Behavioral Constraints on Pricing: Experimental Evidence on Price Discrimination and Customer Antagonism

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Abstract

In this study, we investigate behavioral constraints on pricing by using a novel laboratory experiment in which actual consumption goods are traded. We test different models and provide several insights into pricing and reactions to price discrimination. First, we identify the extent to which sellers voluntarily and strategically avoid price discrimination. Second, we find that sellers strategically overprice low value customers to avoid antagonizing high value customers. Third, we observe that customers are not generally antagonized by price discrimination: while they are less likely to buy if they are charged a higher price than another customer even if they are underpriced, they are more likely to buy if they are charged a lower price even if they are overpriced. These findings are consistent with a reference point model, which assumes that prices for other customers constitute reference points. Finally, we show that our findings hold regardless of whether sellers are monopolists or compete against other sellers. The observed behavioral patterns suggest a novel explanation for sticky prices and impulse purchase behavior.

JEL-Codes: L110, C990.

Keywords: price discrimination, customer antagonism, fairness, reference points.

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1. Introduction

The analysis of individual economic behavior often begins with the fundamental role of prices.[1] Pricing determines the allocation of resources, the fate of sellers, and ultimately, the social welfare of societies. Each seller has to decide on the price for her products and services. Recent developments in information technology and the increasing popularity of internet markets render it likely that many sellers have never had better access to information about customers and more favorable conditions to personalize prices and use third-degree price discrimination (Baker et al., 2001; Fudenberg and Villas-Boas, 2012).[2]

Although information barriers to personalized pricing are crumbling and sellers often have the choice to set prices, uniform pricing is still widespread.[3] [4] Following Kahnemann et al. (1986) who demonstrate behavioral constraints[5] on profit making, one potential explanation for this phenomenon is that there are behavioral constraints on pricing. In particular, it could be that there is resistance from customers to personalized pricing. Additionally, information technology has made it easier to alert other customers if identical products are being offered at different prices to different customers. Consistent with this, there is evidence for price obfuscation and complaints about price discrimination. Amazon.com, for example, stopped offering

[1] This is particularly emphasized in the works of many influential economists who were employed at the University of Chicago such as Gary Becker, Ronald Coase, and Milton Friedman.

[2] Personalized pricing is one central pricing strategy where identical products are sold at different prices to different customers. The optimal incarnation of personalized pricing is third-degree price discrimination, where prices correspond to each customer's maximal willingness to pay.

[3] This is not to say that there is no third-degree price discrimination or that other forms, such as first- and second-degree price discrimination are uncommon. This is also not to say that price discrimination of products *over time* is uncommon. Airline ticket pricing, for example, is an example of a product where there is significant price discrimination across customers. However, most of the price discrimination results from customers buying tickets at different points in time; it is questionable whether an airline ticket bought several months before travel constitutes a product identical to an airline ticket bought some days before travel.

[4] Uniform pricing was also not always the norm. In early markets, it was common that sellers adjusted prices for their goods depending on their estimates of their customers' value or willingness to pay (Geertz, 1978). However, in modern retail markets such personalized pricing was largely replaced by uniform pricing.

[5] Behavioral constraints are different from standard constraints as they take into account the effects of non-standard factors (e.g. psychological, cognitive, social or emotional) on purchase decisions.

identical DVD titles at different prices after some of their customers found out and complained in internet forums about differential pricing for identical products.[6]

However, the extent to which personalized pricing affects purchase decisions and in turn pricing, is unknown. Moreover, it is unclear under what circumstances customers are antagonized by personalized pricing. There are two broad classes of explanations. The first class deals with fairness considerations and the outcomes or intents of personalized pricing. These explanations can be captured with models of social norms, social preferences, and reciprocity. Here, the idea is that customers view personalized pricing as unfair because it shifts benefits from consumers towards producers. In contrast, the second class of explanations focuses on the price itself. These explanations can be captured either with standard models, which assume that prices signal product quality, or with reference point models, which assume that prices constitute reference points. Here, the idea is that personalized pricing can be detrimental as it can lead customers to lower their willingness to pay for a certain product.

This paper presents a framework and experimental data to provide the first insights into behavioral reactions to pricing, with the goal to disentangle the different explanations for customer antagonism. Unable to capture and systematically test the extent and consequences of personalized pricing in the field (Lott and Roberts, 1991), our study is conducted in a laboratory environment. In our experiment, we observe pricing and reaction to prices in systematically different information and market environments, and capture the key features of consumer markets by investigating purchase choices for goods, which have participants' values attached to it.

Our study delivers several new findings. On the seller side, we observe that sellers are often willing to voluntarily refrain from price discrimination but that their restraint weakens when the differences in their customers' willingness to pay increases. Further, we observe that sellers strategically avoid price discrimination. If sellers know that customers are aware of the pricing for other customers, the probability of price discrimination drops significantly. Finally, we observe that pricing

[6] For press coverage of the Amazon.com pricing test, see:
http://news.bbc.co.uk/2/hi/business/914691.stm and
http://www.computerworld.com/article/2588337/retail-it/amazon-apologizes-for-price-testing-program-that-angered-customers.html.

systematically deviates from customer values; low value customers are frequently overpriced if sellers know that customers are aware of pricing for other customers.

On the buyer side, we observe that customers are not generally antagonized by price discrimination: while they are less likely to buy if they are charged a higher price than that charged to another customer, they are also more likely to buy if they are charged a lower price. More precisely, we show that the probability of a purchase decreases for offers priced at or below the willingness to pay if there is disadvantageous price discrimination, and that customers are even willing to buy a good priced above their willingness to pay if they observe that another customer is charged a higher price.

Further, we provide evidence that most of our findings are not constrained to monopoly markets. More precisely, we find that sellers also strategically avoid price discrimination and strategically overprice low value customers if they compete against other sellers. In addition, we find that customers do not prefer to buy from sellers who avoid price discrimination, and that advantageous price discrimination nudges overpriced customers to purchase in competitive markets.

We show that the behavioral patterns of sellers and customers in the different treatments are largely consistent with a reference point model, which assumes that prices constitute reference points (Lichtenstein et al., 1988; Kahneman, 1992; Janiszewski and Lichtenstein, 1999; Kőszegi and Rabin, 2006), but cannot be reconciled with standard economic models and models incorporating fairness considerations. Thus, our study contributes to the experimental literature on the relevance of reference points (Brandts and Sola, 2001; Abeler et al., 2011; Crawford and Meng, 2011; Fehr et al., 2011) and shows their impact on pricing in consumer markets.

This study contributes to different fields of research. First, it contributes to the theoretical literature on price discrimination (Schmalensee, 1981; Varian, 1989; Choudhary et al., 2005; Armstrong, 2006; Liu and Zhang, 2006; Heidhues and Kőszegi, 2008; Rotemberg, 2011; Bergemann et al., 2015) by providing experimental evidence. Second, it contributes to the empirical literature on the role of fairness in markets and behavioral constraints on profit seeking (Kahnemann et al., 1986). While there is substantial evidence from case studies and surveys suggesting that individuals care about ‘fair pricing’ (Huppertz et al., 1978; Frey and Pommerehne, 1993; Blinder et al., 1998; Zbaracki et al., 2004), it is unclear whether and how such stated preferences actually affect purchases and in turn pricing.

Several studies experimentally observe the impact of pricing strategies on purchases (Campbell, 1999; Anderson and Simester, 2001; Anderson and Simester, 2010; Courty and Pagliero, 2010; Garbarino and Maxwell, 2010) and on drivers of price discrimination (Goldberg, 1996; List, 2004). In particular, Anderson and Simester (2010) find that customers are less likely to make subsequent purchases from sellers who reduced prices for products after they had purchased them. List (2004) finds that sellers undertake price discrimination mainly due to statistical reasons and not due to taste-based discrimination. In contrast to these studies, we simultaneously study decisions of customers and sellers under different circumstances. We investigate how systematic changes in the information and the market environment affect pricing and reactions to pricing at the same time. Thus, this study can provide an initial insight into the scope of personalized pricing.

There is manifold laboratory experimental evidence that individuals care about fairness and the equal distribution of monetary payoffs (Fehr et al., 1993, Charness and Rabin, 2002). Moreover, there is experimental evidence that individuals care about relative comparisons and reduce effort if they are paid less than their peers (Cohn et al., 2014), exhibit negative reciprocal reactions if they are charged higher prices (Englmaier et al., 2012), and perceive fairness in a path-dependent manner (Herz and Taubinsky, 2014). Our study deviates from these and other laboratory studies by combining different methodologies to investigate the causal impact of pricing strategies on purchases in actual consumer markets.

Our findings provide a novel view and a potential explanation for price stickiness (Rotemberg, 1982; Hannan and Berger, 1991), resale price maintenance (Marvel and McCafferty, 1984; Deneckere et al., 1997), and price obfuscation (Spiegler, 2006; Ellison and Ellison, 2009). Our findings suggest that personalized pricing can endanger sales because lower prices for other customers constitute reference points and might deter high value customers. Assuming that these reference points are at least to some extent stable over time, it can be beneficial for sellers to stick to one price.[7] In addition, our findings suggest a novel explanation for impulse purchase behavior as we show that there is a significant probability that overpriced customers purchase a good if they observe that they are charged a price lower than that charged to someone else (Cobb and Hoyer, 1986; Beatty and Ferrell, 1998).

2. Experimental Design

The goal of this experiment is to investigate pricing and reactions to price discrimination for goods. A central feature of goods is that they have a value, which is determined by the individual maximal willingness to pay. The value of a particular good often differs between consumers, where consumers assign values to goods depending on their own preferences. Moreover, they may change these values for various reasons, such as receipt of additional information.

To account for these common features of goods, this experiment deviates from standard laboratory experiments. More precisely, we invited subjects to a laboratory experiment in which actual consumption goods were traded. Importantly, instead of using induced values, subjects' values for these goods were endogenous.

Besides incorporating common features of consumer markets, this design also has the advantage that it removes the focus on simple payoff comparisons, which results from using induced values and may bias our understanding of reactions to pricing. There is ample evidence that many individuals care about the distribution of monetary payoffs and they frequently aim to reduce payoff differences, as documented in ultimatum games (Güth et al., 1982) and as accounted for in social preference models (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Charness and Rabin, 2002). However, simple payoff comparisons may be misleading and are impractical in consumer markets, where buyers generate consumer surplus and relation to seller profits is unclear. Our design renders it possible to investigate whether the distribution of consumer benefit and seller profit affects purchase decisions.

One challenge faced when using actual goods is that it can be rational for customers to adjust their willingness to pay if they receive additional information. For

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[7] More precisely, this is true if consumer *i's* purchase decision at point $t+1$ depends with a positive probability on the offer price for consumer j at point t. For example, this is true if you are less likely to buy a watch today for $200 if you know it was offered yesterday to your colleague for $150 (and your initial willingness to pay was higher than $200).

example, if they observe that another customer is charged a lower price, they could decrease their willingness to pay if they believe that the lower price signals lower product quality. While this complicates the qualification of behavioral reactions and forces us to use an elaborate experimental design with additional treatments to detect the quality uncertainty argument, it is a necessary condition to test the relevance of behavioral reactions in typical product markets where quality uncertainty is common.

Our experiment involved two parts. The first part identified the individual maximal willingness to pay for a set of actual goods. The second part identified pricing and reactions to price discrimination for the same set of goods in different information and market environments. To avoid incentives to misrepresent the willingness to pay in the first part, participants received the instructions for the second part only after they had completed the first part.

At the start of the experiment, all subjects received an endowment of $28. They could use the endowment during both parts of the experiment. The subjects received the instructions on paper and the experiment was computerized using Ztree software (Fischbacher, 2007).

2.1 First part: Identifying values

In the first part, all subjects took part in ten auctions. The auctions were second-price sealed bid Vickrey auctions for ten different goods. The goods were always presented in the same order. The goods were physically displayed in the laboratory and subjects also saw pictures of them on their computer screens when making their bids. The details of the goods are in Appendix C.

Participants could bid $0.1–$28 (their endowment) for each of the ten goods. However, it was common knowledge that there will be only one winner in the first part, for only one of the ten goods. In other words, at the end of the complete experiment, one good was randomly selected for payment and then transferred to the highest bidder in the corresponding auction. Thus, the bids for each of the ten goods were independent. All participants were incentivized to bid their true value for each good without needing to spend more than their endowment. The sole winner of the first part was informed only at the time of payment. The winner received the good and the balance amount left from the endowment ($28 – winning bid).

The intent of the first part was to generate a measure of the maximal willingness to pay (value) for each of the ten goods, from each participant. We chose a Vickrey auction because it is incentive-compatible and relatively easy to understand for the participants (Vickrey, 1961).[8] One downside of the Vickrey auction is that there is evidence for overbidding, showing that bids do not always correspond to the maximal willingness to pay (Kagel et al., 1987). This can create noise for choices in the second part rendering the identification of treatment effects more difficult. However, as subjects were randomized into different treatments before the second part, we do not expect that this noise would confound treatment comparisons.

2.2 Second part: customer-seller experiment

The second part was designed to present a simple decision environment to capture the key elements of customer–seller interactions. After the first part, all subjects were randomized into treatments and groups where they were either in the role of a seller or a customer. The groups consisted of either one seller and two customers (monopoly treatments) or two sellers and two customers (Bertrand competition treatments). The participants remained in their groups for ten periods until the end of the experiment.

In each period, each customer could purchase one of the ten goods from the first part. Sellers could sell the same ten items from the first part to the two customers in their group. While the sellers did not own the items and could not keep them, they received a commission for each successful sale (10% or 100% of the purchase price, depending on the commission treatment).

Sellers made one offer to each of their two customers for each good. In the Bertrand competition treatments, sellers simultaneously submitted their offers to each of their two customers. The offer price could range from $0.1 to $28. Sellers could make identical offers (uniform pricing) or price discriminate (personalized pricing). In any case, they had to enter an offer price for each customer. Each seller could sell one good to each of her two buyers. Before making an offer, sellers' received information on their customers' willingness to pay from the first part.

To avoid incentives to misrepresent the willingness to pay in the first part, participants were not informed that the behavior in the first part would be

[8] This contrasts, for example, with the Becker-DeGroot-Marchak method, which can create considerable confusion and misconceptions (Cason and Plott, 2014).

communicated to other participants in the second part. While it is possible that this may have upset some participants in the role of a customer, nobody complained. In any case, it is likely that some customers benefited from sellers knowing their willingness to pay as it helped sellers to prepare offers below their customers' willingness to pay.

Customers simultaneously decided whether to reject or accept after receiving an offer from their seller. If a customer rejected an offer, there was no trade and the payoffs of the seller and buyer were not affected. If a customer accepted an offer, it was implemented with a 1/10 chance; i.e., the seller received a commission and the customer actually obtained the item and paid with her endowment. At the end of the second part, we randomly determined one of the ten periods in which choices became payoff-relevant. In this manner, each purchase decision in the ten periods was independent and there was no risk of negative monetary payoffs.

In addition, the purchase decision should be unaffected by the bids in the first task as we made it clear that participants have the choice to not go through with the trade in the second part in the highly unlikely event that they had already won the same good in the first part.[9] After each period, sellers were informed about the choices of their customers, and this was common knowledge.

2.3 Treatments

This experiment varies (*i*) information, (*ii*) seller incentives, and (*iii*) market structure to investigate different models to understand the behavioral constraints on personalized pricing. Table 1 summarizes our five information treatments NI, SI, CI, FI, and FNI. While sellers know their two customers' values for each item in all information treatments, we vary the information for customers and the information sellers have about their customers' information.

Treatment NI

Treatment NI (*n*o *i*nformation) serves as our baseline information treatment. In NI, it is common knowledge that customers only get to know their own offer price before making a purchase decision. That is, customers are only shown their own offer price

[9] The event is highly unlikely because there is only one winner per experimental session (average session was N = 20) and a 10% probability that the randomly selected goods in parts 1 and 2 were the same.

and sellers are informed that their customers only see their own offer price but not the offer price for the other customer in their group. Thus, there are no strategic incentives for sellers in NI to avoid price discrimination. If we observe that sellers avoid price discrimination in NI, we know it is voluntary.

Treatment SI

In contrast, in treatment SI (*s*ome *i*nformation), customers see the offer price for the other customer in their group and sellers know this. Thus, there can be strategic incentives for sellers in SI to avoid price discrimination. If we observe that sellers avoid price discrimination in SI, we know that it can be voluntary or strategic. By comparing treatment SI to treatment NI, we are able to tease out the strength of the strategic part in SI.

Treatment CI

Treatment CI (*c*omplete *i*nformation) is similar to treatment SI with the key difference that we inform customers that the seller knows their own and the other customer's willingness to pay for each item from the bids in the first part of the experiment. In addition, we inform sellers that customers know that the seller's know their customers' willingness to pay. That is, in CI, customers can better infer the seller's pricing intentions. In particular, as compared to the other treatments, customers can better infer the extent to which sellers try to reduce consumer benefits to increase their own profits. Moreover, they can better infer why sellers price discriminate in CI as compared to in SI.

Treatment FI

Customers have the most information in treatment FI (*f*ull *i*nformation). In FI, customers know the offer prices for the other customer in the group as well as her value for each of the goods. In addition, sellers know that customers see the offer prices for the other customer as well as the other customer's value. Thus, FI renders it possible to investigate the extent to which purchase decisions are determined by the value assigned to a good (willingness to pay) from other customers. Importantly, FI is useful in determining whether customers care about prices for other customers even if customers know the value of another customer and where the price cannot serve as a signal for the value of a good.

Treatment FNI

Customers have access to the same information in treatments FNI and FI. However, in treatment FNI, sellers are only informed that customers see their own offer price but not that customers see p_j and v_j as well. That is, we did not make the full information set of customers explicit to sellers. We also did not inform customers that sellers do not know the customers' full information set. Thus, in FNI, we can determine how customers react to all possible pricing strategies and not just pricing that is constrained by strategic considerations from sellers. By comparing sales in FNI and FI, we can also estimate whether sellers find strategies to successfully implement personalized pricing in an environment where customers are aware of personalized pricing.

TABLE 1: Overview of information treatments

Treatment	**NI**	**SI**	**CI**	**FI**	**FNI**
Customer knows	p_i	p_i, p_j	p_i, p_j,	p_i, p_j, v_j	p_i, p_j, v_j
Customer knows that seller knows			v_i , v_j		
Seller knows	v_i , v_j				
Seller knows that customer know	p_i	p_i, p_j	p_i, p_j,	p_i, p_j, v_j	p_i
Seller knows that customer know that seller knows			v_i , v_j		

Notes: p_i = offer price to customer *i*, p_j = offer price for other customer *j* in group, v_j = willingness to pay from customer *i* in group, v_j = willingness to pay from other customer *j* in group, NI = no information, SI = some information, CI = complete information, FI = full information, FNI = full information for customer, no information for seller.

Seller incentives

The experiment also varied seller incentives. Sellers received either a 10% or a 100% commission on sales, depending on whether they are in the low- or in the high-commission treatment. Seller incentives were common knowledge, and were varied in treatments NI, SI, and CI. In treatments FI and FNI, all sellers were in the high commission treatment. We varied seller incentives to investigate whether the relative (producer vs. consumer) benefits generated from potential purchases determine the customers' likelihood to accept.

Market structure

Lastly, we varied the market structure in treatments NI and SI. In these treatments, we varied whether there was one seller and two customers in a group (Monopoly) or two sellers and two customers per group (4NI and 4SI, Bertrand competition). In treatments CI, FI, and FNI, there was always only one seller per group. Standard economic theory assumes that sellers can freely set prices only in monopoly/monopolistic markets, whereas pricing is trivial and price discrimination is absent in perfectly competitive markets. In our setting, standard theory predicts that in both treatments, offer prices are driven to the minimum; both sellers offer the minimal price to both customers ($0.1), resulting in uniform pricing. However, there is experimental evidence that in Bertrand competition, prices often do not equal marginal costs (Dufwenberg and Gneezy, 2000). We varied the market structure to explore the scope of our findings and whether behavioral reactions to pricing are limited to monopoly markets.

2.4 Models and predictions

Our experimental design renders it possible to test different economic models that can be used to predict pricing and reactions to pricing. We focus on five popular types of models that are frequently used to understand economic transactions: (*i*) standard economic models, (*ii*) social preference models, (*iii*) intention-based models, (*iv*) social norm models, and (*v*) reference point models.

We derive predictions for each these models and focus on three key questions. First, we investigate whether and when these models predict price discrimination. Second, we investigate whether and when these models predict overpricing. Third, we investigate how customers' are predicted to react to different forms of price discrimination. Table 2 summarizes the three main predictions for each of the five different types of models in our experimental design.

TABLE 2: Overview of model predictions for pricing, price discrimination, and reactions to price discrimination

Model type	**Standard / Social preference**	**Standard** (with quality uncertainty)	**Intention-based**	**Social norm**	**Price as reference point**
Do sellers avoid price discrimination?	No	Possibly (SI, CI) No (NI, FI, FNI)	Possibly (SI, CI, FI) No (NI, FNI)	Yes (SI, CI, FI) Possibly (NI, FNI)	Possibly (SI, CI, FI) No (NI, FNI)
Do sellers overprice customers?	No	Possibly (SI, CI) No (NI, FI, FNI)	No	Possibly	Possibly (SI, CI, FI) No (NI, FNI)
Do purchases depend on type of price discrimination?	No	Possibly (SI, CI) No (NI, FI, FNI)	No	No	Yes (SI, CI, FI, FNI) No (NI)

Notes: NI = no information, SI = some information, CI = complete information, FI = full information, FNI = full information for customer, no information for seller.

Standard economic model

The predictions of the standard economic model are straightforward and do not vary with treatments. Customers accept all offers (p) below the value/willingness to pay (v) and are indifferent for offers with $p=v$. Customers do not care about offer prices for other customers, values from other customers, and the commission size for the seller. Sellers anticipate this and maximize their payoffs by providing offers with $p=v–\varepsilon$, where ε is 1 cent (or $p=v$ in case of buyer indifference). Consequently, this model predicts that there is always price discrimination if there are customer value differences (v_i-v_j≠0) and that sellers do not overprice customers ($p>v$).

Standard economic model with incomplete information

The standard economic model assumes that customers have complete information about the quality of the traded goods. This assumption may be too strong. For example, it is possible that customers are uncertain about the taste of the praline good or the sound of the DVDs. If we loosen the information assumption, the standard model takes into account that it is possible that purchases are affected by (*a*) information on offer prices for other customers (p_j) or (*b*) information on other customers' willingness to pay (v_j).

Under (*a*) p_j may provide a signal on the value of a good if there is asymmetric information (Milgrom and Roberts, 1986). In our experimental set-up, sellers have more information on the value of a good than customers because they know the willingness to pay from their two customers (v_i,v_j). Thus, prices can signal the value of a good if a customer believes that the price represents the value from another customer for the same good.[10]

If customer *i* believes that $p_j \approx v_j$, the predictions are treatment dependent. More precisely, we should observe that customer *i's* purchase decisions depend on p_j in treatments SI and CI (but not NI) in the following manner: the willingness to accept an offer should positively depend on the offer price difference ($p_j – p_i$), as higher (lower) prices for other customers provide a signal for higher (lower) quality. In turn, if sellers anticipate this, it will affect their pricing in treatments SI and CI. In particular, it may be beneficial for sellers to overprice customers with low values so as not to risk sales to high value customers. For example, if a seller has a low value customer with v=1 and a high value customer with v=20 for the same good, it can be beneficial to overprice the low value customer as the potential costs of losing a sale are relatively low ($1 in high commission treatment if $p=v$) as compared to the potential costs of losing a sale to the high value customer. Thus, it is possible that sellers then choose to offer the good to both customers at the same price and refrain from price discrimination.

Under (*b*) v_j could also provide a signal on the value of a good and thus affect purchase decisions. In treatments FI and FNI, a customer gets to know v_j before she decides on accepting an offer. Thus, the customers' willingness to accept an offer could then positively depend on the customer value difference ($v_j – v_i$). In contrast, in FI and FNI, there is no reason to expect that the willingness to accept an offer depends on the relative pricing difference ($p_j – p_i$). This is so as the price for another customer carries no additional information as soon as customers know the value of the other customer.

Social preferences

A large body of experimental research shows that social preferences play an important role in the allocation of resources. Social preference models have been proposed to account for typical findings such as the rejection of unfair offers in ultimatum games (e.g. Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000;

[10] In other contexts, prices may signal the quality of a good for other reasons. In particular, higher prices may signal higher production costs, and thus better quality. Such signaling does not play a role in our experiment as there are no production costs.

Charness and Rabin, 2002). Some of the models can be adapted relatively easily to consumer markets in which the allocation of resources leads to consumer and producer surplus. For example, it is straightforward to assume in the inequity-aversion model by Fehr and Schmidt (1999) that customer i derives disutility if producer surplus ($c \times p_i$) exceeds her consumer surplus ($v_i – p_i$), and predict how this should affect reactions to pricing. That is, in the simplified two-player case in our experimental set-up, assuming that there is only disutility of disadvantageous inequity, we have the following utility function for customers:

$$U_i(p_i, v_i, c) = (v_i - p_i) - \alpha_i \, max\{(c \times p_i) - (v_i - p_i), 0\},$$

where c is the commission size (0.1 or 1), and α_i quantifies the strength of disutility resulting from disadvantageous inequity ($\alpha_i \geq 0$).

This adapted inequity-aversion model and related social preference models generate several general predictions for our experimental set-up. Perhaps most importantly, these models predict no treatment differences in reactions to pricing and consequently, pricing other than that between commission size treatments (where they predict that customers are more inclined to reject offers in the high commission treatment than in the low commission treatment, ceteris paribus). Moreover, they provide no intuition as to why sellers should avoid price discrimination and why customers might be averse to price discrimination. That is, they predict that price discrimination always occurs if $v_i \neq v_j$, regardless of treatment. Further, inequity-aversion models posit that offers for other customers are irrelevant as customers can reduce inequity only towards their seller but not towards the other customer. Consequently, customers should never accept overpriced goods ($p_i > v_i$) and sellers have no incentive to overprice.

Intention-based models

Intention-based models assume that individuals care about intentions and punish bad intentions like greed (Rabin, 1993; Dufwenberg and Kirchsteiger, 2004). Rotemberg (2011) presents an intention-based model that is adapted to the consumer market and assumes that customers punish (reward) bad (good) seller intentions by adjusting their purchase behavior. Roughly speaking, intention-based models assume that customers are antagonized by price discrimination if they believe that it was used to minimize their own benefit.[11]

Such intention-based models lead to a number of general predictions in our experiment.[12] First, these models provide a rationale as to why sellers might be hesitant to use price discrimination. Second, these models predict no overpricing. They also do not provide a rationale as to why customers could be willing to accept overpriced offers. Further, these models do not predict that the type of price discrimination matters for purchase decisions.

Social norms

Social norms are based on shared beliefs of how one should behave in a given situation, and are enforced by internal and external sanctions such as shame or punishment (Fehr et al., 2002). Survey evidence (Kahnemann et al., 1986; Frey and Pommerehne, 1993) suggests that there could be a social norm against price discrimination because there are environments in which many customers believe that sellers should not price discriminate and if they do so, they should be avoided. This evidence is also corroborated by anecdotal evidence on the use of personalized pricing.[13]

The simplest social norm model predicts that customers are more likely to reject offers $p_i \neq p_j$ if they know that there is price discrimination. In turn, we should expect that sellers sometimes avoid price discrimination if they know that customers are aware of pricing to other customers (as in our treatments SI, CI, and FI), and possibly even voluntary refrain from using price discrimination (as in our treatments NI and FNI). Moreover, it is possible that sellers overprice customers when refraining from price discrimination as it is unclear at which level they set the uniform price. Further, in the simplest social norm model, we would also not expect that the type of price

[11] Note that Rotemberg's (2011) model provides a different explanation for why sellers have an incentive to avoid price discrimination. His explanation is based on the assumption that the implementation of price discrimination is costly, which triggers customers to infer that sellers have bad intentions. However, this mechanism does not hold in our setting, as the implementation of price discrimination is for free.

[12] Note that the intentions of sellers are not perfectly clear in treatments NI, SI, FI, and FNI because customers are not informed about what information sellers have. This does not apply to treatment CI, in which customers can unambiguously infer the intentions of sellers as they know that their seller knows the customer's willingness to pay.

[13] See e.g. https://www.washingtonpost.com/archive/politics/2000/09/27/on-the-web-price-tags-blur/14daea51-3a64-488f-8e6b-c1a3654773da/ or references in footnote 6.

discrimination matters. In particular, in this model we assume that customers are equally hesitant to accept offers $p_j > p_i$ and $p_j < p_i$.

Reference points

The last model that we test is based on the idea of reference points that affect behavior (Thaler, 1985; Kahneman, 1992; Hart and Moore, 2006). In consumer markets, prices are central, and it seems possible that they constitute reference points that affect purchase decisions. It is possible that customers compare offers (Lichtenstein et al., 1988). If this is true, we should observe that purchase decisions also depend on the price offered to another customer (p_j).

A simple reference point model incorporating these ideas could be formulated as follows:

$$U_i(p_i, v_i, p_j) = (v_i - p_i) - \beta_i (p_j - p_i),$$

where β_i quantifies the strength of the reference point ($\beta_i \geq 0$).

The model assumes that the likelihood to accept an offer depends on relative pricing ($p_j - p_i$). The likelihood of acceptance is lower if there is disadvantageous price discrimination ($p_j < p_i$) as compared to when there is no price discrimination ($p_j = p_i$), and higher if there is advantageous price discrimination ($p_j > p_i$) as compared to no price discrimination. This implies that we should observe this dependency in all treatments where customers know p_j (SI, CI, FNI, and FI). In turn, if sellers anticipate that acceptances depend on the offer price difference/type of price discrimination, it will affect their pricing in SI, CI, FNI, and FI as compared to in NI. Thus, this model predicts that overpricing of low value customers and restraint from price discrimination can increase seller profits. It also can account for purchases of overpriced goods.

3. Experimental Findings

A total of 645 subjects participated in this experiment over 31 sessions. The total number of items sold was 138, with an average purchase price of A$7.24. Table 3 provides an overview on the number of participants in the different treatments. In the monopoly treatments, we observe that the customers' mean willingness to pay for the items (v) was $5.34. Customers rarely have the same willingness to pay in a given group for a given item (8.5%), and often substantially differ in their values. The mean difference in the customers' willingness to pay ($|v_i – v_j|$) was \$6.45. On an average, the sellers choose an offer price that is close to the mean value. The mean offer price (p) was \$5.42. Customers accepted 33.2% of the offers.

TABLE 3: Number of participants per treatment

Treatment	NI	SI	CI	FI	FNI	4NI	4SI	*total*
Seller	48 (25)	48 (25)	32 (16)	25	26	26	28	*233*
Customer	96	96	64	50	52	26	28	*412*

Notes: Numbers in parentheses indicate the subset of sellers in the low commission treatment. Individuals took only part in one treatment.

3.1 Price discrimination, overpricing, pricing strategies

In this section, we investigate the behavior of the sellers in our experiment. We start with the occurrence of price discrimination, then investigate overpricing, and conclude with pricing strategies.

3.1.1 Price discrimination

Our first finding is that sellers often refrain from price discrimination. Overall, there is no price discrimination in 45.3% of the offers where there are customer value differences (N=2226 out of 4914). The frequent avoidance of price discrimination casts doubts on the usefulness to predict pricing with the standard economic model and the social preference models.

The avoidance of price discrimination is partly voluntary. In treatment NI, where we inform sellers that customers do not know the offer price for the other customer in their group, sellers price discriminate with a likelihood of 77% (331 out of 430 offers). Thus, we find that sellers frequently avoid price discrimination and that this cannot be explained by strategic considerations. Table 4 shows that the voluntary resistance to price discriminate weakens with increasing differences in customer values. For example, while price discrimination is even less common than uniform pricing if the value difference between the seller's two customers is smaller than \$1 (44.3%), price discrimination is more common (66.5%) if all value differences up to \$5 are considered. The significant role of the customer value difference for price discrimination is supported in Table 5, where we use a random effects model to predict price discrimination in treatment NI. We control for the size of the seller commission, seller value, customer value difference, and good dummies. In model 1, we can see that the customer value difference is a significant predictor for price discrimination in treatment NI (p=0.001). The voluntary restraint from price discrimination is consistent with our social norm model.

TABLE 4: Likelihood of price discrimination depending on customer value differences in treatment NI

Value difference between customers in $	< 1	< 2	< 3	< 4	< 5	< 10	all
Likelihood of price discrimination	44.3% (n=61)	53.5% (n=114)	58.8% (n=153)	63.2% (n=193)	66.5% (n=227)	74.1% (n=320)	77.0% (n=430)

Notes: Data from treatment NI, in which customers do not know the price offered to the other customer.

TABLE 5: Probability of price discrimination

Model	(1)	(2)
Customer value difference	0.0113***	0.0114***
	(0.0034)	(0.0023)
Seller commission	-0.0012	-0.0019
	(0.0690)	(0.0022)
Seller value	-0.0064*	-0.0019
	(0.0037)	(0.0022)
Treatment FNI		0.0251
		(0.0693)
Treatment SI		-0.4144***
		(0.0542)
Treatment CI		-0.3114***
		(0.0569)
Treatment FI		-0.2608***
		(0.0800)
Constant	0.8274***	0.8022***
	(0.0584)	(0.0510)
R^2	0.052	0.153
N	430 (48)	1638 (179)

Notes: p<.01***, p<.05**, p<0.1*. Random effects linear probability model. Dependent variable = 1 if $p_i \neq p_j$, otherwise = 0. Robust standard errors in parentheses. Models control the different items. Treatment NI is baseline in Model (2). N = Number of groups (sellers) in parentheses. All observations are included where customers had different values for a given item in a given group.

Interestingly, we do not find evidence that there are seller types who voluntarily refrain from price discrimination completely. Almost all sellers use price discrimination at least once (N= 47 out of 48 in treatment NI), whereas three-fourth of the sellers use both price discrimination and uniform pricing. Only 22.9% of the sellers always price discriminate in NI.

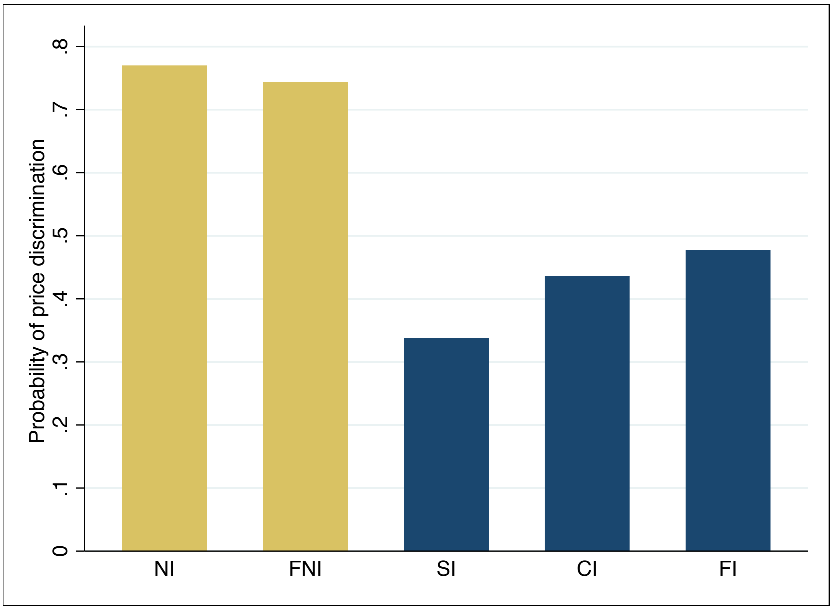
RESULT 1: *Most sellers have a weak preference against price discrimination: they often voluntarily avoid price discrimination if the customer value difference is small but their restraint weakens when this difference gets larger.*

However, while there is substantial voluntary restraint for price discrimination, the main reason for sellers to avoid price discrimination is strategic. Figure 1 illustrates that in the treatments in which sellers know that customers are aware of pricing for other customers (SI, CI, and FI), price discrimination is significantly less likely (p<0.001)[14] than in the treatments in which customers are unaware of pricing for others (NI) or sellers are unaware that customers know pricing for others (FNI). Sellers only price discriminate with a likelihood of 33.7% (456 out of 1353) in treatment SI, as compared to 77% in treatment NI (p<0.001). Thus, when pricing becomes common knowledge, sellers' avoidance of price discrimination almost triples (23% do not price discriminate in NI vs. 66.3% in SI). The likelihood of price discrimination is also significantly lower in treatments CI (43.6%) and FI (47.7%) as compared to in treatment NI (p<0.001, for both). Further corroborating evidence for the strategic nature of uniform pricing comes from treatment FNI. FNI shows that sellers use price discrimination significantly more often in FNI (74.4%) than in SI, CI, and FI (p<0.01, for all three comparisons), and equally often when compared to treatment NI (p=0.98).

[14] If not reported otherwise, we use two-sided Mann-Whitney tests, in which each individual's mean behavior constitutes one observation.

These treatment differences in the incidence of price discrimination are robust. In model 2 (Table 5), we use random effects regression in which we control for treatment, the customer value difference, goods, commission size, and the seller's value for the good. We find that the likelihood of price discrimination drops by 41.4% in treatment SI as compared to NI, with the effect being significant at p<0.001. While the likelihood of price discrimination is lower in SI than in CI and FI (p<0.01), the decrease in the likelihood of price discrimination comparing NI or FNI to CI (31.1%, p<0.001) and FI (26.1%, p<0.001) is also significant. The strategic avoidance of price discrimination is inconsistent with the standard model and the social preference models.

FIGURE 1: Voluntary and strategic avoidance of price discrimination



Notes: In treatments NI and FNI, prices are not common knowledge and sellers can voluntarily avoid price discrimination. In treatments SI, CI, and FI, prices are common knowledge and sellers also have reasons to strategically avoid price discrimination.

RESULT 2: *Sellers strategically avoid price discrimination. If sellers know that customers are aware of pricing to other customers, the probability of price discrimination sharply drops.*

3.1.2 Overpricing

The finding that sellers often shy away from price discrimination implies that prices often deviate from values. There are three main possibilities about how prices deviate from values. It could be that sellers mostly (i) underprice ($p<v$), (ii) overprice ($p>v$), or (iii) simultaneously under- and overprice, i.e., set prices above the value of one customer but below the value of the other customer.

The data shows that sellers frequently under- and overprice. We find that 29.5% of the offer prices are at least \$1 higher than the maximal willingness to pay (i.e., cannot be explained by rounding to the next dollar), and that 30% are underpriced by at least \$1 below the willingness to pay. Only 12.6% of the offer prices equal the willingness to pay, whereas 0.4% of the offer prices are 1 cent below the willingness to pay. While risk aversion is a likely driver for underpricing, it cannot play a role for overpricing. However, it is possible that overpricing is the result of (i) insufficient monetary incentives, (ii) envy, or (iii) strategic and norm considerations as derived in our prediction section.

First, it is possible that sellers carelessly overprice because of low monetary incentives to secure a sale. To test the role of monetary incentives for sellers, our design has two seller incentive treatments. Sellers can either receive a low commission (10% of the price), or a high commission (100% of the price). We do not find that the commission size is significantly related to the extent of overpricing. In the low commission treatments, 29% overprice by at least \$1 (48% for any $p>v$), which is similar to the incidence of overpricing in the high commission treatment (33.6% $p-v\geq\$1$, 43.1% for any $p>v$; $p > 0.26$).[15] [16]

Second, it is possible that sellers overprice because of envy. While standard models incorporating envy do not predict overpricing[17], it is conceivable that sellers experience envy considering selling a good to customers at a price that is lower than their own willingness to pay. Thus, in the extreme, they may be willing to sell items only for a price at or above their own willingness to pay and as a result, may

[15] The percentages and comparisons are for treatments NI, SI and CI only as these are the treatments in which we have varied commission incentives.

[16] A related possible explanation for overpricing is that sellers believe that customers with minimal values (i.e., \$0.1) will never accept an offer, and that sellers are indifferent in price setting. However, we find little evidence for this explanation. If we exclude customers with minimal offers, 30.6% of the offers are still overpriced by at least \$1 in treatments NI/FNI.

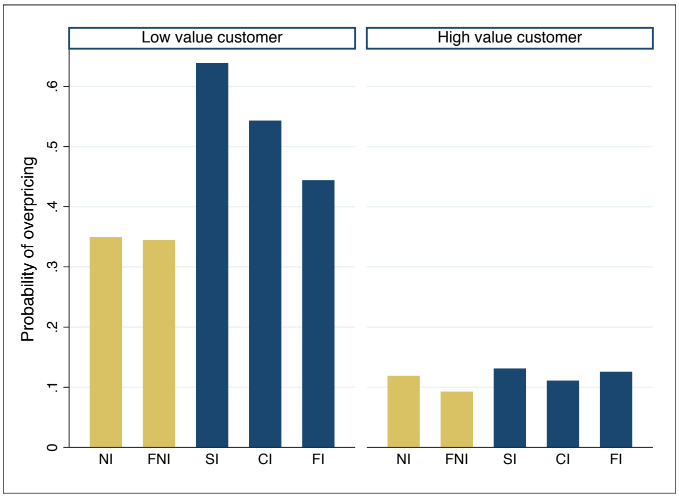
[17] First, standard models that incorporate envy look at the relative distribution of payoffs. In our experiment, there are no payoffs for customers but only a consumer benefit after a sale. Second, and perhaps more importantly, if sellers were to compare their potential monetary payoff to consumer benefit, they would set prices such that the consumer benefit is (close to) zero, which would imply that their monetary payoff exceeds consumer benefit and thus there is no seller envy.

overprice. However, if we look at only offer prices that satisfy this criterion (willingness to pay seller ≥ offer price) and hence exclude this form of envy, we observe no change in the fraction of overpricing (29.6% $p–v≥\$1$, 42.3% for any $p>v$).

The reference point model provides an explanation for strategic overpricing. It posits that a customer does potentially not purchase a good if it is offered at a higher price to her than to another customer. Thus, it can be rational for sellers in treatments SI, CI, and FI to overprice a customer with a low value to secure a sale with a customer who has a high value. Further, the standard model with quality uncertainty posits that a customer potentially does not purchase a good if it is offered at a higher price to her than to another customer if she believes that the lower price corresponds to a low value from the other customer. Consequently, a customer may lower her own value. If this were the case, it would be rational for sellers to overprice low value customers in treatments SI and CI, but not in FI where customers get to know the actual value of the other customer and do not need to make inferences based on prices. Finally, overpricing may be a byproduct of the social norm against price discrimination.

To test why sellers overprice, we distinguish pricing for low value customers and for high value customers. In our experiment, the low value customer is the customer who has the lower value for a given good in a given group. The high value customer is the customer who has the higher value for a given good in a given group. Further, we investigate pricing for these two customer types in the different information treatments.

FIGURE 2: Strategic overpricing of low value customers



Notes: Overpricing is defined as $v–p≥\$1$ to exclude simple rounding to the next dollar amount as explanation, with v being the willingness to pay from part 1 of the experiment and p the offer price in part 2. The low (high) value customer is the customer who has the lower (higher) willingness to pay in a given group for a given item. In treatments NI and FNI, prices are not common knowledge. In treatments SI, CI, and FI, prices are common knowledge and sellers can have reasons to strategically overprice.

Figure 2 illustrates the probability of overpricing depending on the customer type and treatment. On the left side, we observe overpricing for low value customers and on the right side, for high value customers. First, we observe that low value customers are clearly more likely to be overpriced than high value customers ($p<0.001$). More importantly, we observe that overpricing for low value customers is much more common in treatments SI, CI, and FI than in treatments NI and FNI (56.3% vs. 34.7%; $p<0.001$). The difference is particularly pronounced when comparing treatment NI to SI. In SI, overpricing of low value customers almost doubles as compared to in NI (63.9% vs. 36.1%, $p<0.001$). In contrast, overpricing does not become more common when pricing is common knowledge for high value customers (12.4% vs. 10.9%, $p = 0.53$).

Table 6 corroborates these patterns using random effects regressions that control for treatments, customer value, seller value, commission size, and goods. Models 1 and 2 are restricted to low value customers and models 3 and 4 to high value customers. Models 1 and 2 (as well as models 3 and 4) differ on whether we consider only overpricing of at least \$1 or all kinds of overpricing. We find that in all the four models, the customer value and the seller value are highly predictive for overpricing. Customers with lower values are more likely to be overpriced, and the higher the sellers value a good, the more likely they are to overprice it ($p<0.01$).

More importantly, we find that the different information treatments play an important role in overpricing, but only for low value customers. In the first two models, we observe that overpricing is significantly more likely for low value customers in SI as compared to in NI ($p<0.001$). Overpricing is also significantly more likely in treatment CI as compared to in NI ($p=0.004$ in model 1 and $p=0.058$ in model 2). Further, overpricing is marginally more likely in treatment FI as compared to in treatment NI, and thus roughly consistent with the prediction from the reference point model. The positive impact in FI is significant at the 10%-level in model 1, but only insignificantly positive in model 2. Lastly, models 3 and 4 confirm that there are no treatment effects on overpricing for high value customers.

TABLE 6: Probability of overpricing

Model	(1)	(2)	(3)	(4)
Type of overpricing	$v–p≥\$1$	$v>p$	$v–p≥\$1$	$v>p$
Sample	low value customers	low value customers	high value customers	high value customers
Customer value	-0.0406***	-0.0501***	-0.0098***	-0.0129***
	(0.0045)	(0.0044)	(0.0014)	(0.0016)
Treatment FNI	0.0172	0.1258	-0.0182	0.0060
	(0.0740)	(0.0808)	(0.0525)	(0.0697)
Treatment SI	0.2449***	0.2403***	-0.0008	-0.0007
	(0.0575)	(0.0607)	(0.0445)	(0.0609)
Treatment CI	0.1881***	0.1362*	0.0037	-0.0572
	(0.0646)	(0.0718)	(0.0535)	(0.0676)
Treatment FI	0.1184*	0.0766	0.0082	-0.0770
	(0.0713)	(0.0813)	(0.0696)	(0.0776)
Value of seller	0.0094***	0.0064***	0.0064***	0.0047***
	(0.0022)	(0.0023)	(0.0016)	(0.0016)
Seller commission	-0.0517	-0.0292	-0.0395	-0.0356
	(0.0504)	(0.0534)	(0.0400)	(0.0527)
Constant	0.4092***	0.6494***	0.2588***	0.4514***
	(0.0649)	(0.0656)	(0.0523)	(0.0663)

R^2	0.16	0.184	0.098	0.121
N	1638 (301)	1638 (301)	1638 (301)	1638 (301)

Notes: p<.01***, p<.05**, p<0.1*. Random effects linear probability model. Dependent variable = 1 if there is overpricing (either $v–p≥\$1$ or $v>p$), otherwise = 0. Standard errors clustered on seller level in parentheses. Models control the different items. Treatment NI is baseline. N = Number of groups (customers) in parentheses. Low (high) value customer is the customer with the lower (higher) value for a given item in a given group.

RESULT 3: *Pricing systematically deviates from values. Low value customers are frequently overpriced if sellers know that customers are aware of pricing for other customers.*

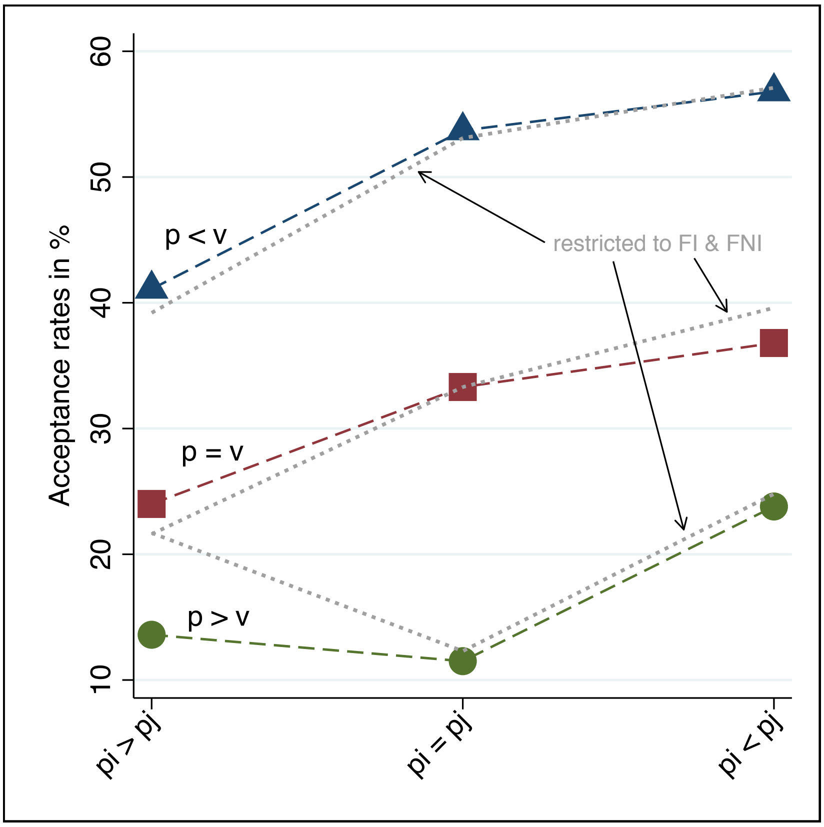
3.2 Reactions to pricing and price discrimination

We now turn to customer reactions to pricing. As expected, the decision to accept an offer strongly depends on the consumer benefit ($v–p$): 51.9% of the offers with positive consumer benefit ($p<v$) were accepted (807 out of 1,556), and 33.5% if $p=v$ were accepted (153 out of 457). We also observe that 14.5% of the offers with negative consumer benefit ($p>v$) were accepted (227 out of 1,567). The findings that almost half of the offers with positive consumer benefit are rejected and that a substantial fraction of the offers with negative consumer benefit is accepted suggest that the price p_i is not the only important variable that determines purchasing decisions.

To further understand purchase decisions, we take into account the price offered to the other customer (p_j). Figure 3 illustrates acceptance rates depending on the type of price discrimination ($p_i<p_j$ = advantageous and $p_i>p_j$ = disadvantageous) and customer benefit ($p>v$, $p=v$, $p<v$), if customers are aware of pricing to other customers (all treatments but NI). For offers with $p<v$, we observe that acceptance rates are lowest if customers face disadvantageous price discrimination (41.1%, N=343), in-between if there is no price discrimination (53.7%, N=570), and highest if there is advantageous price discrimination (56.8%, N=185). The acceptance rate is significantly lower if there is disadvantageous price discrimination as compared to if there is no price discrimination (p=0.0011) or advantageous price discrimination (p=0.0016). The difference in acceptance rates between no price discrimination and advantageous price discrimination is not significant (p=0.531). These findings are consistent with the reference point model, which predicts that disadvantageous price

discrimination lowers the probability of acceptance of offers with positive consumer benefit.

FIGURE 3: Sales depending on type of price discrimination and consumer benefit



Notes: On the left side, we can see the acceptance rates for disadvantageous price discrimination (p_i>p_j); in the middle for uniform pricing (p_i=p_j); on the right side, for advantageous price discrimination (p_i<p_j). Triangles illustrate acceptance rates for offers with positive customer benefit (v>p), squares for offers with zero customer benefit (v=p), and circles for negative customer benefit (v<p). Data comes from all treatments where customers were aware of pricing for other customers (SI, CI, FI, and FNI). Grey dotted lines indicate data for treatments FI and FNI only, in which customers knew the other customer's value.

The acceptance pattern looks similar for offers with p=v. Acceptance rates are lowest if customers face disadvantageous price discrimination (24%; N=50), in-between if there is no price discrimination (33.3%; N=189), and highest if there is advantageous price discrimination (36.8%; N=106). Due to the smaller sample size, however, these differences are not statistically significant using simple non-parametric tests.

Turning to offers with $p>v$, we find that the acceptance rate is higher if there is advantageous price discrimination. While we unsurprisingly find relatively low acceptance rates for offers with $p_i>p_j$ and $p_i=p_j$ (13.6%, N=184 and 11.5%, N=707), the acceptance rate is approximately twice as high in the case of advantageous price discrimination (23.8%, N=286). These differences are highly significant (p=0.0011 comparing $p_i>p_j$ to $p_i<p_j$; p=0.012 comparing $p_i=p_j$ to $p_i<p_j$).

In order to better understand which model can account for the customer reactions, Figure 3 also illustrates the acceptance patterns in treatments FI and FNI. According to the reference point model, acceptances should also depend on the relationship between p_i and p_j in these two treatments, while the standard model with quality uncertainty only predicts such a relationship in treatments SI and CI. We observe that the corresponding grey dashed lines for FI and FNI are very similar to the dashed lines for all treatments, suggesting that the type of price discrimination is still an important driver for acceptances even if customers know the willingness to pay of other customers. For example, customers accept 39.2% of offers with positive consumer benefit if there is disadvantageous price discrimination but 53.1% if there is no price discrimination (p<0.01). These patterns provide further support in favor of the reference point model.

The robustness of these findings is illustrated in Table 7, which uses random effects regressions controlling for offer price, customer value, commission size, goods, and type of price discrimination. Model 1 shows that the likelihood to accept drops by 5.29% for all offers if there is disadvantageous price discrimination as compared to no price discrimination (p=0.023), and that it increases by 5.9% if there is advantageous price discrimination (p=0.012). Model 2 provides a mirror image for treatment NI, and shows that the impact of these two types of price discrimination on acceptance is insignificant when customers do not know p_j. This provides further evidence that the access to information, p_j,, drives the findings. Model 3 shows the significant positive impact of advantageous price discrimination for all offers with $p>v$ (+ 8%, p=0.004). Model 4 shows the significant negative impact of disadvantageous price discrimination for offers with $p=v$ (-19.5%, p=0.02). Similarly, model 5 shows that disadvantageous price discrimination has a significant negative impact on acceptance for offers with $p<v$ (-10.5%, p=0.004). Appendix B, Table A

shows that a continuous measure of price discrimination ($p_j – p_i$) is highly significantly predictive of overall acceptances (model 1), and of underpriced offers (model 4).

Table 8 restricts the sample to treatments FNI and FI, and presents three models to test the relative importance of relative price differences against relative customer value differences. Thus, we can directly compare how well the reference point model fares relative to the standard model with quality uncertainty. Model 1 in Table 8 corresponds to model 1 in Table 7 but uses the restricted sample, and instead of the type of price discrimination, uses a continuous measure ($p_j – p_i$) for relative price differences. We observe that $p_j – p_i$ is significantly positive (p=0.014), showing that acceptance likelihoods increase with a higher offer price for the other customers relative to own offer price. In contrast, customer value differences ($v_j – v_i$) do not have a bearing on acceptances. In model 2, we observe that $v_j – v_i$ is insignificant and has a negative coefficient. Relative customer value difference, $v_j – v_{i,}$ is in fact marginally negatively significant in model 3 (p=0.089), which controls for $p_j – p_i$. In contrast, relative price difference ($p_j – p_i$) predicts acceptances at the 1% significance level in the expected direction. These patterns are consistent with the reference point model but difficult to reconcile with the standard models.

TABLE 7: Probability of sales

Model	(1)	(2)	(3)	(4)	(5)
Customers know pricing for other customers?	yes	no	yes	yes	yes
Price - value relationship	*all*	*all*	$p > v$	$p = v$	$p < v$
Offer price	-0.0278***	-0.0183***	-0.0149***	0.0019	-0.0224***
	(0.0029)	(0.0037)	(0.0025)	(0.0075)	(0.0060)
Customer value	0.0297***	0.0239***	0.0218***		0.0153***
	(0.0026)	(0.0035)	(0.0049)		(0.0037)
Disadvantageous price discrimination	-0.0529**	0.0108	-0.0090	-0.1953**	-0.1052***
	(0.0232)	(0.0402)	(0.0286)	(0.0836)	(0.0353)
Advantageous price discrimination	0.0590**	0.0211	0.0799***	0.0543	0.0680
	(0.0235)	(0.0399)	(0.0276)	(0.0622)	(0.0432)
Seller commission	-0.0012	0.0555	0.0272	-0.0752	-0.0166
	(0.0269)	(0.0471)	(0.0255)	(0.0708)	(0.0472)

Constant	0.1975***	0.0891	0.0890***	0.3491***	0.3739***
	(0.0343)	(0.0572)	(0.0314)	(0.0871)	(0.0701)
R^2	0.144	0.171	0.088	0.095	0.076
N	2620 (262)	960 (96)	1177 (217)	345 (157)	1098 (201)

Notes: p<.01***, p<.05**, p<0.1*. Random effects linear probability model. Dependent variable = 1 if offer is accepted, otherwise = 0. Robust standard errors in parentheses. Models control the different items. N = Number of groups (customers) in parentheses. Customers know pricing for other customers in all treatments but NI. Disadvantageous price discrimination = $p_i > p_j$; advantageous price discrimination = $p_i < p_j$.

TABLE 8: Probability of sales when customers are aware of other customer's values

Model	(1)	(2)	(3)
Offer price	-0.0245***	-0.0255***	-0.0213***
	(0.0039)	(0.0040)	(0.0043)
Customer value	0.0311***	0.0280***	0.0253***
	(0.0026)	(0.0040)	(0.0042)
Price difference $(p_j - p_i)$	0.0113**		0.0143***
	(0.0046)		(0.0050)
Value difference $(v_j - v_i)$		-0.0022	-0.0047*
		(0.0025)	(0.0028)
Seller commission	-0.0101	-0.0091	-0.0058
	(0.0337)	(0.0335)	(0.0338)
Constant	0.1846***	0.2010***	0.1881***
	(0.0428)	(0.0424)	(0.0425)
R^2	0.165	0.17	0.17
N	1460 (146)	1460 (146)	1460 (146)

Notes: p<.01***, p<.05**, p<0.1*. Random effects linear probability model. Sample includes decisions in treatments FI and FNI only. Dependent variable = 1 if offer is accepted, otherwise = 0. Robust standard errors in parentheses. Models control the different items. N = Number of groups (customers) in parentheses.

RESULT 4: *Customers do not have a preference for uniform pricing. While they prefer uniform pricing to disadvantageous price discrimination, they also prefer advantageous price discrimination to uniform pricing. Advantageous price discrimination can even tempt customers to purchase overpriced goods.*

3.3 Temporal patterns of pricing and reactions to price discrimination

In this section, we analyze pricing and reactions to pricing over the course of the experiment. In this manner, we are able to investigate the extent to which our main results are robust, wash out, or manifest. We find that our main results are robust over the 10 periods of the market experiment. We start by looking at the dynamics of price discrimination.

Appendix A, Figure A illustrates the probability of price discrimination in treatments NI and SI for each period of the market experiment. Figure A provides evidence for the robustness of our first two findings. First, the dashed blue line illustrating the probability of price discrimination in treatment NI shows that sellers frequently voluntarily avoid price discrimination when there are differences in their customers' values and that this voluntary restraint does not crowd out over periods. Second, we observe that the dotted red line illustrating the probability of price discrimination in treatment SI is also not increasing, but is rather decreasing, providing evidence that the strategic avoidance of price discrimination does not decrease over periods. Third, we observe that the two lines never intersect and that the gap between them does not shrink. In Appendix B, Table B, we regress the variable price discrimination on our standard set of control variables and see that the interaction between treatments (NI vs. SI in model 1; NI, FNI vs. SI, CI, FI in model 2) and periods is insignificantly negative. This provides econometric support for Figure A that the gap is widening rather than narrowing.

Next, we investigate the dynamics of overpricing. Appendix A, Figure B illustrates the probability of overpricing low value customers in treatments NI and SI over the periods. We observe considerable variance in the probability of overpricing, which is not surprising given that the values are lower for some goods, which renders overpricing as more likely. More importantly, however, we observe that the two lines never intersect. We can see that over periods, overpricing becomes less likely in treatment NI (dashed blue line), while it remains more or less constant in treatment SI (red dotted line). The two lines illustrate that the treatment effect is robust and suggest that overpricing is a stable characteristic of this market. In models 3 and 4 of Appendix B, Table B, we observe that the treatment × period interaction is insignificantly positive, showing that the treatment effect is becoming rather stronger than weaker.

Finally, we look at dynamic reactions to the different types of price discrimination. Appendix A, Figures C and D illustrate the probabilities of accepting an offer over periods, depending on the type of price discrimination. Figure C illustrates acceptances if items are overpriced ($p>v$), and Figure D illustrates acceptances if items are underpriced ($p<v$). While we again need to be cautious when we interpret these findings over periods as goods change, we do observe in Figure C that the importance of relative pricing increases over the course of the experiment. In particular, we observe that the dotted green line increases, illustrating acceptances for overpriced items if there is advantageous price discrimination, and is clearly above the other two lines after period 4. For underpriced items in Figure D, the patterns are less clear. While acceptances for these items are higher at the beginning than for items where there is no price discrimination or disadvantageous price discrimination, this does not hold true for the last three periods.

3.4 Commission size and customer awareness

Our experiment also varied the incentives for sellers by either providing them with a 10% or a 100% commission on the purchase price, which was common knowledge. We used this pronounced difference in commission size to test whether it affects pricing and reactions to pricing. In particular, it seems conceivable that sellers price more conservatively in the high commission treatment, and are more likely to refrain from price discrimination if they fear resistance from customers with certain social preferences. However, we do not find that the commission size affects pricing patterns and reactions to pricing. In regression tables 1-4, we controlled for commission size and do not find that it is a significant predictor for the likelihood of price discrimination, overpricing, and acceptances. Moreover, we find only weak evidence that sellers price more conservatively as prices are insignificantly lower when the commission size is high, and that the effect size is moderate (p=0.103, approximately 75 cents, random effects model).

Another variation in our experimental design is whether customers are aware that sellers know their own willingness to pay. As we argued earlier, it is unclear whether and how customer awareness affects pricing and reactions to pricing. By comparing pricing and reactions to pricing between treatments SI and CI, we can investigate the role of customer awareness.

We find that customer awareness has little bearing on the likelihood of price discrimination and overpricing of low value customers. In Regression Table 1, we observe that sellers are 31.1% less likely to price discriminate in treatment CI as compared to in NI ($p<0.01$). The difference between the CI and SI coefficients is significant at $p=0.096$, showing that price discrimination is marginally more common in CI. In Regression Table 2, we find that the coefficients for SI are somewhat larger than for CI (0.245 vs. 0.188 in model 1; 0.24 vs. 0.136 in model 2), showing that there is insignificantly less strategic overpricing in CI as compared to in SI ($p>0.128$). Nonetheless, overpricing in treatment CI is still more common as compared to in NI ($p<0.01$ in model 1).

Customer awareness also appears to have little influence on purchase decisions. First, the overall acceptance rates between treatments CI and SI is almost identical (30% vs. 30.7%). Second, the acceptance rates depending on customer benefit are similar. More precisely, in treatment CI, 10.9% of offers with $p>v$ and 52.4% of offers with $p<v$ are accepted, which is comparable to SI in which 13.8% of offers with $p>v$ and 50.8% of offers with $p<v$ are accepted. Third, acceptance rates in both CI and SI do not depend on the existence of price discrimination. If there is price discrimination, acceptance rates are 28.5 % and 29.9% in CI and SI respectively, and if there is no price discrimination, acceptance rates are 32.2% and 32.6% in CI and SI respectively. Fourth, the basic pattern of customers being more willing to accept overpriced offers if there is advantageous price discrimination and less willing to accept underpriced offers if there is disadvantageous price discrimination, is also present in treatment CI.

3.5 Bertrand competition

So far, we have analyzed pricing and reactions to pricing in an environment in which sellers have monopoly power. To extend this analysis, in this section, we investigate this behavior in a more competitive market. In our Bertrand competition treatments, two sellers make simultaneous offers to two customers. As hypothesized, we observe that offer prices are lower when there is an additional seller in a group. However, we do not observe that prices drop close to the minimum. The mean offer price in the Bertrand competition treatments is \$3.92, which is 18% lower than in the corresponding monopoly treatments.[18] The lower price contributes to a relatively high acceptance rate of 51.3%.

Despite the competition sellers face, we observe that sellers frequently voluntarily refrain from price discrimination (29.2%) in treatment 4NI. In model 1 of Table 9, we can see that the restraint weakens with increasing customer value differences, just like in treatment NI. Importantly, we observe that there is also considerable strategic avoidance of price discrimination when there is competition between sellers. The probability of price discrimination drops significantly from 70.8% in treatment 4NI to 48.5% in 4SI. In model 2 of Table 9, we can see that this drop is highly significant in a linear probability model ($p<0.01$).

Further, as in the monopoly treatments, we find that sellers strategically overprice low value customers. The probability to overprice low value customers by at least $1 increases from 22.5% to 36.8% when moving from 4NI to 4SI. In models 3 and 4, we can see that this increase is significant at $p=0.056$ and $p=0.090$, respectively.

In the competition treatment, we can also observe whether customers are willing to pay a higher price for a seller who does not price discriminate. Overall, we find that customers are almost always choosing to buy from the cheaper seller (269 out of 277). In treatment 4SI, where customers are aware of pricing for other customers, 96.4% (133 out of 138) of the sales are conducted with the cheaper seller. Only 3 sales are conducted with the more expensive seller who does not use price discrimination. This provides clear evidence that customers are generally unwilling to pay for uniform pricing.

Finally, in models 5-7 of Table 9, we provide some evidence that the customers' likelihood to accept depends on relative pricing in our competition treatments. To better understand relative pricing preferences in the competition context, we focus our attention on the cheaper sellers who offer the lower price for a given item in a given group. We observe that none of the offers ($p>v$) are accepted if there is disadvantageous price discrimination, 12% are accepted if there is no price discrimination, and 32.1% are accepted if there is advantageous price discrimination. Model 6 in Table 9 shows that the likelihood of accepting these offers significantly increases if there is advantageous price discrimination ($p=0.066$). Model 7, in

[18] We compare the high commission treatments NI and SI to 4NI and 4SI (that always had a high commission).

contrast, provides little evidence for the role of relative pricing for offers *p<v*. Model 5 shows that the role of relative pricing for acceptances is not quite significant if we pool over- and underpriced offers.

TABLE 9: Probability of price discrimination, overpricing, and sales in Bertrand competition

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Probability of price discrimination		Probability of overpricing low value customers		Probability of sales		
Sample restrictions			*v-p ≥$1*	*v>p*		*p>v*	*p<v*
Customer value difference	0.0129***	0.0116***					
	(0.0049)	(0.0037)					
Treatment 4SI		-0.2283***	0.1753*	0.1807*			
		(0.0793)	(0.0917)	(0.1067)			
Customer value			-0.0394***	-0.0584***	0.0346***	0.0191	0.0231***
			(0.0105)	(0.0146)	(0.0073)	(0.0165)	(0.0058)
Offer price					-0.0435***	0.0006	-0.0436***
					(0.0125)	(0.0234)	(0.0144)
Disadvantageous price discrimination					-0.0289	-0.1325	-0.0265
					(0.0684)	(0.1589)	(0.0677)
Advantageous price discrimination					0.0916	0.2110*	-0.0125
					(0.0776)	(0.1149)	(0.1184)
Constant	0.8068***	0.7261***	0.6264***	0.8607***	0.1870*	-0.1327*	0.4328**
	(0.0837)	(0.0712)	(0.1143)	(0.1023)	(0.0967)	(0.0710)	(0.1748)
R^2	0.044	0.086	0.168	0.211	0.274	0.369	0.189
N	240 (26)	512 (54)	256 (49)	256 (49)	318 (28)	94 (18)	205 (27)

Notes: p<.01***, p<.05**, p<0.1*. Random effects linear probability model. Models 1 & 2: Dependent variable = 1 if pi≠pj, otherwise = 0. N = Number of groups (sellers) in parentheses. All observations are included where customers had different values for a given item in a given group. Models 3 &4: Dependent variable = 1 if there is overpricing (either v–p≥$1 or v>p), otherwise = 0. Treatment 4NI is baseline in Models 1-4. Models 5-7: Data only from Treatment 4SI. Dependent variable = 1 if offer is accepted, otherwise = 0. Robust standard errors in parentheses. Models control the different items. N = Number of groups (customers) in parentheses. Data is restricted to the lower offer of the two sellers in a given group for a given item. Disadvantageous price discrimination = pi>pj ; advantageous price discrimination = pi<pj.

RESULT 5: *Our four main findings are largely robust in Bertrand markets. Even when sellers compete for a purchase, there is (1) voluntary restraint from price discrimination, (2) strategic avoidance of price discrimination, (3) strategic overpricing, and (4) the increased willingness to accept overpriced offers if there is advantageous price discrimination.*

3.6 The benefits and costs of price discrimination, intensity of price discrimination and uniform price levels

We first investigate whether and when it is optimal for sellers to price discriminate. In Table 10, we regress seller profits in a given period on the existence of price discrimination and commission size in a random effects model. Models 1 – 5 show the impact of price discrimination on profits in treatments NI, FNI, SI, CI, and FI. We observe that price discrimination indeed causes higher seller profits in NI when customers are unaware ($p<0.01$). In treatment FNI, we can see that price discrimination has no significant impact on seller profits when sellers are unaware that customers are aware of price discrimination (coefficient = 0.015, $p=0.967$). This provides evidence that there is no overall cost to the kind of price discrimination sellers use when they believe that customers are unaware of pricing for other customers. In Models 3 – 5, we observe whether sellers can adjust price discrimination in order to increase profits when they are aware that customers are aware. We do not find that sellers are successfully implementing price discrimination. When sellers use price discrimination, their profits do not statistically increase ($p>0.542$).

TABLE 10: Seller profits with and without price discrimination

Model *Treatment*	(1) *NI*	(2) *FNI*	(3) *SI*	(4) *CI*	(5) *FI*
Price discrimination	0.5377*** (0.1678)	0.0146 (0.3529)	0.1151 (0.1889)	0.0494 (0.1960)	-0.0977 (0.3359)
Seller commission	1.5282*** (0.2162)		1.4075*** (0.3061)	1.5395*** (0.3659)	
Constant	-0.1849 (0.1266)	1.9789*** (0.3696)	0.1470** (0.0702)	0.1104 (0.0841)	1.7696*** (0.3325)
R^2	0.181	0.001	0.157	0.149	0.008
N	480 (48)	260 (26)	480 (48)	320 (32)	250 (25)

Notes: p<.01***, p<.05**, p<0.1*. Random effects linear probability model. Dependent variable = 1 if there is price discrimination ($p_i \neq p_j$), otherwise = 0. Robust standard errors clustered on seller level in parentheses. N = Number of periods (seller) in parentheses.

Next, we look at the extent to which sellers price discriminate if they decide to deviate from uniform pricing. We find that sellers cautiously price discriminate.

Overall, we observe that in all cases where sellers price discriminate, the average customer value difference (7.09) is much larger than the average price difference (3.89). Moreover, we observe that there is even significant voluntary avoidance to fully employ price discrimination. If we restrict our sample to treatment NI, we still observe that sellers, on an average, use only approximately 56% of the customer value difference to price discriminate ($|p_i-p_j|$= 4.45; $|v_i-v_j|$=7.97). The use of the intensive margin is less pronounced in treatments where prices are public. For example, in treatment SI, we observe that sellers use only approximately 42% of the intensive margin ($|p_i-p_j|$= 2.74; $|v_i-v_j|$=6.61).

Finally, we take a look at the price level if sellers decide to price uniformly. We investigate whether sellers set the uniform price below or at the low value customer's value, between the low and high value customers' values, or at or above the high value customer's value. Overall, we observe that 26.2% choose a uniform price below or at the low value customer's value, 44.5% choose a uniform price between the low and high value customers' value, and 29.3% at or above the high value customer's value. At first sight, there seem to be no clear differences between information treatments. For example, the corresponding percentages for treatments NI (SI) are: 24.4% (18.7%), 39.2% (46.2%), 36.4% (35.1%). However, if we focus on cases where there are larger customer value differences (>7), we observe that uniform pricing between the low and high customer value becomes much more likely in treatment SI (83%) than in NI (42.8%). A closer look at pricing in treatment SI shows that the uniform price is often set roughly in the middle of the low and high value customer's value.

4. Discussions and Conclusion

We lack knowledge on the actual use of personalized pricing. This is not surprising as sellers often view personalized pricing as the "holy grail of retailing"[19] and are reluctant to reveal their pricing strategies. Perhaps more importantly, we lack an understanding of the behavioral constraints on personalized pricing. One possible explanation is that customers avoid buying from sellers who use personalized pricing.

[19] See e.g. http://abcnews.go.com/Business/supermarkets-introduce-personalized-pricing/story?id=21010246

There is indeed suggestive evidence that buyers sometimes oppose personalized pricing, and assuming that this actually affects purchase decisions, it may explain why we observe relatively little of it. If this were true, one should expect that behavioral constraints on pricing systematically vary with the information buyers have about personalized pricing. Thus, to truly generate a first glimpse into the scope of personalized pricing, we not only need to be able to observe it but also be able to investigate it in systematically different information landscapes, while holding all other factors (e.g. product, seller, time etc.) constant.

This is what our study offers. We experimentally test whether there are any behavioral constraints on personalized pricing in different environments. Our approach is to use a novel laboratory experiment that integrates crucial field elements by investigating pricing and purchase decisions for actual goods in different treatment conditions. Our findings show that there are significant behavioral constraints on personalized pricing. While customers do not generally oppose personalized pricing, they are less likely to purchase if their offer price is higher than the offer price for someone else. On the other hand, they are more likely to purchase if their offer price is lower than that for someone else. Sellers work around these constraints by frequently avoiding price discrimination and overcharging low value customers.

Besides capturing pricing and reactions to personalized pricing in different environments, we present an experimental design that renders it possible to test different models that provide a rationale for why customers are antagonized by personalized pricing. Our results suggest that reference points play a crucial role for pricing and the avoidance of price discrimination, and the standard model and non-standard preference models do not square well with the data.

Our methodology is a hybrid between a laboratory and field experiment. We designed the experiment to capture crucial features of the laboratory and field at the expense of compromises on different levels. Our experiment is more complex than a standard laboratory experiment as it involves two parts and does not rely on induced values. Further, customers in our experiment are endowed with money and then decide over purchasing a set of arbitrary goods, which contrasts with typical purchase decisions in the field where customers usually spend money that they have earned for targeted goods. It is possible that pricing and reactions to pricing vary with these factors and it seems worthwhile to investigate whether there are systematic patterns to better determine the scope of personalized pricing.

We view our study as a first step towards understanding the role of behavioral constraints for price discrimination, and hope that it serves as a starting point for future research. In particular, it would be interesting to understand why exactly prices for other customers serve as reference points. One potential explanation is that customers want to avoid being duped into paying more for a good. A related question is whether reactions to personalized pricing depend on customer characteristics. One potentially important characteristic is wealth, which might lead customers to be less antagonized by disadvantageous price discrimination if other customers are poorer.

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