Hunting Unicorns? Experimental Evidence on Exclusionary Pricing Policies

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Abstract

We study the effects of above-cost exclusionary pricing and the efficacy of three policy responses by running experiments involving a monopoly incumbent and a potential entrant. Our experiments show that under a laissez-faire regime, the threat of postentry price cuts discourages entry and allows incumbents to charge monopoly prices. Current US policy does not help because it only bans below-cost pricing. In contrast, we find that a ban on postexit price hikes encourages entry; a ban on deep price cuts reduces preentry prices and encourages entry. While both these alternatives have less competitive outcomes after entry than laissez-faire does, they nevertheless both increase consumer welfare. For the latter proposal, this consumer gain is at the cost of lower overall welfare from attracting inefficient entrants, while for the former, overall welfare is comparable to current US policy.

1. Introduction

When should competition authorities or competition law worry about price cuts by an incumbent monopolist following entry? The standard legal approach is to view such price cuts as problematic, and call them predatory pricing, only if they are below the incumbent's cost. In the United States, this is the policy adopted by the Supreme Court in *Brooke Group Ltd. v. Brown & Williamson Tobacco Corp.* (509 U.S. 209 [1993]). Relatedly, some studies, like Ordover and Willig (1981)

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and Melamed (2005), advocate condemning pricing as predatory only if it deviates from short-run optimal behavior and involves sacrifice.

The *Brooke Group* rule provides broad scope for an incumbent monopolist with a known cost or other advantage over potential rivals to exclude those rivals. Consider, for example, American Airlines flights to and from Dallas Fort Worth International Airport in the 1990s. Generally, American charged high prices, but when attacked by other carriers, American charged low prices and expanded capacity. After rivals exited, "American generally resumed its prior marketing strategy, reducing flights, and raising prices to levels roughly comparable to those prior to the period of low-fare competition" (*United States v. AMR Corp.,* 335 F.3d 1109, at 5 [10th Cir. 2003]). The US Department of Justice sued American for monopolization (predatory pricing) but lost because American's prices were found to be above its costs. American was able to drive other airlines out with above-cost prices because it enjoyed advantages: economies of scope from having a Dallas–Fort Worth hub meant that the economic costs of other airlines—even so-called low-cost carriers—were higher for any given route.

Similar examples arise in other contexts. The incumbent cable company in Sacramento, California, rebuffed entrants by signing up subscribers at steep discounts, though there is no indication that the discounted prices were below the incumbent's own cost (see Hazlett 1995). Pacific, which had a monopoly on mechanical snubbers for nuclear power plants, used above-cost price cuts to recapture business threatened by Barry Wright, an entrant (*Barry Wright Corp. v. ITT Grinnell Corp.,* 724 F.2d 227 [1st Cir. 1983]). Northwest drove an entrant, Spirit Airlines, from the Detroit-Boston and Detroit-Philadelphia markets with deep price cuts that the district court found to be above cost (*Spirit Airlines v. Northwest,* 431 F.3d 925, 958 [2005]).[1] In 2014, Willamette Valley Company, an incumbent monopolist of patch, a product that fills imperfections in plywood, faced an entrant that initially offered significantly lower prices and drove the entrant from the market with large discounts. The entrant lost its predatory-pricing case, however, because the appellate court thought that Willamette's discounted prices probably exceeded its cost even assuming the allegations of the complaint were true (see *Clean Water Opportunities, Inc. v. Willamette Valley Company,* CV No. 16-227-JWD-EWD, at 4–5 [2018]; *Clean Water Opportunities v. Willamette Valley Company,* 2019 WL 113681).

Motivated by such competition policy cases and the idea that incumbent advantages often explain monopoly, we depart from most of the theoretical literature on predatory pricing, in which asymmetric information looms large. Instead, we focus on situations in which an initial cost advantage of the monopolist is common knowledge. In theory, a monopolist known to have low costs can charge high prices without fear of entry so long as it is free to respond to entry with prices below its rivals' costs but above its own. If those prices are an equilibrium of the short-run competition game, there is no issue of credibility, and so

[1] The appellate court thought that whether prices were above or below cost depended on whether low-fare tickets were a market and thought a jury needed to decide the market. No jury did.

no rational firm will ever enter. That means the incumbent can charge monopoly prices forever, or at least until a lower-cost firm materializes. From the vantage of consumers, this is a bad deal.

In this paper, we call pricing exclusionary if its effect is to induce exit or discourage entry, regardless of the intent underlying the pricing. We avoid the term predatory pricing because many define predatory pricing to be pricing below the predator's cost or pricing that involves sacrifice and that the predator implements only because of its exclusionary effects. Behavior can be exclusionary in our sense even if it is a short-run Nash response and involves no sacrifice or predatory intent; indeed, that is exactly the way our model and experiment are constructed. Whether there can be benefits from regulating such behavior is a question of the paper.

Because of cases like those discussed above, there has been a debate about the legality of above-cost exclusionary prices in the legal literature (see discussions in Edlin 2002, 2012, 2018; Salop 2005, 2006; Popofsky 2006; Hovenkamp 2005; Elhauge 2003)[2] and proposals that in theory could address this behavior. For instance, a policy suggested by Baumol (1979) would prevent an incumbent from raising prices after having fought off an entrant with price cuts (even above-cost price cuts). This rule clearly reduces an incumbent's incentives to cut prices. However, if entry takes place, it may still be in the incumbent's interest to reduce prices so much that entry would not be profitable. Anticipating this response, entry might not happen, in which case the incumbent can charge monopoly prices without fear of entry. To deal with such problems, Edlin (2002) suggests an alternative policy that would prohibit incumbents from reducing prices by too much after entry. That proposal may improve welfare through two closely related channels. First, entry will take place if the incumbent sets prices too high. Second, to avoid this, the incumbent may reduce prices in the first place.

Our paper's goal is to provide an experimental evaluation of these policies. To capture situations in which the disadvantage of the entrant is common knowledge, we assume perfect information. There is an incumbent monopolist with low costs and a rival with costs that are higher but still below the incumbent's monopoly price. An unregulated monopolist can thus drive the rival from the market while still earning positive profits. In fact, the short-run equilibrium price for the monopolist (after entry) is to price below the rival's cost. This makes exclusionary pricing an entirely credible, and indeed predictable, reaction if no law intercedes. Our main questions are whether firms enter, how firms price, and how entry and pricing depend on the policy environment.

We consider dynamic Bertrand-style price competition over 4 market periods, allowing for four policy treatments: laissez-faire, which has no regulation; *Brooke Group,* which is based on the court ruling and bans below-cost pricing; Baumol,

[2] In a famous predatory-pricing case (*Barry Wright Corp. v. ITT Grinnell Corp.*, 724 F.2d 227 [1st Cir. 1983]), Judge Stephen Breyer (as a district court judge) acknowledged that above-cost price cuts could be undesirable but worried that problematic price cutting could not be distinguished from desirable limit pricing that discourages entry but provides persistent low prices to consumers.

which makes postentry price cuts permanent; and Edlin, which bans postentry price cuts exceeding 20 percent. These policies affect entry and exit as well as pre- and postentry pricing; thereby they influence consumer and total welfare.

Under the first three policies, any equilibrium involves monopoly pricing in all periods with no entry: the policies make no link between preentry prices and future prices, so that the incumbents will charge monopoly prices prior to entry. Moreover, the rival will not enter because the incumbent will respond with price reductions, which drives the entrant from the market and makes entry unprofitable. Under the Edlin rule, there is likewise no entry, but to ensure this, the monopolist must price low prior to entry, because it is not free to cut prices after entry.[3] In theory, the Edlin rule thus leads to both greater consumer surplus and greater total welfare because it makes the market contestable. The high-cost entrant plays an efficiency-enhancing role without entering the market.

To assess the policies experimentally, we study exclusionary pricing and the effects of competition policies in a laboratory environment. While a laboratory approach has certain well-known disadvantages relative to empirical work, it has the great advantage of avoiding two central problems of any empirical approach to our questions. First, there is insufficient policy variation to study empirically the effects of different regimes on entry or pricing. In practice, we mainly observe the *Brooke Group* policy, and not the Baumol, Edlin, or laissez-faire policies, and without a point of comparison, it is impossible to gather empirical evidence on the consequences of even the *Brooke Group* rule that we observe. Second, and connected to that, it is difficult to identify exclusionary pricing at all. The prospect of such pricing may deter entry without exclusionary pricing ever being observed. Would-be entrants, willing to price much lower than a monopolist, do not enter for fear of being wiped out in a subsequent price war, and the econometrician never observes the would-be entrant or the exclusionary price.[4] Identifying such a problem in the field is challenging. How can we know that entry is insufficient, and if we do know, how can we attribute it to exclusionary pricing?

In the experiment, under the laissez-faire and *Brooke Group* policies, the incumbent usually charges the monopoly price before entry, as theory predicts. However, contrary to theory, there is significant entry, so we get to observe the incumbent's reaction: after entry, the incumbent typically charges exclusionary prices below the entrant's break-even level but above the incumbent's own cost because of its cost advantage.

Entry levels are higher under both the Edlin and Baumol rules, with the effect particularly strong under the Edlin rule. We attribute this boost in entry to these

[3] An exception is the final period, when it charges the monopoly price because of end-game effects.

[4] A notable exception is Goolsbee and Syverson (2008). They investigate how incumbent airlines respond to announcements from Southwest Airlines—the most famous potential competitor in the industry—that it will begin operating a route. The announcements are made before Southwest starts flying the route, and thus the authors can identify the entry threat separate from actual entry. They find that incumbents cut fares significantly when threatened by Southwest's entry and that the price cuts are only on threatened routes.

policies protecting entrants from dramatic postentry price cuts, with the Edlin rule simply banning them and the Baumol rule making them more costly.

The experiment reveals several benefits for consumers from protecting entrants from dramatic price cuts: lower prices prior to entry under the Edlin rule, lower prices after exit with the Baumol rule, and additionally increased time spent with low duopoly prices because of the increased entry under both policies. The cost of these policies to consumers is higher prices (less-intense competition) during periods of duopoly. Compared with the laissez-faire benchmark, consumers gain 17 percent in surplus under the Edlin rule and 11 percent under the Baumol rule when subjects have experience with the game. However, the Edlin rule performs relatively poorly from a total-welfare perspective, contrary to theory. The problem is that it increases entry, which leads to costly replication of fixed costs and inefficient production by the high-cost entrant. Under the Baumol rule, total welfare is roughly the same as under the laissez-faire and *Brooke Group* policies, as the reduction in deadweight loss from lower prices roughly balances with the higher production costs.

We see our theoretical and empirical results as an initial step in improving the design of competition policies. Roth (2002) discusses the role of economists as engineers in market design and calls for combining theoretical and experimental tools, because people in practice do not always follow theory and because experiments can offer more control than empirical observations of practice. Designing competition policies is a similar exercise. As airplane designers use wind tunnels, our "wind tunnel" provides evidence for advantageous effects of the Baumol and Edlin rules for consumer welfare under idealized conditions. Further studies may combine theoretical and empirical tools to investigate the robustness of these effects in the light of the various frictions of a real-world scenario and whether consumer benefits ever or often outweigh production inefficiencies.[5]

Our results are subject to varying interpretations. Economists concerned exclusively with total surplus can read our results as supporting laissez-faire or the status quo: in particular, total surplus is lower under the Edlin rule than under either the *Brooke Group* rule or laissez-faire, and the Baumol rule does no better than laissez-faire. On the other hand, competition policy analysts like Salop (2010) and Hovenkamp (1985, 2013), who think that competition policy should promote consumer gains, can read the experiment as providing support for policies like the Edlin and Baumol rules that use price drops or price increases to trigger liability.[6]

[5] See Edlin (2002) and Elhauge (2003) for discussions of some administrability issues of both these rules and the *Brooke Group* rule.

[6] While there will always be room for debate, there is ample support for the idea that antitrust either is or should be mainly pursuing consumer welfare or at least should give consumer welfare more weight than producer welfare. The US Supreme Court stated that "Congress designed the Sherman Act as a consumer welfare prescription" (*Reiter v. Sonotone Corp.,* 442 U.S. 330, 343 [1979]). Salop (2010) argues that competition policy should focus exclusively on consumer gains and losses, or more accurately on the gains and losses to those on the other side of the market from the allegedly anticompetitive activity (that is, focusing on the victims). Lande (1982, p. 151) surveys the history of US antitrust law and finds that "[t]he antitrust laws were enacted to become broad and

Our findings point to a problem with the equally-efficient-competitor test for monopolization that has taken hold in both the United States and Europe. Our theoretical and empirical analyses suggest that exclusionary pricing can exclude less-efficient competitors to the detriment of consumers, even if an equally efficient competitor would not be excluded by the same pricing. This consumer injury is a shortcoming of an equally-efficient-competitor test of legality, at least to those who are trying to protect consumers, a mandate that the United States and European competition authorities largely embrace.

Our paper is broadly related to the predatory-pricing literature, though that literature tends to focus on below-cost exclusionary pricing. There are several ways in which predation can be rationalized in game-theoretic models. Examples include reputation building (Kreps and Wilson 1982), signaling models (Milgrom and Roberts 1982; Scharfstein 1984; Fudenberg and Tirole 1986; Saloner 1987), and financial constraints (Bolton and Scharfstein 1990). These theories are mostly based on information asymmetries. In such models, the anticipation of predation can have an entry-deterrent effect even though entry improves welfare if it occurs. This finding is similar to ours, although, contrary to this literature we consider situations with symmetric information.[7] More recent theoretical contributions focus on the exclusionary potential of different pricing practices (for example, Karlinger and Motta 2012; Vasconcelos 2015) but emphasize below-cost pricing.

There is also some systematic empirical work that identifies predatory pricing with field data (for example, Lerner 1995; Scott Morton 1997; Podolny and Scott Morton 1999; Genesove and Mullin 2006). This work does not, however, analyze policy effects. The experimental literature on predatory pricing (see, for example, Isaac and Smith 1985; Harrison 1988; Jung, Kagel, and Levin 1994; Goeree and Gomez 1998; Capra et al. 2000; Chiaravutthi 2007; Bruttel and Glöckner 2011) focuses on whether predatory pricing exists, is credible, and induces exit. Contrary to our paper, that literature does not address above-cost price cuts and the policy proposals that are the focus of our analysis.

Our paper is closely linked to the literature that studies excessive pricing of dominant firms. That literature considers the legal treatment of excessive pricing (Motta and de Streel 2006; Ezrachi and Gilo 2009, 2010) and explains how and why legal approaches may differ across jurisdictions (Gal 2004). An innovative recent paper, Gilo and Spiegel (2018), examines excessive pricing when the following rule is adopted: if, after entry of a rival, the price of the dominant firm falls, its preentry price is deemed excessive, and it has to pay a fine proportional to its preentry excessive revenue. Like the Edlin rule, such a rule may benefit con-

flexible economic mandates to improve 'consumer welfare,' as Congress defined this term." Kirkwood and Lande (2008) argue that the courts have overwhelmingly adopted the consumer-welfare standard. And Hovenkamp (2013, p. 2477) concludes that "antitrust policy in the United States follows a consumer welfare approach" and that "Congress had no real concept of efficiency and was really concerned with protecting consumers from unfavorable wealth transfers" (1985, p. 250).

[7] Theories of predation that do not rely on information asymmetries include Harrington (1989), Cabral and Riordan (1994, 1997), and Fumagalli and Motta (2013).

sumers because the dominant firm would not only lower its preentry price but also increase its postentry price, thereby encouraging entry. Like the Edlin rule, this rule hinges liability on the relationship between the preentry price and the postentry price. The legal interpretation differs from the Edlin rule in a way that will be meaningful to lawyers—in the Edlin rule the low price is illegal, whereas for Gilo and Spiegel the high price is illegal—but the fundamental economic mechanism is quite similar, and so the Edlin rule and the Gilo and Spiegel rule are kindred.

The remainder of this paper is organized as follows. Section 2 introduces the model and experimental design and derives theoretical predictions. Section 3 presents the results. Section 4 discusses policy implications and concludes.

2. Theory and Experimental Design

2.1. The Game

We now explain the four variants of the game used in the experiment—laissez-faire, *Brooke Group,* Baumol, and Edlin. In all four cases, two firms, a low-cost incumbent L and a high-cost potential entrant H (henceforth, the rival), can produce a homogeneous good and participate in a 4-period game. In period 1, only the incumbent is in the market. In periods 2–4, both firms simultaneously decide whether to participate in the market. The firms then observe whether their competitor is in the market and simultaneously choose a price.

A firm that stays out earns a payoff of 50 per period from an outside option. To participate in the market, a firm has to pay 250 per period. Thus, including the opportunity cost from the forgone outside option, the fixed costs are 300.[8] We opt for per-period costs, rather than only one-shot setup costs, because recurring fixed costs such as rents are realistic and required to make exit different from no production. We do not include additional setup costs to reduce the complexity of the experiment. For simplicity, we do not allow firms to reenter after exit.

Market demand is given by $D(p) = 80 - p$. If only one of the firms $i = \mathrm{L}, \mathrm{H}$ is active in the market, its demand equals market demand, and it chooses its price as a monopolist. If both firms are active, they simultaneously and independently choose a price p_i. Their action sets are integers in an interval $[\underline{p}, \overline{p}]$ with treatment-specific boundaries. Consumers buy at the lowest price. Hence, each firm faces the following demand:

$$D_i(p_i, p_j) = \begin{cases} 80 - p_i & \text{if } p_i < p_j \\ \frac{1}{2}(80 - p_i) & \text{if } p_i = p_j \\ 0 & \text{if } p_i > p_j \end{cases}.$$

[8] We chose to work with a positive outside option to avoid a possible framing bias in favor of entry: subjects that are confronted with an outside option of 0 might think that staying out of the market is particularly unattractive, which might be less salient in our (formally equivalent) formulation with an outside option of 50.

Firm i's duopoly payoff in a given period is $\pi_i = (p_i - c_i)D_i(p_i, p_j) - 250$, where c_i is the marginal cost. Marginal costs are $c_L = 20$ and $c_H = 30$.

A firm is considered dominant in period t if it produced and served the entire market in period $t - 1$, either because it was a monopolist or a duopolist that undercut its rival in $t - 1$. The four game variants differ with respect to the interval $[\underline{p}, \overline{p}]$ in which the dominant firm can choose its price. A firm that is not dominant can choose its price in the full interval [0, 80]. In our baseline laissez-faire game, the dominant firm can also choose its price anywhere in the interval [0, 80].

In the *Brooke Group* game, the dominant firm cannot respond to entry with a price below its cost. In particular, if firm i is dominant in time period t (which means that it had the whole market in $t - 1$, either as monopolist or as undercutting duopolist) and firm i is in a duopoly in t, then firm i cannot price in t below its marginal cost; that is, $p_i^t \in [c_i, 80]$.[9]

The Edlin game limits deep price cuts of the dominant firm once a rival enters and it is in a duopoly. Then the dominant firm cannot price in t below 80 percent of its $t - 1$ price; that is, $p_i^t \in [.8 \times p_i^{t-1}, 80]$.

In the Baumol game, a restriction on pricing is triggered after the exit of the nondominant firm. If exit occurred in t, then at t and thereafter the dominant firm cannot raise its price above its $t - 1$ price; that is, $p_i^{t+k} \in [0, p_i^{t-1}]$ for $k = 0, 1, \ldots, 4 - t$.

We implement games that are as simple as possible but rich enough to study the strategic incentives created by the policies. Thus, we made the following design decisions: no reentry, a finite time horizon, asymmetric marginal costs, and a specific choice of the Edlin parameter (.8). Our choice of the allowable price reduction (20 percent, as suggested in Edlin [2002]) is guided by the consideration that it should give incentives for the incumbent to reduce preentry prices to deter entry and incentives to an entrant to meaningfully undercut the prices of a high-price incumbent in order to earn protection.[10]

2.2. Predictions

We now describe the subgame-perfect equilibria (SPE) outcome and the most important features of the equilibrium strategies in a nontechnical way. Online Appendix OA contains the technical details and proofs. Assuming continuous price sets, we first introduce some terminology. The break-even price p_θ^B for $\theta \in \{L, H\}$ is given by $(p_\theta^B - c_\theta)D(p_\theta^B) = F$. An incumbent's postentry price is exclusionary if it is below the entrant's break-even price p_H^B. The entry-deterring price p^* of L in the Edlin game is defined by $.8p^* = p_H^B$.

The break-even price is calculated by setting the economic profit equal to 0. An

[9] Our game simplifies the *Brooke Group* rule to make the experiment manageable; the actual restriction on below-cost pricing applies only if there is a prospect of later recouping the loss from below-cost pricing. As we will show, even our stricter implementation of the *Brooke Group* rule is indistinguishable from the laissez-faire regime, so this simplification seems of little consequence.

[10] It will be clear from the analysis below that, with a sufficiently large allowable reduction, the incumbent could keep the preentry price at the monopoly level and still fight off the entrant.

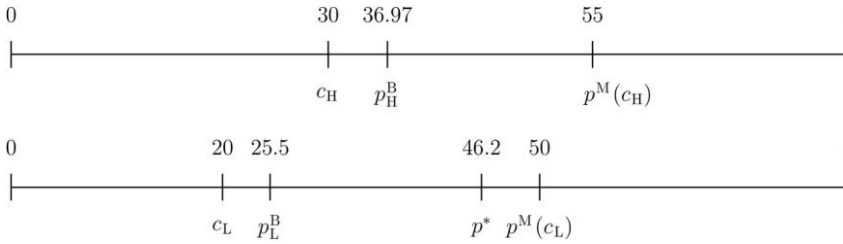

Figure 1. Prices and costs

exclusionary price by an incumbent guarantees that an entrant loses money from entry.

Figure 1 gives an overview of the relevant prices and marginal costs. While most aspects of the ordering depicted there hold for all conceivable parameterizations, two comparisons are specific to our parameterization: first, the break-even price p_L^B of firm L is below the marginal cost c_H of firm H. Thus, we are studying a situation with a substantial cost advantage for the incumbent.[11] Second, the entry-deterring price p^* is below the monopoly price of the low-cost firm ($p^M(c_L)$). This reflects the choice of a sufficiently binding Edlin restriction as discussed above.

2.2.1. Laissez-Faire and *Brooke Group* Games

The analysis for the laissez-faire and *Brooke Group* games is essentially the same. Both firms are essentially free to set arbitrary prices in both games; the *Brooke Group* ban on pricing below own costs is irrelevant because a rational incumbent does not choose such prices anyway. Prices therefore do not affect future choice sets, and historical prices do not matter for the equilibrium strategies. In each period, firms set short-term optimal prices. In particular, in duopoly periods, the incumbent undercuts the entrant charging an exclusionary price of 30. Anticipating this, the rival will not enter. Proposition 1 summarizes these conclusions; its formal proof is in Online Appendix OA.

Proposition 1. In both the laissez-faire and *Brooke Group* games, the incumbent charges the monopoly price, and there is no entry along the equilibrium path of the unique subgame-perfect equilibrium. In the event of off-equilibrium entry, the incumbent responds with an exclusionary price, and the entrant loses money and exits.

2.2.2. Baumol Game

The Baumol game is more complex. After entry, the incumbent knows that if it undercuts the rival, its duopoly price will be an upper bound for future prices if the rival exits. This reduces the incumbent's incentives to fight with low prices

[11] Without this assumption, further equilibria could emerge.

and might thereby protect entrants from exclusionary pricing. The incumbent must weigh the short-term benefits from undercutting against the long-term benefits from monopoly prices. As we show in the Online Appendix, in duopoly subgames this trade-off leads to multiple equilibria in which prices do not necessarily equal the rival's marginal cost. However, there is no entry in any equilibrium because prices in all of these equilibria are exclusionary so that the entrant cannot break even. In short, the Baumol rule discourages cutting price to Bertrand levels but does not prevent exclusionary pricing in SPE if there is off-equilibrium entry. Proposition 2 summarizes the equilibria, which are very much like the equilibria in the laissez-faire and *Brooke Group* games.

Proposition 2. In the Baumol game, the incumbent charges the monopoly price, and there is no entry along the equilibrium path of all SPE. In the event of off-equilibrium entry, the incumbent responds with an exclusionary price, and the entrant loses money and exits.

The equilibrium outcome is the same as in the laissez-faire and *Brooke Group* games. The difference exclusively concerns off-equilibrium behavior when exclusionary prices may be above the marginal cost of the high-cost firm but below its average cost.

2.2.3. Edlin Game

The Edlin game equilibria involve lower pricing than the three previous cases. If the incumbent charges more than p^* during periods 1–3, then its rival engages in hit-and-run entry. Anticipating this, the incumbent has two options. First, it can choose the monopoly price, which will attract entry. Second, it can choose an entry-deterring price, thereby avoiding entry but earning lower preentry profits. The second option is more attractive. The Edlin rule links the preentry price with postentry pricing possibilities, and the incumbent responds by investing in a lower price in order to be free to fight an entrant and in fact to credibly commit to fight an entrant.

Proposition 3. In the Edlin game, although the incumbent charges the monopoly price during period 4, the incumbent charges the lower entry-deterring price p^* during periods 1–3, and there is no entry along the equilibrium path of all SPE. In the event of off-equilibrium entry, the incumbent responds with an exclusionary price, and the entrant loses money and exits.

By limiting aggressive postentry pricing (which does not occur on the equilibrium path), the Edlin rule shifts aggressive pricing to preentry states that do occur and matter for consumers and efficiency. Although the SPE do not involve entry, the Edlin rule has a desirable effect on preentry prices because of the threat of entry. This differs from the previous games in which entry does not occur regardless the incumbent's preentry price.

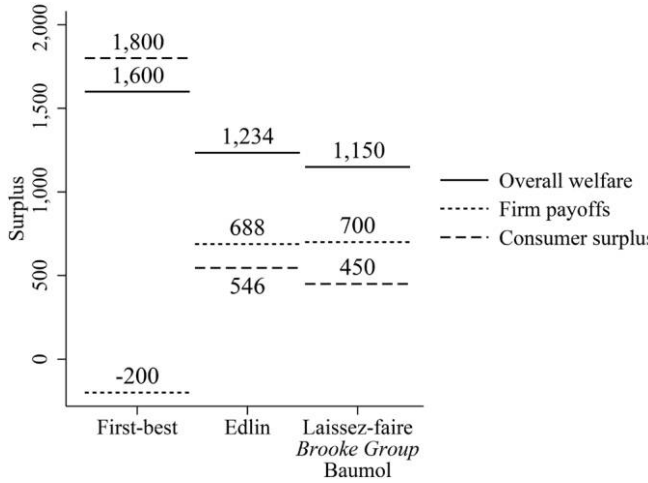

Figure 2. Per-period welfare benchmarks

2.2.4. Welfare

Figure 2 shows the equilibrium welfare results. For comparison, we plot the first-best regulation (low-cost monopoly under marginal-cost regulation, where consumers compensate the incumbent for the loss of 250 and consequently enjoy a surplus of 1,550 per period). Because the rival does not enter the market, it earns the payoff from the outside option (50), which makes total welfare 1,600. At the other extreme, we consider an unregulated low-cost monopoly, which results in low consumer surplus and total welfare but high payoffs for firms. This corresponds to the outcome of the laissez-faire, *Brooke Group,* and Baumol games. If the regulator or court cannot observe the incumbent's cost, it might seem like this is the best that could be expected.

The Edlin game, however, does better than the other policies and, unlike marginal cost regulation, does not require the court or regulator to observe cost. Any SPE of the Edlin game involves no entry and entry-deterring prices in periods 1–3. In the discrete version of the game, the price is thus 46, which results in firms' profits of 684 (including 50 of the rival) and a consumer surplus of 578. The numbers in Figure 2 take into account that this outcome applies only to periods 1–3, while in period 4 the outcome of the Edlin game is identical to that from the other three policies. The Edlin game results in a higher level of consumer surplus and total welfare than laissez-faire, the *Brooke Group* game, and the Baumol game because preentry prices are lower and production is equally efficient.

2.3. Experimental Design and Procedures

We apply a between-subjects design in which each subject is assigned to one of the experimental treatments: laissez-faire, *Brooke Group,* Baumol, or Edlin.

Each treatment consists of seven rounds of the 4-period game described above. At the beginning of each round, groups of two subjects are randomly drawn from the subjects in a matching group (stranger matching). In each group and each round, the roles (incumbent or rival) are randomly reassigned within the groups. When a new round starts and the subjects are newly matched, neither subject knows anything about the previous decisions of the other firm. Within a round, the firms and their roles remain the same. At the end of each period, subjects are informed about the market price, the output sold, and the payoffs realized by each firm in their group.

The sessions were run in the WiSo experimental research laboratory of the University of Hamburg in July 2015.[12] We provided written instructions that informed the subjects of the features of the markets (for a translation of the detailed instructions, see Online Appendix OC). As in other studies on experimental oligopolies—for example, Huck, Normann, and Oechssler (2004) and Roux and Thöni (2015)—we used an economic framing, explaining the strategic situation in terms of firms, prices, and quantities.[13] At the beginning of the session, subjects were endowed with 1,500 units of an experimental currency (points) to cover potential losses. The subjects' payments consisted of a €5 show-up fee plus the sum of the payoffs over the course of the experiment. The sessions lasted for about 90 minutes, with average earnings of €16.80. We conducted 10 sessions—two per treatment for the laissez-faire and *Brooke Group* treatments and three per treatment for the Baumol and Edlin treatments—with a total of 228 participants. The subjects were undergraduate students at the University of Hamburg.

3. Results

We first show that in the laissez-faire treatment above-cost exclusionary pricing is common. As a result, many participants do not enter, and those who do often exit. We then investigate the potential of the three policies to improve the situation. We distinguish between three market structures: preentry, the phase before entry when the incumbent needs to worry about future entry;[14] the duopoly phase, after the rival has entered and the two firms compete (when exclusionary behavior might arise); and the postexit phase, after one of the two firms—typically the rival—has left the market and, thus, no entry threat exists. Finally, we discuss the dynamics across rounds.

[12] The experiments were programmed in z-Tree (Fischbacher 2007) with recruitment by hroot (Bock, Baetge, and Nicklisch 2014). Subjects were randomly allocated to computer terminals in the laboratory so that they could not infer with whom they would interact. Throughout the experiment, communication was not allowed.

[13] Prior to the start of the treatment, subjects had to answer control questions. Subjects had access to a payoff calculator allowing them to calculate the payoff of hypothetical combinations of their actions and the actions chosen by their competitors.

[14] More precisely, we define the preentry phase as any period in which the rival has not so far entered, except period 4. We exclude the final period because the incumbent no longer can have any concerns about future market entry.

3.1. Exclusionary Pricing under Laissez-Faire

Above, we defined pricing as exclusionary if it prevents a rival from breaking even; such pricing provides rivals with the incentive to exit a market or not to enter in the first place. By this definition, when the incumbent charges 37 or below, pricing is exclusionary because the entrant cannot help but lose money by being in the market.[15] The definition encompasses both below-cost and above-cost exclusionary pricing.

Prior to entry (in the preentry phase), the incumbent is a monopolist and prices as such in the laissez-faire treatment. The average observed price is 49.6, with 83 percent of the cases at exactly the monopoly price of 50. Entry lowers the average incumbent's price substantially to 34.9, which is in the exclusionary range of 37 and below.[16]

Figure 3 shows the frequency of incumbents' duopoly prices for different price ranges. No incumbent prices below its own marginal cost of 20, so there is no below-cost exclusionary pricing. However, most incumbents (75 percent) respond to entry with above-cost exclusionary pricing: 26 percent of the prices are above the incumbent's marginal cost but below the rival's marginal cost, while around half of the observations (49 percent) are between the rival's marginal cost and its break-even point. Thus, entrants earn a positive profit in only 13 percent of the cases when they are in competition with an incumbent, with an average loss of 235 per period. Most entrants leave the market: among the 93 cases in which rivals join the duopoly market in periods 2 or 3, 57 (61 percent) leave the market at some point.

The other important effect of exclusionary pricing is that rivals do not contest the incumbent in the first place. Over the seven rounds, entry rates decline substantially from 96 percent at the outset to 42 percent by the final round. Once the rivals anticipate the incumbents' likely reaction, the majority of rivals no longer enter.

After the incumbent has pushed the entrant out, the game is in the postexit structure. The incumbents essentially switch back to monopoly pricing with an average price of 50.7.[17]

Result 1. In the laissez-faire treatment, firms charge monopoly prices when alone. On entry, incumbents generally engage in above-cost exclusionary pricing. They usually succeed in pushing the entrants out of the market and apparently dissuade the majority of experienced rivals from entering.

These observations largely match the predictions, except for the prevalence of

[15] In the discrete version of the game, the rival cannot break even if the incumbent sets price at 37. It cannot profitably undercut the incumbent as $36 < p_H^B$, and the duopoly profit margin when both firms charge 37 does not cover fixed costs.

[16] The decrease is highly significant ($p = .008$, exact Wilcoxon signed-rank test). This and all subsequent nonparametric tests are based on independent matching group averages.

[17] There are rare instances in which the incumbent leaves the market, which makes the entrant a monopolist. The average price in these situations is 54.8, which is very close to the rival's monopoly price of 55.

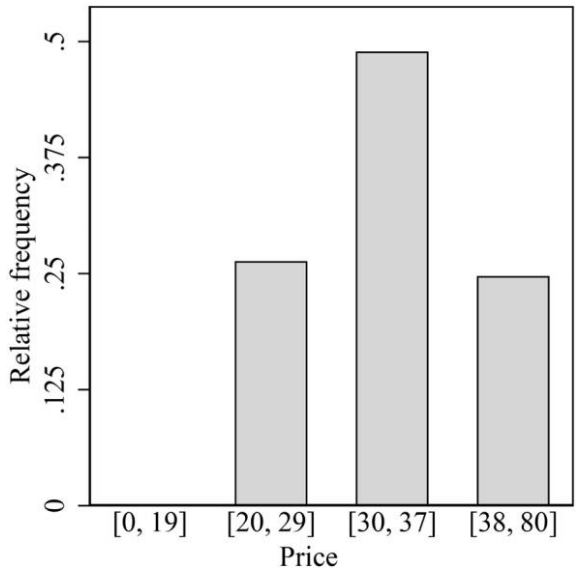

Figure 3. Incumbent prices in the laissez-faire duopoly structure

entry when theory predicts no entry. There are several potential explanations for the entry behavior. Rivals may initially be completely naive about the possibility of exclusionary pricing. Slightly more sophisticated rivals may be concerned about postentry price reductions, but they may not understand how much they need to earn to profitably enter the market, as they have to keep track of different notions of costs: variable costs (30 per unit), fixed operating costs (250), and opportunity costs (50). Finally, rivals may be aware of the potential problem but hope that the incumbent tries to get away with high prices. All of these possibilities are consistent with the observation that entry becomes far less common over time as subjects learn that it is usually not profitable.

3.2. Policy Effects

Section 3.1 shows that above-cost exclusionary pricing occurs under a laissez-faire regime. Fear of such behavior may discourage entry; however, one cannot be sure without comparing the laissez-faire results with a situation in which regulation makes exclusionary pricing more difficult. In this section, we provide such a benchmark. We compare the laissez-faire treatment with the *Brooke Group,* Baumol, and Edlin treatments. If we see more entry under the alternative policies, this will show that fear of price cuts by the incumbent discourages entry in the laissez-faire treatment.

Policy can affect market outcomes via two channels. First, it may influence entry and hence the frequency of the three market structures (the preentry, duopoly,

and postexit phases). Second, policy may affect prices under each market structure. We isolate these two effects below.

3.2.1. Prices under Different Market Structures

Preentry Structure. Theory predicts that in the laissez-faire, *Brooke Group,* and Baumol games, the incumbent charges the monopoly price of 50 in the preentry phase, because its price does not affect entry. In the Edlin game, the incumbent charges 46 to deter entry. Motivated by our theoretical analysis, Figure 4 bins the observed prices into three categories. The intermediate category [47, 53] contains the monopoly price and slightly higher and lower prices as predicted for the first three treatments. Low prices in the interval [0, 46] are those that qualify as entry deterring under the Edlin rule, because the incumbent can ensure that the entrant loses money in the following period. High prices in the interval [54, 80] are not predicted by our theoretical model for any treatment.

Figure 4 shows that in the laissez-faire, Baumol, and *Brooke Group* treatments, the incumbent usually prices in the intermediate category at or near the monopoly level. The average preentry price is close to the monopoly price of 50 in these treatments, with 49.6 in the laissez-faire treatment, 49.1 in the *Brooke Group* treatment, and 50.0 in the Baumol treatment. The Edlin treatment has substantially different results, with 45 percent of the observations in the low-price bin and an average price of 46.2, very close to the theoretical prediction for the Edlin treatment.[18] We find that firms systematically respond to the Edlin rule and frequently choose entry-deterring prices as expected.

Duopoly Structure. Advocates of strict exclusionary-pricing rules want to reduce the frequency of exclusionary pricing, while advocates of the laissez-faire and *Brooke Group* policies worry about the consumer or efficiency losses from discouraging price wars. As there is some entry in all treatments, we can investigate the policy effects on exclusionary pricing.

Figure 5*A* shows the frequency of exclusionary pricing (37 or lower) by incumbents in the periods when they compete with their rivals. Spikes indicate standard errors, calculated with clustering on matching groups. The frequency is 75 percent in the laissez-faire treatment, 69 percent in the *Brooke Group* treatment, 66 percent in the Baumol treatment, and 50 percent in the Edlin treatment. In the Edlin treatment, the frequency is significantly lower than in any of the other treatments.[19] Incumbents in the Edlin game are less apt to make exclusionary price cuts because the rule often binds and prevents such price cuts. When incumbents are not restricted by the rule, they make such exclusionary price cuts 88 percent of the time in the Edlin treatment.[20]

These observations reflect our expectations. In the laissez-faire and *Brooke*

[18] The differences across all treatments are significant at $p = .011$ (Kruskal-Wallis test).

[19] The differences are significant at $p < .003$ (Wilcoxon rank-sum test on average frequency in the matching group). All other bilateral comparisons are insignificant ($p > .129$).

[20] Incumbents are not restricted when either no rule applies to them or the rule allows exclusionary prices.

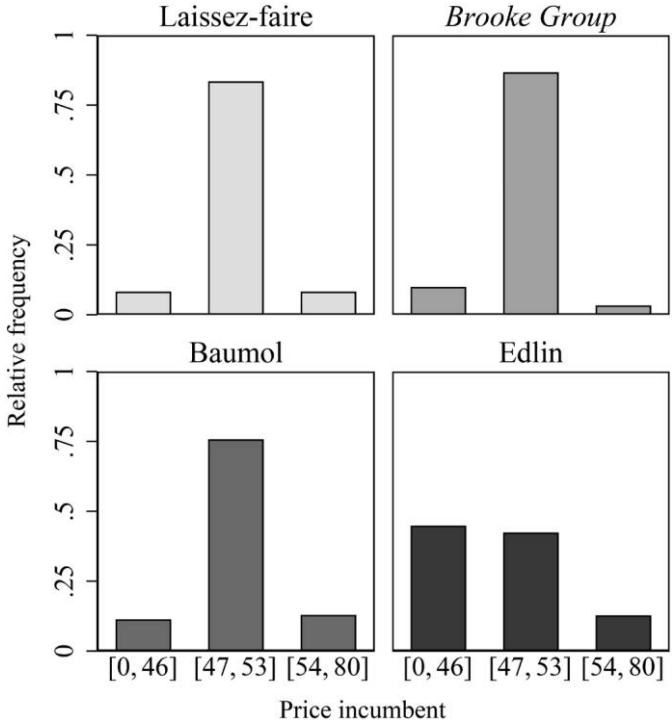

Figure 4. Incumbent prices in the preentry market structure

Group treatments, nothing prevents the incumbents from setting above-cost exclusionary prices, and it is optimal for them to do so. In the Baumol treatment, firms can set duopoly prices freely, but they must worry about the adverse consequences for postexit prices. Finally, in the Edlin treatment, incumbents are not allowed to pursue exclusionary pricing after high preentry prices.

Figure 5*B,* which shows the market prices in the duopoly phase, is essentially the mirror image of Figure 5*A*. The laissez-faire and *Brooke Group* treatments produce the most competitive duopoly prices, followed by the Baumol and Edlin treatments.[21] The differences between adjacent bars are not significant, but the comparison between Edlin and the first two treatments is significant ($p < .004$). If we pool the observations from the laissez-faire and *Brooke Group* treatments and test against the Baumol treatment, the differences become significant at .043. Thus, while the *Brooke Group* treatment does not have an effect, the two other

[21] In all treatments, prices are clearly above the entrant's marginal cost. This is in contrast to the results of Boone et al. (2012), who find prices close to the marginal cost of the less-efficient firm, while other experimental studies on Bertrand oligopolies with asymmetric costs find prices above the Nash equilibrium (Argenton and Müller 2012; Dugar and Mitra 2016). An important difference between our design and those studies is that, in our case, the entrant faces fixed costs.

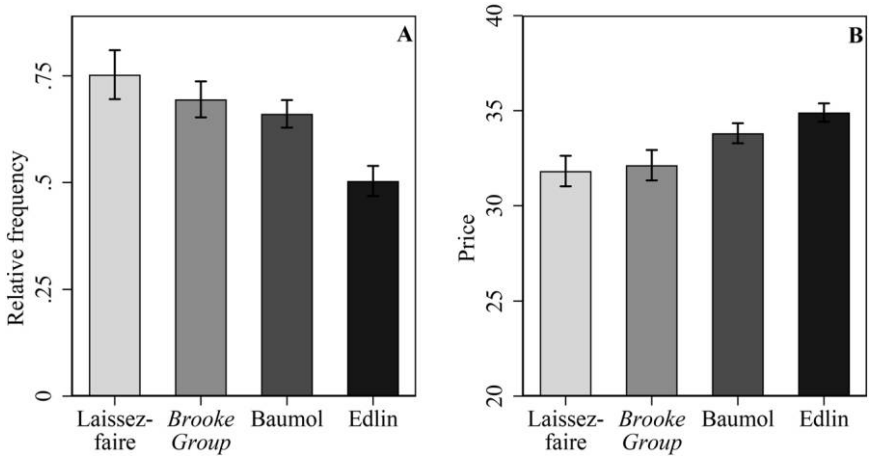

Figure 5. Exclusionary pricing (*A*) and market prices (*B*) in the duopoly market structure

policies lead to higher prices than in the laissez-faire treatment when entry occurs.

Postexit Structure. In the postexit structure, the remaining firm has a monopoly and does not face the threat of entry. As expected, such firms set the monopoly price: incumbents' average prices are very close to 50, with 78 percent or more at exactly 50 in the laissez-faire, *Brooke Group,* and Edlin treatments. In the Baumol treatment, we observe significantly lower prices because of the price cap. Virtually all firms (98 percent) price at the Baumol price cap whenever the Baumol price restriction applies. The average postexit price of the incumbents is 39. Result 2 summarizes.

Result 2. A benefit of protecting entrants from dramatic price cuts is lower prices prior to entry (Edlin treatment) and lower prices after exit (Baumol treatment) than in the laissez-faire and *Brooke Group* treatments.

Result 3. A cost of protecting entrants from dramatic price cuts is higher duopoly prices under both the Edlin and Baumol treatments than under the laissez-faire and *Brooke Group* treatments.

The first half of result 2 is consistent with the predictions. Restrictions on postentry price reductions like the Edlin rule can induce low preentry prices, while incumbents that can adjust prices freely after entry have no incentive to deviate from the monopoly price. In theory, the benefit of keeping price low after exit under the Baumol rule should have been realized only off the equilibrium path, but as entry and exit are both common, this benefit is frequently realized.

Result 3 reveals a cost of aggressive rules that ban or discourage postentry price cuts: these rules raise price in duopoly periods by limiting price wars. This cost does not arise on the theoretical equilibrium path because entry never occurs.

In the experiment, however, the fear of courts and commentators about chilling competition after entry becomes real and important. This finding lends support to the worries of Judge Breyer, who was concerned in the Barry Wright case about chilling postentry price wars and commented that "[t]he antitrust laws very rarely reject such beneficial 'birds in hand' for the sake of more speculative (future low-price) 'birds in the bush'" (*Barry Wright,* 724 F.2d 227, at 24).

3.2.2. Market Structure Effects

We show above how the price effects of policy depend on market structure. The overall policy effects also depend on how often each of the three market structures will arise under each policy.

Table 1 shows the percentage of periods in which the market is in a given structure for rounds 5–7, after firms have some experience with the game. There is substantially more entry under both the Edlin and Baumol treatments than under the laissez-faire or *Brooke Group* treatment, and this corresponds with much higher fractions of time spent in the preentry phase in the latter two treatments. Over 70 percent of the time is spent in the preentry phase under the laissez-faire and *Brooke Group* treatments, compared with 40 percent under the Edlin treatment and 57 percent under the Baumol treatment. This makes sense, as both the Edlin and Baumol treatments protect entrants by either banning (Edlin) or discouraging (Baumol) deep price cuts. The preentry phase is particularly rare in the Edlin treatment.

Consumers benefit from the extra time spent in the duopoly phase under the Edlin and Baumol treatments because prices are lower in that phase. Justice Breyer is wrong to see the benefits of duopoly competition as analogous to birds in hand. The benefits from price wars materialize only after entry, and more time is spent in the duopoly phase under the Edlin and Baumol treatments than under the *Brooke Group* and laissez-faire treatments.

Result 4. A consumer benefit of protecting entrants from dramatic price cuts is significantly more entry and more time spent in the price war state of duopoly under both the Edlin and Baumol treatments than under the laissez-faire and *Brooke Group* treatments.

Overall, entry in period 2 is significantly more likely under the Edlin and Baumol treatments than under the laissez-faire and *Brooke Group* treatments (73 percent and 61 percent versus 52 percent and 45 percent, respectively). The additional entry under the Edlin treatment arises mainly in cases in which the incumbent has priced at monopoly levels instead of the predicted entry-deterring levels. If we refer to Figure 4, we see that under the Edlin treatment incumbents charge low, entry-deterring prices about half the time. But because roughly half of incumbents continue to charge monopoly prices, the Edlin policy attracts more entry than the other policies.

Table 1
Frequency of Market Structures

Structure	Laissez-Faire	*Brooke Group*	Baumol	Edlin
Preentry	71	73	57	40
Duopoly	18	12	21	28
Postexit	11	15	22	32

Note. Values are the percentages of periods with a given market structure in rounds 5–7. In addition to the cases in which the incumbent needs to worry about future entry, the preentry category contains period 4 interactions for which the rival has not previously entered. In addition to the cases in which one of the firms has left the market, the postexit category contains the few cases in which both firms exited the market.

3.3. Dynamics

Investigating the dynamics across the rounds gives us an indication of whether play converges toward the theoretical predictions once subjects become more experienced with the strategic environment. We first study the dynamic in prices and then in market structure.

Prices. To explore trends in prices from round 1 to round 7 (time trends) we ran ordinary least squares estimates for the incumbents' preentry prices in the first period (Table OB1 in the Online Appendix). No statistically significant time trends emerge for these prices in the laissez-faire, *Brooke Group,* and Baumol treatments. In fact, in all rounds, preentry prices under the laissez-faire, *Brooke Group,* and Baumol treatments are close to the monopoly price, with an overall average of 81 percent of prices set at exactly the monopoly level.

In contrast, the Edlin treatment has statistically significant time trends, and prices come down meaningfully below monopoly levels in later rounds. In rounds 1–4, only 33 percent of the incumbents choose entry-deterring prices in the preentry phase, whereas in rounds 5–7, this percentage increases to 59 percent. The difference suggests that subjects learn how to react to the strategic incentives provided by the Edlin rule over time.

Table OB1 also shows that market prices in the duopoly phase are significantly higher in the Baumol and Edlin treatments than in the laissez-faire and *Brooke Group* treatments. The time trend is significantly negative, which suggests that competition becomes fiercer in later rounds.

Market Structure. Figure 6 shows the fraction of games in which the rival enters at some point. Across all treatments, we observe that there is less entry when subjects gain experience. The drop is particularly strong in the laissez-faire and *Brooke Group* treatments. In contrast, under the Edlin treatment entry rates drop slowly, with the rate for the Baumol treatment somewhere in between. Continued high entry under the Edlin and Baumol treatments makes sense, as those policies provide protection to entrants. In particular, the incremental entry in the Edlin

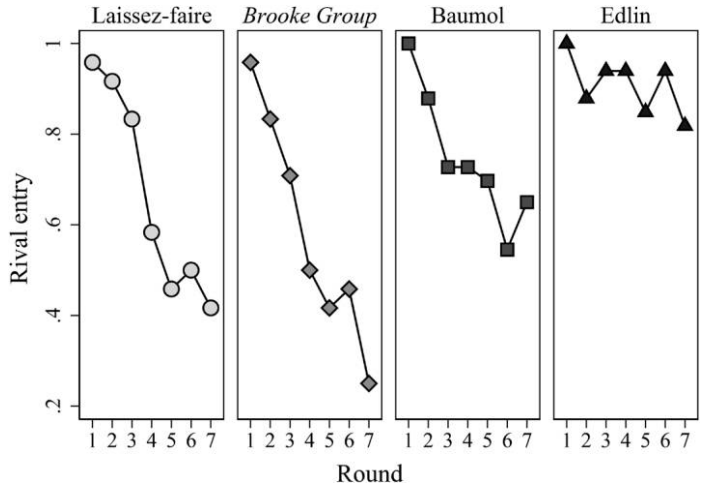

Figure 6. Frequency of rivals' entry

treatment over that in the *Brooke Group* and laissez-faire treatments is largely explained by rivals that rationally react to the monopoly prices of incumbents who fail to realize that they should charge entry-deterring prices. Because the strategic incentives set by the different policies require experience to understand, in our welfare analysis below, we emphasize the results of the games with experienced subjects and restrict the analysis to the second half of the experiment (rounds 5–7).

3.4. Welfare Implications of the Policies

The welfare implications of the treatments flow from the observations above about price and market structure effects. The Edlin treatment has lower prices prior to entry and so dominates the other policies in the preentry phase in terms of both consumer surplus and total welfare. Consumer surplus is 44 percent higher in the preentry phase compared with a pooling of results from the laissez-faire and *Brooke Group* treatments, and the difference between the Edlin treatment and each of the other three treatments is highly statistically significant for both consumer surplus and total welfare ($p < .002$, Wilcoxon rank-sum tests, rounds 5–7). In the postexit structure, the Baumol treatment has the lowest prices and offers significantly higher consumer surplus and overall welfare than the unregulated monopolies observed under the remaining treatments ($p < .001$). In the duopoly structure, we observe the highest consumer surplus in the laissez-faire and *Brooke Group* treatments, but the differences across the four treatments remain insignificant ($p = .155$, Kruskal-Wallis test). To analyze the overall welfare implications, we aggregate the policy effects across market structures. Figure 7 shows the average per-period consumer surplus and overall wel-

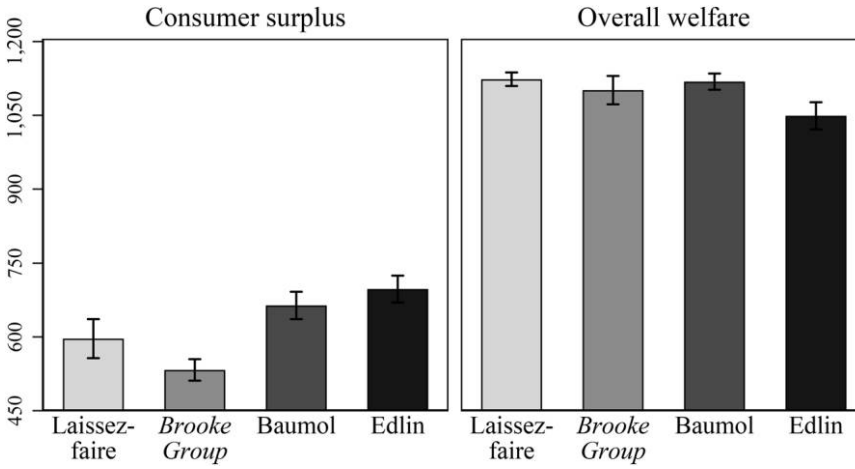

Figure 7. Welfare implications in rounds 5–7

fare for experienced subjects (rounds 5–7). Bars show averages over the 4 periods and all groups, and spikes indicate standard errors (with clustering on matching groups).

Both the Baumol and Edlin treatments yield substantially more consumer surplus overall than the other two treatments.[22] The Edlin treatment yields 23 percent more consumer surplus than a pooling of the laissez-faire and *Brooke Group* treatments (697 versus 565 per period). We can decompose this gain into an increase to 651 from lower pricing, holding market structure frequencies as they were in the laissez-faire and *Brooke Group* treatments, with the rest of the gain from shifts in the frequency of the market structures (for example, more entry and time spent in duopoly price wars and less in high-priced preentry states).[23] A similar decomposition for the Baumol treatment indicates a small increase in consumer surplus to 578 from lower pricing, with the remaining gain to 664 from market-structure changes.

On the other hand, overall welfare is lowest under the Edlin treatment, with the other three policies clustered together. The low total welfare in the Edlin treatment is the downside of particularly pronounced (off-equilibrium) entry. Entry leads not only to duplication of fixed costs but also to more (undesired) production by the high-cost rival and (desired) competitive pressure.

Result 5. The Edlin rule dominates the laissez-faire rule prior to entry, the

[22] Differences in consumer surplus relative to pooled values of the laissez-faire and *Brooke Group* treatment results are highly significant: $p = .010$ against the Baumol treatment and even more so against the Edlin treatment.

[23] In decomposing this way, we consider a thought experiment of first changing prices from the laissez-faire and Brooke treatments and then market structure. The decomposition would look different if the order were reversed and there is no natural order.

Baumol rule does so after exit, and both policies yield the benefit of increased entry and time spent in the low-priced duopoly state. However, both policies come at the cost of weaker competition in the duopoly state. The overall welfare effects depend on the frequency of these market structures. The Edlin rule is favorable from a consumer perspective, with the Baumol rule a close second when firms are sufficiently experienced with the rule. Overall welfare is lowest under the Edlin rule, while the other three rules produce very similar results.

4. Policy Discussion and Conclusion

While he was chairman of the UK Office of Fair Trading, John Vickers asserted, "Clearly there are circumstances in which the entry of less-efficient rivals can improve social welfare because the gain in allocative efficiency through lower prices can outweigh the loss in productive efficiency through higher costs." He further argued that "there is little basis in economic theory for a rule that always permitted above-cost price discrimination by dominant firms in response to competition" (Vickers 2005, p. F256). Indeed, if firms are always free to charge any price above their cost, as they are under the *Brooke Group* and laissez-faire treatments, then a monopoly with advantages over would-be entrants can charge monopoly prices with little fear of entry because entrants know that they will not survive postentry price wars.

Our experiment provides support for the idea that encouraging the entry of inefficient firms or the threat of their entry, by protecting entrants as the Edlin and Baumol rules do, could improve consumer welfare. It does not, however, provide support for the idea that exclusionary-pricing policies can improve overall social welfare over laissez-faire or *Brooke Group*.

In the 1980s, courts began to think that low prices were so unlikely to be anticompetitive (that is, predatory) that anticompetitive low pricing was as rare as unicorns. Such skepticism led the United States, Europe, and many other jurisdictions to give firms either an outright safe harbor (the United States) or a nearly free pass (Europe), so long as a firm prices above its cost. The leading case in the United States is *Brooke Group,* which requires plaintiffs to prove both below-cost pricing and the prospect of recovering losses with higher prices later to successfully attack an incumbent's price cut. The current EU enforcement policy also assumes that above-cost prices are not problematic. A guidance note on the European Commission's application of article 82 of the Treaty Establishing the European Community (now Treaty on the Functioning of the European Union, art. 102) says, "If the data clearly suggest that an equally efficient competitor can compete effectively with the pricing conduct of the dominant undertaking, the Commission will, in principle, infer that the dominant undertaking's pricing conduct is not likely to have an adverse impact on effective competition, and thus on consumers, and will therefore be unlikely to intervene" (Guidance on the Commission's Enforcement Priorities in Applying Article 82 of the EC Treaty to Abusive Exclusionary Conduct by Dominant Undertakings, 2009 O.J. [C45] 11). The preceding condition is satisfied if a firm prices above its own costs.

While a safe harbor for above-cost pricing is the general rule in the United States, Europe (see, for example, Organisation for Economic Co-operation and Development 2005), and around the world, it is not entirely unchallenged, and there are exceptions. Indeed, in the American Airlines case, the US Department of Justice argued (albeit unsuccessfully) that price cuts are predatory if they are unprofitable, even if price remains above cost. Similarly, the US Department of Transportation (2001) issued an enforcement policy in the waning days of the Clinton administration declaring a similar standard for judging unfair competition under its own competition statute. In a few cases with European companies—notably Akzo, Compagnie Maritime Belge, and Irish Sugar—the European Union found abuse of dominance when above-cost price cuts had the purpose of eliminating an entrant.[24] In addition, German and Korean competition authorities say that under their nation's laws, prices can be illegal even when above cost. Indeed, Korea appears to take an approach similar to the Edlin rule for dominant firms (Organisation for Economic Co-operation and Development 2005, pp. 8, 134, 163).[25]

Do our experimental results support proposals to change policy with respect to above-cost price cuts and to expand the cases for which these cuts are deemed problematic? The interpretation of our results depends on the observer's point of view.

We do provide support for the plausibility of above-cost price cuts excluding firms from the market by limiting entry. In particular, exclusionary price cuts are a common reaction to entry in our experiment, and when the Edlin rule bans deep postentry price cuts, we observe substantially increased entry, so roughly half as much time is spent in the preentry states in the Edlin treatment as in the laissez-faire or *Brooke Group* treatments. In the Baumol treatment, where exclusionary price cuts are more costly to the incumbent, the time spent in the preentry state lies in between that for the Edlin and Baumol treatments. The fact that the Edlin and Baumol rules both encourage entry does not by itself make them superior to laissez-faire or *Brooke Group* rules, however.

On the one hand, proponents of laissez-faire or *Brooke Group* rules can take heart from our experiment. Whereas theory suggests that the Edlin rule dominates because it has lower prices and equally efficient production, in the experiment, the Edlin rule performs considerably worse under a total-welfare standard than the laissez-faire and *Brooke Group* rules because the Edlin rule creates inefficient entry and high-cost production. In the Baumol treatment, the benefits from

[24] Key cases in this line include *Compagnie Maritime Belge Transps. SA v. Commission* (1996 E.C.R. II-1201), affirmed by joined Cases C-395/96 P and C-396/96 P, *Compagnie Maritime Belge Transps.*, in which the European Court of Justice affirmed that selective above-cost price cuts to meet an entrant were illegal when a firm with over 90 percent market share has the purpose of eliminating an entrant, and *Irish Sugar PLC v. Commission* (1999 E.C.R. II-2969), which was affirmed on other grounds (Case C-497/99 P, 2001 E.C.R. I-5333).

[25] With regard to predatory pricing by dominant enterprises, in Korea "[a]ctivities . . . which are likely to exclude their competitors by providing goods and services at lower prices than ordinary prices," are illegal (Organisation for Economic Co-operation and Development 2005, p. 163).

the low prices the Baumol rule produces are roughly balanced by the costs of inefficient entry and inefficiently high-cost production.

On the other hand, the experiment provides reason for consumer welfare advocates such as the antitrust authorities in the United States and Europe to support policies like the Edlin and Baumol rules, as both rules do better under a consumer-welfare standard than either laissez-faire or the *Brooke Group* rule. The consumer-welfare gains result because the rules promote entry and low prices. In the Edlin treatment, roughly 60 percent of the incumbents charge low entry-deterring prices in later rounds, and in the Baumol treatment, price wars after entry lead to substantial and enduring consumer benefits.

Of course, one must recognize that our experiments necessarily rely on specific parameterizations. If the game were longer than 4 periods, those pricing improvements might come to be more important, whether before entry, as in the Edlin case, or after entrants eventually leave the market, as under the Baumol rule.[26] Another factor in favor of the Edlin rule that does not appear in the experiment is that entrants may become more efficient over time through learning by doing such as in Cabral and Riordan (1994), Besanko et al. (2010), and Besanko, Doraszelski, and Kryukov (2013). Finally, some results could be sensitive to the technologies and demand we assume. For example, adding a sunk setup cost might lower entry levels and tilt the outcome in favor of the Edlin rule. Substantial product differentiation is likely to lower the impact, both positive and negative, of the Edlin and Baumol rules, as deterring entry is difficult with substantial product differentiation and as incumbents are correspondingly less apt to respond to entry with deep price cuts.

Much like an empirical study of an industry, our results are only about a particular industry. While concerns about specific parameters might be addressed by doing more experiments, other concerns cannot. The experiment, by design, does not shed any light on administrability issues of the rules nor on how the rules would fare in a more complex Hayekian environment that concedes that much information is controlled by the parties and unavailable to courts.

For the Edlin and Baumol policies, identifying price cuts and price increases is critical, and when there are many prices (as with an airline) or when product quality varies over time, this can be problematic. Entry is also not necessarily easy to identify in practice. There is finally the question of how long price restrictions are imposed under the Edlin or Baumol rule. Such administrability concerns push many commentators to favor dovish predatory-pricing policies (see, for example, Easterbrook 1981), but it is not entirely clear that the problems of administering the dovish *Brooke Group* rule are smaller than the problems of administering dynamic pricing restrictions. Traditional cost-based tests have the same problems of the Edlin and Baumol rules in measuring price in a complex environment. Moreover, cost-based tests add the difficulty of measuring cost and of deciding what cost is relevant to compare with price (marginal cost, average

[26] It also seems likely that, under the Baumol rule, equilibria with entry would emerge with sufficiently low fixed costs: it would be unattractive for the incumbent to reduce price sufficiently to induce exit; anticipating this, the rival would enter.

variable or avoidable cost, average incremental cost or average total cost) and whether opportunity costs should be counted as costs and, if so, how to properly measure them.[27]

A key feature of both the Edlin and Baumol rules is a dynamic nature: under those rules, pricing patterns can be illegal regardless of price level. Although our experiment makes the distinction between static rules and dynamic rules stark, existing law emphasizes a static price-cost comparison but incorporates similar dynamic considerations. In particular, under the *Brooke Group* precedent, a plaintiff needs to demonstrate both below-cost pricing and that the predator can raise price sufficiently to recoup the losses from below-cost pricing. In a sense, this loss-recoupment requirement is like the Baumol rule. The differences are that any price increase is illegal under the Baumol rule, whereas the *Brooke Group* rule focuses only on large increases and only after below-cost pricing.[28] The price drops that trigger the Edlin rule's restrictions are likewise relevant under existing law. Although price drops are not an element of illegality under the *Brooke Group* rule, price drops nonetheless are usually what precipitates an inquiry or complaint, and then the focus becomes whether price is below cost.

Our results make one wonder whether other policies might be better than the four we consider. For example, one might consider a rule-of-reason approach that involves intertemporal linkages akin to those in the Edlin and Baumol policies but that limits the protection of inefficient entrants. For instance, liability might depend on some combination of the size of the price cut and how close price gets to below-cost pricing. That could limit the possibility of inefficient entry while still providing some incentives for incumbents to price low prior to entry. Similarly, a variant of the Baumol rule might have liability triggered by large price increases following near-cost pricing but not following prices that are substantially above cost. Future experiments might explore whether such policies could allow consumers to gain without significant losses in total welfare or even with increases in total welfare.

We see experiments like ours as a useful input for the design of competition policies. Admittedly, experiments have an obvious limitation: people outside the lab may behave differently than people inside the lab. And yet a parallel critique can be made of the theoretical literature: people outside economic models may behave differently than agents inside the models. True behavior might lie somewhere between theory and experiment. It would be wonderful to simply rely on empirical work, but given that the Baumol and Edlin rules are not applied by antitrust authorities, such investigations are impossible. For this reason, wind tunnel experiments like ours are an important complement to theoretical analyses and provide a relatively cheap way to investigate the functioning of different policies with real actors.

[27] See Hemphill and Weiser (2018) and Edlin (2018) for recent discussions of the complexities of comparing price with cost under the *Brooke Group* rule.

[28] As we described when introducing the games, the experiment did not include the loss-recoupment prong of the *Brooke Group* rule given its complexity, but this omission is likely without loss since the below-cost element by itself made the *Brooke Group* treatment indistinguishable from the laissez-faire treatment.

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