Experimenting with Purchase History Based Price Discrimination: a Comment

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Abstract

Brokesova, Deck and Peliova [Int. J. Ind. Organ. 37 (2014) 229-237] have shown that comparative static results from two-period behavior-based pricing models hold in laboratory experiments, but they observed significant differences from point predictions. We report findings in conformity with these point predictions throughout a uniform pricing benchmark, a replication of Brokesova, Deck and Peliova's behavior-based pricing treatment and a follow-up experiment. Reference dependence seems to shift participants' second-period pricing behavior upwards. A post hoc analysis shows that considering myopic consumers instead of strategic consumers explains a downward shift of first-period prices and rationalizes the findings of Brokesova, Deck and Peliova. Volatile price levels affect price-based welfare measures such as sellers' profits and customers' total costs. We show that transport costs serve as a robust welfare measure, alleviating the impact of distorted prices. These findings are relevant for the design of experiments and when assessing the efficiency of experimental markets.

Keywords: Behavior-based price discrimination, pricing experiment

JEL Codes: D43, L13

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1 Introduction

The majority of papers on behavior-based pricing originated from Fudenberg and Tirole (2000, henceforth F&T). Most commonly, the models in these papers are characterized by a two-period structure, where consumers are served by two sellers at uniform prices in the first period and at differentiated prices in the second period. The second-period prices are differentiated according to the first-period purchasing decisions of consumers. Among these papers is Chen and Pearcy (2010) who study the role of varying degrees of preference dependence and price pre-commitment. Brokesova et al. (2014, henceforth BDP) implement the model of Chen and Pearcy (2010) experimentally by varying the ability to price pre-commit and the persistence of preferences. Their first case directly corresponds to the simple short-term contracts with independent preferences from F&T, while their second case corresponds to poaching under short-term contracts (behavior-based pricing) from F&T.

With their results BDP support the comparative static predictions of Fudenberg and Tirole (2000) and Chen and Pearcy (2010). However, they encounter discrepancies between the models' point predictions and their findings. BDP's observed profits and customer costs are driven by the skewed price levels and predominantly do not reflect the theoretical predictions either. This paper aims to clarify two issues. First, we want to explore why point the predictions for prices do not hold and whether there are circumstances under which they do. Second, we want to show that transport costs are a more appropriate welfare measure whenever price predictions do not hold, albeit comparative static results do.

We introduce a benchmark uniform pricing treatment following F&T for which we observe convergence towards price predictions in both periods. This contrasts the first case of BDP, where first-period prices are similar to our experiment, while participants chose lower than predicted second-period prices. In our second treatment, where behavior-based pricing is permitted, we observe that first-period prices converge towards price predictions which contrasts BDP's second case, while second-period prices diverge from price predictions in line with BDP. In a follow-up experiment we only consider the second period, using simulated first-period cutoffs. There we do not observe divergence of second-period prices.

The most puzzling discrepancy is the difference in first-period prices between the second case of BDP and our behavior-based pricing treatment. Unlike BDP we observe higher prices and a peak in the distribution at the theoretical point prediction. The most evident explanation for this difference is that BDP actually implemented myopic instead of strategic consumers and subjects use experimentation rather than deduction in their pricing decisions in the experiment. We show that assuming myopic consumers leads to a theoretical prediction, which is in line with the observed prices in BDP's second case.

Welfare measures such as customer costs and profits are directly derived from prices. When prices are volatile and prone to behavioral biases, then the same is true for these measures. We show that transport costs serve as a robust welfare measure, which is independent of price levels but captures the impact of price dispersion and poaching efforts by sellers.

2 An experiment on uniform and behavior-based pricing

BDP analyzed behavior-based pricing while varying two dimensions: the ability to price pre-commit and the extent of preference dependence. We step back from this by contrasting whether sellers can employ behavior-based pricing or not. We do not consider price pre-commitment and we only consider perfectly dependent preferences. Taken together our set-up boils down to a comparison of uniform pricing and behavior-based pricing as laid out by F&T.

2.1 Theoretical background

The market structure underlying this experiment closely follows F&T. Two sellers $i, j \in \{A, B\}$ with $i \neq j$ are located on either endpoint of a linear city model a la Hotelling with length $\bar{\theta}$. We assume that A is located at 0 and B is located at $\bar{\theta}$. Both sellers produce nondurable goods at constant marginal costs of c over two periods $n \in \{1, 2\}$. Consumers are distributed uniformly over the interval $[0, \bar{\theta}]$ and demand one at most unit per period. The consumers' valuation of the good is v and they incur transport costs which corresponds to the distance travelled. Thus, a consumer located at $\hat{\theta}$ receives utility $v - p_A - \hat{\theta}$ when buying from seller A and $v - p_B - (\bar{\theta} - \hat{\theta})$ when buying from seller B. Sellers, as well as consumers do not discount the second period. Throughout we assume v is sufficiently high to ensure full market coverage.

Uniform pricing

In the first case, both sellers post a uniform price p_i^n in each period n. After observing prices p_A^n and p_B^n, there is a consumer at θ_n who is indifferent between buying from A or B. The consumers' according indifference condition is

$$v - p_A^n - \theta_n = v - p_B^n - (\bar{\theta} - \theta_n). \tag{1}$$

From this we can derive θ_n as the location of the indifferent consumer as

$$\theta_n = \frac{p_B^n - p_A^n + \bar{\theta}}{2}. \tag{2}$$

In each period sellers face a static optimization problem

$$\text{Seller A: } \underset{p_A^n}{max}\ (p_A^n - c) \cdot \theta_n \quad \text{Seller B: } \underset{p_B^n}{max}\ (p_B^n - c) \cdot (\bar{\theta} - \theta_n). \tag{3}$$

We use the first order condition to find the response functions

$$p_i^n = \frac{p_j^n + c + \bar{\theta}}{2}. \tag{4}$$

By symmetry we find the according equilibrium prices

$$p_i^n = \bar{\theta} + c. \tag{5}$$

This corresponds to the theoretical prediction for Case 1 "Independent preferences and no price pre-commitment" of BDP, as every price is the one-shot Nash equilibrium price.

Behavior-based pricing

In the second case, both sellers post a uniform price in period 1 (p_A^1 and p_B^1) and employ behavior-based pricing in the second period. Behavior-based pricing allows them to set differentiated prices for old costumers (p_A^O and p_B^O) and new costumers (p_A^N and p_B^N), dependent on the first-period purchasing decisions. A consumer who bought from firm i in the first period is considered an old costumer for firm i and a new costumer for firm j and vice versa. We solve the game via backward induction. When entering the second period first-period prices p_A^1 and p_B^1 determine the location of the indifferent consumer θ_1, which sellers observe. Consumers on the interval $[0, \theta_1]$ bought from seller A in period 1 and are denoted as A's turf, while consumers on the interval $[\theta_1, \bar{\theta}]$ bought from firm B and are denoted as B's turf. Both sellers charge the old customer price (p_A^O and p_B^O) towards their own turf and the new costumer price (p_A^N and p_B^N) towards the other seller's turf. On A's turf consumers are faced with the prices p_A^O by A and p_B^N by B. Given these prices we can set up the indifference condition for the consumer at location $\theta_A \in [0, \theta_1]$

$$v - p_A^O - \theta_A = v - p_B^N - (\bar{\theta} - \theta_A). \tag{6}$$

From this we solve for θ_A and get

$$\theta_A = \frac{p_B^N - p_A^O + \bar{\theta}}{2}. \tag{7}$$

Similarly, we derive $\theta_B \in [\theta_1, \bar{\theta}]$

$$\theta_B = \frac{p_B^O - p_A^N + \bar{\theta}}{2}. \tag{8}$$

In the second period sellers solve the following optimization problems as functions of θ_1:

$$\begin{aligned} &\textit{Seller A: } \max_{p_A^O, p_A^N} \; (p_A^O - c) \cdot \theta_A + (p_A^N - c) \cdot (\theta_B - \theta_1), \\ &\textit{Seller B: } \max_{p_B^O, p_B^N} \; (p_B^O - c) \cdot (\bar{\theta} - \theta_B) + (p_B^N - c) \cdot (\theta_1 - \theta_A). \end{aligned} \tag{9}$$

Using the first order conditions we can derive the optimal second-period prices as

$$\begin{aligned} p_A^O &= \frac{1}{3}(2\theta_1 + \bar{\theta} + 3c), \qquad & p_A^N &= \frac{1}{3}(3\bar{\theta} - 4\theta_1 + 3c), \\ p_B^O &= \frac{1}{3}(3\bar{\theta} - 2\theta_1 + 3c), \qquad & p_B^N &= \frac{1}{3}(4\theta_1 - \bar{\theta} + 3c). \end{aligned} \tag{10}$$

In the first period, forward-looking consumers can anticipate these pricing strategies. The first-period cutoff θ_1 denotes the consumer who is indifferent between *i)* buying from seller A in the first period and switching to seller B in the second period and *ii)* buying from seller B in the first period and switching to seller A in the second period. The indifference condition is

$$v - p_A^1 - \theta_1 + v - p_B^N - (\bar{\theta} - \theta_1) = v - p_B^1 - (\bar{\theta} - \theta_1) + v - p_A^N - \theta_1. \tag{11}$$

Using p_A^N and p_B^N from 10 we can solve this for θ_1 and find

$$\theta_1 = \frac{3}{8}(p_B^1 - p_A^1) + \frac{\bar{\theta}}{2}. \tag{12}$$

In the first period forward-looking sellers face the following optimization problems:

$$\begin{aligned} &\max_{p_A^1} \; (p_A^1 - c)\theta_1 + (p_A^O - c)\theta_A + (p_A^N - c)(\theta_B - \theta_1), \\ &\max_{p_B^1} \; (p_B^1 - c)(\bar{\theta} - \theta_1) + (p_B^O - c)(\bar{\theta} - \theta_B) + (p_B^N - c)(\theta_1 - \theta_A). \end{aligned} \tag{13}$$

We plug in the expressions for θ_1 from 12 and for p_A^O, p_A^N, p_B^O and p_B^N from 10 and solve the resulting first order conditions for p_A^1 and p_B^1 to yield the symmetric equilibrium prices as

$$p_i^1 = \frac{4}{3}\bar{\theta} + c \qquad p_i^O = \frac{2}{3}\bar{\theta} + c \qquad p_i^N = \frac{1}{3}\bar{\theta} + c. \tag{14}$$

This is equivalent to Case 2 “Constant preferences and no price pre-commitment” of BDP.

2.2 Experimental design

We implement an experiment in line with BDP with two treatments, corresponding to our two cases from Section 2.1. The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher, 2007). Like BDP we chose $\bar{\theta} = 120$ and $c = 50$, so that results are directly comparable. As shown in Table 1, our predictions for Treatment 1 "Uniform pricing" correspond to the predictions of Case 1 of BDP, where the two afternoon prices (*Price for loyal customers* and *Price for new customers*) of BDP are condensed into the single *Second-period price*. Treatment 2 "Behavior-based pricing" is a replication of Case 2 of BDP.[1]

Treatment	1	2
	Uniform pricing	Behavior-based pricing
Introduction price	170	210
Old customer price		130
New customer price		90
Second-period price	170	

a) Price predictions in our Treatments.

Case	1-Baseline	2
Buyer Preferences	Independent	Fixed
Price pre-commitment	No	No
Morning price	170	210
Price for loyal customers	170	130
Price for new customers	170	90

b) Excerpt from Table 1 in BDP.

Table 1: Price predictions.

There are two minor differences between our experiment and that of BDP. First, BDP framed the task as ice-cream vendors on a beach, whereas we kept the task general, stating the participants take the role of a seller who is located at location 0 of a line, with another seller at the opposing end at 120. However, as in BDP they learn that they compete for computerized buyers who are uniformly distributed along the line. They were informed that buyers make decisions under consideration of prices and transport costs of both periods and seek to minimize their total expenditures.[2] Second, in contrast to BDP who used matching groups of 4, we use the whole group of 20 participants in the first and 18 participants in the second treatment as a matching group. As in BDP participants play over 20 rounds, where one round lasts for two periods, corresponding to the theoretical market. Hence, each participant is matched with each other participant slightly more than once on average in our experiment. While this reduces the number of independent groups, it also decreases reputation effects that could lead to tacit collusion.

[1] Our *Introduction price* corresponds to the *Morning price*, our *Old customer price* corresponds to the *Price for loyal customers* and our *New customer price* corresponds to the *Price for new customers*.

[2] Instructions and review questions were handed out in print and are available upon request.

The experiment was conducted in the experimental laboratory at TU Berlin with participants drawn from the WZB ORSEE pool (Greiner, 2015). The experiments lasted around 90 minutes. On average participants earned €7.20 in the first treatment and €7.75 in the second treatment in addition to a €5 show-up fee. Participants were 25 years old on average. Around one third of the subjects were female. About two thirds of the participants were in their undergraduate studies, with industrial engineering and natural sciences as the most common fields of study.

2.3 Results

Table 2 shows aggregate behavior between our two treatments on the left and the two cases of BDP on the right, where p-Values are based on random-effects GLS regressions on the difference among observed and predicted prices at the individual level.

Treatment	1	2
	Uniform pricing	Behavior-based pricing
Introduction price		
Observed mean	147.3	174.2
Model prediction	170	210
p-Value	<0.001	<0.001
Old customer price		
Observed mean		149.77
Model prediction		130
p-Value		0.013
New customer price		
Observed mean		114.6
Model prediction		90
p-Value		<0.001
Second-period price		
Observed mean	141.4	
Model prediction	170	
p-Value	<0.001	

a) Prices by treatment in our experiment.

Case	1-Baseline	2
Buyer Preferences	Independent	Fixed
Price pre-commitment	No	No
Morning price		
Observed mean	141.5	138.2
Model prediction	170	210
p-Value	0.002	<0.001
Price for loyal customers		
Observed mean	119.7	129.2
Model prediction	170	130
p-Value	<0.001	0.750
Price for new customers		
Observed mean	116.5	114.1
Model prediction	170	90
p-Value	<0.001	<0.001

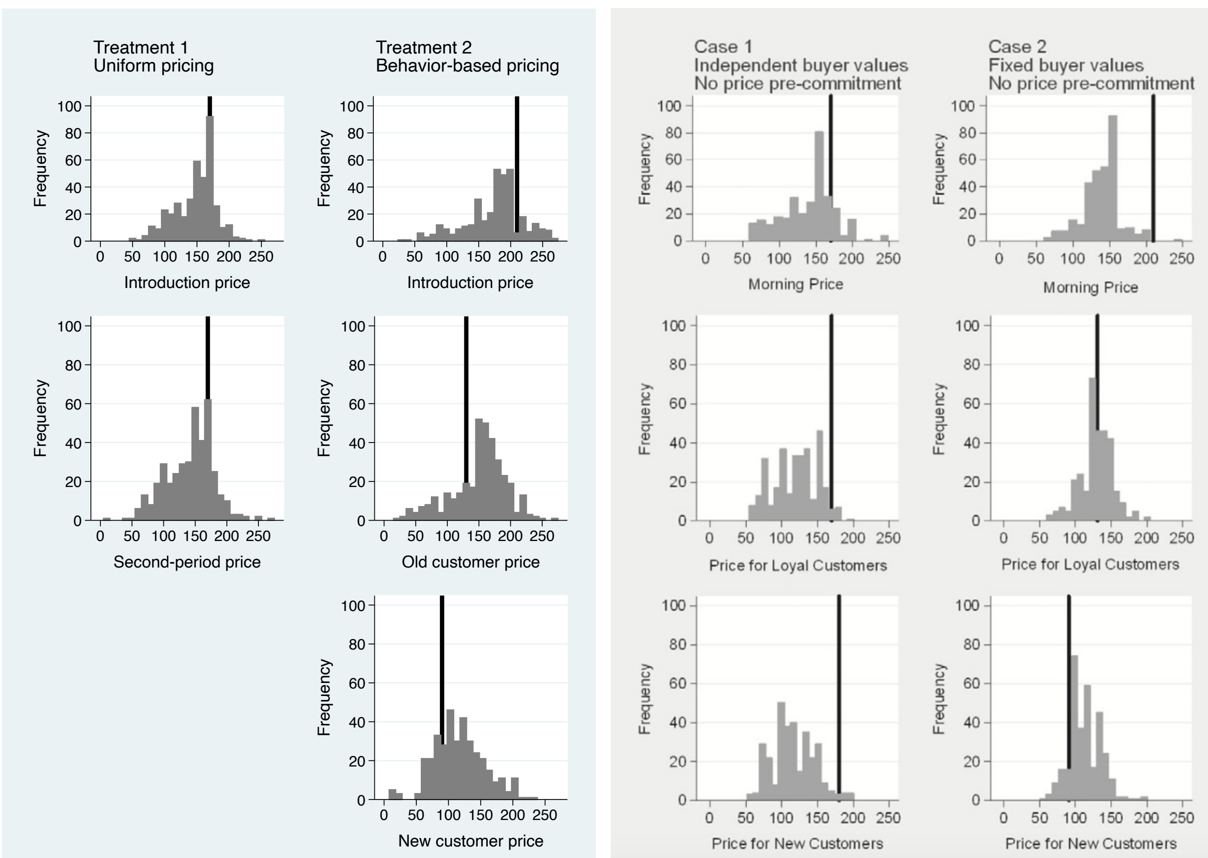
b) Excerpt from Table 2 in BDP.

Table 2: Comparison of observed prices.

While BDP observed no significant difference in their Case 1 between both second-period prices, they found a difference between second-period prices and the first-period price (see

Afternoon price effect in Table 2 of BDP). We do not find a significant difference between the corresponding introduction price and second-period price in our first treatment (see Table 6 in the Appendix). Likewise, the distributions of introduction and second-period prices are very similar in our experiment, as shown in Figure 1a, in contrast to BDP, as shown in Figure 1b.

We observe a substantially larger average introduction price in Treatment 2 compared to Case 2 of BDP. We also observe a larger old customer price, but a similar new customer price. As shown in the distribution of prices in Figure 1a we observe similar patterns for the introduction prices in both treatments, with a left-skewed distribution which peaks close to the theoretical prediction. This is not the case in BDP, as seen in Figure 1b. Accordingly, as shown in Table 6 in the Appendix, we observe a much larger second-period price effect compared to the corresponding *Afternoon price effect* in Table 2 of BDP, as well as a larger old customer price effect compared to the corresponding *Loyal customer price effect* in Table 2 of BDP.



(a) Treatments 1 and 2 in our experiment. (b) Cases 1 and 2 in BDP.

Figure 1: Comparison of distribution of prices (solid lines represent predicted prices).

The introduction price in our Treatment 2 is significantly larger than in Treatment 1 (see Table 7 in the Appendix), confirming a treatment effect on the first-period price in line with the comparative static prediction of the model. This effect was absent in BDP. In contrast to BDP we see a larger rightwards shift for old customer prices.

In Figure 3 in the Appendix, we show the average prices over rounds. We find that prices converge towards their prediction in Treatment 1, which we confirm by round-wise OLS regressions on the difference of observed and predicted prices, as shown in Table 8 in the Appendix. By the last round this difference is close to and insignificantly different from zero for both the introduction price and the second-period price. We observe a similar pattern for the introduction price in Treatment 2. Yet, we find a different pattern for the second-period prices in Treatment 2. Both old and new customer prices are insignificantly different from their predictions in the beginning, but significantly larger than their predictions in the second half of the experiment.[3]

In the spirit of backward induction, we first explore the apparent divergence from predicted levels of the second-period prices in behavior-based pricing experiments, which is observed in BDP and our experiment. Subsequently, we show a potential explanation for the disparity of first-period prices between BDP and our experiment.

3 Reference dependence impacts second-period prices

First-period prices converge towards the price predictions in both of our treatments. Second-period prices in Treatment 2 seemingly diverge from their price predictions. In this chapter we explore why that is the case by limiting our attention to the second period. First, we show that theoretical subgame predictions for second-period prices increase whenever the cutoff is not sufficiently centered. This increase, however, is not substantial and does not explain the higher observed prices. Second, we show results of a follow-up experiment, where we simulate the first-period cutoffs based on our prior findings. In this follow-up experiment participants act close to the price predictions throughout all 20 rounds.

3.1 Theoretical preamble

In Case 2 of BDP and our Treatment 2 second-period prices were remarkably higher than theoretically predicted. In the following we want to rule out asymmetric market shares as a driver for these observations. The equilibrium in (14) is symmetric and implies $\theta_1 = \bar{\theta}/2$.

[3] Results in Figure 3 and Table 8 use the subgame corrected predictions which are introduced in Chapter 3.1 and are even stronger when not using the correction.

In our Treatment 2, we observe first-period cutoffs between the full range of 0 and $\bar{\theta} = 120$, while only 3.89% of the observed cutoffs are exactly $\bar{\theta}/2 = 60$. Hence, we need to check whether first-period cutoffs of $\theta_1 \neq \bar{\theta}/2$ affect second-period prices.

Let us fully specify the best-response functions from (10) for firm A

$$p_A^O = \begin{cases} \frac{1}{3}(2\theta_1 + \bar{\theta} + 3c) & \text{if} \quad \theta_1 \geq \frac{1}{4}\bar{\theta} \\ \bar{\theta} - 2\theta_1 + c & \text{if} \quad \theta_1 < \frac{1}{4}\bar{\theta} \end{cases}, \quad p_A^N = \begin{cases} \frac{1}{3}(3\bar{\theta} - 4\theta_1 + 3c) & \text{if} \quad \theta_1 \leq \frac{3}{4}\bar{\theta} \\ c & \text{if} \quad \theta_1 > \frac{3}{4}\bar{\theta} \end{cases}. \tag{15}$$

Similar for firm B we get

$$p_B^O = \begin{cases} \frac{1}{3}(3\bar{\theta} - 2\theta_1 + 3c) & \text{if} \quad \theta_1 \leq \frac{3}{4}\bar{\theta} \\ 2\theta_1 - \bar{\theta} + c & \text{if} \quad \theta_1 > \frac{3}{4}\bar{\theta} \end{cases}, \quad p_B^N = \begin{cases} \frac{1}{3}(4\theta_1 - \bar{\theta} + 3c) & \text{if} \quad \theta_1 \geq \frac{1}{4}\bar{\theta} \\ c & \text{if} \quad \theta_1 < \frac{1}{4}\bar{\theta} \end{cases}. \tag{16}$$

Now we denote the average prices for *old* and *new* customers respectively as $\bar{p}_O = (p_A^O + p_B^O)/2$ and $\bar{p}_N = (p_A^N + p_B^N)/2$ dependent on θ_1 and get

$$\left(\bar{p}^O, \bar{p}^N\right) = \begin{cases} \left(\bar{\theta} - \frac{4}{3}\theta_1 + c,\ \frac{\bar{\theta}}{2} - \frac{2}{3}\theta_1 + c\right) & \text{if} \qquad \theta_1 < \frac{1}{4}\bar{\theta} \\ \left(\frac{2}{3}\bar{\theta} + c,\ \frac{\bar{\theta}}{3} + c\right) & \text{if} \quad \frac{1}{4}\bar{\theta} \leq \theta_1 \leq \frac{3}{4}\bar{\theta} \\ \left(\frac{4}{3}\theta_1 - \frac{\bar{\theta}}{3} + c,\ \frac{2}{3}\theta_1 - \frac{\bar{\theta}}{6} + c\right) & \text{if} \qquad \theta_1 > \frac{3}{4}\bar{\theta} \end{cases}, \tag{17}$$

where we can take the first derivate with respect to θ_1:

$$\left(\frac{\partial \bar{p}^O}{\partial \theta_1}, \frac{\partial \bar{p}^N}{\partial \theta_1}\right) = \begin{cases} \left(-\frac{2}{3},\ -\frac{1}{3}\right) & \text{if} \qquad \theta_1 < \frac{1}{4}\bar{\theta} \\ \left(\ 0,\ 0\ \right) & \text{if} \quad \frac{1}{4}\bar{\theta} \leq \theta_1 \leq \frac{3}{4}\bar{\theta} \\ \left(\ \frac{2}{3},\ \frac{1}{3}\right) & \text{if} \qquad \theta_1 > \frac{3}{4}\bar{\theta} \end{cases}. \tag{18}$$

A change in the first-period cutoff does not affect the average old and new customer prices while $\theta_1 \in [\bar{\theta}/4,\ 3 \cdot \bar{\theta}/4]$. When correcting the model predictions for Treatment 2 according to equation 15 we would expect an average old customer price of 132.55 instead of 130 and an average new customer price of 91.275 instead of 90.[4] As the results shown in Figure 3 and Table 8 are created under the corrected model predictions, we can rule out asymmetric first-period market shares as a driver for higher second-period prices.

[4]First-period cutoffs were not sufficiently centered in 1/6 of our observations and caused a change in the average predicted prices.

3.2 Experimental follow-up

We conduct an additional Treatment 3 "Follow-up experiment" in which we forego the first period of Treatment 2. We provide participants the required information, the first-period cutoff, without being confounded by the theoretically unnecessary information of first-period prices. In the follow-up experiment participants were confronted with a similar market situation as in the original experiment, only that the first period has already been played. Similar to before, participants took the role of sellers and posted prices for 'near' and 'far' customers. The 'near' customers correspond to the old costumers, while 'far' customers correspond to the new customers from Treatment 2.[5] Participants were faced with randomly simulated cutoffs and learned that these were derived from earlier experiments.

In Figure 5 in the Appendix, we show the distribution of first-period cutoffs in Treatment 2. Using a qq-plot (see Figure 4 in the Appendix), Shapiro-Wilk tests and Shapiro-Francia tests, we confirmed that the first-period cutoffs follow normal distributions, both overall and for each individual period. However, around 60% of the observations are actually multiples of 3.75, which results whenever the difference of chosen prices is a multiple of 10. To account for this, we draw the according share of cutoffs from a truncated normal distribution of multiples of 3.75[6] and the rest out of a normal distribution of multiples of 0.375[7]. Further we account for the fact that 3.75 is a multiple of 0.375, when specifying the respective shares. We do this, by first drawing from a uniform distribution on the interval $[0, 1]$ to determine from which of the two normal distributions to draw, given a critical value. The critical value is derived from the observed share of cutoffs which are multiples of 3.75 called s_{10} and those that are not s_{-10} by solving the following system of equations:

$$\begin{aligned} s_{10} &= s_{10}^{crit} + \frac{s_{-10}^{crit}}{10}, \\ s_{-10} &= \frac{9}{10} s_{-10}^{crit}, \\ s_{-10} &= 1 - s_{10}. \end{aligned} \tag{19}$$

For example, if for a given round the first-period price difference was a multiple of 10 in 6 out of 10 markets, i.e. $s_{10} = 0.6$, we would find the critical cutoff value $s_{10}^{crit} = 0.\overline{55}$. To keep the draws as close to the original observations as possible and avoid situations for the participants that did not occur in the original experiment, we fix the mean at 60, but vary the lower bound, upper bound, standard deviation and the critical value s_{10}^{crit} for

[5]For the remainder of this paper we will refer to the customers in Treatment 3 as old and new customers.
[6]3.75 is $\frac{3}{8} \cdot 10$, the most common integer step of differences between two prices
[7]0.375 is $\frac{3}{8} \cdot 1$, the smallest integer step of differences between two prices

each round according to the original experimental values of the respective round. Truncated normal distributions are achieved by redrawing an observation when it is either below the lower bound or above the upper bound. Given that the lower bounds (upper bounds) are well below (above) the mean at a considerably low standard deviation, this approach is highly efficient (see Robert, 1995; Chopin, 2011). In Figure 6 in the Appendix, we show the distribution of simulated cutoffs in Treatment 3 against the distribution of cutoffs in Treatment 2.

As in the first two treatments participants, were drawn from the WZB ORSEE pool and shared similar demographic characteristics (age, gender, field of study). The experiment was slightly shorter in duration at 60 minutes, as no first period was played. The participants earned €6.24 on average in addition to a €5 show-up fee. The exchange rate was increased so that the total payment remained similar to the first two treatments.

3.3 Findings

A comparison of aggregate prices in Table 3[8] and the distribution of prices in Figure 2 reveals that second-period prices are insignificantly different from their model prediction at a 5% significance level in Treatment 3. Further, both prices are significantly lower in Treatment 3 compared to Treatment 2 (see Table 7 in the Appendix).

Treatment	2	3
	Behavior-based pricing	Follow-up experiment
Old customer price		
Observed mean	149.77	125.06
Model prediction	130	130
p-Value	0.013	0.068
New customer price		
Observed mean	114.6	83.65
Model prediction	90	90
p-Value	<0.001	0.088

Table 3: Analysis of Prices (follow-up).

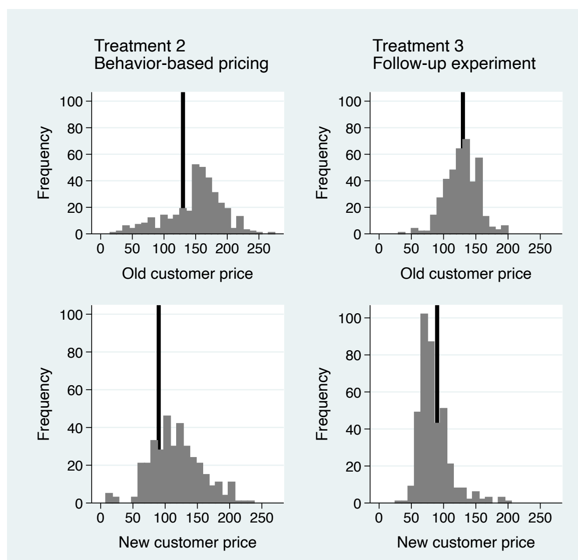


Figure 2: Distribution of prices (follow-up).

For the subsequent discussion we correct the model predictions by calculating second-

[8] Again, p-Values are based on random-effects GLS regression among observed and predicted prices at the individual level.

period predictions following equation 15. However, we only find a marginal impact of these corrections with an average predicted old customer price of 131.53 and an average predicted new customer price of 90.76.

We find that in Treatment 2, second-period prices increase together with the introduction price, as shown in Figure 3 in the Appendix. In Treatment 3, where the first period is absent we do not observe a considerable change of prices over rounds. This is confirmed by round-wise OLS regressions shown in Table 8 in the Appendix. We only observe two rounds in which both the old and new customer price are significantly different from their predictions and three instances where one of the two prices is significantly different from the prediction.[9]

We still observe a significant old customer price effect with a similar effect size as in the behavior-based pricing treatment, as shown in Table 6 in the Appendix. We conclude that the presence of the first period does impact overall price levels in the second period, but does not affect the poaching efforts within the second period.

4 Myopic consumers induce lower first-period prices

While we have shown that the upwards price shift in the second period is driven by the availability of the first-period prices, there are remarkable differences between the chosen first-period prices in Case 2 of BDP compared to the second treatment in our experiment. In the following we conjecture that this might be driven by a faulty fraction in the computation of the first-period cutoff in the code of BDP. We show that this may in fact represent a case of behavior-based pricing with myopic consumers.

Behavior-based pricing with myopic consumers

Whether consumers are naïve or strategic only alters their actions in the first period. Hence we can readily skip the analysis of the second period, as it is identical to the case of behavior-based pricing in section 2.1. When going back to period one naivety of consumers will change the indifference condition from (11) to

$$v - p_A^1 - \theta_1' = v - p_B^1 - (\bar{\theta} - \theta_1'). \tag{20}$$

This condition is akin to (1) with θ_1' instead of θ_1 and thus yields the same cutoff as (2)

$$\theta_1' = \frac{p_B^1 - p_A^1 + \bar{\theta}}{2}. \tag{21}$$

[9]Note that we performed these regressions at a complaisant significance level of 90%. Four out of the seven aforementioned significant differences would not hold under a significance level of 95%.

The maximization problems of firms are similar to (13) with θ_1' plugged in instead of θ_1:

$$\begin{aligned} &\underset{p_A^1}{max}\ (p_A^1 - c)\theta_1' + (p_A^O - c)\theta_A + (p_A^N - c)(\theta_B - \theta_1'), \\ &\underset{p_B^1}{max}\ (p_B^1 - c)(\bar{\theta} - \theta_1') + (p_B^O - c)(\bar{\theta} - \theta_B) + (p_B^N - c)(\theta_1' - \theta_A). \end{aligned} \tag{22}$$

Solving the maximization problems for p_A^1 and p_B^1 with consideration of θ_1' from (21) and the response functions from (10), where we replace θ_1 by θ_1', yields

$$p_i^1 = \bar{\theta} + c. \tag{23}$$

This result is identical to the uniform pricing result in (5).[10]

Case 1 of BDP and the just presented "behavior-based pricing with myopic consumer" share the term $(p_B^1 - p_A^1 + \bar{\theta})/2$ as their first-period cutoff. Case 2 of BDP and our behavior-based pricing case are different in this term as shown in equation 12, where the difference in prices $p_B^1 - p_A^1$ is multiplied by 3/8 instead of 1/2. We have shown in Treatment 1 and Treatment 2 in our experiment, complemented by Case 1 of BDP that there is a peak in the price distribution close to the model prediction whenever a uniform price is chosen in the first period. This only fails for Case 2 of BDP, where prices are similar to their Case 1 and our Treatment 1, with a peak in the price distribution at a similar point, just short of 170. This would be in line with the price prediction in equation 23.

While this does not fit the instructions of BDP according to which consumers are strategic in their first period decision, it is a surprising testament of how powerful the price predictions are in this model. Note that BDP's instructions are somewhat vague concerning buyer behavior in the first period. Buyers are described minimize their total expenditures with their first period decision, considering their location and the current prices, while anticipating optimally chosen prices in the second period. On the other hand, second-period behavior is described very explicit, covering precise calculations of the location of the indifferent consumer and the resulting cutoff. It may not be immediately imminent to an uninformed participant that a consumers' strategic decision in the first period entails a lowered willingness to buy from the far seller. Rather than relying on the instructions participants seemed to have experimented over the course of the experiment to optimize their pricing decisions.

[10]The uniform pricing benchmark is identical for myopic and strategic consumers, due to the independence of the periods.

5 Transport costs as a robust welfare measure

As chosen prices are prone to distortions, as we discussed earlier, we cast doubt on the reliability of consumer costs and profit as welfare measures as used by BDP. Both measures are easily shifted by price levels and mask the efficiency of the market. Instead we propose to measure total welfare directly by means of the transport costs. While this is not necessarily the preferred welfare measure in terms of policy recommendations, it is superior to assess an experimental markets' efficiency. It is sensitive to comparative static implications such as poaching and to efficiency losses due to price dispersion, but insensitive to distorted price levels. Under uniform pricing the total welfare is given by

$$W = \int_0^{\theta_1} (v - \theta)\ d\theta + \int_{\theta_1}^{\bar{\theta}} (v - (\bar{\theta} - \theta))\ d\theta + \int_0^{\theta_2} (v - \theta)\ d\theta + \int_{\theta_2}^{\bar{\theta}} (v - (\bar{\theta} - \theta))\ d\theta. \tag{24}$$

By rearranging we can separate gains and costs as

$$W = 2 \cdot \int_0^{\bar{\theta}} v\ d\theta - \Big(\int_0^{\theta_1} \theta\ d\theta + \int_{\theta_1}^{\bar{\theta}} (\bar{\theta} - \theta)\ d\theta + \int_0^{\theta_2} \theta\ d\theta + \int_{\theta_2}^{\bar{\theta}} (\bar{\theta} - \theta)\ d\theta \Big), \tag{25}$$

where the first term denotes the gains G under full market coverage

$$G = 2 \cdot \int_0^{\bar{\theta}} v\ d\theta = 2\bar{\theta}v, \tag{26}$$

while the remainder denotes the transport costs that are subtracted from the gains:

$$T = \int_0^{\theta_1} \theta\ d\theta + \int_{\theta_1}^{\bar{\theta}} (\bar{\theta} - \theta)\ d\theta + \int_0^{\theta_2} \theta\ d\theta + \int_{\theta_2}^{\bar{\theta}} (\bar{\theta} - \theta)\ d\theta. \tag{27}$$

Similarly we can derive the transport costs under behavior-based pricing as

$$\tilde{T} = \int_0^{\theta_1} \theta\ d\theta + \int_{\theta_1}^{\bar{\theta}} (\bar{\theta} - \theta)\ d\theta + \int_0^{\theta_A} \theta\ d\theta + \int_{\theta_A}^{\theta_1} (\bar{\theta} - \theta) + \int_{\theta_1}^{\theta_B} \theta\ d\theta + \int_{\theta_B}^{\bar{\theta}} (\bar{\theta} - \theta)\ d\theta. \tag{28}$$

The gains from (26) are independent of the consumers purchasing decisions when the market is fully covered. Hence, it is sufficient to consider the losses in form of transport costs in (27) and (28) to evaluate welfare effects.

In Table 4 we show that profits for sellers and total costs for consumers were lower in uniform pricing compared to behavior-based pricing in the first period in contrast to BDP who found no effect. This is driven by higher introduction prices in our Treatment 2 compared to Case 2 of BDP. However, transport costs were insignificantly different in the

	Seller's	Customers'		Seller's	Customers'	
	profit	total costs	transport costs	profit	total costs	transport costs
Treatment 1	-1374.7***	-2820.8***	-71.48	572.2**	386.1	-758.2***
	(158.5)	(366.8)	(73.40)	(174.0)	(405.9)	(90.28)
Treatment 3				-1396.2***	-2821.9***	-29.46
				(151.6)	(342.5)	(95.54)
Constant	5150.0***	20339.9***	4039.9***	3844.9***	18344.3***	4654.5***
	(324.6)	(876.5)	(114.7)	(243.0)	(627.1)	(132.6)
Base case	Treatment 2	Treatment 2	Treatment 2	Treatment 2	Treatment 2	Treatment 2
Considered period	First	First	First	Second	Second	Second
Observations	760	380	380	1158	579	579

Standard errors in parantheses. Estimation by OLS regressions with round fixed-effects. Analysis is done on individual level for sellers and on market level for customers. Treatment 1 - Uniform pricing, Treatment 2 - Behavior-based pricing, Treatment 3 - Follow-up experiment. ** and *** denote significance at the 1% and 0.1% level, respectively.

Table 4: Treatment effects on welfare measures in the first and second period

first period between both treatments. The difference in total costs is fully explained by the difference in prices payed (product costs).

In Table 4, we further show that second-period profits and total costs are larger in Treatment 1 compared to Treatment 2, which is opposite to the findings of BDP. Transport costs are significantly different between the uniform pricing and behavior-based pricing treatments in the second period. In contrast, there are no differences in transport costs between the follow-up experiment and the behavior-based pricing treatment, while profits and total costs were significantly smaller in the follow-up experiment compared to the behavior-based pricing treatment. This is a direct consequence of the lower prices chosen by the participants.

We show the effect of disjoining the decision process in Table 5. There we calculated hypothetical mean profits, mean total costs and mean transport costs for three cases. The first and second case correspond to the first and second treatment. In the third case we combine the follow-up experiment as the second period findings with the results of the first period of the behavior-based pricing treatment. Both mean profits and total costs are lower in the combined case compared to the uniform pricing treatment, whereas they were

Considered treatment in	First period + Second period	Uniform pricing + Uniform pricing	Behavior-based pricing + Behavior-based pricing	Behavior-based pricing + Follow-up Experiment
Sum of mean	profits	10485.44	11287.95	9895.11
	total costs	20498.92	21716.29	20308.95
	transport costs	4013.48	4428.334	4413.841

Table 5: Sum of mean profits, total costs and transport costs between cases.

originally larger in the behavior-based pricing treatment compared to the uniform pricing treatment. In contrast, both the sign and the magnitude in the differences of transport costs between the behavior-based pricing and the uniform pricing treatment, respectively the combined case and the uniform pricing treatment, remain similar. This shows that price-based measures (profits and total costs) are volatile and may obfuscate the actual effects on efficiency. Transport costs are independent of prices and more suitably reflect the efficiency of the market.

6 Discussion

We designed an experiment on theoretical grounds provided by F&T and in the vein of an experiment by BDP. In contrast to BDP we can confirm the positive first-period price effect of behavior-based pricing over uniform pricing, validating an additional comparative static result from F&T's model. We show that this is potentially caused by an error in the code of the program of BDP. We pursued whether there are explanations for other instances in which observed prices did not meet their model predictions. We find that in the case of behavior-based pricing second-period prices are driven upwards when participants play the first period themselves, but not when both periods are disjoint and played by different participants.

Disjoining the decisions of the first and second period reveals a volatility of chosen strategies. Going forward this insight can be helpful in the design of experiments. For multi-period experiments separating the individual stages might be necessary to conclusively reveal whether participants play according to predictions. Further, when volatility is expected measures of interest should be chosen carefully. Transport costs and brand preferences are usually not observable in real markets. However, we have shown that transport costs are a suitable welfare measure that is robust to the aforementioned confounding factors.

A couple of questions remain open and might be answered in future research. It is still unclear how exactly first-period prices drive second-period prices upward in the behavior-based pricing cases in BDP and in our experiment. Are prices interpreted as a signaling device? Do prices shift beliefs about second period behavior? Or is it possible that that first-period prices serve as pure anchors in their impact on decision making? Furthermore, we cannot explain why participants in BDP's Case 1 chose lower second-period prices. Did they misunderstand the task and perceived a certain risk? Or did they expected prices in the second period to carry more meaning than they actually had? One could probably answer these questions by separating the confounding factors that are in play here, similar to what we have done in the case of behavior-based pricing with our follow-up experiment.

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7 Appendix

	Uniform pricing	Behavior-based pricing	Follow-up experiment
Second-period price effect	-5.890 (4.484)	-59.54*** (5.393)	
Old customer price effect		35.13*** (5.751)	41.41*** (4.371)
Constant	147.3*** (3.795)	174.2*** (7.104)	83.65*** (3.685)
Reference Price	Introduction price	Introduction price	Old customer price
Observations	800	1080	796

Standard errors in parantheses. Estimation by OLS regressions with standard errors clustered at the subject level. *** denotes significance at the 0.1% level.

Table 6: Analysis of prices within treatments.

	Introduction price	Old customer price	New customer price
Behavior-based pricing	26.85***	24.71**	30.94***
	(7.936)	(8.281)	(7.191)
Constant	147.3***	125.1***	83.69***
	(3.749)	(2.672)	(3.652)
Base case	Uniform pricing	Follow-up experiment	Follow-up experiment
Observations	760	758	758

Standard errors in parantheses. Estimation by random-effects GLS regressions with standard errors clustered at the subject level. ** and *** denote significance at the 1% and 0.1% level, respectively.

Table 7: Analysis of prices between treatments.

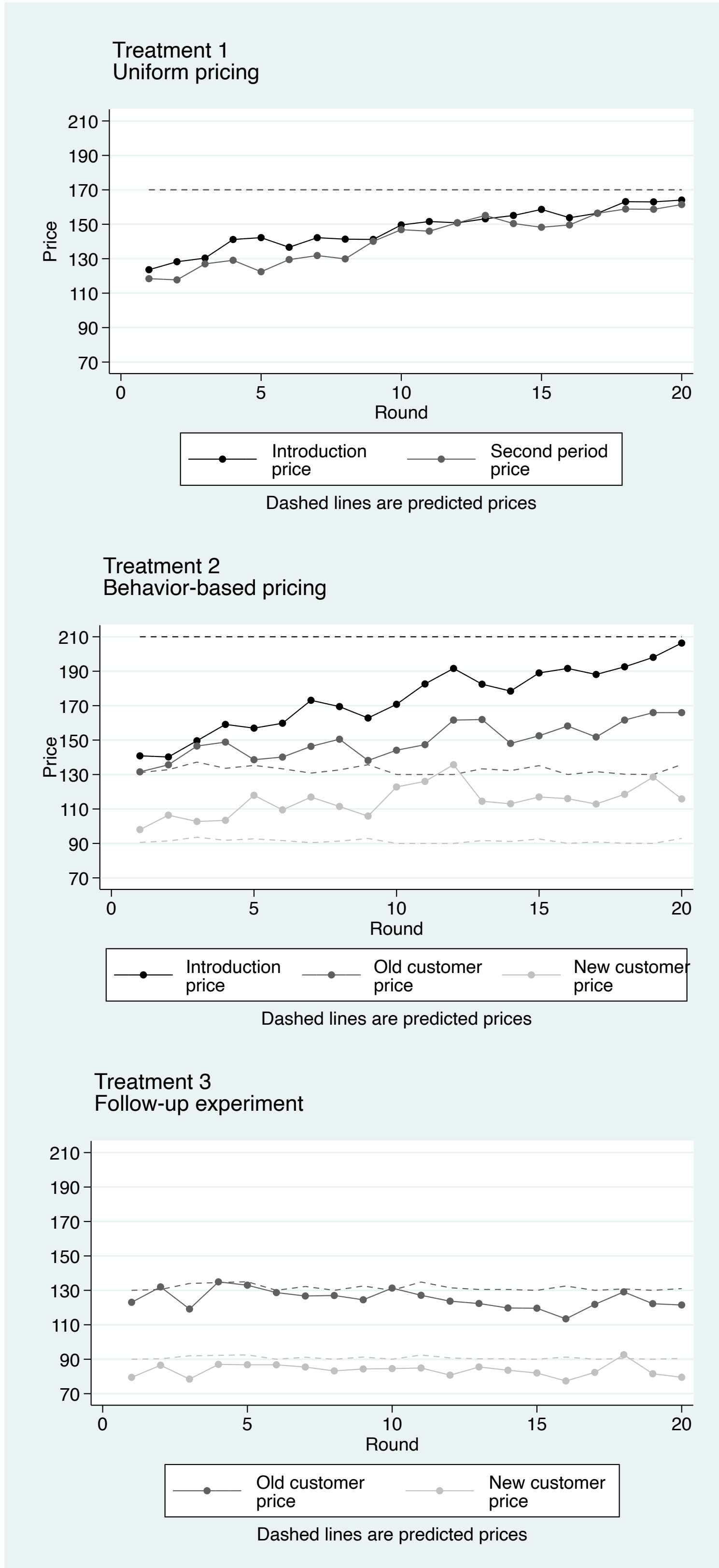

Figure 3: Average observed prices per round by treatments.

	Treatment 1 Uniform pricing		Treatment 2 Behavior-based pricing			Treatment 3 Follow-up experiment	
	Introduction price	Second period price	Introduction price	Old customer price	New customer price	Old customer price	New customer price
Round							
1	-46.40***	-51.60***	-69.17***	0.444	7.444	-6.944	-10.56**
	(7.294)	(7.399)	(10.76)	(10.59)	(8.632)	(7.839)	(5.269)
2	-41.75***	-52.30***	-69.78***	2.833	14.97	1.500	-3.750
	(7.820)	(8.163)	(10.40)	(11.90)	(11.98)	(8.390)	(7.626)
3	-39.65***	-43.00***	-60.39***	9.333	9.111	-14.85*	-13.55*
	(7.093)	(7.408)	(12.72)	(14.25)	(10.85)	(7.953)	(7.033)
4	-28.85***	-40.90***	-50.89***	15.22	11.58	0.400	-5.250
	(7.071)	(7.376)	(11.11)	(12.01)	(8.244)	(6.517)	(10.09)
5	-27.75***	-47.55***	-53.06***	3.333	25.31*	-2.000	-5.700
	(6.486)	(8.890)	(13.16)	(13.83)	(14.77)	(8.470)	(10.78)
6	-33.35***	-40.50***	-50.22***	6.778	17.78	-1.300	-3.250
	(6.932)	(6.771)	(10.60)	(11.94)	(10.81)	(6.641)	(7.775)
7	-27.80***	-38.15***	-36.89***	15.50	26.47***	-5.550	-5.675
	(6.296)	(8.601)	(11.05)	(11.40)	(9.035)	(7.881)	(8.784)
8	-28.65***	-40.10***	-40.56***	17.83	20.11	-3	-6.800
	(7.536)	(9.523)	(10.72)	(11.16)	(13.32)	(5.468)	(4.351)
9	-28.80***	-29.90***	-47.17***	2.444	12.97	-8.000	-6.900
	(7.019)	(8.034)	(11.54)	(10.91)	(9.963)	(5.462)	(8.724)
10	-20.40**	-23.10**	-39.22***	14.11	32.78***	1.300	-5.450
	(8.451)	(10.73)	(7.870)	(8.999)	(10.80)	(6.227)	(5.879)
11	-18.40**	-24**	-27.39***	17.33	36.00***	-7.750	-7.525
	(9.240)	(11.33)	(7.903)	(12.82)	(11.17)	(7.772)	(9.521)
12	-19.15***	-19.15***	-18.39**	31.61***	45.72***	-7.800*	-10
	(6.986)	(7.304)	(7.867)	(11.82)	(12.40)	(4.690)	(8.398)
13	-16.85**	-14.85**	-27.56***	28.61***	22.78**	-8.150	-4.750
	(6.944)	(7.495)	(9.107)	(9.617)	(11.18)	(5.697)	(10.49)
14	-14.90**	-19.60**	-31.56**	15.78	21.86*	-10.75	-6.650
	(7.376)	(7.917)	(12.19)	(14.08)	(12.56)	(7.283)	(6.883)
15	-11.35*	-21.75***	-21**	17.33	24.36**	-10.40*	-8.000
	(6.140)	(7.465)	(9.986)	(11.94)	(11.01)	(5.540)	(5.410)
16	-16.20**	-20.40**	-18.39***	28.17***	26**	-19.05***	-13.90**
	(7.649)	(8.408)	(7.001)	(9.779)	(11.44)	(6.669)	(6.912)
17	-13.60**	-13.60*	-21.89**	20.11*	22.00**	-8.150	-7.650
	(6.076)	(7.237)	(9.465)	(11.42)	(10.77)	(5.430)	(6.580)
18	-6.850	-11.15	-17.44**	31.44***	28.42***	-1.700	2.200
	(4.343)	(6.787)	(7.375)	(10.51)	(10.96)	(9.692)	(12.20)
19	-7.000*	-11.30**	-11.94	35.94***	38.56***	-7.750	-8.450
	(3.669)	(5.590)	(8.432)	(12.01)	(11.64)	(5.786)	(5.496)
20	-5.950	-8.550	-3.667	30.17**	22.94**	-9.500	-11
	(4.529)	(5.196)	(10.68)	(12.98)	(11.23)	(5.784)	(7.498)

Standard errors in parantheses. Estimation by round-wise OLS regressions. Coefficients are the difference between observed and predicted prices. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table 8: Regressions on difference between observed and predicted prices per round and treatment.

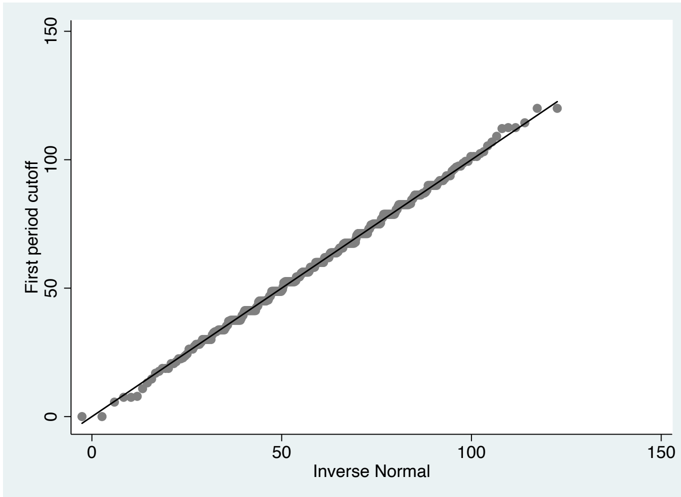

Figure 4: Quantiles of first period cutoff in Treatment 2 against quantile of normal distribution.

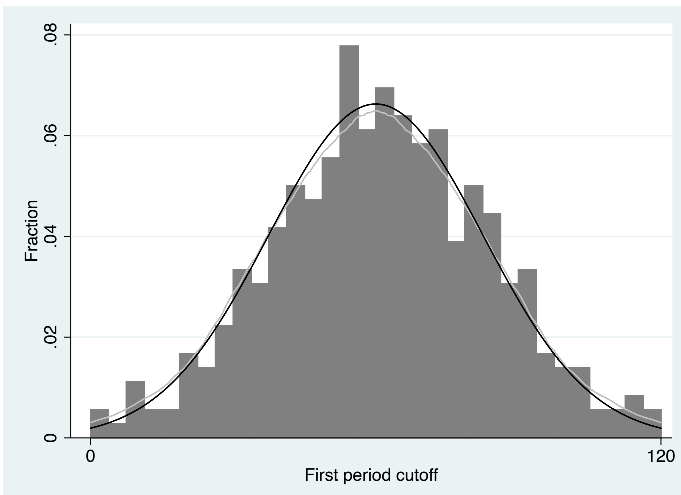

Figure 5: Distribution of cutoffs in Treatment 2 with normal density (black) and kernel density (light gray).

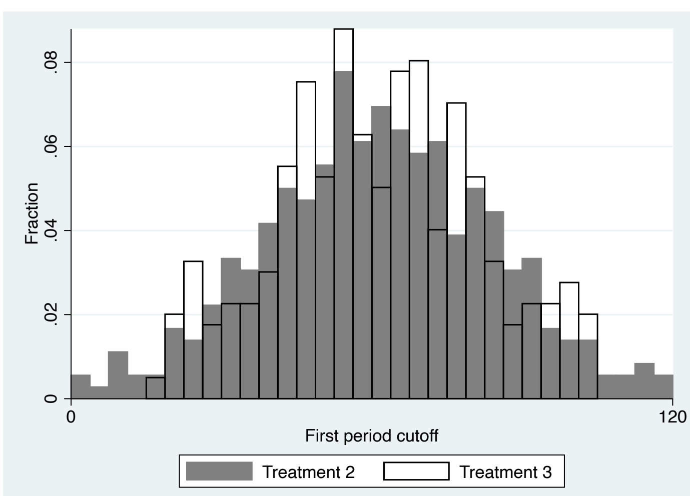

Figure 6: Distribution of cutoffs in Treatment 2 and Treatment 3.