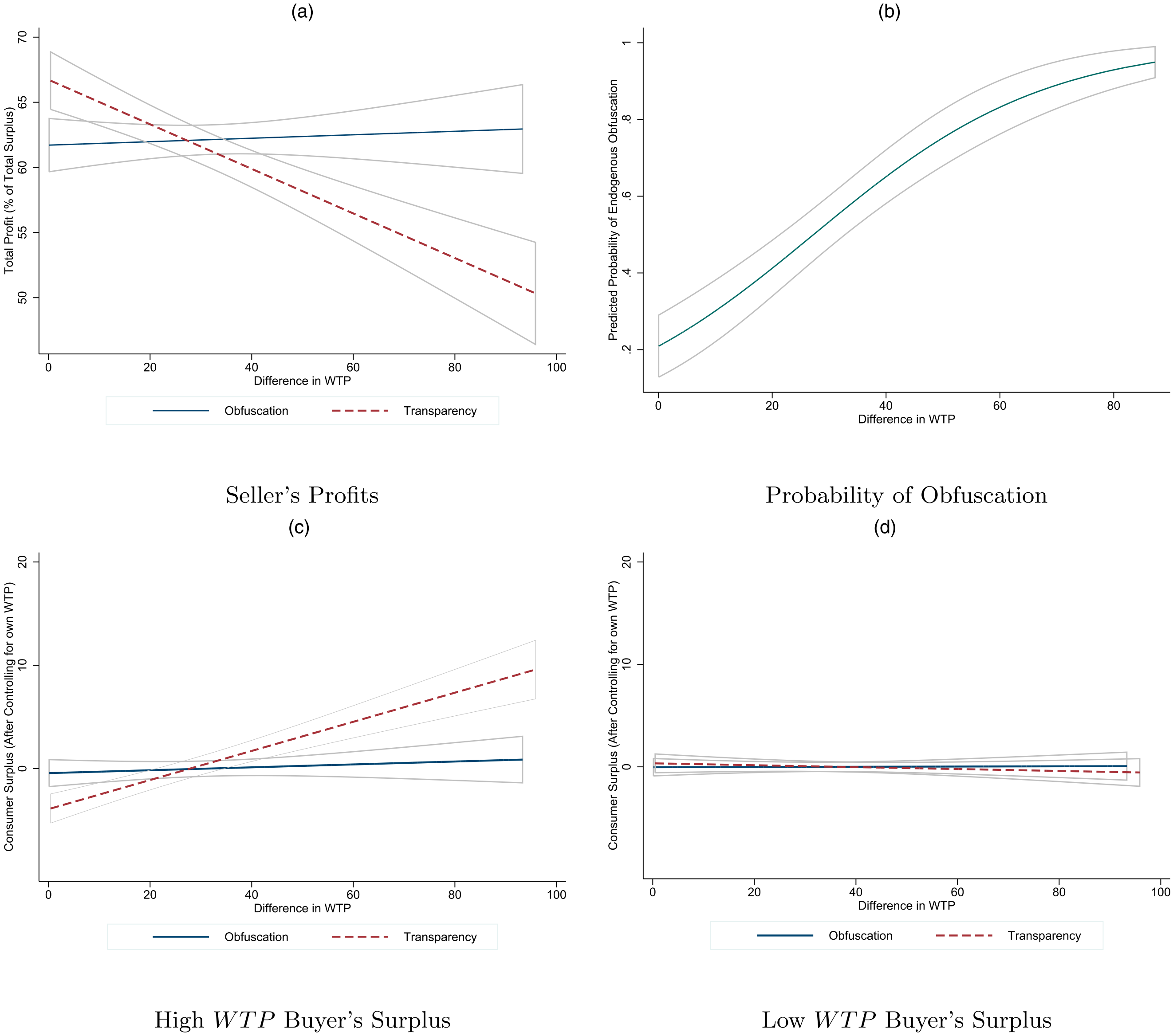
2. Next, recall that under transparency, the discount the high WTP buyer receives decreases in w_l because the high WTP buyer observes the low WTP buyer's price. Under obfuscation, however, the discount is based only on the high WTP buyer's conditional expectation of the other buyer's price. Thus, our theoretical model predicts that the average price offered to the high WTP buyer under the exogenous obfuscation treatment will be higher than that in the exogenous transparency treatment. This prediction is supported by the experiment data: $p_h^{obf} = 92.29 > p_h^{trp} = 89.53$ ($p = 0.029$, $t. = 2.188$).

3. Proposition 2 states that for a given w_h, the seller should endogenously choose obfuscation (transparency) if w_l is sufficiently low (high). Thus, in the endogenous obfuscation treatment, we should observe the same patterns described in the first two points above. This prediction is supported by the experiment data for the endogenous case: $p_h^{obf} = 101.61 > p_h^{trp} = 88.24$ ($p = 0.000$, $t. = 6.331$) and $p_l^{obf} = 70.04 < p_l^{trp} = 75.55$ ($p = 0.019$, $t. = 2.353$).

4. Proposition 1 predicts that seller's profit in the exogenous transparency game is decreasing in $w_h - w_l$ and that it is independent of $w_h - w_l$ in the exogenous obfuscation case. This prediction is illustrated graphically in Figure 4(a), where we plot the predicted profit (expressed as a percentage of the total possible surplus) as a function of $w_h - w_l$ in both treatments with the corresponding 95% confidence intervals marked in light grey. As predicted, profits are decreasing in $w_h - w_l$ in the exogenous transparency case (slope = −0.1711, $t. = -2.65$) and are independent of $w_h - w_l$ in the exogenous obfuscation case (slope = 0.0133, $t. = 0.65$).

5. Another way to operationalize the prediction above is to regress the seller's total profit on both buyers' WTP and compare the coefficients on w_l and w_h across the two treatments. The theory would predict that the coefficients would be different (similar) in the transparency (obfuscation) treatment. This prediction is also supported by the data. Columns (1) and (2) in Table 2 provide the regression results for the relationship between the seller's total profits and the WTP of both buyers for the exogenous transparency and exogenous obfuscation treatments, respectively. Column (1) shows that the estimated coefficient for w_l (0.9085) is much higher than the estimated coefficient for w_h (0.5211) in the exogenous transparency treatment, and these coefficients are statistically significantly different from each other ($p = 0.006$). Column (2),

Figure 4. (Color online) Experiment Outcomes as a Function of the Difference in WTP



(a) Seller's Profits

(b) Probability of Obfuscation

(c) High WTP Buyer's Surplus

(d) Low WTP Buyer's Surplus

on the other hand, shows that in the exogenous obfuscation case, the coefficients (0.6632 versus 0.6849) are very similar and not statistically significantly different from each other ($p = 0.685$).

6. Proposition 1 also suggests that profits under exogenous obfuscation will be higher (lower) than profits under exogenous transparency when the difference in WTP, $w_h - w_l$, is high (low). This prediction is borne out in the data and illustrated in Figure 4(a). We see that the predicted profit lines as a function of the $w_h - w_l$ in two treatments intersect. We confirm that the average profit under transparency is higher than the average profit under obfuscation in regions with low $w_h - w_l$, that is, to the left of the intersection point, $w_h - w_l = 27.14$ ($p = 0.002$, $t. = 2.869$), and the average profit under obfuscation is higher than that under transparency in regions with high $w_h - w_l$, that is, to the right of the intersection point ($p = 0.0001$, $t. = 3.918$).

7. Proposition 2 predicts that the seller would endogenously choose to obfuscate when the difference in WTP, $w_h - w_l$, is high, which our model-free evidence strongly supports. When comparing $w_h - w_l$ between the situations when sellers chose to obfuscate the prices ($w_h - w_l = 42.97$) and when they chose to keep prices transparent ($w_h - w_l = 21.66$), it is clear that sellers chose to obfuscate when differences in WTP were higher ($p = 0.000$, $t. = 8.473$). Furthermore, as the marginal effect of the logistic regression reported in column (3) of Table 2 shows, as $w_h - w_l$ increases, the probability of choosing to endogenously obfuscate increases ($p = 0.000$, $t. = 4.01$). Specifically, in our experiment, holding everything constant,

Table 2. Model-Free Evidence for the Theoretical Model: Seller Outcomes

	(1)	(2)	(3)
	Seller's total profit		
	Exogenous obfuscation	Exogenous obfuscation	Probability of endogenous obfuscation
w_h	0.5211***	0.6632***	
	(8.42)	(19.20)	
w_l	0.9085***	0.6849***	
	(13.00)	(18.82)	
$w_h - w_l$			0.012***
			(4.01)
N	432	357	270
R^2	0.823	0.873	0.169

Note. The *t*-statistics, based on standard errors clustered at the seller level, are reported below the parameter estimates in parentheses.
***indicates a significance level of 1%.

as the difference in WTPs increases by $1, the probability of obfuscation increases by 1.2%. This predicted relationship based on our experiment data is illustrated graphically in Figure 4(b).

8. Lemma 1 predicts that under exogenous transparency, the surplus offered to the high buyer increases in the difference in WTPs, $w_h - w_l$, and the surplus offered to the low WTP buyer is independent of this difference. The model-free evidence reported in Table 3 supports this lemma. Specifically, we find that as $w_h - w_l$ increases, the additional surplus offered to the low buyer is independent of this difference (column (1) in Table 3), whereas the surplus offered to the high buyer increases in $w_h - w_l$, and this relationship is highly statistically significant ($p = 0.001$, $t. = 3.12$; see column (3) in Table 3). Figure 4(c) illustrates this predicted relationship graphically with 95% confidence intervals based on the estimates in Table 3 for both high and low price buyers.

9. Finally, Lemma 2 predicts that under exogenous obfuscation, the surpluses of the low and high WTP buyers will not depend on the difference in their WTP, $w_h - w_l$, but will be a function only of their own WTP. That is indeed the case confirmed in columns (2) and (4) in Table 3 as well as in Figure 4(d).[12]

Overall, the descriptive results above provide strong support for the theoretical model because all of the predictions are supported by the experimental data. Next, we present an empirical model that incorporates both demand- and supply-side decisions from the experiment data to estimate the key theoretical parameters.

6. Empirical Model and Results

Recall that Proposition 2 predicts that both pricing choices, transparency and obfuscation, can systematically arise in the equilibrium of the endogenous game if obfuscation mitigates PIF concerns (i.e., lowers ρ_d). Furthermore, Proposition 3 showed that the same result can arise if obfuscation shifts attention to DF concerns (i.e., raises δ). We now specify a structural model that utilizes both demand- and supply-side observed decisions and allows for separate parameter estimates under obfuscation and transparency.

Table 3. Model-Free Evidence for Theoretical Model: Buyer Outcomes

	(1)	(2)	(3)	(4)
	Low WTP buyer's surplus		High WTP buyer's surplus	
	Exogenous transparency	Exogenous obfuscation	Exogenous transparency	Exogenous obfuscation
$w_h - w_l$	–0.0121	0.0014	0.1757***	0.0181
	(–1.02)	(0.22)	(3.12)	(0.78)
w_i	0.2658***	0.3371***	0.3312***	0.3170***
	(9.61)	(16.31)	(12.02)	(10.64)
N	327	343	537	371
R^2	0.634	0.756	0.488	0.524

Note. The *t*-statistics, based on standard errors clustered at the seller level, are reported below the parameter estimates in parentheses.
***indicates a significance level of 1%.

6.1. Demand

Let $s \in \{trp, obf\}$ be an index variable to denote whether prices are transparent or obfuscated. In line with the theoretical model, the utility of buyer i when offered a price p_i is given by

$$U_i^s = \begin{cases} \alpha_i^s CS_i + \delta_i^s PS_i + \rho_d^s DI_i^s + \rho_a^s AI_j^s + \beta_{0,T} + \varepsilon_i & \text{if accept,} \\ 0 & \text{if reject,} \end{cases}$$

where $CS_i = w_i - p_i,\ PS_i = p_i - c - \tau I_{obf}$,

$$DI_i^s = \begin{cases} \max\{0, p_i - p_j\} & \text{if } I_{obf} = 0, \\ \Pr(p_j < p_i)(p_i - \mathbb{E}[p_j \mid p_j < p_i, I_{obf} = 0]) & \text{if } I_{obf} = 1, \end{cases}$$

and

$$AI_i^s = \begin{cases} \max\{0, p_j - p_i\} & \text{if } I_{obf} = 0, \\ \Pr(p_i < p_j)(\mathbb{E}[p_j \mid p_i < p_j, I_{obf} = 0] - p_i) & \text{if } I_{obf} = 1. \end{cases} \tag{13}$$

In the equations above, CS_i denotes buyer i's objective surplus, and PS_i denotes the seller's (or producer's) surplus. The binary variable I_{obf} takes the value 1 if obfuscation was *endogenously* chosen by the seller and 0 otherwise to capture the expected additional obfuscation costs in the endogenous treatment. The term DI_i^s (AI_i^s) indicates the degree of disadvantageous (advantageous) inequity. The terms DI_i^s and AI_i^s will differ depending on whether the pricing environment is transparent ($s = trp$) or obfuscated ($s = obf$). In the case of price transparency, DI_i^{trp} (AI_i^{trp}) is the difference between the prices offered by the seller to the two buyers if buyer i's price is higher (lower) than buyer j's price. In the case of price obfuscation, buyers do not observe each other's price, but can form an expectation of the other buyer's price; thus, DI_i^{obf} and AI_i^{obf} measure the difference between a buyer's own price and the conditional expected price of the other buyer.[13] We also include treatment fixed effects, $\beta_{0,T}$, to control for the pricing environment. Finally, ε_i is an i.i.d. error term that reflects unobserved differences in expectations and preferences among buyers, and it is assumed to have a standard logistic distribution with a scale parameter equal to 1. With this distributional assumption, the probability of buyer i accepting the seller's offer, $\Pr(U_i^s > 0)$, takes on the familiar logit probability expression.

The parameters we estimate capture subjects' utility from their own objective surplus (α^s) within the experiment and their response to concerns regarding distributional fairness (δ^s) and peer-induced fairness (ρ_d^s and ρ_a^s). By estimating separate parameters for the high and low WTP buyers, we test Fehr and Schmidt's (1999) hypothesis that concern for peer-induced fairness differs. Consistent with our theoretical model, we allow these parameters to vary by the pricing environment ($s \in \{trp, obf\}$). Notably, the model-free analysis showed that, consistent with Propositions 2 and 3, sellers are significantly more likely to endogenously choose obfuscation over transparency as the difference in WTP increases. However, the theoretical results also show that such an equilibrium can arise only if obfuscation mitigates PIF concerns. The empirical model can provide further support to our theoretical insights if the estimates show that $\rho_d^{trp} > \rho_d^{obf}$ and $\delta^{trp} < \delta^{obf}$.[14]

Finally, note that the utility function (Equation (13)) used for empirical estimation has a positive sign in front of all the parameters. Thus, negative values for ρ_d^s and δ^s are consistent with the theoretical analysis.

6.2. Supply

Next, we describe the seller's optimal pricing and obfuscation decisions based on the buyer's demand model given in Equation (13). Sellers choose prices conditional on the two buyers' observed WTPs and, in the endogenous obfuscation treatment, whether to obfuscate. Within our empirical framework, the analyst observes the prices offered to both buyers, their WTPs, and both the acceptance and (if applicable) obfuscation decisions. The seller chooses the price to charge each buyer such that profit is maximized, or

$$\pi^{trp*} = \max_{p_i, p_j}\Big[\Pr\Big(U_i^{trp} > 0\Big)(p_i - c) + \Pr\Big(U_j^{trp} > 0\Big)(p_j - c)\Big], \tag{14a}$$

$$\pi^{obf*} = \max_{p_i}\Big[\Pr\Big(U_i^{obf} > 0\Big)(p_i - c)\Big] + \max_{p_j}\Big[\Pr\Big(U_j^{obf} > 0\Big)(p_j - c)\Big] - \tau I_{obf}, \tag{14b}$$

where c is the marginal cost to the seller, which is set to EC50 in the experiment and is public knowledge to all participants, and τ is the observed cost of obfuscation, which varies from EC5 to EC15 with an equal probability (and this range is also known by the buyers) under endogenous choice of price obfuscation, that is, $I_{obf} = 1$ (see the Online Appendix B for more details about the experiment).

For estimation purposes, there are two options for computing the optimal prices, p_i^{s*} and p_j^{s*}, that solve the optimization problem in Equations (14): numerically solve the first-order conditions (FOCs) or employ a grid search for the prices that yield maximum profits. We utilized the second approach because it was computationally faster.[15] Thus, for transactions within the exogenous transparency (obfuscation) treatments, we compute the pair of optimal prices p_i^{trp*} and p_j^{trp*} (p_i^{obf*} and p_j^{obf*}) that result in maximized profits of π^{trp*} (π^{obf*}) as per Equation (14a) (Equation (14b)).

In the endogenous obfuscation treatment, the seller strategically chooses transparency over obfuscation if it yields higher profits, and vice versa. Thus, we compute both pairs of optimal prices, (p_i^{trp*}, p_j^{trp*}) and (p_i^{obf*}, p_j^{obf*}), and the corresponding maximized profits, π^{trp*} and π^{obf*}. We model the probability that the seller endogenously chooses price obfuscation as

$$\Pr\left(I_{obf} = 1\right) = \Pr\left(\pi^{obf*} > \pi^{trp*} + \xi\right). \tag{15}$$

The difference between the expected profits, ξ, is assumed to be logistically distributed so the probability of obfuscation takes on a familiar logit form.[16]

Equations (13), (14), and (15) highlight the logic behind the structural model. On the demand side, we observe buyers' acceptance/rejection decisions. Equation (13) captures their utility from acceptance based on their beliefs and expectations about the prices offered to their peers. On the supply side, we observe sellers' prices in all treatments and their obfuscation decisions in the endogenous obfuscation treatment. The former is captured by Equations (14), and the latter is captured by Equation (15). Naturally, buyers' utility in Equation (13) enters into Equations (14) and (15).

6.3. Empirical Model Estimation and Results

We begin by investigating two simpler empirical specifications that focus solely on demand, and conclude with a discussion involving the complete model that includes demand, prices, and the probability of obfuscation. In column (1) of Table 4, we present the results from estimating the logit demand probability alone, whereby the likelihood of accepting the price is a function of consumer surplus, distributional fairness, and both advantageous (low WTP) and disadvantageous (high WTP) peer-induced fairness concerns as defined in Equation (13).

The main problem with the specification in column (1) is that price shows up in all the right-hand-side terms (CS_i, PS_i, DI_i^s, and AI_i^s) of the utility in Equation (13), which causes multicollinearity. Thus, in column (2), we present the results of the specification that uses proportional differences to measure inequity instead of the absolute differences as reported in column (1) and described in Equation (13).[17] Here, we construct PS_i to reflect the surplus that the seller keeps for herself (if the offer is accepted) as a proportion of the total surplus, and DI_i^s and AI_i^s to capture peer-induced inequity as a proportion of the buyer surplus offered, that is, $DI_i^s = (p_i - p_j)/(w_i - p_i)$ and $AI_i^s = (p_j - p_i)/(w_i - p_i)$.[18] This utility scaling preserves all of the intuition and predictions from the theoretical model and allows us to evaluate whether the specification with absolute or proportional differences explains the experiment data better. Based on the log-likelihood of the proportional inequity specification compared with the absolute inequity specification shown in Table 4, −819.758 versus −847.740, respectively, the proportional inequity specification fits the data better and is thus our preferred inequity construct that we subsequently use in the equilibrium model.

Finally, column (3) in Table 4 presents the results from the full equilibrium model, which accounts for both buyer and seller decisions described in

Table 4. Empirical Model Results

	(1) Demand only (absolute inequity)		(2) Demand only (proportional inequity)		(3) Equilibrium buyer and seller model	
	Estimate	t-stat.	Estimate	t-stat.	Estimate	t-stat.
α^{trp}	0.098***	8.70	0.011***	1.21	0.257***	3.06
α^{obf}	0.118***	8.40	0.029***	2.87	0.213***	2.92
δ^{trp}	−0.036***	−7.12	−6.939***	−11.30	−5.331***	−10.96
δ^{obf}	−0.055***	−3.56	−7.042***	−10.94	−5.531***	−12.04
ρ_d^{trp}	−0.008	−1.27	−0.117*	−1.69	−3.354***	−4.15
ρ_d^{obf}	0.039	1.52	−0.014	−0.56	−0.004	−0.03
ρ_a^{trp}	0.005	0.77	0.0004	0.61	0.000	0.07
ρ_a^{obf}	0.031**	2.64	0.0001	0.39	0.001	0.14
$\beta_{0,trp}$	0.126***	5.67	0.611***	12.05	4.653***	11.75
$\beta_{0,obf}$	−0.647**	−2.36	−0.488*	−1.74	0.060	0.28
$\beta_{0,end}$	0.087	0.44	1.666	0.81	0.401**	2.42
Log-likelihood	−847.740		−819.758		−553.786	

Notes. The t-statistics, based on robust standard errors, are reported alongside the estimates. The β terms are treatment fixed effects. The column (3) specification is based on proportional inequity.
*, **, and ***indicate significance levels of 10%, 5%, and 1%, respectively.

Sections 6.1 and 6.2, that is, that buyers make their decisions to accept or reject the seller's offer with the knowledge that sellers have the ability and the option to obfuscate prices. Moreover, in the endogenous obfuscation case, sellers know that buyers will update their beliefs and expectations about peer price accordingly. Utilizing both buyers' and sellers' decisions also addresses any potential endogeneity issues that could arise when using buyer decisions alone.

We use maximum likelihood to estimate the models shown in Table 4. In particular, the estimation approach for the preferred specification in column (3) is to jointly (i) maximize the likelihood of observed buyers' acceptance/rejection decisions based on Equation (13), (ii) minimize the sum of squared differences between the observed prices and the predicted optimal price based on the grid search solution to Equations (14), and (iii) maximize the likelihood of sellers' transparency/obfuscation decisions in the endogenous treatment based on Equation (15). This way, sellers' pricing and obfuscation decisions are fully consistent with buyers' decisions to accept or reject the sellers' offers.

Next, we discuss the results from our preferred specification shown in column (3) of Table 4 that capture both buyer and seller decisions. Buyers' compensation for participating in the experiment was affected only by the objective surplus ($w_i - p_i$) that they accumulated throughout the experiment. Thus, not surprisingly, the total surplus the seller offered had a positive and highly statistically significant effect ($\alpha^{trp} > 0$ and $\alpha^{obf} > 0$) on the buyer's decision to accept the price. Moreover, the importance buyers placed on their accumulated surplus did not differ significantly across the transparent or obfuscated conditions.

Distributional fairness is likely to be important to buyers if they think the pricing mechanism is inherently unfair, regardless of the prices offered to others. The results in Table 4 suggest that in both pricing environments, distributional fairness has a statistically significant, negative effect on the likelihood of accepting an offer ($\delta^{trp} < 0$ and $\delta^{obf} < 0$). As mentioned above, buyers' actual monetary compensation at the end of the experiment depended only on the accumulated objective surplus, which would have been maximized only if all prices were accepted, regardless of whether they were perceived as fair or not. The significance of DF concerns highlights the fact that buyers have an inherent tendency to refuse offers that they perceive as unfair even if such refusal makes them economically worse off.

In terms of the peer-induced fairness concerns, the results in Table 4 imply that buyers respond differently depending on whether they are given the higher or lower price, relative to their peers ($|\rho_a^{trp}| \neq |\rho_d^{trp}|$). When buyers are able to see what others are offered, they are especially sensitive to their position relative to their peers, and are significantly less likely to accept if they are given a higher price. However, when buyers are offered a better deal compared with their peers, their utility is not affected by the advantageous position (i.e., ρ_a^{trp} is not statistically different from zero).

Notably, the structural model results support the insights of the theoretical model. Proposition 2 of our theory model suggests that the equilibrium where both obfuscation and transparency can coexist is possible only when $|\rho_d^{trp}| > |\rho_d^{obf}|$.[19] This is exactly what we find with the equilibrium model results reported in column (3) of Table 4: price obfuscation effectively eliminated the peer-induced fairness concerns ($|\rho_d^{trp}| > |\rho_d^{obf}|$). This is consistent with our theoretical conjecture (outlined in Proposition 2) of obfuscation mitigating the fairness concerns (i.e., $0 < \lambda < 1$).

Furthermore, the results also suggest that although obfuscation can be highly effective at reducing PIF concerns, at the same time, it can increase distributional fairness concerns ($|\delta_d^{trp}| < |\delta_d^{obf}|$). This is consistent with an attention shifting explanation (Reutskaja et al. 2011, Orquin and Loose 2013). In a transparent environment, the buyer directly observes seller's cost as well as the peer price. Because both are salient, he directly evaluates the distributional and the peer-induced inequity. On the other hand, in an obfuscation environment, peer price is not directly observed, which makes it less salient and shifts attention/weight to the more salient and directly observed distributional inequity. Thus, our results suggest an interesting trade-off between the distributional and peer-induced fairness that is also predicted in Proposition 3 of our theoretical model: although obfuscation is highly effective at overcoming disadvantaged buyers' peer-induced fairness concerns, which allows the seller to charge higher prices, this pricing power is constrained by increased distributional fairness concerns.

Finally, our fixed effect estimates (specifically, positive and statistically significant fixed effects for the exogenous transparency treatment) suggest that buyers have an inherent preference for transparency after all of the behavioral and nonbehavioral drivers of decision making are controlled for.

7. Concluding Remarks

Firms are increasingly collecting and analyzing individual customer data that facilitate their ability to determine not only each buyer's WTP for goods, but also the value buyers place on the attributes of the items and potential add-on products. However, a company's ability to charge different prices is constrained by perceptions that paying a higher price than someone else is inherently unfair. In this paper, we theoretically and empirically study how buyers respond to sellers strategically obfuscating price information while accounting for both peer-induced and distributional fairness concerns.

The theoretical analysis shows that price obfuscation can be a sustainable outcome in equilibrium, even if consumers know that this pricing practice is chosen strategically by the seller. We find that with price transparency, sellers are able to price discriminate the lower priced consumer more effectively and at the same time reduce the difference in prices offered to the buyers. In addition, consistent with our theoretical predictions, we find that obfuscation can be profitable in equilibrium when differences in consumer WTP are sufficiently high, and when obfuscation effectively reduces PIF concerns. However, as the differential between buyers' WTP narrows, and/or obfuscation becomes increasingly costly, it may be more profitable to maintain a transparent pricing regime.

We test our theoretical predictions with a two-sided experiment whereby a price-discriminating seller is randomly and anonymously matched with two utility-maximizing buyers. We find that price obfuscation is highly effective at mitigating consumer peer-induced fairness concerns. At the same time, our empirical results suggest that there is a trade-off between the peer-induced and distributional fairness concerns: once the prices are obfuscated, consumers shift their attention to evaluate the distributional inequity more scrupulously.

This paper derives rich insights from the theoretical model and verifies its predictions using experimental data. The main strength of this approach is its ability to rule out alternative mechanisms that might be at play and focus on the interaction between strategic price obfuscation and peer-induced fairness concerns. A laboratory environment as well as anonymous and random seller and buyer matching allows us to isolate consumer fairness concerns from other confounding effects such as reciprocity, betrayal, or altruism that are present in transactional data. This does not necessarily mean that our approach is better than another one that analyzes actual transaction data. We believe both are complimentary; our approach has higher explanatory power, and the latter approach will have higher external validity. It is important to note that although we cannot claim that our approach has the same level of external validity as using actual transaction data, our theoretical model and experimental setup capture the essential elements faced by firms who may practice price discrimination in the presence of PIF concerns. In particular, our model captures consumer uncertainty regarding the valuations/prices of others as well as how they update their beliefs upon observing sellers' pricing and obfuscation strategies.

Our findings have a number of implications for managerial practice in a range of settings. First, in online environments, where price discrimination is likely to be both more profitable and technologically feasible, price transparency will likely become a thing of the past as sellers realize the value in keeping "firewalls" around their one-on-one deals with individual customers. Second, the practice of obfuscating price discrimination is also likely to become more prominent in the public policy conversation as buyers begin to realize that they are paying more for relatively common items compared with a fully transparent market. Nonetheless, if privacy concerns in online commerce dominate, then consumers may become less likely to want to share information on how much they paid in any particular transaction. Third, greater complexity, both in product attributes and pricing structures, will become the rule for selling when prices are potentially transparent. Easily sold as providing value through "customization" to fit specific needs, complexity and obfuscation are two sides of the same coin.

Our findings are also potentially important for price-regulation policy. In terms of the welfare effects on consumers, our model suggests that buyers will still make a purchase if they have positive surplus, but the amount of surplus earned can be lower (higher) for high (low) WTP buyers compared with when no obfuscation is allowed. How is it possible that buyers knowingly allow themselves to be prevented from seeing other prices and yet still purchase? In reality, there are many instances where consumers know that retailers charge different prices to different consumers (e.g., widespread coupon usage, personalized offers, etc.). Consumers might know that firms are keeping their price-discrimination strategies hidden and might grumble about the prices they pay, but they still willingly make purchases. This is especially true when other buyers' prices are sufficiently obfuscated. That said, if the seller is discriminating effectively, then some consumers will pay a lower price than the one the seller will charge under a uniform pricing policy. Even though the seller makes more profit, total welfare may, in fact, rise as more consumers are served, and some may pay a lower price (Varian 1985). It is now well understood that the welfare effects of first- and third-degree price discrimination are fundamentally ambiguous, so it is not possible to say absolutely that total consumer surplus decreases by a practice that enables price discrimination (for the conditions required for monopoly price discrimination to raise social welfare, see Aguirre et al. 2010). In this case, our analysis presents an interesting conundrum where seemingly sensible regulation intended to prevent price discrimination (promote price transparency) can actually be welfare decreasing. This possibility has not gone unnoticed by regulators, as staff economists at the Federal Trade Commission have formally questioned whether price transparency in the healthcare industry is in fact a good idea (Koslov and Jex 2015, Shapiro 2018).

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Appendix A. Technical Lemmas

Lemma A.1. *Let $F(x)$ be a cumulative distribution function of a random variable, $X \in [\underline{x}, \overline{x}] \subseteq \mathbb{R}$, and let $g(\cdot)$ be a strictly increasing function such that $g(\underline{x}) < g(x) < g(\overline{x})$ for all $x \in (\underline{x}, \overline{x})$. Then,*

i. $g(\underline{x}) < \mathbb{E}[g(X)] < g(\overline{x})$;

ii. $g(x_1) < \mathbb{E}[g(X) \mid x_1 < X < x_2] < g(x_2)$ *for all* $x_1, x_2 : \underline{x} \leq x_1 < x_2 \leq \overline{x}$.

Proof. Rewrite the result in part i as $X_1 < 0 < X_2$, where $X_1 \equiv g(\underline{x}) - \mathbb{E}[g(x)]$ and $X_2 \equiv g(\overline{x}) - \mathbb{E}[g(x)]$. Because $\int_{\underline{x}}^{\overline{x}} dF(x) = 1$, $g(\underline{x}) = \int_{\underline{x}}^{\overline{x}} g(\underline{x}) dF(x) \Rightarrow X_1 = \int_{\underline{x}}^{\overline{x}} [g(\underline{x}) - g(x)] dF(x) < 0$ because the integrand is negative. Similarly, $X_2 = \int_{\underline{x}}^{\overline{x}} [g(\overline{x}) - g(x)]\, dF(x) > 0$ because the integrand is positive. This completes the proof for part i. For part ii, we have $\mathbb{E}[g(X) \mid x_1 < X < x_2] = \int_{x_1}^{x_2} g(x) \frac{dF(x)}{F(x_2) - F(x_1)}$. Because $\int_{x_1}^{x_2} \frac{dF(x)}{F(x_2) - F(x_1)} = 1$, the proof can proceed in the same steps as part i. □

Lemma A.2. *Let $H(x, y)$ be a continuous function, strictly increasing (decreasing) in x (y) on $[\underline{x}, \overline{x}] \times [\underline{y}, \overline{y}] \subseteq \mathbb{R}^2$. Furthermore, $H(x, \underline{y}) > 0$ and $H(x, \overline{y}) < 0$ for all x, such that a unique function, $\hat{y} : [\underline{x}, \overline{x}] \to [\underline{y}, \overline{y}]$, satisfies $H(x, \hat{y}(x)) = 0$ and $H(x, y) > 0 \Leftrightarrow y < \hat{y}(x)$ for all x. Then, $\hat{y}(\cdot)$ must be strictly increasing.*

Proof. Consider any two arbitrary values, $x_1, x_2 : \underline{x} \leq x_1 < x_2 \leq \overline{x}$. By definition, $H(x_1, \hat{y}(x_1)) = H(x_2, \hat{y}(x_2)) = 0$. Because H is increasing in x, we must have $H(x_2, \hat{y}(x_1)) > H(x_1, \hat{y}(x_1)) = 0$. Because H is decreasing in y, $H(x_2, \hat{y}(x_2)) = 0$, and $H(x_2, \hat{y}(x_1)) > 0$, $\hat{y}(x_2) > \hat{y}(x_1)$ for all $x_1, x_2 : \underline{x} \leq x_1 < x_2 \leq \overline{x}$. □

Lemma A.3. *Let $G, H : [\underline{x}, \overline{x}] \to \mathbb{R}$ be two continuous functions, where G is concave and H is linear and decreasing. If $G(\overline{x}) = H(\overline{x})$ and $G(\underline{x}) > H(\underline{x})$, then $G(x) > H(x), \forall x \in [\underline{x}, \overline{x})$.*

Proof. Let $\widehat{H}(x)$ represent the line connecting the two points $(\underline{x}, G(\underline{x}))$ and $((\overline{x}, G(\overline{x}))$. Because H is linear, $G(\overline{x}) = H(\overline{x})$, and $G(\underline{x}) > H(\underline{x})$, $\widehat{H}(x) > H(x), x \in [\underline{x}, \overline{x})$. Because G is concave, we must have $G(x) > \widehat{H}(x)$, for all $x \in [\underline{x}, \overline{x})$, which implies that $G(x) > \widehat{H}(x) > H(x)$, for all $x \in [\underline{x}, \overline{x})$. □

Lemma A.4. *Under any price obfuscation regime, the seller's optimal price is always increasing in WTP regardless of the buyers' information set and pricing expectations. Hence, buyers rationally expect prices to increase in WTP. The optimal price, $p^*(w_i)$, must also satisfy $U_i(w_i, p^*(w_i)) = 0$.*

Proof. From buyer i's perspective, buyer j's WTP, W_j, is a random variable. Let the CDF, $\hat{\mu}(w_j) = \Pr(W_j < w_j \mid \Omega_i)$, represent buyer i's beliefs about buyer j's WTP based on an arbitrary information set Ω_i.[20] Buyer i also has an expectation about the seller's pricing strategy as a function of WTP, $p^{\exp}(W_j)$. Thus, the obfuscated price that the seller offers buyer j is also a random variable from buyer i's perspective: $P_j \equiv p^{\exp}(W_j)$ with a CDF $\hat{G}(p_j) = \Pr(P_j < p_j \mid \Omega_i)$ on some interval $[\underline{p}, \overline{p}]$. Thus, $\Pr(P_j < p_i \mid \Omega_i) = \hat{G}(p_i)$, and $\mathbb{E}[P_j \mid P_j < p_i; \Omega_i] = \int_{\underline{p}}^{p_i} \frac{p_j}{\hat{G}(p_i)}\, d\hat{G}(p_j)$. Direct substitution into the utility function in (1) yields

$$U_i(w_i, p_i; \Omega_i) = \alpha(w_i - p_i) - \delta(p_i - c) - \rho_d\, \hat{G}(p_i) \times \left(p_i - \int_{\underline{p}}^{p_i} \frac{p_j}{\hat{G}(p_i)}\, d\hat{G}(p_j)\right).$$

Let $\Delta U \equiv U_i(w_i, p_2; \Omega_i) - U_i(w_i, p_1; \Omega_i)$ denote the difference in utility at two arbitrary prices, $p_1 < p_2$. Direct substitution yields

$$\Delta U = -\rho_d\left[p_2\hat{G}(p_2) - p_1\hat{G}(p_1) - \left(\int_{\underline{p}}^{p_2} p_j\, d\hat{G}(p_j) - \int_{\underline{p}}^{p_1} p_j\, d\hat{G}(p_j)\right)\right] - (p_2 - p_1)(\alpha + \delta).$$

Using the properties $\int_{\underline{p}}^{p_2} p_j\, d\hat{G}(p_j) - \int_{\underline{p}}^{p_1} p_j\, d\hat{G}(p_j) = \int_{p_1}^{p_2} p_j\, d\hat{G}(p_j)$ and $\mathbb{E}[P_j \mid p_1 < P_j < p_2] = \frac{\int_{p_1}^{p_2} p_j d\hat{G}(p_j)}{\hat{G}(p_2) - \hat{G}(p_1)}$, we can rewrite the equation above as follows (note that Lemma A.1 established that $p_2 > \mathbb{E}[P_j \mid p_1 < P_j < p_2]$)

$$\Delta U = -\rho_d\big[(G(p_2) - G(p_1))(p_2 - \mathbb{E}[P_j \mid p_1 < P_j < p_2]) + (p_2 - p_1)G(p_1)\big] - (p_2 - p_1)(\alpha + \delta) < 0.$$

Thus, the utility function is strictly decreasing in price. The seller's optimization problem is $\max_{p_a, p_b} p_a + p_b$, subject to $U_i(w_i, p_i; \Omega_i) \geq 0$, for all, $j \in \{a, b\}, i \neq j$. The maximand is increasing in price; thus, the constraint must be binding at the solution, and the optimal price, $p^*(w_i)$, must satisfy $U_i(w_i, p^*(w_i)) = 0$. From Lemma A.2, the optimal price must be increasing in the WTP. □

Appendix B. Proofs

Proof of Lemma 1. The seller objective function (constraints) in Equation (3) is (are) strictly increasing (decreasing) in prices; hence, both constraints must be binding at the solution, yielding the equilibrium prices in (4). The rest follows directly. □

Proof of Lemma 2. Use $\Pr(W_j \le w_i) = \frac{w_i - \underline{w}}{\overline{w} - \underline{w}}$ and $\mathbb{E}[p^{obf*}(W_j) \mid W_j \le w_i] = \int_{\underline{w}}^{w_i} \frac{p^{obf*}(w_j)}{w_i - \underline{w}}\, dw_j$ to rewrite (6) as

$$p^{obf*}(w_i) = \frac{(\overline{w} - \underline{w})(\alpha w_i) + \rho_d \int_{\underline{w}}^{w_i} p^{obf*}(w_j)\, dw_j}{(\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_i - \underline{w})}$$
$$\Rightarrow \left[(\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_i - \underline{w})\right] p^{obf*}(w_i)$$
$$= (\overline{w} - \underline{w})(c\delta + \alpha w_i) + \rho_d \int_{\underline{w}}^{w_i} p^{obf*}(w_j)\, dw_j.$$

Differentiate both sides of the equation above with respect to w_i to get

$$\rho_d\, p^{obf*}(w_i) + \left((\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_i - \underline{w})\right) \frac{dp^{obf*}(w_i)}{dw_i}$$
$$= \rho_d\, p^{obf*}(w_i) + \alpha(\overline{w} - \underline{w}) \Rightarrow \frac{dp^{obf*}(w_i)}{dw_i}$$
$$= \frac{\alpha(\overline{w} - \underline{w})}{(\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_i - \underline{w})} > 0.$$

Hence, p^{obf*} is increasing in w_i. Moreover, the solution to the differential equation above is $p^{obf*}(w_i) = \frac{\alpha(\overline{w} - \underline{w}) \log((\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_i - \underline{w}))}{\rho_d} + C_1$. From (6), we must have $p^{obf*}(\underline{w}) = p^{\max}(\underline{w})$, which can be used to solve for the integration constant, C_1, yielding the explicit expression for prices in Equation (7a). This completes the proof of parts i and ii. By definition, $t^{trp*}(w_i) = p^{obf*}(w_i) - p^{\max*}(w_i)$; thus, part iii follows directly from $\frac{dp^{\max}}{dw_i} - \frac{dp^{obf*}}{dw_i} = \frac{\alpha \rho_d (w_i - \underline{w})}{(\alpha+\delta)((\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_i - \underline{w}))} > 0.$ □

Proof of Proposition 1. Define $\Psi(w_h, w_l) \equiv \pi^{obf*}(w_h, w_l) - \pi^{trp*}(w_h, w_l) = t^{trp*}(w_h, w_l) - t^{obf*}(w_h) - t^{obf*}(w_l)$. Because $t^{obf*}(\underline{w}) = 0$, $\Psi(w_h, \underline{w}) > 0 \Leftrightarrow t^{trp*}(w_h, \underline{w}) > t^{obf*}(w_h)$. By direct substitution from (6) and (4), the inequality is written as

$$\frac{\rho_d\left(p^{\max}(w_h) - p^{\max}(\underline{w})\right)}{\alpha + \delta + \rho_d}$$
$$> \frac{\rho_d \Pr\left(W_j \le w_h\right)\left(p^{\max}(w_h) - \mathbb{E}\left[p^{obf*}(W_j) \mid W_j \le w_h\right]\right)}{\alpha + \delta + \rho_d \Pr\left(W_j \le w_i\right)}$$
$$\Leftrightarrow \Psi(w_h, \underline{w}) > 0.$$

Because the expression $\frac{\rho_d x}{\alpha + \delta + \rho_d x}$ is strictly increasing in x, for all $x > 0$, we must have $\frac{\rho_d}{\alpha + \delta + \rho_d} \ge \frac{\rho_d \Pr(W_j \le w_h)}{\alpha + \delta + \rho_d \Pr(W_j \le w_i)}$. Therefore, we can now work with the following stricter, but simpler, inequality: $p^{\max}(w_h) - p^{\max}(\underline{w}) > p^{\max}(w_h) - \mathbb{E}[p^{obf*}(W_j) \mid W_j \le w_h]$. Rearranging yields

$$\mathbb{E}\left[p^{obf*}(W_j) \mid W_j \le w_h\right] > p^{\max}(\underline{w}) \Rightarrow \Psi(w_h, \underline{w}) > 0. \quad \text{(B.1)}$$

Because $\mathbb{E}[p^{obf*}(W_j) \mid W_j \le w_h] = \int_{\underline{w}}^{w_i} \frac{p^{obf*}(w_j)}{w_i - \underline{w}} dw_j$, $p^{obf*}(\cdot)$ is strictly increasing, and $p^{obf*}(\underline{w}) = p^{\max}(\underline{w})$ (see Lemma 2), (B.1) must be true (see Lemma A.1).

Because $t^{trp*}(w_h, w_h) = 0$ (see Lemma 1),

$$2\, t^{trp*}(w_h) > 0 \Rightarrow \Psi(w_h, w_h) < 0. \quad \text{(B.2)}$$

From Lemma 2, the inequality in (B.2) must be true for all $w_h \in (\underline{w}, \overline{w}]$. Also, by definition, we have

$$\frac{\partial \Psi(w_h, w_l)}{\partial w_l} = \frac{-\alpha}{\alpha + \delta} \times \left(\frac{\rho_d (w_l - \underline{w})}{(\overline{w} - \underline{w})(\alpha + \delta) + (w_l - \underline{w})\rho_d} + \frac{\rho_d}{\alpha + \rho_d + \delta}\right) < 0. \quad \text{(B.3)}$$

Taken together, (B.1), (B.2), and (B.3) establish that for all $w_l, w_h : \underline{w} \le w_l \le w_h \le \overline{w}$, there must exist a unique function $B(w_h) \in [\underline{w}, w_h)$ such that $w_l < B(w_h) \Leftrightarrow \Psi(w_h, w_l) > 0$. From the implicit function theorem,

$$\frac{\partial B(w_h)}{\partial w_h} = -\left.\frac{\partial \Psi(w_h, w_l)/\partial w_h}{\partial \Psi(w_h, w_l)/\partial w_l}\right|_{w_l = B(w_h)}$$
$$= \frac{(\alpha + \delta)(\overline{w} - w_h)\left(\rho_d (A(w_h) - \underline{w}) + (\overline{w} - \underline{w})(\alpha + \delta)\right)}{\left((\overline{w} - \underline{w})(\alpha + \delta) + \rho_d (w_h - \underline{w})\right)\left((\alpha + \delta)(A(w_h) - \underline{w} + \overline{w} - \underline{w}) + 2\rho_d (A(w_h) - \underline{w})\right)} > 0,$$

which directly establishes that $B(\underline{w}) = \underline{w}$, $B'(\underline{w}) = 1$, $0 < B'(w_i) < 1$ for all $w_i \in (\underline{w}, \overline{w})$, $B'(\overline{w}) = 0$, and $\underline{w} < B(w_i) < w_i$ for all $w_i \in (\underline{w}, \overline{w}]$. □

Proof of Lemma 3. Let the arbitrary posterior CDF, $\hat{\mu}(w_j) = \Pr(W_j < w_j \mid I_{obf} = 1)$, denote buyer i's posterior beliefs on W_j conditional on observing obfuscation. The seller's optimal price in Equation (9) can be written as $p^{eobf}(w_i) = p^{\max}(w_i) - t^{eobf}(w_i)$, where

$$t^{eobf}(w_i) = \frac{\lambda\, \rho_d\, \hat{\mu}(w_i)}{\alpha + \delta + \lambda\, \rho_d\, \hat{\mu}(w_i)} \left(p^{\max}(w_i) - \frac{\int_{\underline{w}}^{w_i} p^{eobf}(w_j) d\hat{\mu}(w_j)}{\hat{\mu}(w_i)}\right).$$

Define $\Phi(w_h, w_l) \equiv \pi^{eobf}(w_h, w_l) - \pi^{trp*}(w_h, w_l) = t^{trp*}(w_h, w_l) - t^{eobf}(w_h) - t^{eobf}(w_l)$. The proof proceeds by showing that (i) $\Phi(w_h, \underline{w}) > 0$, (ii) $\Phi(w_h, w_h) < 0$, and (iii) $\Phi(w_h, w_l)$ is increasing in w_h. Substituting $w_l = \underline{w}$ and $p^{\max}(\underline{w}) = p^{eobf}(\underline{w})$ yields

$$\Phi(w_h, \underline{w}) = \frac{\rho_d X_1}{\alpha + \rho_d + \delta} + \frac{(\alpha + \delta)\left(1 - \lambda \hat{\mu}(w_h)\right) X_2}{\alpha + \lambda\, \rho_d\, \hat{\mu}(w_h) + \delta} > 0, \quad \text{(B.4)}$$

where $X_1 \equiv \left(\frac{\int_{\underline{w}}^{w_h} p^{eobf}(w_j) d\hat{\mu}(w_j)}{\hat{\mu}(w_h)} - p^{eobf}(\underline{w})\right)$ and $X_2 \equiv \left(p^{eobf}(\overline{w}) - \frac{\int_{\underline{w}}^{w_h} p^{eobf}(w_j) d\hat{\mu}(w_j)}{\hat{\mu}(w_h)}\right)$, such that $X_1, X_2 > 0$, as per Lemma A.1. Because $t^{trp*}(w_h, w_h) = 0$,

$$\Phi(w_h, w_h) = -2t^{eobf} < 0. \quad \text{(B.5)}$$

Define $\Delta_\Phi \equiv \Phi(w_2, w_l) - \Phi(w_1, w_l)$ for all $w_l, w_1, w_2 : \underline{w} \le w_l \le w_1 < w_2 \le \overline{w}$. Next, we show that Φ is increasing in w_h by showing that Δ_Φ is positive. Define the functions $g_1, g_2, G, H, Y : [\underline{w}, w_2] \to \mathbb{R}$, where

$$g_1(w_1) \equiv \frac{\alpha + \delta - \lambda\hat{\mu}(w_1)(\alpha + \rho_d + \delta)}{\alpha + \delta + \rho_d} > 0,$$
$$g_2(w_1) \equiv \frac{\alpha w_2}{\alpha + \delta} - \frac{\alpha w_1}{\alpha + \delta} > 0,$$
$$G(w_1) \equiv g_1(w_1)\, g_2(w_1) > 0,$$
$$H(w_1) \equiv \lambda\big(\hat{\mu}(w_2) - \hat{\mu}(w_1)\big)\left(p^{eobf}(w_2) - \frac{\int_{\underline{w}}^{w_2} p^{eobf}(w_j)d\hat{\mu}(w_j)}{\hat{\mu}(w_2)}\right) > 0,$$
$$Y(w_1) \equiv \lambda\hat{\mu}(w_1)\left(t^{eobf}(w_2) - t^{eobf}(w_1) + \frac{\int_{\underline{w}}^{w_2} p^{eobf}(w_j)d\hat{\mu}(w_j)}{\hat{\mu}(w_2)} - \frac{\int_{\underline{w}}^{w_1} p^{eobf}(w_j)d\hat{\mu}(w_j)}{\hat{\mu}(w_1)}\right) > 0.$$

Hence, $\Delta_\Phi = \frac{\rho_d}{\alpha+\delta}(G(w_1) - H(w_1) + Y(w_1))$. Because $Y(w_1) > 0$, showing that $= G(w_1) - H(w_1) > 0$ is sufficient to prove that $\Delta_\Phi > 0$. Because the prior on W_j is uniform, the posterior CDF, $\hat{\mu}$, must be linear and increasing. In turn, g_1 must also be linear and increasing. Furthermore, because $\hat{\mu}(\cdot) \le 1$, $\lambda \le \frac{\alpha+\delta}{\alpha+\delta+\rho_d}$ ensures that $g(w_1) > 0$. Thus, the function G must be positive and concave because it is the product of two positive linear functions, one of which is increasing (g_1) and the other of which is decreasing (g_2). The function $H(w_1)$ is linear and decreasing in w_1. Define $g_3(w_2) \equiv \frac{\int_{\underline{w}}^{w_2} p^{eobf}(w_j)d\hat{\mu}(w_j)}{\hat{\mu}(w_2)} - p^{eobf}(\underline{w}) > 0$ and

$$G(\underline{w}) - H(\underline{w}) = \lambda\hat{\mu}(w_2)\big(g_3(w_2) + t^{eobf}(w_2)\big) + \left(\frac{\alpha(w_2 - \underline{w})}{\alpha + \delta}\right)\left(\frac{\alpha + \delta}{\alpha + \delta + \rho d} - \lambda\hat{\mu}(w_2)\right) > 0.$$

Because G is concave, H is linear, $G(w_2) = H(w_2) = 0$, and $G(\underline{w}) > H(\underline{w})$, we have $G(w_1) > H(w_1)$, for all $w_1 \in [\underline{w}, w_2)$ (see Lemma A.3). To summarize, for all $w_1, w_2 : \underline{w} \le w_1 < w_2 \le \overline{w}$,

$$\lambda \le \frac{\alpha + \delta}{\alpha + \delta + \rho_d} \Rightarrow G(w_1) > H(w_1) \Rightarrow \Delta_\Phi \equiv \Phi(w_2, w_l) - \Phi(w_1, w_l) > 0. \tag{B.6}$$

Taken together, the inequalities in (B.4), (B.5), and (B.6) imply that for any arbitrary set of consumer beliefs, there must exist a unique increasing function, $A(\cdot)$, satisfying $\Phi(w_h, A(w_h)) = 0$, and the resulting optimal obfuscation policy given in (10) follows directly. □

Proof of Lemma 4. Buyer i's prior on W_j is $F(w_j) = \Pr(W_j < w_j) = \frac{w_j - \underline{w}}{\overline{w} - \underline{w}}$. Upon observing obfuscation, buyer i updates his beliefs using Bayes' rule: $\Pr(W_j < w_j | I_{obf} = 1) = \frac{\Pr(W_j < w_j)\Pr(I_{obf} = 1 | W_j < w_j.)}{\Pr(I_{obf} = 1)}$. Because both the conditional and unconditional obfuscation probabilities, $\Pr(I_{obf} = 1 \mid W_j < w_j)$ and $\Pr(I_{obf} = 1)$, also depend on w_i, we derive two separate cases.

Case 1 ($w_i < A(\overline{w})$). Obfuscation occurs when either $W_j < A(w_i)$ or $w_i < A(W_j) \Leftrightarrow W_j > A^{-1}(w_i)$. Therefore, $\Pr(I_{obf} = 1) = F(A(w_i)) + 1 - F(A^{-1}(w_i)) = \frac{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)}{\overline{w} - \underline{w}}$, and

$$\Pr(I_{obf} = 1 \mid W_j < w_j) = \begin{cases} 1 & \text{if } \underline{w} \le w_j \le A(w_i), \\ \frac{F(A(w_i))}{F(w_j)} = \frac{A(w_i) - \underline{w}}{w_j - \underline{w}} & \text{if } A(w_i) < w_j \le A^{-1}(w_i), \\ \frac{F(w_j) - F(A^{-1}(w_i)) + F(A(w_i))}{F(w_j)} = \frac{w_j - A^{-1}(w_i) + A(w_i) - \underline{w}}{w_j - \underline{w}} & \text{if } A^{-1}(w_i) < w_j \le \overline{w}. \end{cases}$$

Direct substitution into Bayes' rule yields

$$\mu^*(w_j; w_i < A(\overline{w})) = \begin{cases} \frac{w_j - \underline{w}}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} & \text{if } \underline{w} \le w_j \le A(w_i), \\ \frac{A(w_i) - \underline{w}}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} & \text{if } A(w_i) < w_j \le A^{-1}(w_i), \\ \frac{A(w_i) - \underline{w}}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} + \frac{w_j - A^{-1}(w_i)}{A(w_i) - \underline{w} + \overline{w} - A^{-1}(w_i)} & \text{if } A^{-1}(w_i) < w_j \le \overline{w}. \end{cases} \tag{B.7}$$

Case 2 ($w_i \ge A(\overline{w})$). Because $A(\cdot)$ is increasing, $w_i \ge A(\overline{w}) \Leftrightarrow A^{-1}(w_i) \ge \overline{w} \Rightarrow A^{-1}(w_i) \ge W_j$, and obfuscation occurs only if $W_j < A(w_i)$. Thus, $\Pr(I_{obf} = 1) = F(A(w_i)) = \frac{A(w_i) - \underline{w}}{\overline{w} - \underline{w}}$, and

$$\Pr(I_{obf} = 1 \mid W_j < w_j) = \begin{cases} 1 & \text{if } \underline{w} \le w_j \le A(w_i), \\ \frac{F(A(w_i))}{F(w_j)} = \frac{A(w_i) - \underline{w}}{w_j - \underline{w}} & \text{if } A(w_i) < w_j \le \overline{w}. \end{cases}$$

Direct substitution into Bayes' rule yields

$$\mu^*(w_j; w_i \ge A(\overline{w})) = \begin{cases} \frac{w_j - \underline{w}}{A(w_i) - \underline{w}} & \text{if } \underline{w} \le w_j \le A(w_i), \\ 1 & \text{if } A(w_i) < w_j \le \overline{w}. \end{cases} \tag{B.8}$$

The posterior CDF in (11) is a succinct representation of (B.7) and (B.8). The remainder of the lemma follows directly. □

Proof of Proposition 2. First, we prove part iv. Suppose buyers expect a pricing strategy of $\hat{p}(w)$ under obfuscation, such that $\hat{p}(\cdot)$ is increasing; hence, $\Pr(\hat{p}(W_j) \le p_i) = \Pr(W_j \le \hat{p}^{-1}(p_i))$. Buyer i's utility under obfuscation from the lower prong of Equation (8) becomes

$$U_i^{end}(w_i, p_i; \hat{p}(\cdot)) = \alpha(w_i - p_i) - \delta p_i - \lambda\rho_d \Pr\big(W_j \le \hat{p}^{-1}(p_i)\big) \times \big(p_i - \mathbb{E}[P_j \mid W_j \le \hat{p}^{-1}(p_i), I_{obf}]\big).$$

The seller's equilibrium pricing strategy must satisfy the optimality condition: $p^{end*}(w_i) = \arg\max_{p_i} p_i$, subject to $U_i^{end}(w_i, p_i; \hat{p}(\cdot)) \ge 0$. The constraint $U_i^{end} \ge 0$ is binding at the solution. Note that U_i^{end} is strictly decreasing (increasing) in price (WTP). In addition, it is strictly positive (negative) at $p_i = 0$ (at $p_i = p^{\max}(w_i)$). Thus, for any $w_i \in [\underline{w}, \overline{w}]$, there must exist a unique $p^{end*}(w_i)$ such that $p^{end*}(w_i)$ is strictly increasing and satisfies $U_i^{end}(w_i, p^{end*}(w_i); \hat{p}(\cdot)) = 0$. Moreover, because buyers' expectations are rational, in equilibrium,

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we must have $\hat{p}(\cdot) = p^{end*}(\cdot)$, and $\Pr(W_j \leq \hat{p}^{-1}(p_i))$ must reduce to $\mu^* \equiv \Pr(W_j \leq w_i)$. Finally, according to the posterior beliefs in Lemma 4, $\Pr(A(w_i) < W_j < w_i \mid I_{obf} = 1) = 0$. Therefore, $\mathbb{E}[\hat{p}(W_j) \mid W_j < w_i] = \int_{\underline{w}}^{w_i} \hat{p}(w_j) d\mu^*(w_j) = \int_{\underline{w}}^{A(w_i)} \hat{p}(w_j) d\mu^*(w_j)$. Part iv of the proposition follows such that $p^{end*}(w_i) = p^{\max}(w_i) - t^{end*}(w_i)$, where

$$t^{end*}(w_i) = \frac{\lambda \rho_d \mu^*(w_i)\left(p^{\max}(w_i) \quad - \int_{\underline{w}}^{A(w_i)} p^{end*}(w_j) d\mu^*(w_j)\right)}{\alpha + \delta + \lambda \rho_d \mu^*(w_i)}.$$

Next, we prove that if $\lambda = 1$, the obfuscation region collapses and the seller always chooses transparency. The proof proceeds by contradiction. Note that $t^{end*}(w_i) \geq 0 \Rightarrow p^{\max}(A(w_i)) \geq p^{end*}(A(w_i))$, which, taken together with Lemma A.1, establishes that the following inequality must be true:

$$p^{\max}(A(w_i)) \geq p^{end*}(A(w_i)) > \int_{\underline{w}}^{A(w_i)} p^{end*}(w_j) d\mu^*(w_j). \tag{B.9}$$

Set $\lambda = 1$, and suppose that the equilibrium obfuscation decision follows Equation (10) such that $A(w) > \underline{w}$ and the shaded regions in Figure 3(a) are nonempty. Suppose that $w_h > A(\overline{w}) \Rightarrow \mu^*(w_h) = 1$ and $w_l = A(w_h)$. By definition of $A(\cdot)$, the seller must be indifferent between obfuscation and transparency such that

$$t^{end*}(w_h) + t^{end*}(A(w_h)) = t^{trp*}(w_h, A(w_h)).$$

Because $t^{end*}(A(w_h)) > 0$, we must have

$$0 < t^{trp*}(w_h, A(w_h)) - t^{end*}(w_h)\big|_{\lambda=1} = \frac{\rho_d\left(\int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j) - p^{\max}(A(w_h))\right)}{\alpha + \delta + \rho_d},$$

which contradicts the true inequality in (B.9).

Next, we prove part i by showing that the obfuscation/transparency strategy in Equation (10) is optimal given buyers' beliefs (i.e., sequentially rational), while restricting attention to cases where $\lambda < 1$. Define $\Delta(w_h, w_l) \equiv \pi^{end*}(w_h, w_l) - \pi^{trp*}(w_h, w_l) = t^{trp*}(w_h, w_l) - t^{end*}(w_h) - t^{end*}(w_l)$. Because $t^{trp*}(w_h, w_h) = 0$,

$$\Delta(w_h, w_h) = -2t^{end*}(w_h) < 0. \tag{B.10}$$

We also have

$$\begin{aligned}
\Delta(w_h, \underline{w}) &= \frac{\alpha w_h + \lambda \rho_d \mu^*(w_h) \quad \int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j)}{\alpha + \delta + \lambda \rho_d \mu^*(w_h)} \\
&\quad - \frac{\alpha w_h + \rho_d p^{\max}(\underline{w})}{\alpha + \delta + \rho_d}, \frac{\alpha w_h + \lambda \rho_d \mu^*(w_h) \int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j)}{\alpha + \delta + \lambda \rho_d \mu^*(w_h)} \\
&\geq \frac{\alpha w_h + \rho_d \int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j)}{\alpha + \delta + \rho_d}, \text{ and} \\
&\quad \frac{\alpha w_h + \rho_d \int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j)}{\alpha + \delta + \rho_d} - \frac{\alpha w_h + \rho_d p^{\max}(\underline{w})}{\alpha + \delta + \rho_d} \\
&= \frac{\rho_d\left(\int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j) - p^{\max}(\underline{w})\right)}{\alpha + \delta + \rho_d} > 0.
\end{aligned} \tag{B.11}$$

The last inequality in (B.11) must be true by Lemma A.1. Thus, we can establish that

$$0 < \frac{\rho_d\left(\int_{\underline{w}}^{A(w_h)} p^{end*}(w_j) d\mu^*(w_j) - p^{\max}(\underline{w})\right)}{\alpha + \delta + \rho_d} \leq \Delta(w_h, \underline{w}). \tag{B.12}$$

Now, define w_1 and w_2 such that $\underline{w} \leq w_1 < w_2 \leq \overline{w}$. By direct substitution,

$$\begin{aligned}
\Delta(w_h, w_1) - \Delta(w_h, w_2) = &\left(1 + \frac{\rho_d}{\alpha + \delta + \rho_d}\right)\left[p^{\max}(w_2) - p^{\max}(w_2)\right] \\
&- \left[p^{end*}(w_2) - p^{end*}(w_2)\right] > 0.
\end{aligned} \tag{B.13}$$

Note that $p^{end*}(\cdot) = p^{\max}(\cdot) - t^{end*}(\cdot)$. Because $t^{end*}(\cdot)$ is increasing, $p^{\max}(\cdot)$ must be increasing faster than $p^{end*}(\cdot)$, which is sufficient to ensure that the inequality above is true.

Inequality (B.10) (inequality (B.12)) establishes that $\Delta(w_h, w_l)$ is negative (positive) at $w_l = w_h$ ($w_l = \underline{w}$), and inequality (B.13) establishes that $\Delta(w_h, w_l)$ is decreasing in w_l. Therefore, for every w_h, there must exist a unique $A(w_h)$ such that $\Delta(w_h, w_l) > 0 \Leftrightarrow w_l < A(w_h)$. Furthermore, as λ goes up (down), $\Delta(w_h, w_l)$ and $A(w_h)$ go down (up), and the obfuscation regions in Figure 3(a) shrink (expand). At the extreme, $A(\cdot) \to \underline{w}$ if $\lambda \to 1$, and the obfuscation region becomes empty. This concludes the proof of part i. The remainder of the results directly follow.

Finally, for part vi, Lemma 3 established that the condition $\lambda \leq \frac{\alpha+\delta}{\alpha+\delta+\rho_d}$ is sufficient to ensure that the sellers follow the obfuscation strategy in (10) regardless of buyers' beliefs. In turn, there cannot not exist any alternative set of beliefs and optimal strategies that satisfy the sequential rationality and Bayesian consistency requirements. □

Proof of Proposition 3. The equilibrium transparency prices and profits are identical to those in Lemma 1. Because obfuscation eliminates PIF concerns, optimal obfuscation prices simply set the utility to zero, such that $p^{end*}(w_i) = \frac{\alpha w_i}{\alpha+\psi\delta}$. The optimal obfuscation decision directly follows from comparing profits. □

Endnotes

[1] For ease of exposition, throughout this paper, we refer to a male buyer (using pronouns he, his, and him) and a female seller (using pronouns she, hers, and her).

[2] We can add a positive PIF term, $\rho_a \Pr(p_i < P_j \mid \Omega_i)(\mathbb{E}[P_j \mid p_i < P_j; \Omega_i] - p_i)$, which captures the positive utility a buyer gets from getting a lower price than the other buyer, weighted by a parameter $\rho_a \geq 0$. Adding such a term, however, sacrifices a great deal of parsimony without providing additional insights. In the empirical model, we allow for a positive PIF term. For expositional clarity, and without loss of generality, we assume that $\rho_a = 0$ in the theoretical analysis. All of the predictions of the model are maintained as long as $\rho_a < \rho_d$, which is a reasonable assumption given prospect theory (Kahneman and Tversky 1979, 1992).

[3] See Lemma A.4 in Appendix A, which shows that the seller's optimal price is increasing in WTP regardless of buyers' expectations and beliefs.

[4] The constraint $U_i^{obf} \geq 0$ is binding at the solution. Note that U_i^{obf} is strictly decreasing (increasing) in price (WTP). In addition, it is strictly positive (negative) at $p_i = 0$ (at $p_i = p^{\max}(w_i)$). Thus, for any $w_i \in [\underline{w}, \overline{w}]$, there must exist a unique $p^{obf*}(w_i)$ such that $p^{obf*}(w_i)$ is strictly increasing and satisfies $U_i^{obf}(w_i, p^{obf*}(w_i); p^{obf*}(\cdot)) = 0$. Moreover, in equilibrium, $\Pr(W_j \leq \hat{p}^{-1}(p_i))$ must reduce to $F(w_i) \equiv \Pr(W_j \leq w_i)$.

[5] We omitted this effect in the previous exogenous analyses to simplify the exposition and make the intuition as clear as possible. Adding any $\lambda \in (0, 1)$ will simply expand the region in which exogenous obfuscation is more profitable. All the previous results and intuition remain qualitatively and directionally the same.

[6] Recall that we used the superscript *obf* to denote exogenous obfuscation variables. Because endogenous obfuscation yields different equilibrium outcomes, we use the superscript *eobf*. In contrast, endogenous and exogenous transparency yield the same equilibrium outcomes, and we use the same superscript, *trp*, for both.

[7] Without imposing any conditions on λ, we can show that if buyers believe that the seller's obfuscation strategy follows Equation (10), it will be optimal for the seller to actually use that strategy (sequential rationality requirement), and that such a belief satisfies the Bayesian consistency requirement. Thus, the equilibrium will hold for any λ, but it will not be possible to analytically prove uniqueness. It is also worth noting that although this condition is sufficient but not necessary to analytically prove uniqueness, numerical solutions across the entire parameter space suggest that the equilibrium is indeed unique for any $\lambda \in (0, 1)$.

[8] Recall that Proposition 1 showed that when the obfuscation/transparency decision was not strategic (exogenous), obfuscation yielded more profits to the seller when the difference in buyers' WTP was sufficiently high.

[9] The reverse case is trivial. Suppose that the WTP draws imply an obfuscation equilibrium strategy, but the seller chooses transparency instead. In this case, buyers do not have to form any new beliefs, as they will simply observe each other's price, rendering that deviation suboptimal for the seller.

[10] Participant interaction was facilitated using the z-Tree software, which is the Zurich Toolbox for Readymade Economic Experiments (Fischbacher 2007).

[11] Subjects were paid \$20 for their participation in the experiment, which was the minimum we could pay based on the experimental laboratory's guidelines. The additional payment of \$0–\$10 was based on total surplus earned in experimental credits, which was converted to the real U.S. currency. See Online Appendix B for more details.

[12] In Figure 4, (c) and (d), we graph residualized consumer surplus after controlling for own WTP.

[13] When prices are obfuscated, we operationalize $\Pr(p_j < p_i)$ ($\Pr(p_i < p_j)$) by dividing the number of times an obfuscated price was set below (above) p_i within the same treatment by the total number of times an obfuscated price was set within treatment. We also operationalize $\mathbb{E}[p_j \mid p_j < p_i, s = obf]$ ($\mathbb{E}[p_j \mid p_i < p_j, s = obf]$) by averaging all obfuscated prices set below (above) p_i within treatment.

[14] Stating that $\rho_d^{trp} > \rho_d^{obf}$ is equivalent to $\lambda < 1$ in the theoretical model, and $\delta^{trp} < \delta^{obf}$ is equivalent to $\psi > 1$.

[15] The FOCs included fractions where both the denominator and numerator were very small numbers (approached zero) and required computing limits. Given the finite space of possible prices (between \$50 and \$150), it was computationally much faster to utilize a grid search approach.

[16] The extreme value theorem states that the limiting distribution of the $\max\{\pi^{obf}, \pi^{trp}\}$ will belong to one of the generalized extreme value probability distributions as long as the underlying distribution of π^{obf} and π^{trp} is the same for both, regardless of the distribution itself. Similar to the idea that a consumer will choose the option that yields the most intrinsic value, we assume that the distribution of the seller's transparency or obfuscation choice will also follow a type 1 extreme value distribution.

[17] Relative income has been shown to be a more significant driver for subjective happiness levels than absolute income (for a good review, see, e.g., Clark et al. 2008). In our case, for example, a \$10 difference in prices offered to two buyers is likely to be judged differently when the offered consumer surplus is \$20 (a 50% difference) versus when offered consumer surplus is \$50 (a 20% difference).

[18] As such, proportional DI_i^s (AI_i^s) captures the boost (reduction) in consumer i's surplus if he received p_j (or $\mathbb{E}[p_j \mid \cdot]$) instead of p_i. For instance, $DI_i^{trp} = \frac{(w_i - p_j) - (w_i - p_i)}{w_i - p_i} = \frac{p_i - p_j}{w_i - p_i}$, if $p_j < p_i$. The same logic applies for AI_i^s.

[19] Note that in our theory model, we posit that $\rho_d > 0$ and $\delta > 0$, but they enter the theoretical utility function with negative signs. In the empirical portion of this paper, we do not restrict these parameters to be positive or negative; thus, we report the estimated coefficients with their respective signs; that is, a negative estimated ρ_d is equivalent to the positive ρ_d in the theory model

[20] Under exogenous obfuscation (Section 3.2), $\hat{\mu}(W_j)$ converges to the uniform prior. Under endogenous obfuscation (Section 3.4), $\hat{\mu}(W_j)$ is updated according to Bayes' rule depending on the buyer's beliefs about the seller's obfuscation strategy.

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