We analyze a durable-goods monopoly selling a single unit of a good to a buyer whose value of the good is private information. The discount factors of the buyer and the seller may differ and are also privately known. We derive the closed-form solution of a two-period game and compare it to the behavior observed in experiments. The data are to a large extent consistent with the predictions. (JEL C90, L12, C73)

I. INTRODUCTION

Ever since Plato’s Republic, people seem to be aware that they may suffer from rational anticipation of own future behavior. A very prominent intrapersonal decision conflict is one faced by the durable-goods monopolist introduced by Coase (1972). In a market with a durable good, a monopolistic seller could easily collect the monopoly profit by excluding any future price cut. Buyers will, however, anticipate that future prices are opportunistically chosen by the monopolist; in particular, that the good will be sold cheaper in later periods. For this reason, the monopolist loses market power.

Coase conjectured that this can even lead to competitive and thus efficient market results. Much of the literature on durable-goods monopoly has focused on the question under which conditions the Coase conjecture proves to hold and when it does not hold. For example, Stokey (1981) and Gul et al. (1986) show that there is an equilibrium in which the price is arbitrarily close to marginal cost if the number of successive sales periods is infinitely high. Others have shown that product durability does not necessarily reduce the monopolist’s market power (see Ausubel and Deneckere 1989; Bagnoli et al. 1989). Güth and Ritzberger (1998) show that a durable-goods monopolist may even increase profits when the model allows for a difference between the discount factor of the monopolist and that of the potential buyers. Under this assumption, Güth and Ritzberger (1998) show that even over a finite number of periods, the monopolist may significantly increase market power, provided the buyer has a lower discount factor. This is the so-called Pacman conjecture, termed by Bagnoli et al. (1989). If the seller has a lower discount factor, he loses profits compared to a one-period monopolist.

In this article, we follow Güth and Ritzberger (1998) in that we allow for a difference between the discount factor of the monopolist and that of the potential buyers. Under this assumption, Güth and Ritzberger (1998) show that even over a finite number of periods, the monopolist may significantly increase market power, provided the buyer has a lower discount factor. This is the so-called Pacman conjecture, termed by Bagnoli et al. (1989). If the seller has a lower discount factor, he loses profits compared to a one-period monopolist.

4. There is the substantial myopia or short-termism literature. Takeover threats, career concerns, and risk considerations can induce managers not to maximize the discounted value of the firm but to choose projects with a high return early. Such factors are likely to differ across
Commonly known impatience of players seems unlikely—at least, it requires further justification. How eager sellers and buyers are to obtain monetary rewards over time is presumably difficult to observe for others. So the assumption of privately known discount factors seems less restrictive. More specifically, we assume that discount factors can be either high or low for both the monopolist and the buyer. Which state is realized is private information. For this scenario, we analyze a two-period game with one seller and one buyer whose valuation is also private knowledge and derive the solution play in closed form.

In addition, we provide experimental evidence. Experimental data may reveal to what extent subjects’ behavior conforms to (rational expectations) theory, but it may also show that bounded rationality limits the predictive power of standard theory in durable-goods games. The theory has a number of interesting implications in our market. Will sellers with a high discount factor charge higher prices, as predicted? Similarly, will buyers with a high discount factor refuse to purchase in period one more often? Considering bounded rationality, two kinds of behavior may be important. First, buyer subjects may withhold demand, that is, they may reject profitable purchases because of fairness reasons. Such behavior may soften the monopolist’s pricing behavior and may generally limit the predictive power of standard theory in durable-goods games. Second, it seems possible that seller subjects might feel committed by mere intentions about their future behavior—even when there is no formal commitment device. This again could limit the predictive power of the theory. The conflict of a durable-goods monopolist between avoiding the effects of intrapersonal price competition and reacting opportunistically, and how this enters the price expectations of the buyer, seems an exciting topic of experimental analysis.

Previous experimental papers on durable-goods monopoly include Cason and Sharma (2001), Guth et al. (1995), and Reynolds (2000). Supporting the predictions, there is strong evidence that monopolists indeed lose monopoly power when selling a durable good. However, a large number of observations have been made that indicate that subjects’ behavior is inconsistent with the predictions. Reynolds (2000) observed that initial prices were higher in multiperiod experiments than in single-period monopoly experiments. In all experiments, there is more demand withholding than theory predicts. For example, Cason and Sharma (2001) observed more trading periods than predicted due to higher demand withholding. Finally, durable-goods experiments seem to require a number of repetitions due to their complexity. In Guth et al. (1995), there was no opportunity for learning. Prices failed to conform to comparative statics predictions and were often higher than the theoretical benchmark. With experienced subjects, observed prices were closer to the prediction, but participants still had serious difficulties understanding the crucial aspects of such dynamic markets.

In view of these previous experiments and their results, it seems important to limit attention to the simple case of markets with two periods. We also have provided ample opportunities for learning by letting participants play the same market repeatedly in our computerized experiment. This allows us to incorporate a further complexity, namely, that relative impatience is private information.

In sections II and III, we present the model and derive the game-theoretic solution play for two-period markets. Section IV explains the design of the experiment whose results are described and statistically analyzed in section V. We conclude in section VI.

II. THE BASIC MODEL

The monopolistic seller has an indivisible commodity which he or she evaluates by zero, whereas the only buyer evaluates the commodity by $v \in [0, 1]$. The value $v$ is, however, the buyer’s private information. The distribution of $v$ is uniform over the unit interval $[0, 1]$, and this is commonly known.

We consider two successive sales periods. The discount factor $\zeta \in (0, 1)$ represents the seller’s weight for future (period $t = 2$) versus present (period $t = 1$) profit. Similarly, $\delta$ reflects the buyer’s impatience where $\delta \in (0, 1)$. We denote by $p_1$ the price in period $t = 1$ and by $p_2$ the price in period $t = 2$.

5. Only the assumption $\delta < 1$ is actually necessary for deriving a well-defined solution play. The boundary case $\delta = 1$ can only be analyzed via $\delta < 1$ (see Guth and Ritzberger 1998). Note that $\delta = 1$ renders buying in period $t = 1$ or $t = 2$ as homogeneous trades in view of
The decision process is as follows:

1. Period $t = 1$:
   - The seller chooses the sales price $p_1 \in [0, 1]$ for this period.
   - Knowing $p_1$ and her value $v$, the buyer decides whether to buy. If she does, this ends the interaction; otherwise period $t = 2$ follows.

2. Period $t = 2$:
   - The seller chooses the sales price $p_2 \in [0, 1]$ for this period.
   - Knowing $p_2$ and her value $v$, the buyer decides whether to buy. This ends the interaction.

The profit of the seller is $p_1$ if there is trade in period $t = 1$, it is $\zeta p_2$ if trade occurs in period $t = 2$, and it is 0 if there is no trade. For the buyer, the payoff is $v - p_1$ for trade in period $t = 1$, it is $\delta (v - p_2)$ for trade in period $t = 2$, and it is 0 in the case of no trade.

If both discount factors are commonly known, and if the seller is risk-neutral, the solution prices $p_1^*$ and $p_2^*$ depend on the discount factor $\zeta$ of the seller and $\delta$ of the buyer as follows:

\[
\begin{align*}
(1) & \quad p_1^* = (2 - \delta)^2 / (2[4 - 2\delta - \zeta]), \\
(2) & \quad p_2^* = (2 - \delta) / (2[4 - 2\delta - \zeta]).
\end{align*}
\]

Note that, with just one trading period, the monopoly price would be $p^* = 1/2$, implying a profit of 1/4. The polar cases of relative impatience correspond to

- $\zeta > 0$ and $\delta < 1$ with $\lim p_1^* = 1/4 = \lim p_2^*$: as only buyers with $v \geq 1/2$ buy in period $t = 1$, the seller earns only half of what he would earn as a usual monopolist, namely $1/4 \cdot 1/2 = 1/8$ in period $t = 1$ (revenues in period $t = 2$ are neglected because $\zeta \searrow 0$).

- $\zeta < 1$ and $\delta > 0$ with $\lim p_1^* = 2/3$ and $\lim p_2^* = 1/3$: the (extremely patient) seller engages in price discrimination over time by collecting $p_1^* = 2/3$ whenever $v$ is in the interval $1 \geq v \geq 2/3$ and $p_2^* = 1/3$ when $2/3 > v \geq 1/3$. This yields an expected profit of $(2/3 + 1/3) \cdot 1/3 = 1/3$, more than the static monopoly profit.

We assume that discount factors are private knowledge. In addition to information about their discount factors, players observe the following. In period $t = 1$, the buyer is informed about his valuation and the seller’s price offer. If there is trade in period $t = 1$, the seller learns that there is trade. If there is no trade in period $t = 1$, the buyer additionally observes the price $p_2$, and the seller learns whether or not she sold the commodity in period $t = 2$. To simplify the analysis, we assume that the discount factors of buyers and sellers can adopt only two values, low or high. That is, we assume

\[
(3) \quad 0 < \delta < \delta < 1 \quad \text{and} \quad 0 < \zeta < \bar{\zeta} < 1
\]

where the probability for $\delta$ is $w \in (0, 1)$ and that for $\zeta$ is $\omega \in (0, 1)$. To allow for a clearcut benchmark solution, we assume that all the parameters $\delta, \bar{\delta}, \zeta, \bar{\zeta}, w$, and $\omega$ are commonly known.

### III. The Solution Play

Our first point is obvious but useful to note. Whenever $p_2 \geq p_1$, the buyer would not buy in period $t = 2$ because $\delta < 1$. We therefore obtain

**PROPOSITION 1.** The solution play of the two-period game involves a price decrease, that is, $p_1 > p_2$.

Given the buyer’s discount factor $\delta \in \{\delta, \bar{\delta}\}$, when will she buy the commodity? Consider the decision to buy in period $t = 1$ or $t = 2$. If a type $v \in [0, 1]$ has not bought in period $t = 1$ at price $p_1$, she will buy in period $t = 2$ at price $p_2$ whenever $v \geq p_2$. Assume now a type $v \geq p_2$ who anticipates the actual solution prices $p_1$ and $p_2$. Because buying in period $t = 1$

8. Except for highly special games, for example, when all players have unique undominated strategies, game-theoretic analysis requires commonly known rules of the game.
yields $v - p_1$, whereas delaying it yields $\delta(v - p_2)$, type $v$ prefers to buy early if
\begin{equation}
\begin{align*}
v - p_1 &\geq \delta(v - p_2) \quad \text{or} \\
v &\geq (p_1 - \delta p_2)/(1 - \delta).
\end{align*}
\end{equation}
This establishes

PROPOSITION 2. If the solution play involves prices $p_1$ and $p_2$,

(i) sale occurs in period $t = 1$ if
\begin{equation}
v \geq \left\{ \begin{array}{ll}
v = (p_1 - \delta p_2)/(1 - \delta) & \text{for } \delta = \delta \nonumber \\
v = (p_1 - \delta p_2)/(1 - \delta) & \text{for } \delta = \delta \nonumber 
\end{array} \right.
\end{equation}
and sale occurs in period $t = 2$ if
\begin{equation}
v > v \geq p_2 \quad \text{for } \delta = \delta \nonumber \\
v > v \geq p_2 \quad \text{for } \delta = \delta, \nonumber
\end{equation}
whereas
(ii) $v < p_2$ implies no sales at all.

Note that Proposition 1 implies that the two thresholds $v$ and $\bar{v}$ in Proposition 2 satisfy $v < \bar{v}$.

Next, we discard the possibility that the seller serves only the $\delta$-buyer types in period $t = 2$. Assume, by contrast, that this is true. Then the $\delta$-buyer would only switch between buying at price $p_1$ in period $t = 1$ and not buying at all, implying that only $\delta$-buyers with $v \geq p_1$ buy in period $t = 1$. But because $p_1 > p_2$, $\delta$-buyer types $v$ with $p_1 > v \geq p_2$ would like to buy in period $t = 2$, contradicting the assumption that only $\delta$-buyer types are served in period $t = 2$. Thus we have proved

PROPOSITION 3. Trade in period $t = 2$ involves both buyer types $\delta \in \{\delta, \delta\}$ with positive probability, that is, $v > p_2$.

We can now proceed to derive the full solution play of the game. We start by solving the last period. Note that in period $t = 2$, the seller knows that the $\delta(\delta)$-buyer has no value $v \geq v(\bar{v})$. Thus, his posterior probability of trade in period $t = 2$ at price $p_2$ is
\begin{equation}
\begin{align*}
D(p_2) &= [(1 - w)(v - p_2) + w(\bar{v} - p_2)] \\
&\quad /[(1 - w)v + w\bar{v}],
\end{align*}
\end{equation}
where, in view of Proposition 3, both terms of the numerator on the right-hand side are positive. Maximization of $p_2 D(p_2)$ yields
\begin{equation}
p_2 = p_2(v, \bar{v}) = ((1 - w)v + w\bar{v})/2.
\end{equation}
Substituting $p_2$ in (5), the equations for $v$ and $\bar{v}$, yields a system of two equations with two unknowns
\begin{equation}
v = (2p_1 - \delta w)/(2 - \delta(1 + w)),
\end{equation}
\begin{equation}
\bar{v} = (2p_1 - \delta(1 - w))/(2 - \delta(2 - w)).
\end{equation}
This system can readily be solved as
\begin{equation}
v = p_1[(2 - \delta w - \delta(1 - w))/(2 - \delta(1 + w) - \delta(2 - w) + \delta \delta)],
\end{equation}
\begin{equation}
\bar{v} = p_1[(2 - \delta(1 + w) - \delta(1 - w))/(2 - \delta(1 + w) - \delta(2 - w) + \delta \delta)].
\end{equation}
Because the optimal price $p_2 = ((1 - w)v + w\bar{v})/2$ depends on $v$ and $\bar{v}$, it can be expressed as a function of $p_1$ only:
\begin{equation}
p_2(p_1) = p_1[(1 - \delta w - \delta(1 - w))/2 - \delta(1 + w) - \delta(2 - w) + \delta \delta)]]
\end{equation}
We will use $\gamma = (1 - \delta w - \delta(1 - w))$ and $\varepsilon = (1 - \delta - \delta + \delta \delta)$ to simplify the notation. Then we have $v = p_1(\gamma + 1 - \delta)/(\gamma + \varepsilon)$, $\bar{v} = p_1(\gamma + 1 - \delta)/(\gamma + \varepsilon)$, $p_2(p_1) = p_1\gamma/(\gamma + \varepsilon)$.

With the help of these derivations, the expected profit from trade over the two sales periods can be defined as a function of $p_1$, the price of period $t = 1$, namely,
\begin{equation}
p_1[(1 - w)(1 - v(p_1)] + w(1 - v[p_1]) + \zeta p_2(p_1)]](1 - w)(v[p_1] - p_2[p_1]) + w(\bar{v} - p_2[p_1]),
\end{equation}
where, $\zeta \in \{\zeta, \zeta\}$. Maximizing this function with respect to $p_1$ yields
\begin{equation}
p_1(\zeta) = (\gamma + \varepsilon)^2/(2\gamma[2(\gamma + \varepsilon) - \zeta \gamma])
\end{equation}
and thus

\[
\begin{align*}
\psi(\zeta) &= \frac{[\gamma + \varepsilon][\gamma + 1 - \delta]}{2\gamma[2(\gamma + \varepsilon) - \zeta\gamma]}, \\
\phi(\zeta) &= \frac{[\gamma + \varepsilon][\gamma + 1 - \delta]}{2\gamma[2(\gamma + \varepsilon) - \zeta\gamma]}, \\
p_2(\zeta) &= \frac{(\gamma + \varepsilon)}{2[2(\gamma + \varepsilon) - \zeta\gamma])}.
\end{align*}
\]

Hence, we have derived the solution play described by

**PROPOSITION 4.** For \( \zeta \in \{\zeta_0, \zeta_1\} \), the solution play of the two-period game is as follows:

- In period \( t = 1 \), the price is \( p_1(\zeta) \), which induces all buyers with \( \nu \geq \nu(\zeta) \), and \( \delta = \delta_0 \) and those with \( \nu \geq \nu(\zeta) \) and \( \delta = \delta \) to buy.
- In period \( t = 2 \), all buyers with \( \phi(\zeta) > \nu \geq p_2(\zeta) \) and \( \delta = \delta_0 \) and those with \( \phi(\zeta) > \nu \geq p_2(\zeta) \) and \( \delta = \delta \) buy, whereas
- All remaining buyer types abstain from trading.

According to \( p_1(\zeta) \), the seller with time preference \( \zeta \in \{\zeta_0, \zeta_1\} \) reveals his impatience by his first-period price \( p_1 \). Therefore, the buyer can rationally anticipate \( p_2(\zeta) \) after observing \( p_1 \). The seller in turn only learns after the first sales period whether the buyer has bought in this period. Thus, his demand expectations for the second sales period are as expressed by \( D(p_2) \).

**IV. EXPERIMENTAL DESIGN**

Our experimental design exactly matches the above setup of the durable-goods monopoly with privately known impatience. We employ the parameters \( \delta = \zeta_0 = 0.3 \), \( \delta_2 = \zeta_0 = 0.7 \), \( \omega = 0.5 \). These parameters imply the values in Table 1. If the buyers’ valuations are drawn from the unit interval, as assumed in the theory section, the two columns on the left apply. In the experiment, we took buyers’ valuations from the interval \([50, 150]\). Therefore, the absolute price prediction is according to the two right columns of Table 1. For the sake of plausibility of the frame, we introduced a production cost of 50, which was charged if demand was positive. Sellers could choose prices from the interval \([0, 200]\).

We ran six sessions, each consisting of two matching groups, giving us 12 entirely independent observations. Each round was conducted exactly as follows: (see Appendix B for the instructions). One group consisted of three sellers and three buyers. Within the groups, sellers and buyers were randomly rematched after each round. Subjects learned their role, seller or buyer, only after they had read the instructions (see Appendix B), and they did not switch roles during the experiment. To allow for learning, we decided to run the experiment over 40 rounds.

Sellers learned their discount factor, then they had to choose their price. Knowing their discount factor and value, buyers had to decide whether or not to buy at the period-one price \( p_1 \). If they decide not to, period two commences, and so forth. At the end of each round, subjects were informed about their private earnings in the previous round as well as their cumulative earnings up to this round.

The computerized experiments were conducted at Humboldt University, Berlin, in December 2001 and January 2002, using the software z-tree (Fischbacher 1999). The 72 participants were mainly business and economics

<table>
<thead>
<tr>
<th>( v \in [0, 1] )</th>
<th>( v \in [50, 150] )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_1(\zeta) )</td>
<td>0.47</td>
</tr>
<tr>
<td>( p_2(\zeta) )</td>
<td>0.33</td>
</tr>
<tr>
<td>( \psi(\zeta) )</td>
<td>0.53</td>
</tr>
<tr>
<td>( \phi(\zeta) )</td>
<td>0.79</td>
</tr>
<tr>
<td>( \delta )</td>
<td>0.67</td>
</tr>
</tbody>
</table>

9. A pooling equilibrium, based on the expected patience parameter \( \zeta = (1 - w)\zeta_0 + w\zeta_1 \) would not satisfy sequential rationality because both seller types would like to deviate from the common price \( p_1(\zeta) \) as shown by our derivation.

10. For the more patient seller, it does not pay to mimic the price \( p_1(\zeta) \) because the additional revenue in period \( t = 1 \) is overcompensated by the \( \zeta_0 \)-weighted revenue loss in period \( t = 2 \). For \( \zeta = \zeta_0 \), the opposite is true. Note that the period \( t = 2 \) solution price \( p_2 \) is optimal regardless of the discount rate of the monopolist.

11. Participants were not informed that they were randomly matched in a group of six only, which should have further discouraged repeated-game effects.

students who were recruited via e-mail and telephone. Payments were 16 euros on average, including a show-up fee of 2.5 euros. Sessions lasted roughly 90 minutes.

V. EXPERIMENTAL RESULTS

Let us first check whether buying and pricing behavior is consistent with a few qualitative theoretical implications. It seems worth emphasizing that consistency even with very basic principles cannot be taken for granted in a complex durable-goods setting. For example, Güth et al. (1995) report a surprising amount of inconsistency in a durable-goods experiment. Similarly, Reynolds (2000) emphasizes the necessity of experience with the trading environment. Therefore, we find it useful to check consistency first.

Consider the buyers. Basic understanding of the situation implies that buyers would never purchase at a price above their valuation. It seems impossible that some argument based on repeated games or bounded rationality could plausibly support such loss-inducing purchases. Out of 1,440 possible sales, we observed 1,037 actual purchases. In all but six purchases, buyers had valuations above the prices. That is, there are virtually no such loss-making purchases, and we can conclude that basic buyer behavior was consistent in this sense.13

Buyers knew that profits from sales made in period \( t = 2 \) are discounted. Thus, \( \delta \)-buyers should reject a profitable purchase in period \( t = 1 \) more often than a \( \delta \)-buyer. Given any path of (expected) seller prices \( \{ p_1, p_2 \} \), the impatient buyer has to purchase early more often because her second-period opportunities are less attractive. Even if we take repeated-game effects like demand withholding into account, it seems implausible for the more impatient buyer to reject more often because it is more costly for her to reject. Confirming this, the data show that in period \( t = 1 \), the \( \delta \)-buyers reject profitable offers (i.e., offers with \( p_1 \leq v \)) significantly more often than \( \delta \)-buyers. Because of possible dependence of observations within the groups of six subjects, we count group averages including all periods as one observation. Unless otherwise mentioned, all tests reported herein are therefore based on matching group averages. See Appendix A for summary statistics of all matching groups. Relative acceptance rates are lower with \( \delta \) for all groups, the according nonparametric test is highly significant (one-sided Wilcoxon, \( p = 0.0002 \)). We conclude that buyers do understand the basic impact of discounting.

Now consider the sellers. Did they understand the implication of discounting? If so, sellers with a high discount factor should charge a higher price in both periods than sellers with a low discount factor. As shown in Table 1, this is the prediction. Even if subjects do not behave according to the solution play, it should be apparent to them that a high discount factor makes it relatively more attractive to charge a high price in period \( t = 1 \) because there is still another profitable opportunity to come. As both types of sellers should (and indeed did) reduce their price in \( t = 2 \), a higher period \( t = 1 \) price for high discount factor types also implies higher period \( t = 2 \) prices. By contrast, the impatient seller has to make his sales early and therefore charges lower prices. The data show that average prices of \( \zeta \) sellers (91 and 81 in \( t = 1 \) and \( t = 2 \), respectively) were higher than those of \( \zeta \) sellers (84 and 78, respectively) prices in all groups and in both periods. Accordingly, the test is highly significant (one-sided Wilcoxon, \( p = 0.006 \)). It appears that sellers understood the impact of their discount factor.

Proposition 1 states that sellers should charge lower prices in period \( t = 2 \) compared to period \( t = 1 \). The intuition is that a discounting buyer has no incentive to buy at a higher price in period \( t = 2 \). If sellers want to exploit the opportunity to sell in period \( t = 2 \), they should lower the price. However, the prediction of a price decrease over the two periods is not the only plausible behavior. Boundedly rational sellers may refuse to charge a lower period \( t = 2 \) price in an attempt to solve the commitment problem.

In 750 cases, there is no trade in period \( t = 1 \), and therefore a period \( t = 2 \) price is observed. In the vast majority of these cases, sellers actually charged a lower price in period \( t = 2 \).
In total, only 33 out of 750 period $t = 2$ prices were strictly higher than $p_1$, and this figure gets even smaller over time. Over the last 10 rounds, only 3 out of 155 period $t = 2$ prices were strictly higher than $p_1$. In many of those cases (13 out of 33 and 3 out of 3 cases, respectively), the maximum price of 200 is chosen in period $t = 2$, and all but 1 of these 13 observations were caused by a single seller.\footnote{This seller followed a pricing policy of $p_1 = 75$ and $p_2 = 200$ in many rounds. With an expected value of $v$ of 100, this splits the expected surplus of 50 evenly in period $t = 1$. If this price is not accepted, this seller refused to transact at all by offering a price above the buyer’s value ($p_2 = 200 > 150 > v$). As a referee pointed out, this seller might have tried to build up a reputation despite the random matching scheme (which he or she may have misunderstood).} In these cases, the higher price does not appear to be a mistake but a signal. In addition, there are another 33 observations (7 over the last 10 rounds) in which the price was constant over the two periods. The vast majority of these cases can be attributed to only a few sellers.\footnote{Four sellers followed this pricing policy four or more times, explaining 27 out of 33 observations.}

We never observed a seller who regularly behaved as a one-period monopolist in the sense of $p_1 = p_2 = 100$. To summarize, we find only few violations of Proposition 1. A few subjects occasionally charged $p_2 = p_1$ or $p_2 = 200 > p_1$. This may be interpreted as attempts to solve the durable-goods monopolist’s commitment problem. The remaining number of inconsistencies is small and scattered over time and subjects.

\textbf{Result 1: Subjects’ behavior is consistent with several qualitative predictions. Buyers virtually never make unprofitable purchases. Almost all sellers systematically lowered prices in period $t = 2$. Patient buyers reject profitable purchases in period $t = 1$ more often. Patient sellers charge higher prices in both periods.}

Let us now compare the data to the exact predictions of $p_1$, $p_2$, \(\bar{v}\) and \(\bar{v}\). Consider buyer behavior first. Buyers withhold demand whenever an offer $v > p$ is rejected. The prediction is that any price offer smaller than $v$ (in period $t = 2$) or smaller than $\bar{v}$ or $\bar{v}$ (in period $t = 1$) should be accepted independently of the history of the game. There can be rational and boundedly rational (or irrational) demand withholding. In period $t = 1$, when $v > p_1$ but $v < \bar{v}$ or $v < \bar{v}$, respectively, a rejection is rational. In period $t = 2$, there is no rational demand withholding. Although demand withholding as part of boundedly rational strategy has been frequently observed (see, e.g., Ruffle 2000), in this experiment, demand withholding to establish a reputation for aggressive buyer behavior is particularly difficult. First, there is random rematching, and the design does not allow identifying buyers. Moreover, sellers do not know whether their offer was rejected because of demand withholding or because it was not profitable. By contrast, in many posted-offer experiments, buyers’ evaluations are known, and demand withholding can much better serve as a signal.

Buying behavior in period $t = 2$ is simple to analyze because there are no future effects to consider. Buyers’ period $t = 2$ behavior is also independent of $\delta$. Any $p_2 \leq v$ should be accepted by all buyers. Table 2 reports the numbers of observed price offers, their acceptance conditional on the relation of price offer and threshold $\bar{v}$ and $v$ for both negotiation periods. In the data, we find that 68 out of 413 offers (16.5%) with $p_2 \leq v$ were rejected (see the column $p_2 \leq v$ in Table 2). These rejected offers typically left only a small profit margin for the buyers. This margin was $(v - p_2)/v = 0.0693$ on average across rejected offers. Two-thirds of all rejections involved a margin of less than 8%. Regarding accepted offers, buyers often were willing to accept even low margins and, in four cases, buyers accepted a period $t = 2$ price at which they just broke even. Two-thirds of all accepted prices gave them a less than 26%
profit margin. Buyers never rejected margins of more than 25%. Figure 1 illustrates the acceptance and rejection averages of \((v - p_2)/v\) for the 12 groups (provided \(v - p_2 \geq 0\)). Over all groups, offers that left on average at least 13% of the buyers’ valuation were accepted. As the acceptance and rejection average margins are not overlapping, there seems to exist a quite robust acceptance threshold margin interval of \([11\%, 13\%]\) below and above which offers are rejected and accepted, respectively. Recall that buyers knew the production cost of the seller (50). Therefore, besides the impact of the discount factor, they were able to identify the seller’s profit and compare it to their own. Take buyers’ reaction to the median period \(t = 2\) price, \(p_2 = 75\), as an example. Buyers with \(v < 100\) knew that the seller would get a larger profit from the sale, but they rejected only in 9 out of 38 cases (taking only buyers with \(v \geq p_2 = 75\) into account). Thus, it seems that aversion against disadvantageous inequality played only a little role here. Nevertheless, there is demand withholding in period \(t = 2\).

We turn to buyer behavior in period \(t = 1\). The prediction is that, after observing the solution price \(p_1(\xi)\), buyers with \(v > \hat{v} > p_1\) and \(v > \hat{v} > p_1\) should accept. For out-of-equilibrium prices \(p_1\), buyers with \(v \geq \hat{v}(p_1) > p_1\) and \(v \geq \bar{v}(p_1) > p_1\) should accept. The corresponding numbers are listed in Table 2. (Henceforth, we will refer to \(\bar{v}\) whenever we want make a statement about \(v\) or \(\bar{v}\).) First, consider buyers with \(\bar{v} > v > p_1\), which are predicted to reject (these are cases of rational demand withholding). Out of 206 cases (see column \(p_1 \leq v < \bar{v}\)), buyers rejected in 174 cases (84.5%). That is, to a large extent, buyers’ behavior was in accordance with the theory. There are, however, some inconsistencies, namely, the 32 accepted offers, yielding a profit margin of \((v - p_1)/v = 0.159\). These buyers did not realize that a lower period \(t = 2\) price should have given them a higher discounted margin. Second, did buyers with \(v \geq \bar{v}\) accept? If \((v - \bar{v})/v > 0.1\), even 96% of all offers were accepted. If \((v - \bar{v})/v > 0.1\), the average rejected margin was \((v - p_1)/v = 0.115\). Note that this margin is larger than the one in period \(t = 2\), so there is more demand withholding in period 1. These are cases of irrational (or boundedly rational) demand withholding.

Result 2: Buyers’ behavior is to a large extent consistent with the prediction. Buyers usually accepted profitable offers in period \(t = 2\), whereas, in period \(t = 1\), they accepted only if the offer gave them a more than positive profit margin. Both in period \(t = 1\) and \(t = 2\), there is some irrational (or boundedly rational) demand withholding, that is, buyers sometimes reject margins higher than those predicted.

Now consider seller behavior. We report deviations from the (conditional) predictions rather than absolute values because the optimal prices \(p_2\) depend on the realization of \(p_1\), and \(p_1\) is often different from the predictions \(p_1(\xi) = 90\) and \(p_1(\bar{\xi}) = 97\). Accordingly, we refer to \(p_2(p_1)\) rather than \(p_2(\xi)\) and \(p_2(\bar{\xi})\), and we define \(\Delta p_1(\xi) = p_1 - p_1(\xi)\), \(\Delta p_2 = p_2 - p_2(p_1)\). Note that \(\Delta p_2\) does only depend on \(p_1\) but not on the realization of \(\xi\). We find that \(\Delta p_1(\xi) = -4.73\), \(\Delta p_1(\bar{\xi}) = -6.46\), and \(\Delta p_2 = +0.89\). We find that both \(\Delta p_1(\xi)\) are significantly different from zero (two-sided Wilcoxon, \(p = 0.006\)), and \(\Delta p_2\) is not. In absolute terms, the average prices charged are \(p_1(\xi) = 84\) and \(p_1(\bar{\xi}) = 91\).

Given that buyers charged prices in period \(t = 1\) partly far away from the prediction, it is more difficult to analyze period \(t = 2\) pricing
behavior. If we interpret the $p_1 \notin \{90, 97\}$ as decision errors, and if we assume that both buyers and sellers behave fully rationally in the continuation game, then the appropriate period $t = 2$ price is $p_2(p_1)$ as in equation (13). As mentioned, we report the difference between actual prices in $t = 2$ and this prediction: $\Delta p_2 = p_2 - p_2(p_1)$. Now, $\Delta p_2 = 0.89$ is surprisingly small, what we interpret as support of the rationality hypothesis when the situation is simple (in $t = 2$, sellers do not have to anticipate own future choices any longer). But there is much variability in individual decisions. Regrading group averages, Figure 2 shows that all except one group have a rather small $\Delta p_2$, whereas the $\Delta p_1$ observations are more dispersed and clearly negative. We do not distinguish between the two $\xi$ values because the picture is roughly the same. The fact that $\Delta p_2$ average is slightly positive does not mean that pricing behavior in period $t = 2$ changes qualitatively from that in period $t = 1$. Sellers start with a lower price, reducing it by the proportion predicted. Hence, whatever accounts for the lower prices in period $t = 1$, this behavior carries over to period $t = 2$.

Result 3: Sellers charge prices lower than predicted, both in period $t = 1$ and period $t = 2$. The reduction of period $t = 2$ prices is consistent with (conditional) rationality.

To conclude the analysis of seller behavior, the only significant deviation from the prediction are the lower period $t = 1$ prices. This is a robust finding in that it is very similar for both discount rates $\xi$ and $\xi$. One explanation might lie in the specific design of the experiment. Instead of a continuous demand function, we have assumed a single buyer whose value is private information. The density of the value plays the role of the continuous demand function. Theoretically, this does not matter much for the outcome, but it may matter behaviorally because in such bilateral encounters fairness concerns may become stronger, and this could account for low first-period prices (which would imply more balanced distributions of surplus from trade). Alternatively, risk considerations (an attitude of sellers to ensure trade) may explain the result. We did not control for fairness concerns nor for risk aversion of sellers. Because the buyer's valuation is private knowledge, sellers only know the expected buyer profit. Though it is possible for buyers to make interpersonal profit comparisons, it is quite difficult to do so, and regarding profits made in the second period, there is uncertainty about the discount factor. Therefore, compared to pure bargaining experiments, it seems less likely that fairness matters, suggesting that the lower period $t = 1$ prices rather reflect the risk attitude of sellers.

We finally analyze the impact of the distribution of the discount factors. It is a central feature of our model that the discount factor of the seller, as compared to the buyer's, determines whether the seller suffers from intrapersonal competition or gains by price discrimination. In this sense, a higher discount factor implies higher "power," affecting both acceptance rates and profits. We already reported the impact of discount factors separately for buyers and sellers. Here, we compare acceptance rates and profits for all $(\xi, \delta)$ seller-buyer combinations.

We start with the percentage of accepted offers. Let $a_1(\xi, \delta)$ denote the rate of acceptance for some $(\xi, \delta)$ seller-buyer combination in period $t$ (see Appendix A for the data of the matching groups). Theory predicts that sellers with a high discount factor charge higher prices both in period $t = 1$ and period $t = 2$, and that buyers with a high discount factor reject profitable purchases in period $t = 1$ more often. This immediately implies that in period $t = 1$, $a_1(\xi, \delta)$ should have the smallest and $a_1(\xi, \delta)$
the highest acceptance rate, whereas $a_1(\zeta, \delta)$ and $a_1(\zeta, \delta)$ should be intermediate. Deducing acceptance rates from Table 1, the prediction is $a_1(\zeta, \delta) < a_1(\zeta, \delta)$. This turns out to hold in our data (see Table 3). The acceptance rates for the four combinations are $a_1(\zeta, \delta) < a_1(\zeta, \delta) < a_1(\zeta, \delta)$ with corresponding significance level of the one-sided Wilcoxon tests above the inequality signs. Intuitively, the acceptance rates in period $t = 2$ must exhibit the opposite inequality signs: If there are fewer acceptances in period $t = 1$ more buyers are left to accept in period $t = 2$. In accordance with this intuition, one can deduce $a_2(\zeta, \delta) > a_2(\zeta, \delta) > a_2(\zeta, \delta) > a_2(\zeta, \delta)$ from Table 1. We find that $a_2(\zeta, \delta) > a_2(\zeta, \delta) > a_2(\zeta, \delta)$ as predicted and significantly so (one-sided Wilcoxon test), but neither $a_2(\zeta, \delta) > a_2(\zeta, \delta)$ (as predicted) nor $a_2(\zeta, \delta) > a_2(\zeta, \delta)$ (not predicted) were significant.

Now consider profits (see Appendix A for the group data). Predictions are simple. Given the discount factor of the other player, a high own discount factor implies a higher profit. Given the own discount factor, a high discount factor of the other player implies a lower profit. It turns out that this holds in the experimental data for all possible $(\zeta, \delta)$ combinations (see Table 4). That is, though high and low discount factor types can actually realize the same profit in period $t = 1$, high discount factor types make larger profits because of the trade shifted to period $t = 2$. Let $u_S(\zeta, \delta)$ and $u_B(\zeta, \delta)$ indicate the average profits made in a $(\zeta, \delta)$ seller-buyer encounter. The average $u_S(\zeta, \delta)$ was roughly 19, and the average $u_B(\zeta, \delta)$ was about 21. The following inequalities are significant (with the corresponding significance level of the one-sided Wilcoxon tests above the inequality signs). We find that $u_S(\zeta, \delta) > u_S(\zeta, \delta)$, and $u_B(\zeta, \delta) > u_B(\zeta, \delta)$ for the buyer. Further, we find $u_S(\zeta, \delta) > u_B(\zeta, \delta)$ and $u_B(\zeta, \delta) > u_B(\zeta, \delta)$ for the buyer. Further, we find $u_S(\zeta, \delta) > u_S(\zeta, \delta)$ and $u_B(\zeta, \delta) > u_B(\zeta, \delta)$ because of the high rejection rates a $(\zeta, \delta)$ combination implies.

Result 4: In line with the prediction, high discount factors of either the seller or the buyer reduce the probability of a successful trade in period $t = 1$. Participants realize higher average earnings if their opponent has a low discount factor.

### VI. CONCLUSION

The literature substantiating the intuition of Coase’s (1972) durable-goods monopolist has inspired much theory but only few experiments. In this article, we have extended both lines of research. We solve, for the first time, the simplest case where discount factors are private information. Second, by conducting a laboratory experiment, we provide a test of the theory. Participants behaved rather reasonably according to qualitative predictions—possibly because we provided enough opportunity for learning. There are few unprofitable purchases, and there are generally lower prices in the second period, as predicted. Furthermore, participants reacted adequately to changes in discount factors (within-subject comparisons), and, as buyers, maintained higher acceptance thresholds in the first than in the second period. Ceteris paribus, a higher discount factor of at

### TABLE 3

| Shares (%) of Accepted Offers for All Discount Rate Combinations |
|----------------------|------------------|
|                      | $\delta = 0.3$   | $\delta = 0.7$   |
| $t = 1$              |                 |                 |
| Seller $\zeta = 0.3$ | 60.4            | 41.7            |
| $\zeta = 0.7$        | 49.8            | 31.9            |
| $t = 2$              |                 |                 |
| Seller $\zeta = 0.3$ | 43.6            | 54.7            |
| $\zeta = 0.7$        | 36.1            | 54.6            |

### TABLE 4

| Seller and Buyer Profits for All Discount Rate Combinations |
|----------------------|------------------|
|                      | $\delta = 0.3$   | $\delta = 0.7$   |
| $t = 1$              |                 |                 |
| Seller $\zeta = 0.3$ | $u_S: 20$        | $u_B: 22$        |
| $\zeta = 0.7$        | $u_S: 22$        | $u_B: 19$        |
| $t = 2$              |                 |                 |
| Seller $\zeta = 0.3$ | $u_S: 26$        | $u_B: 29$        |
| $\zeta = 0.7$        | $u_S: 32$        | $u_B: 28$        |
least one player shifts more trade to the second period. Whenever the situation becomes rather simple, as for instance in the second period, conditional rationality can account for most of the decision data.

It has already been indicated in the introduction that we view durable-goods monopolies as very intriguing. They challenge the conventional wisdom that several competitors are needed to induce competitive outcomes; they are also philosophically challenging by claiming intrapersonal decision conflict. After all, it is due to rational anticipation of own future behavior that the durable-goods monopolist may earn so much less than a usual monopolist. It seems remarkable that such insights seem to have been well understood by the participants.

APPENDIX A: SUMMARY STATISTICS

The summary statistics for all variables are reported in Table A-1 at the matching group level. Notation is as in the main part of the article except the new notation $a_1(\zeta, \delta)$ and $a_1(\zeta, \delta)$, which distinguishes acceptance rates of buyers with low and high discount factors. The complete data set with all individual decisions from the experiment, that is, all 1,440 negotiations, is available online at www.wiwi.hu-berlin.de/~skroeger/dgm/.

APPENDIX B: INSTRUCTIONS

The experiment was conducted in German language, and the original experimental instructions were also in German (available on request). This is a slightly shortened translated version of the instructions. Participants read the paper instructions before the computerized experiment started. In the beginning of the instructions, subjects were informed that the instructions are the same for every participant, that the instructions are the same for every participant, that the instructions are the same for every participant, that the instructions are the same for every participant. After all, it is due to rational anticipation of own future behavior that the durable-goods monopolist may earn so much less than a usual monopolist. It seems remarkable that such insights seem to have been well understood by the participants.

TABLE A-1
Summary Statistics

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<th>Group</th>
<th>$p_1$</th>
<th>$p_2$</th>
<th>$a_1(\zeta, \delta)$</th>
<th>$a_1(\zeta, \delta)$</th>
<th>$u_S(\zeta, \delta)$</th>
<th>$u_B(\zeta, \delta)$</th>
<th>$\Delta p_1(\zeta)$</th>
<th>$\Delta p_2(\zeta)$</th>
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<td>-0.29</td>
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<td>18.91</td>
<td>21.23</td>
<td>-6.08</td>
<td>0.79</td>
</tr>
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</table>
is the same, and the values are randomly determined at the beginning of each period independently for seller and buyer. All four constellations have the same probability. Only $S$ knows which of the two values $\zeta$ has been selected. Correspondingly, only $B$ knows his realized $\delta$ value.

At the beginning of each period, you are, according to your role, informed about:

- As seller $S$: Your discount rate $\zeta$.
- As buyer $B$: Your discount rate $\delta$ and your valuation for the product $v$.

At the end of each period, you will be informed about your profit in each period and your total payoffs.

Thank you for participating!

REFERENCES


