

Nitsche, Rainer

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**On the Effectiveness of Anti-Predation
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Rainer Nitsche

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Wissenschaftszentrum Berlin für Sozialforschung gGmbH,
Reichpietschufer 50, 10785 Berlin, Germany, Tel. (030) 2 54 91 – 0
Internet: www.wz-berlin.de

ABSTRACT

On the Effectiveness of Anti-Predation Rules

by Rainer Nitsche*†

Current anti-predation rules are designed to detect and prevent actions that are only taken to drive out a rival. We evaluate the performance of these rules in a simple entry game. We find that the rules used by competition authorities fail to encourage sustained competition in the market. Moreover, despite the rules an inefficient incumbent cannot be replaced by a more efficient entrant unless the difference in efficiency is extreme. One reason for these failures is that incumbents choose a strategic response to the legal environment. Large incumbents, for instance, crowd the product space. This is detrimental to welfare and consumer surplus.

Keywords: competition policy, entry

JEL Classification: K42, L41

ZUSAMMENFASSUNG

Die Effektivität von Wettbewerbsregeln gegen Verdrängungspreisverhalten

Wettbewerbsbehörden stützen sich auf Wettbewerbsregeln, um Unternehmen an Handlungen zu hindern, die nur dann profitabel sind, wenn sie zum Marktaustritt des Rivalen führen. Der Autor analysiert die Effektivität dieser Regeln in einem einfachen Markteintrittsspiel und zeigt, daß die Regeln keinen dauerhaften Wettbewerb im Markt erzeugen. Darüber hinaus verfehlen die Regeln ein weiteres Ziel: auch bei perfekter Durchsetzung der Regeln kann ein effizienterer Marktneuling in einem Verdrängungskampf nicht gegen das alteingesessene Unternehmen gewinnen, es sei denn, die Effizienzunterschiede sind extrem. Ein Grund für dieses Scheitern ist, dass sich die alteingesessenen Unternehmen strategisch an die rechtlichen Rahmenbedingungen anpassen. Wenn ein Markteintritt von effizienteren Unternehmen droht, so entscheiden sie sich eher für eine Angebotserhöhung als den Markteintritt zu gestatten. In dem untersuchten Spiel mindert dies Wohlfahrt und Konsumentenrente.

* Rainer Nitsche, Charles River Associates, Brussels, rmitsche@crai.be. This work was conducted while the author was affiliated with the Wissenschaftszentrum Berlin.

† The author expresses his gratitude to Paul Geroski, Paul Heidhues, and Lars-Hendrik Rööller for their helpful comments and criticisms.

On the Effectiveness of Anti-Predation Rules

Rainer Nitsche*[†]

2002

Abstract

Current anti-predation rules are designed to detect and prevent actions that are only taken to drive out a rival. We evaluate the performance of these rules in a simple entry game. We find that the rules used by competition authorities fail to encourage sustained competition in the market. Moreover, despite the rules an inefficient incumbent cannot be replaced by a more efficient entrant unless the difference in efficiency is extreme. One reason for these failures is that incumbents choose a strategic response to the legal environment. Large incumbents, for instance, crowd the product space. This is detrimental to welfare and consumer surplus.

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1 Introduction

The enforcement of measures against predation has recently received considerable attention. The Microsoft case stands out, but efforts by the U.S. Transportation and Justice departments to develop new approaches to analyse predation cases in the airline industry are of potentially greater importance given their character as a guideline. At the same time the European Commission and competition authorities elsewhere have implemented a number of behavioural anti-predation rules on a case by case basis as remedies against market power in merger control procedures. These practical efforts by competition authorities to deal more effectively with predation cases has been accompanied by theoretical attempts to draw more consistently on the findings of advanced industrial organisation theory (Bolton et al. 2000). Indeed, since the early 1980s it is clear that some of the legal arguments that evolved for example in the Brooke case in the United States are difficult to sustain on the basis of economic theory. This paper attempts to support the efforts to re-align the practice of competition authorities and courts with the findings of economic theory.

Our contribution is to analyse the existing anti-predation rules in two ways: First, we try to pin down the implied procedures in a precise but reduced form. Building on these stylised rules we then, second, analyse the strategic behaviour of firms given these rules. With this approach we can address some shortcomings of the existing literature, which we claim is inconsistent in its findings, ignores important welfare implications, and neglects the strategic impact of new rules on the behaviour of the firms.

In particular we find that all existing anti-predation rules lead to a regulation induced first-mover advantage that causes the likely failure of one important feature of competition: selecting the most efficient firms. Thus, rules are biased in two ways. On the one hand, they are based on the general presumption that entry will be in the public interest, which is not correct. On the other hand, they put the incumbent in a better position by taking his capacity as given when determining the legality of his pricing behaviour. While we do make cautious remarks regarding potential advancements of the existing approaches, we do not attempt to develop a full fledged alternative procedure. Indeed, our cause is served, if we can deepen the discussion on the existing procedures and proposals.

We define six distinct anti-predation rules. All definitions intend to capture practiced rules (U.S., U.K.) or rules that have played a role in the

literature (a rule proposed to the E.U., Baumol Rule, Williamson Rule). In order to evaluate the enforcement rules we employ a very simple model of spatial competition based on Salop 1979. Although popular in the literature, the model uses a particular demand function. Despite this loss of generality we employ this model since it illustrates our results well. By placing buses or airplanes around a circle, it makes the decisions on entry location, frequency and price more transparent than any other model. Moreover, it incorporates the trade-off between the “love for variety” and the “business-stealing” effects. Because of these features, it has been used in the transport context and there exist calibrated demand functions.¹ While we do not make use of the latter in order to obtain analytic solutions, we check the robustness of our results by comparing them to calibrated models.

In extensive form reputation games the payoff of fighting depends on the initial probability that a large firm is an aggressive type which always fights. These models are notoriously difficult to solve. This may be one reason why the performance of anti-predation rules has, to our knowledge, never been systematically tested in the literature. We pursue the analysis of predation in a simple complete and perfect information entry game that captures the intuition derived in the incomplete information reputation games as well as in the complete information extensive form long purse games.

The effectiveness of anti-predation rules depends on both detection capabilities and the powers to react to evidence of predation. The latter has been limited in the past. Effective intervention may require measures like punishment of the predator, compensation for the prey, and rights to stop any particular action before the investigation is concluded. Currently, no competition authority has all those means readily at hand. Nevertheless, since in this paper we focus on the detection quality of rules only, we take for granted that competition authorities are equipped with enough power to set incentives such that predation will not occur if it is detected by the rule under consideration. However, it should be born in mind that effective enforcement of anti-predation rules takes more than good detection quality, even if developing good detection rules is a natural first step to anti-predation enforcement.

In order to focus our thoughts we will use transport markets as a natural reference. This allows us to draw on specific proposals to deal with predation in the airlines and the bus industries that deliberately attempt to take

¹See for example Foster and Golay (1986), Evans (1987, 1990), and Ireland (1991).

into account the findings of modern industrial organisation theory. Moreover, we will use these industries to provide examples and illustrations of our approach.

The remainder of the paper is organised as follows. In Section 2 we introduce a model that intends to reflect findings of modern industrial organisation literature that has inspired the current debate on re-designing anti-predation rules. For the purpose of the analysis, we develop a framework in which firms are distinct in three dimensions: size, cost, and incumbency. We then, in Section 4, develop stylised reduced form rules based on current practice and existing proposals. In Section 5 we apply these rules and in Section 6 we discuss the strategic and welfare implications of legal policy. Sections 7 and 8 discuss alternative entry scenarios and rules designed to avoid ex-post investigations. Finally, in Section 9, we conclude.

2 The market model

There are two firms, an incumbent that operates in $s_I + 1$ identical markets and an entrant that considers entering one of the incumbent's markets and is itself an incumbent in s_E identical markets. Our analysis focuses on the entry decision of the entrant in a representative market where the following three stage entry game is played.

Pre-entry The incumbent chooses the number, n_I , of buses departing with equal headways on a circular schedule and the uniform price p_I .

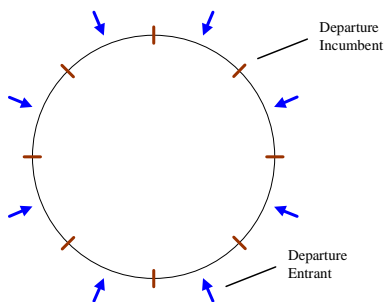
Entry The entrant decides whether to enter the representative market or not. If the firm stays out, the game ends. If the firm enters it also determines how. We initially focus on full scale entry midway of the incumbent's timetable so that the entrant only needs to determine the price.

Post-entry If the firm enters, it is the incumbent's turn to choose a price response or exit. In the next period it is the entrant's turn again to choose a price response or exit, and so on.

We will investigate a finite game; those firms that are in the market during period T exit in that period. Payoffs are realised each period. We abstract from discounting. While it is possible to design a number of entry strategies

we initially restrict our analysis to full scale entry midway of the incumbent's timetable (see Figure 1). This is the standard approach (see Norman and Thisse 1996). We will discuss alternative entry scenarios in Section 7.

Figure 1: Full-scale midway entry



A consumer will travel with a bus only if the benefit of using the bus, u , is greater than the associated generalised cost, which consists of the price p_i and the deviation from the ideal departure time (rescheduling cost). Let τ denote the period of rescheduling time (“distance” to the ideal time of departure) and v the cost per unit of time, then the maximum price for a given rescheduling time follows from (see Appendix A for a detailed derivation of demand)

$$\max_p u - v\tau - p \geq 0. \quad (1)$$

We normalise the mass of passengers on the circumference to one. For each of the entrant's buses the boundary of its own market will be at a time at which the generalised costs are equal to those of using the incumbent's neighbouring bus.

$$p_E + v\tau = p_I + v\left(\frac{1}{n} - \tau\right), \quad (2)$$

where p_I and p_E denote the prices of the incumbent's and the entrant's buses respectively and $n = n_I + n_E = 2n_I$ denotes the total number of buses. Solving for the critical $\tilde{\tau}$, which implies indifference between taking either bus, yields the demand for entrant's bus by passengers that would prefer to

depart later. Taking into account passengers that would prefer to depart earlier, total post entry demand for a firm is:²

$$\frac{n}{2}q_i(p_I, p_E; n) = \frac{n}{2}2\tilde{\tau} = \frac{n}{2} \left(\frac{p_j - p_i}{v} + \frac{1}{n} \right), \text{ with } i, j \in \{I, E\} \text{ and } i \neq j. \quad (3)$$

By normalizing constant marginal costs per passenger to zero, total costs per bus are given by fixed cost F_i . Use k as an index for the bus of the incumbent and per period profits in the representative market are

$$\pi_i = \sum_{k=1}^{\frac{n}{2}} \pi_{i,k}(p_i; n) = \frac{n}{2} \left(p_i \left(\frac{p_j - p_i}{v} + \frac{1}{n} \right) - F_i \right). \quad (4)$$

Before analysing the implications of the fact that firms may operate in several markets let us recall the outcome of the standard static simultaneous move Bertrand-Nash equilibrium and compare this with a sequential move equilibrium.

Table 1. Best-response functions and outcome

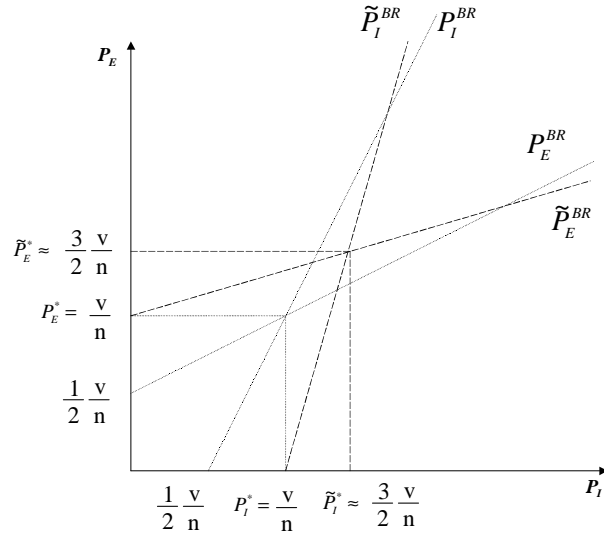
Timing of moves	simultaneous	sequential
Number of periods	1	T
BR functions	$p_i^{BR} = \frac{p_j}{2} + \frac{v}{2n}$	$\tilde{p}_i^{BR} \approx \frac{1}{3}p_j + \frac{v}{n}$
Eq prices	$p^* = \frac{v}{n}$	$\tilde{p}^* \approx \frac{3}{2}\frac{v}{n}$

Table 1 shows that the main characteristics of the sequential move game do not differ significantly from those of the standard static simultaneous move equilibrium: In the sequential move game firms take into account the implication of current pricing decisions on future periods. This generally leads to higher prices than in the simultaneous move equilibrium.

²Note that for symmetric entry $p_i < p_j - v\frac{1}{n}$ implies that firm j has no demand. Moreover markets may, in principle, not overlap. Appendix C shows that an unconstrained monopolist will choose a number of buses that implies overlapping markets at monopoly prices.

Consider the simultaneous move game. It follows from p_i^{BR} in Table 1 that, if one firm charges a higher price than the equilibrium price, the rival's best-response is to undercut. The resulting price will be higher than the equilibrium price. If one firm charges a lower price than the equilibrium price, then the competing firm's most profitable response is to charge a higher price, which will be lower than the equilibrium price (see Figure 2).

Figure 2: Best response functions



This standard result provides a helpful benchmark and we will refer to p_i^{BR} as the short-run best-response. However, it is *not* the outcome of the sequential game that we defined above. If firms move sequentially in a finite game, then any best-response will take into account the effect of the current pricing decision on the rival's pricing decision in the next period. Suppose that both firms continue strategic interaction in the product market until period T (that is ignore the option to exit the market). Then by applying the standard backward induction analysis we find that as the number of remaining periods becomes large, the sequential-move best-response function can be approximated by $\tilde{p}_i^{BR} \approx \frac{1}{3}p_j + \frac{v}{n}$ and the long-run competitive price approaches $\tilde{p}^* \approx \frac{3}{2}\frac{v}{n}$ (see Appendix B). This sequential-move best-response function has some interesting implications. First, independent of the initial

price, prices approach a level above the short-run competitive price $\frac{v}{n}$. Second, if the first-mover charges a price below the short-run competitive price, the rival will respond with a price higher than the short-run competitive price and in the ensuing continuation game the price again approximates the long-run competitive price.

3 Predation

In order to capture the feasibility of predation, we make the following assumptions about per period payoffs in the post-entry game. If the entrant E stays out, per period payoffs are $\Pi_E^m = s_E \pi_E^m$ and the incumbent earns $\Pi_I^m = (s_I + 1) \pi_I^m$ per period. Table 2. provides the payoffs if the entrant enters.

Table 2. Post-entry payoffs in period $t \in \{1, \dots, T\}$

i 's action leads to	firm i	firm j
$\pi_j < 0$	$\pi_i^{pred} + s_i \pi_i^m$	$\pi_j^{prey} + s_j \pi_j^m$
$\pi_j \geq 0$	$(s_i + 1) \pi_i^d$	$(s_j + 1) \pi_j^d$
i exits or is out	0	$(s_j + 1) \pi_j^m$

$$i, j \in \{I, E\}, j \neq i$$

Whenever a firm chooses a response that induces losses for the rival, even if that rival chooses a best-response, total per period profits are $\Pi_i^{pred} = \pi_i^{pred} + s_i \pi_i^m$. This reflects the idea that local predation deters entry in the remaining markets. If a firm responds without inducing losses for the rival, total per period payoffs are the duopoly profits $\Pi_i^d = (s_i + 1) \pi_i^d$. This intends to capture that peaceful local behaviour will encourage entry in other markets. We interpret π_i^{pred} as the highest profit (lowest loss) that is compatible with inducing rival's losses. Then the prey's per period payoffs are $\Pi_i^{prey} = \pi_i^{prey} + s_i \pi_i^m$, where $\pi_i^{prey} < 0$. If a firm chooses to exit a market, it signals that it is a weak firm. Thus, it will be driven out in all markets and future payoff is zero. The winning firm, on the other hand, will earn monopoly profits in all its markets, so that per period payoffs are $\Pi_i^m = (s_i + 1) \pi_i^m$. If the entrant stays out, both firms $i \in \{I, E\}$ continue to earn monopoly profits π_i^m in all home markets in all future periods T . The incumbent's per

period payoff is then $\Pi_i^m = (s_I + 1) \pi_I^m$ and the entrant's per period payoff is $\Pi_i^m = s_E \pi_E^m$.

Definition 1 (large, small) *A firm is “large”, whenever $\Pi_i^{pred} > 0$ and $\Pi_i^{pred} > \Pi_i^d$. A firm is “small” whenever $s_i = 0$.*

Note that this implies that small firms and only small firms lose money in a period of fighting. Moreover, large firms prefer fighting to acquiescing in each period. We now solve the equilibrium outcome of this entry game when there are no anti-predation rules. Two properties follow immediately from the definition of large and small firms.

Remark 1 *In the unique SPE outcome neither a large nor a small firm enters the market of a large firm.*

By Definition 1 the large firm prefers fighting to acquiescing in each period and a small entrant loses money as a prey, $\pi_i^{prey} < 0$, in each period. Therefore, a small firm prefers not to enter which yields negative profits. A large entrant prefers fighting to acquiescing in each period, as does the large incumbent. Hence, if the large firm enters both earn negative profits in the representative market yielding $s_i \pi_i^m + \pi_i^{pred} < s_i \pi_i^m$. Thus, a large entrant prefers to stay out too.

Remark 2 *In the unique SPE outcome a large firm enters the market of a small firm and drives out the incumbent.*

By Definition 1 the large firm prefers fighting to acquiescing once it has entered the market of the small firm. Then the small incumbent loses money in each period as a prey, $\pi_i^{prey} < 0$. Thus, it prefers to exit, which yields zero. Hence, entering yields $(s_i + 1) \pi_i^m > s_i \pi_i^m$ and the large entrant enters.

All properties of the equilibria of the model presented here can be interpreted as reduced form results of the predation games discussed in the introduction. As the remarks show our assumptions create an environment in which large firms predate. In the following Section we discuss various rules applied by competition authorities to stop predation.

4 The Rules

Currently competition authorities and courts focus in their predation investigations on three areas: predation must be feasible, there must be evidence of intent, and evidence of a loss. We discuss each area in turn.

The feasibility test is designed to establish whether predation could be a rational strategy. Naturally, this requires that the short-term losses can be compensated by future gains or gains in other markets. One indicator for this is the creation of barriers to entry due to the reputation effect: in a multimarket industry local investment in predatory behaviour may be profitable as it gives the predator a reputation of being aggressive and deters entry in other markets. Furthermore, predation is less costly if the action can be limited to those commercial activities that are affected by entry. It follows that, if there is localised competition, feasibility is more likely. Finally, feasibility depends on the ability of the predator to sustain losses longer than the rival. This is more likely if the prey is financially strong, e.g. due to market power in other markets, which gives access to internal funds (cross-subsidy). We summarize these notions by the “feasibility” test.³ Let $t^{crit} \in \{1, \dots, T\}$ denote the period in which the rival firm exits in equilibrium.

Definition 2 (feasibility) *In the first period predation by firm i is feasible if the future payoffs with predation are higher than the those without, i.e. if $\sum_{t=1}^{t^{crit}} \Pi_{i,t}^{pred} + \sum_{t=t^{crit}+1}^T \Pi_{i,t}^m > \sum_1^T \Pi_{i,t}^d$.*

Competition authorities also analyse intent. They investigate whether the acceptance of losses was deliberate, whether the action was targeted against the rival and whether the rival did indeed suffer losses that can be attributed to the alleged predator’s behaviour (Myers 1994). Let $\pi_{i,k}$ denote the local

³Bolton, Brodley and Riordan recently advanced a so called “strategic approach” to predatory pricing (Bolton et al. 2000). They claim that their approach would augment the existing U.S. practice in that it would permit proof of predation based on modern economics. They suggest that prima facie elements should include (1) a facilitating market structure. Predation must be a feasible strategy, e.g. due to entry and reentry barriers. The latter can be due to reputation effects. (2) It needs to be shown that predation is plausible ex ante, this follows directly if modern theories sustain the scheme of predation. Closely linked is (3) the ex post probability of recoupment. This encompasses two aspects: “...the exclusion or disciplining of rivals or potential rivals is the intended instrument of the predatory scheme, and the anticipated effect is the future raising of prices or increased revenues in a strategically related market.” (Bolton et al. 2000, p. 2268). These aspects should also be captured by the definition of feasibility proposed here.

profit of firm i in market k with $k = 1$ being the representative market. We define intent as follows.

Definition 3 (intent) *Intent is given if local profits are smaller than elsewhere and negative, i.e. $\pi_{i,1} < \pi_{i,k \neq 1}$ and $\pi_{j,1} < 0$, with $i, j \in \{I, E\}$, $i \neq j$.*

It follows directly from the payoffs of large and small firms and Remark 1 that in a rivalry between a large and a small firm, there is never evidence of feasibility and intent for a small firm and always evidence of feasibility and intent for a large firm i if $\pi_{j,1} < 0$.

The third area of investigation is whether there is evidence of a loss. Traditionally, predation tests have focused on whether the behaviour involves below cost pricing (Areeda and Turner 1975). There is a long and intensive debate in the literature (and in predation investigations) on the pros and cons of different cost rules (Ordover and Saloner 1989). In more recent approaches these absolute cost tests have lost their importance. In June 1997 for instance Roger W. Fones of the U.S. Department of Justice (DoJ) outlined how the Antitrust Division would identify predatory behaviour in the airline industry (Fones 1997). One out of three basic principles that he suggests in order to distinguish illegal predation from legitimate competition is that the incumbent's prices must be below an appropriate measure of its own costs. However, the latter will generally be identified with those costs that the incumbent could have avoided had it not embarked on the pricing/capacity strategy under scrutiny. This cost measure is then compared to the revenue that is due to the strategy (local and attributable connecting revenue). Thus, de facto, cost tests like these are profitability tests. Note that a variety of interpretations are possible: a legal response could be (1) any action that improves profits relative to doing nothing, (2) an action that constitutes a short-run best-response to the entry behavior of the entrant, (3) an action that is the best-response to the entry behaviour of the entrant, taking into account the continuation game that follows, and (4) the best-response computed in a static simultaneous move Nash-equilibrium. We define three anti-predation rules, each of which employs a different profitability test.

In April 1998, the U.S. Department of Transportation (DoT) issued a proposal for an enforcement policy on predatory behaviour in aviation. The proposal considers a behaviour as unfair exclusionary practice (in violation of 49 U.S.C. 4 17 12) if "...in response to new entry into one or more of its local hub markets, it pursues a strategy of price cuts or capacity increases,

or both, that either (1) causes it to forgo more revenue than all of the new entrant’s capacity could have diverted from it or (2) results in substantially lower operating profits - or greater operating losses - in the short-run than would a reasonable alternative strategy for competing with the new entrant” (DoT 1998, p. 17920). We interpret this rule as follows.

Definition 4 (Best Response Rule) *A proof of predation requires (1) an action, (2) feasibility, (3) intent, and (4) a proof that the firm’s action is not a short-run best-response to the rival’s action, $\pi_i < \pi_i^{BR}$.*

Note that given this definition an entrant will be found predating if predation is feasible and the relevant action (entry) leads to a loss given the service level and pricing of the incumbent, $\pi_E < 0$ (i.e. an entrant’s best-response to unprofitable entry is to stay out). Note further that contrary to the standard game theoretic use of the term action in the context of anti-predation rules an action is defined as a change of a strategic variable. Thus, if the incumbent sets the pre-entry price in the first post-entry period, this is not considered as an “action” as defined in this context. A relevant question is whether predation requires an action or whether not choosing a best-response can be seen as predation.⁴ Here, we follow the usual practice that predatory behaviour requires an action. Under the Best-Response Rule an action that does not yield the profit level of a best-response is predatory.

The British competition authorities have, in their investigations, also focused on feasibility and intent. Moreover, there must be evidence of an incremental loss, defined as the difference between the profitability given the potentially predatory action and the profitability had the alleged predator continued to pursue its pre-entry policy (Myers 1994, p. 29, MMC 1995, p. 44). Let π_i^{NR} denote the profits of a firm that does not respond to the previous action of the rival. We interpret the Incremental Loss Rule as follows.⁵

Definition 5 (Incremental Loss Rule) *A proof of predation requires (1) feasibility, (2) intent, and (3) a proof that the action leads to a lower profitability than maintaining the previous policy $\pi_i < \pi_i^{NR}$.*

⁴In the proposal there is little discussion on the “alternative strategy” we take this as the short-run best response. Moreover the proposal does not consider the possibility that the entrant may be the predator. Thus $\pi_E < 0$ is my interpretation.

⁵Note that listing the requirement of “an action” would be redundant since not acting will by definition not lead to an incremental loss.

By this rule an entrant will be found predating if predation is feasible and the relevant action (entry) leads to a loss, given the service level and pricing of the incumbent, $\pi_E < 0$. Compared to the Best-Response Rule the Incremental Loss Rule allows a wider range of responses to a rival's action, since $\pi_i^{NR} \leq \pi_i^{BR}$.

Philips, who suggested new anti-predation rules to the E.U.-Commission in 1987 (Philips 1987), defines predatory behaviour as "...a pricing policy that turns a profitable entry opportunity for an entrant into an unprofitable one. To discover whether such an opportunity exists, that is, whether there is room for an additional firm in a market, it is necessary to find out whether the entrant would make a profit in a noncooperative Nash equilibrium. It is only if the entrant could have made profits that predatory behaviour can be claimed" (Philips 1996, S. 504). Let π_E^* denote the entrant's profits in the static simultaneous-move Nash equilibrium.

Definition 6 (Entry Opportunity Rule) *If there is no profitable entry opportunity, $\pi_E^* < 0$, and entry occurs, the entrant predates. If $\pi_E^* > 0$, subsequent actions by the incumbent or entrant are predatory, if they deny the rival a profitable best-response $\pi_i^{BR} < 0$. The firm that takes a predatory action first is identified as a predator.*

If $\pi_E^* < \pi_E^{BR}$, the Entry Opportunity Rule requires lower cost for the entrant than the Incremental Loss or the Best-Response Rule in order to allow non-predatory entry. The key difference regarding the post entry strategic interaction is that the Entry Opportunity Rule focuses on the impact of an action on the rival's hypothetical profits had he chosen a best-response to that action. The other rules focus on the impact of the action on the acting firm's profits. The focus on the rival's profits is motivated by the possibility of Stackleberg warfare,⁶ which the proponents of the Entry Opportunity Rule do not want to outlaw. Only if the rival cannot avoid losses, will an action be considered predatory.

⁶Dodgson et al. (1992, p. 67) define Stackleberg warfare as a situation, "...where each firm seeks to establish market leadership but *not* to eliminate its rival."

5 Applications

5.1 Small entrant challenges large incumbent

In this section we analyse the performance of the anti-predation rules in the most standard constellation: Will a small entrant successfully enter the market of a large incumbent, if both firms' behaviour is effectively constrained by one of the discussed anti-predation rules? It follows from Section 3 that the large incumbent will prey on the small entrant in order to prevent small firms in other markets from entering, if this is a legal strategy. Thus, in what follows we focus on the most harmful action that can be legally taken by the large incumbent in response to the entry of the small rival. Only if the most harmful legal response to entry inflicts losses on the small entrant it will deter the entrant from entering in the first place. We also look at the pre-entry options available to the incumbent and whether he has an incentive to take pre-entry actions that deter entry despite of the rules. We distinguish four different outcomes of the entry game. "Blockaded entry" means that although the incumbent behaves like an unconstrained monopolist and earns monopoly profits and despite of the rules the expected intensity of post-entry competition prevents the small firm from entering. We say that entry is "deterred" if the incumbent will change his pre-entry behaviour to keep the entrant out. The other possible outcomes are "duopoly" and "displacement" where the latter indicates that the small firm enters and the large firm chooses to exit. We find that the outcome depends on the relative efficiency of the two players.

5.1.1 Entry Opportunity Rule

We begin by investigating the outcome of the entry game when the Entry Opportunity Rule is applied.

Lemma 1 (blockaded entry EOR) *If $F_E \geq \frac{1}{2}F_I$, the large incumbent earns monopoly profits and remains unchallenged by a small entrant although the Entry Opportunity Rule is effectively enforced.*

Proof. The large incumbent earns monopoly profits if he behaves like an unconstrained monopolist and no entry occurs. In Appendix C we show that

an unconstrained monopolist chooses

$$n_I^m = \sqrt{\frac{v}{2F_I}} \quad (5)$$

$$p_I^m = u - v \frac{1}{2n_I^m}. \quad (6)$$

By Definition 6 the Entry Opportunity Rule identifies the entrant as a predator (and forces its exit) whenever $\pi_E^* < 0$. We have $\pi_E^* < 0$ if

$$p^* \frac{1}{n} - F_E < 0. \quad (7)$$

Then, since symmetric entry implies $n = 2n_I$ and by Table 1 $p^* = \frac{v}{n}$, the minimum number of buses that deter entry is⁷

$$n_I^{ed} \geq \frac{1}{2} \sqrt{\frac{v}{F_E}}. \quad (8)$$

Thus, optimal pre-entry pricing is

$$p_I(n_I^{ed}) = u - \frac{v}{4n_I^{ed}}. \quad (9)$$

The number of buses that an unconstrained monopolist will choose is entry deterring whenever $n_I^m \geq n_I^{ed}$. Using (8) and (5) we have $n_I^m \geq n_I^{ed}$ if $F_E \geq \frac{1}{2}F_I$. Thus, if this condition holds entry is blockaded.

Now suppose that $F_E < \frac{1}{2}F_I$, then $\pi_E^* \geq 0$ and the entrant is not identified as a predator. Then, clearly, the entrant will also earn positive profits if the incumbent charges a higher price, like p^m . Thus, the small firm can enter profitably by choosing p^* and, since by Definition 6 the incumbent is not allowed to take any action that denies the entrant a profitable response, the most harmful legal action cannot drive the entrant out. ■

⁷Note that the entry deterring number of buses is due to indivisibilities in the sense that the entrant cannot cover its fixed cost F when $n_I \geq \frac{1}{2} \sqrt{\frac{v}{F_E}}$. If we require the number of buses to be an integer, the minimum entry deterring number of buses is given by the smallest integer for which the equation (43) holds. Of course, if the size of buses and hence, F , could be varied continuously, the fact that the number of buses needs to be an integer could not be exploited.

Note that Lemma 1 implies that the number of buses a profit maximizing monopolist chooses is also entry deterring, even if the entrant is more efficient than the incumbent. Only if the entrant's cost are less than half of the incumbent's costs, the incumbent's behaviour will be affected by the rule. In order to understand the intuition behind this result consider the following. The more buses a monopolist runs, the higher the price it can charge before consumers switch to the outside good. Thus, although each bus costs additional fix costs F_I , the monopolist has an incentive to provide a "high" frequency, even if unconstrained by entry. Moreover, entry leads to a significant change in the market as the number of buses on the route doubles. Thus, total fixed costs on the route double while competitive post entry pricing yields significantly lower prices. Thus, it turns out that as long as $F_E \geq \frac{1}{2}F_I$ the entrant cannot legally enter even if its costs are half of the incumbent's.

Now suppose that the entrant is significantly more efficient than the incumbent, $F_E < \frac{1}{2}F_I$. Then the next Lemma shows that the incumbent will deter entry by product proliferation.

Lemma 2 (entry deterrence EOR) *If $F_E < \frac{1}{2}F_I$ and $u > \sqrt{(vF_E)\frac{2F_E+F_I}{2F_E}}$, the incumbent chooses product proliferation. Otherwise it exits on entry.*

It follows from Lemma 1 that if the incumbent behaves like an unconstrained monopolist and if $F_E < \frac{1}{2}F_I$, the entrant will not be identified as a predator if entry occurs. Clearly, if the incumbent chooses monopoly prices and frequency the entrant can choose to undercut the incumbent and make positive profits in the first period post entry. The incumbent has basically three options in this constellation. (1) The incumbent may accomodate entry and earn duopoly profits thereafter. (2) He may increase the frequency in order to make entry illegal or unprofitable ("product proliferation") or the incumbent may set prices so low that entry is not profitable for the entrant ("limit pricing"). In the proof we show that product proliferation is the preferred option.

Proof. If $F_E < \frac{1}{2}F_I$, the entrant earns positive profits at p^* . Hence, entry at p^* is legal and, if the incumbent's pre-entry price is $p_I = p_I^m > p^*$, also profitable. Given entry, no party is allowed to choose a price that denies the rival a profitable response. Thus, driving out the entrant by predation is not feasible and the entrant enters. By Table 1 post entry competition will lead to $\tilde{p}^* > p^*$, implying π_I^d . We now show that the incumbent prefers product proliferation to allowing entry and to limit pricing.

Incumbent prefers product proliferation to duopoly

First, choose any number of buses n_I that leaves a profitable entry opportunity and that leads to a post-entry equilibrium in which the incumbent earns a positive profit per bus $\pi_{I,k}^d > 0$. Then the incumbent earns $n_I \pi_{I,k}^d$ on the route whereas in case of proliferation he could have earned at least $2n_I \pi_{I,k}^m$. Clearly, for a given n_I $\pi_{I,k}^d \leq \pi_{I,k}^m$ and therefore $n_I \pi_{I,k}^d < 2n_I \pi_{I,k}^m$. Thus, the incumbent prefers product proliferation to allowing entry. Now choose any number of buses n_I that leaves a profitable entry opportunity and that leads to a post-entry equilibrium in which the incumbent does not earn positive profits per bus $\pi_I^d \leq 0$. Then the incumbent will choose product proliferation whenever the number of buses that deters entry yields positive profits per bus ($p_I(n_I^{ed}) \frac{1}{n_I^{ed}} - F_I > 0$).

Profitability constraint

In Appendix G we show that product proliferation is profitable if and only if $u > \sqrt{(vF_E) \frac{2F_E + F_I}{2F_E}}$. If this condition is not met and $F_E < \frac{1}{2}F_I$, there is a profitable entry opportunity and the incumbent does not earn positive profits if entry occurs. Thus, the small firm enters and the large firm exits on entry.

Incumbent prefers product proliferation to limit pricing

In order to avoid entry the incumbent can either choose limit pricing or product proliferation. Thus, it remains to be shown that the incumbent prefers product proliferation to limit pricing. As shown in Appendix D, limit pricing is profitable if and only if $F_E \geq \frac{1}{2}F_I$, i.e. when it is not needed. ■

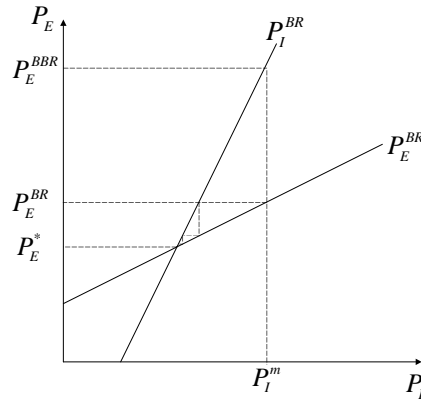
5.1.2 Best-Response Rule

We now apply the Best-Response Rule. This rule, and indeed also the Incremental Loss Rule discussed later, have a number of noteworthy differences to the Entry Opportunity Rule. The most obvious difference is that the small entrant cannot be identified as a predator under the Best-Response and the Incremental Loss Rule since predation is not feasible (see Definition 2) and feasibility is required by these rules in order to find predation. Moreover, while the Entry Opportunity Rule judges behaviour compared to a hypothetical benchmark (as if the rival was forced to choose a best response) the other rules judge the behaviour given the prices and frequency of the rival.

The Best Response rule limits actions to best-responses. Thus, even if other actions would yield positive profits, the fact that no response is always a legal strategy has an important implication. The entrant may benefit since he

can choose a high price that allows him to earn profits even if the incumbent responds by undercutting: the entrant then takes no action since his best-response would lead to further undercutting by the rival (see Figure 3). As a result, given the number of buses an unconstrained monopolist would run, the set of successful entrants is larger than under the Entry Opportunity Rule.

Figure 3: High Price Entry



Lemma 3 (blockaded entry BRR) *If $F_E > \frac{9}{16}F_I$, a large incumbent earns monopoly profits and remains unchallenged by a small entrant although the Best-Response Rule is effectively enforced.*

Proof. The large incumbent earns monopoly profits if he behaves like an unconstrained monopolist and no entry occurs. By Definition 4 a proof of predation requires an action, feasibility, intent, and a proof that the firm's action is not a short-run best-response to the rival's action, $\pi_i < \pi_i^{BR}$. For the small firm predation is not feasible. Thus, there are no legal constraints to entering and the small firm will enter whenever post entry competition leads to positive profits. Taking pre-entry monopoly behaviour as given, we now investigate the most harmful post entry strategies available to the incumbent and when they lead to the entrant making losses.

Incumbent's post entry strategy

Clearly, if prices are above the short-run equilibrium price, the incumbent's most harmful strategy is to choose the lowest legal price, which is the short-run best response to the entrant's price.

Entrant's undercutting strategy

Given this strategy of the incumbent the optimal undercutting strategy will eventually lead to p^* and the entrant will make losses if $F_E > \frac{1}{2}F_I$.

Entrant's mark-up strategy

Alternatively, the entrant may set prices once and then choose not to react to the short-run best-response of the incumbent. Substituting p_I^{BR} , which is given by Table 1, into profit function (4) we obtain the profits of this strategy

$$\pi_E(p_I^{BR}) = \frac{3}{4}p_E - \frac{n_I^m}{2v}p_E^2 - n_I^m F_E. \quad (10)$$

Thus, the most profitable mark-up price is

$$\hat{p}_E = \frac{3}{4} \frac{v}{n_I^m}. \quad (11)$$

Profitability constraint

Given optimal mark-up pricing, \hat{p}_E , and using n_I^m the entrant will make a loss if

$$F_E > \frac{9}{16}F_I.$$

Thus, the mark-up strategy provides the binding constraint.

Now suppose that $F_E \leq \frac{9}{16}F_I$. Since the small entrant earns zero if it does not enter, it enters and sets $p_E = \hat{p}_E$. The incumbent chooses a best-response. These prices are kept until period T if the incumbent moves in T . If the entrant has the move in period T , it will undercut in that last period. ■

Lemma 4 (entry deterrence BRR) *If $F_E < \frac{9}{16}F_I$ and $u > \frac{\sqrt{2}v(16F_E+9F_I)}{24\sqrt{(vF_E)}}$, the incumbent chooses product proliferation. Otherwise it exits on entry.*

Proof. see Appendix E. ■

The proof follows the line of reasoning developed in the proof of Lemma 2. Product proliferation is preferred to allowing entry since either post-entry competition is profitable for the incumbent and then the incumbent would prefer running all buses rather than half or it is unprofitable for the incumbent, then clearly any profitable proliferation strategy is preferred to allowing a profitable entry opportunity. However, given the option to choose a high

price entry strategy under the Best-Response Rule, the frequency required to deter entry is higher than under the Entry Opportunity Rule. Thus, compared to the Entry Opportunity Rule we identify a different threshold when product proliferation is unprofitable. Comparing the alternative deterrence strategies shows that product proliferation yields higher profits than limit pricing.

5.1.3 Incremental Loss Rule

As with the Best-Response Rule, the entrant can, under the Incremental Loss Rule, choose a no response strategy by setting a price that may allow the entrant to earn profits even if the incumbent responds by undercutting. The key difference compared to the Best-Response Rule is that under the Incremental Loss Rule the incumbent can legally choose a fiercer than the best-response whenever the entrant's entry price is set such that the incumbent's pre-entry price is not equal to the best-response to the entrant's price. Despite this higher degree of freedom the key result is the same. The reason for this is that at least one firm has an incentive to change prices in the next period unless the incumbent's price is a best-response to the entrant's. If the incumbent's price is higher than a the best-response price the incumbent can legally lower the price and since this harms the entrant it will do so. If the incumbent's price is below the best response to the entrant's price, the entrant can increase its profits by lowering the price to a level at which the incumbent's price is a best response. Thus, as we show in the proof of the following Lemma, in equilibrium the entrant chooses a price for which the lowest legal response is also the best-response.

Lemma 5 (blockaded entry ILR) *If $F_E > \frac{9}{16}F_I$, a large incumbent earns monopoly profits and remains unchallenged by a small entrant although the Incremental Loss Rule is effectively enforced.*

Proof. The large incumbent earns monopoly profits if he behaves like an unconstrained monopolist and no entry occurs. So suppose the incumbent chose p_I^m and n_I^m in the pre-entry stage.

Incumbent's post-entry strategy

By Definition 5 the lowest legal price response to any entry price p_E is given by the price p_I at which the incumbent's profit equals its profits had

it not chosen a response. Setting $\pi_I(p_I^m, p_E) = \pi_I(p_I, p_E)$ we have

$$p_I^m \left(\frac{p_E - p_I^m}{v} + \frac{1}{2n_I^m} \right) = p_I \left(\frac{p_E - p_I}{v} + \frac{1}{2n_I^m} \right),$$

solving for p_I we obtain the lowest legal price response in the first period after entry

$$p_I^{legal} = \begin{cases} p_E - p_I^m + \frac{v}{2n_I^m} & \text{if } p_E < 2p_I^m - \frac{v}{2n_I^m} \\ p_I^m & \text{if } p_E \geq 2p_I^m - \frac{v}{2n_I^m} \end{cases}. \quad (12)$$

More generally, if in period t the incumbent charges p_I^t and the entrant responds with p_E^t , the incumbent can, in the next period $t+1$, legally charge

$$p_I^{t+1,legal} = \begin{cases} p_E^t - p_I^t + \frac{v}{2n_I^t} & \text{if } p_E^t < 2p_I^t - \frac{v}{2n_I^t} \\ p_I^t & \text{if } p_E^t \geq 2p_I^t - \frac{v}{2n_I^t} \end{cases} \quad (13)$$

Entrant's undercutting strategy

It follows from (13) that whenever the entrant undercuts the incumbent, the latter can charge a legal price below the Nash equilibrium price $p^* = \frac{v}{2n_I^m}$. Suppose the entrant matches the pre-entry price of the incumbent. We then have $p_I^{legal} = p^* = \frac{v}{2n_I^m}$ and, clearly, the best-response of the entrant to the most harmful legal response is to choose p^* . Then, in the next round, the most harmful legal price the incumbent can choose is

$$p^* \frac{1}{2n_I^m} = p_I \left(\frac{p^* - p_I}{v} + \frac{1}{2n_I^m} \right),$$

but given that p^* already is a best response, there is no alternative that yields the same level of profits. Thus, the entrant will not undercut.

Entrant's mark-up strategy

We now investigate whether the entrant will choose a mark-up. For this purpose it is helpful to express the mark-up as a fraction of the equilibrium price, i.e.

$$p_E^t = p_I^t + xp^* = p_I^t + x \frac{v}{2n_I^m}$$

Substituting yields

$$p_I^{t+1,legal} = \begin{cases} (1+x) \frac{v}{2n_I^m} & \text{if } p_I^t + x \frac{v}{2n_I^m} < 2p_I^t - \frac{v}{2n_I^m} \\ p_I^t & \text{if } p_I^t + x \frac{v}{2n_I^m} \geq 2p_I^t - \frac{v}{2n_I^m} \end{cases}$$

It follows that if $p_I^t + x \frac{v}{2n_I^m} < 2p_I^t - \frac{v}{2n_I^m}$, the lowest price the incumbent may legally charge can be determined by applying the same mark-up to the equilibrium price than the mark-up of the entrant's price over the incumbent's previous price, namely $x \frac{v}{2n_I^m}$. Thus, the lowest legal price is can be expressed independent of the incumbent's price in the previous round by the mark-up over this price chosen by the entrant.

Now, for any combination of the entrant's and the incumbent's prices to be an equilibrium, the incumbent's price must be a best-response to the entrant's price. Suppose the entrant chose a price so that the the incumbent's price is higher than the best-response price. Then the incumbent could, in the following round, choose to lower the price further and thereby harm the entrant. Hence, this cannot be an equilibrium. Suppose the entrant chose a price so that the incumbent's price is below the best response price. Then the entrant would forego profits it could make by lowering the price to the the level at which the incumbent's price is a best-response.

Moreover, we have already established that x must be positive (no undercutting), it is also straight forward that $x < 1$ since at $p_E^t - p_I^t \geq \frac{v}{2n_I^m}$ the entrant has no demand. Thus, in equilibrium $0 < x < 1$.

Suppose the incumbent always chose to pick the lowest legal price. Then the entrant's task is to identify a mark-up over the current price of the incumbent that will yield the highest profits after the incumbent chose the lowest legal price and the entrant adjusted its price so that the mark-up remains the same. Thus, we can formulate the problem as maximizing π_E when $p_I^t = (1 + x)p^*$ and $p_E^t = (1 + 2x)p^*$ or

$$\pi_E = \left[(1 + 2x)p^* \left(\frac{(1 + x)p^* - (1 + 2x)p^*}{v} + \frac{1}{2n_I^m} \right) - F_E \right] n_I^m.$$

which gives us the optimal $x = \frac{1}{4}$.

It remains to be shown that the incumbent will indeed always choose the lowest legal response. Clearly, for any given mark-up, the lower the price the lower the profits of the entrant unless the entrant's price is so high that customers switch to the outside good. Given that the entrant can always choose the mark-up, the most harmful strategy of the incumbent is to choose the lowest legal price. But then the entrant will indeed choose a mark-up of $\frac{1}{4}p^*$.

Finally, we show that given the pricing strategy of the entrant we have $p_E < 2p_I^m - \frac{v}{2n_I^m}$, i.e.

$$p_I^m + \frac{1}{4} \frac{v}{2n_I^m} < 2p_I^m - \frac{v}{2n_I^m}.$$

Note for demand at zero prices to be positive we must have $u > v$. We look at multi-product firms, i.e. $n_I^m \geq 2$. Thus, $u > 4\frac{v}{2n_I^m}$ and we have $p_I^m = u - \frac{v}{2n_I^m} > 3\frac{v}{2n_I^m}$ and the inequality holds.

Suppose the entrant sets $p_E < 2p_I^m - \frac{v}{2n_I^m}$. Then $p_I^{legal} = p_E - p_I^m + \frac{v}{2n_I^m}$. It follows that

$$\Delta p = p_E - p_I^{legal} = p_E - \left(p_I^m + \frac{v}{2n_I^m} \right) > 2\frac{v}{2n_I^m}$$

and the entrant has no demand. Thus, there are no restrictions on the response of the entrant.

Suppose the entrant sets $p_E \geq 2p_I^m - \frac{v}{2n_I^m}$. Then $p_I^{legal} = p_I^m$ and the entrant's profits are

$$\pi_E = \left[p_E \left(\frac{p_I^m - p_E}{v} + \frac{1}{2n_I^m} \right) - F_E \right] n_I^m$$

and maximum profits are given at

$$p_E = \frac{1}{2} (p_I^m + p^*).$$

Hence, since $p_I^m > p^*$ the entrant will want to undercut if $p_E + \frac{v}{2n_I^m} > 2p_I^m$. But then $p_E - p_I^m + \frac{v}{2n_I^m} < 2p_I^m$.

Profitability constraint

Given optimal pricing and using n_I^m the entrant will make a positive profit if

$$F_E < \frac{9}{16} F_I.$$

Since the small entrant earns zero if it does not enter, it enters and sets $p_E = \hat{p}_E$. The incumbent chooses a best-response. These prices are kept until period T if the incumbent moves in T . If the entrant has the move in period T , it will undercut in that last period. If

$$F_E > \frac{9}{16} F_I,$$

then the small entrant makes a loss and exits. ■

Lemma 6 (entry deterrence ILR) *If $F_E < \frac{9}{16}F_I$ and $u > \frac{\sqrt{2}v(16F_E+9F_I)}{24\sqrt{(vF_E)}}$, the incumbent chooses product proliferation. Otherwise it exits on entry.*

Since we have the same price for which entry is blockaded as under the Best-Response Rule, the proof is identical to the proof of Lemma 4.

Proof. see Appendix E. ■

5.2 Large entrant challenges small incumbent

The incumbent is small and cannot drive out a large rival. The large entrant on the other hand will enter only if the incumbent exits. Hence, we analyse whether the entrant can enter and induce exit of the rival under the anti-predation rules.

Once the large entrant has entered it prefers, by definition, predation to accommodation. Thus, the incumbent will exit whenever the entrant can legally induce $\pi_I < 0$.

Lemma 7 (blockaded entry EOR) *If $F_E \geq \frac{1}{2}F_I$, the small incumbent earns monopoly profits and remains unchallenged by a large entrant although the Entry Opportunity Rule is effectively enforced.*

Proof. Suppose $F_E \geq \frac{1}{2}F_I$ then the proof of Lemma 1 applies: By definition the Entry Opportunity Rule identifies the entrant as a predator (and forces its exit) whenever $\pi_E^* < 0$. Then the number of buses that an unconstrained monopolist will choose is also entry deterring whenever $n_I^m \geq n_I^{ed}$. Using (7) and (5) we have $n_I^m \geq n_I^{ed}$ if $F_E \geq \frac{1}{2}F_I$. ■

Lemma 8 (entry deterrence EOR) *If $F_E < \frac{1}{2}F_I$ and $u > \frac{1}{2}\sqrt{(F_E v)}\frac{2F_E+F_I}{F_E}$, the incumbent chooses product proliferation. Otherwise it exits on entry.*

Proof. Suppose $F_E < \frac{1}{2}F_I$. Contrary to the constellation of Lemma 2 the entrant will stay out if it cannot force the incumbent to exit, even if there is a profitable entry opportunity. This follows from the large firm's payoffs $s_i\pi_i^m > s_i\pi_i^m + \pi_i^{pred} > (s_i + 1)\pi_i^d$. Thus, if the entrant cannot succeed in predation, no product proliferation or limit pricing is required. Hence, we have to compare two different strategies for stage one. Either the incumbent chooses less than optimal buses in order to avoid losses in case of entry, or it chooses more than optimal buses in order to deny the entrant a profitable entry opportunity.

We begin with the former. The Entry Opportunity Rule allows the entrant to set $p_E = p^* = \frac{v}{2n_I}$. This is also the most harmful price the entrant can legally set. Suppose the incumbent chose the profit maximizing pre-entry number of buses $n_I^m = \sqrt{\frac{v}{2F_I}}$. Then the upper bound on post entry profits is given by the best-response profits

$$\pi_I = \frac{1}{2}p^* - n_I^m F_I = \frac{v}{4\sqrt{\frac{v}{2F_I}}} - \sqrt{\frac{v}{2F_I}} F_I < 0.$$

Thus, the incumbent can deter entry by choosing a number of buses that yields $\pi_I = \frac{1}{2}p^* - n_I F_I = \frac{1}{2}\frac{v}{n_I} - n_I F_I \geq 0$ or

$$n_I^{low} \leq \frac{\sqrt{2}\sqrt{(vF_I)}}{2F_I}.$$

This yields $\pi_I(n_I^{low}) = n_I^{low} \left(\left(u - v\frac{1}{2n_I^{low}} \right) \frac{1}{n_I^{low}} - F_I \right)$. Note that $\pi_I(n_I^{low}) > 0$ if $u^2 > 2vF_I$.

Alternatively, the incumbent can choose product proliferation so that $\pi_E^* < 0$. By (8) the minimum number of buses that induce negative profits of the entrant are $n_I^{ed} \geq \frac{1}{2}\sqrt{\frac{v}{F_E}}$. This yields $\pi_I(n_I^{ed}) = n_I^{ed} \left(\left(u - v\frac{1}{2n_I^{ed}} \right) \frac{1}{n_I^{ed}} - F_I \right)$. Note that $\pi_I(n_I^{ed}) > 0$ if $u > \frac{2vF_E + vF_I}{2\sqrt{(vF_E)}}$.

Comparing profits we have $\pi_I(n_I^{ed}) > \pi_I(n_I^{low})$ if

$$F_E < \frac{1}{2}F_I.$$

Thus, entry deterrence is always more profitable than choosing a low number of buses. But then we can apply exactly the same reasoning as in the proof of Lemma 2 which shows (1) that product proliferation is the equilibrium strategy if profitable and (2) that it is profitable whenever $u > \frac{1}{2}\sqrt{(F_E v) \frac{2F_E + F_I}{F_E}}$. ■

Lemma 9 (blockaded entry BRR) *If $F_E > \frac{u^2}{4v}$, a small incumbent earns monopoly profits and remains unchallenged by a large entrant although the Best-Response Rule is effectively enforced.*

Proof. The entrant will stay out if it cannot force the incumbent to exit, even if there is a profitable entry opportunity. The rule does not allow entry if that involves an absolute loss. Suppose profitable entry is possible

given monopoly behaviour of the incumbent. Then the incumbent can either maintain monopoly prices or choose to undercut the rival with a short-run best-response. Undercutting will lead to p^* which is unprofitable for the incumbent given n_I^m (see previous proof) and will therefore lead to the incumbent's exit. Suppose the incumbent maintains its pre-entry price p_I^m and the entrant chooses a best-response price $p_E^{BR} = \frac{1}{2}p_I^m + \frac{1}{2}p^*$. Since $p_I^m = u - p^*$ we have $p_E^{BR} = \frac{1}{2}u$. Hence, the incumbent's profits are

$$\pi_I = n_I^m \left((u - p^*) \left(\frac{\frac{1}{2}u - (u - p^*)}{v} + \frac{1}{2n_I^m} \right) - F_I \right). \quad (14)$$

Note that π_I decreases in u : Making use of $p^* = \frac{v}{2n_I^m}$ we have $\frac{\partial \pi_I}{\partial u} = \frac{1}{4} - \frac{n}{v}u$. Since $u > v$ and $n_I^m \geq 1$ we have $\frac{\partial \pi_I}{\partial u} < 0$. Since $p_I^m = u - p^*$ we have $p_I^m \geq p^*$ only if $u \geq 2p^*$. (Note that if $p_I^m \leq p^*$ the incumbent will make a loss in the post-entry equilibrium if the entrant charges p^* . Since we are trying to identify positive profits for the incumbent, assuming $u \geq 2p^*$ is not restrictive, see 34.) With $\frac{\partial \pi_I}{\partial u} < 0$ maximum profits must be given at $u = 2p^*$. Substituting in the profit function yields

$$\pi_I = n_I^m \left(p^* \frac{1}{2n_I^m} - F_I \right) = \pi_I^*.$$

Thus not responding to a best-response entry price does not yield higher profits for the incumbent than responding to entry with a best-response which will lead eventually to π_I^* . Since we have shown earlier that $\pi_I^* < 0$ if $n = 2n_I^m$, entry is not blockaded if there is a price that allows legal entry, $\pi_E = 0$.

We now check whether setting a best-response price as the entry price is profitable for the entrant and therefore legal. Given p_I^m , the entrant's profits are $\pi_E = n_I^m \left(p_E \left(\frac{u - v \frac{1}{2n_I^m} - p_E}{v} + \frac{1}{2n_I^m} \right) - F_E \right)$. Then maximum profits are given at $p_E^{BR} = \frac{1}{2}u$ by $\pi_E^{BR} = \frac{1}{4}n_I \frac{u^2 - 4F_E v}{v}$. It follows that $\pi_E \geq 0$ whenever

$$\begin{aligned} \frac{1}{4}n_I \frac{u^2 - 4F_E v}{v} &\geq 0 \\ F_E &\leq \frac{u^2}{4v}. \end{aligned}$$

Thus if $F_E > \frac{u^2}{4v}$ there is no price at which the entrant can enter and make positive profits given that the incumbent has chosen n_I^m and p_I^m . ■

Lemma 10 (entry deterrence BRR) *If $F_E \geq \frac{1}{2}F_I$ and $F_E \leq \frac{u^2}{4v}$, the incumbent chooses limit pricing. If $F_E < \frac{1}{2}F_I$ and $F_E \leq \frac{u^2}{4v}$ the incumbent exits on entry.*

Proof. It follows from the previous proof that the threshold for profitable entry is independent of the number of buses the incumbent runs. Thus product proliferation does not deter entry if $F_E \leq \frac{u^2}{4v}$. Moreover, it follows that allowing entry will lead to exit of the incumbent. Thus the small incumbent chooses limit pricing if this is a profitable strategy. Otherwise the incumbent exits on entry. In Appendix D we show that limit pricing is a profitable strategy whenever $F_E \geq \frac{1}{2}F_I$. ■

Lemma 11 (ILR) *If $F_E > \frac{u^2}{4v}$, a small incumbent earns monopoly profits and remains unchallenged by a large entrant although the Incremental Loss Rule is effectively enforced. If $F_E \geq \frac{1}{2}F_I$ and $F_E \leq \frac{u^2}{4v}$, the incumbent chooses limit pricing. If $F_E < \frac{1}{2}F_I$ and $F_E \leq \frac{u^2}{4v}$ the incumbent exits on entry.*

Proof. By definition the entry constraint under the Incremental Loss Rule is equivalent to the entry constraint under the Best-Response Rule, $\pi_E \geq 0$. The small incumbent cannot improve on either no response or a best-response since it cannot drive out the entrant. Hence, the proofs of the Lemmas 9 and 10 apply. ■

5.3 Large entrant challenges large incumbent

A large entrant will only enter a market of a large incumbent if it can drive out the rival. However, a large incumbent prefers in each period fighting to acquiescing or exiting since both actions would lower its profits in the remaining markets. Thus, independent of whether post entry competition yields fighting or acquiescing, the large entrant is better off staying out, since this does not harm its reputation. The result of the no rules equilibrium extends to all rules whether they have bite or not. Since both firms prefer fighting to acquiescing and since fighting yields negative payoffs in the local market, the entrant prefers staying out of the representative market and continues to earn monopoly profits in the remaining markets: $s_i \pi_i^m > s_i \pi_i^m + \pi_i^{pred} > (s_i + 1) \pi_i^d$.

6 Evaluation

Anti-predation rules may affect welfare in two ways. First, they may fail to make competition effective in selecting the most efficient operator. While competition may not be effective without the rules, they may fail to improve the outcome or even make it worse. Second, rules may induce, either through product proliferation or through encouraging entry, overbussing, i.e. more buses than optimal from a welfare (or, indeed, consumer surplus) point of view. We will investigate each argument in turn.

The following table summarizes the results of Lemmas 1 to 11.

Table 3. Results

Rule	Entry is	
	blockaded	deterred
I_l vs E_s		
None	<i>always</i>	
EOR	$F_E \geq \frac{1}{2}F_I$	$u > \sqrt{(vF_E)} \frac{2F_E+F_I}{2F_E}$
BRR	$F_E \geq \frac{9}{16}F_I$	$u > \frac{\sqrt{2v} (16F_E+9F_I)}{24 \sqrt{(vF_E)}}$
ILR	$F_E \geq \frac{9}{16}F_I$	$u > \frac{\sqrt{2v} (16F_E+9F_I)}{24 \sqrt{(vF_E)}}$
I_s vs E_l		
None	<i>never</i>	<i>never</i>
EOR	$F_E \geq \frac{1}{2}F_I$	$u > \frac{1}{2} \sqrt{(F_E v)} \frac{2F_E+F_I}{F_E}$
BRR	$F_E > \frac{u^2}{4v}$	$F_E \geq \frac{1}{2}F_I$
ILR	$F_E > \frac{u^2}{4v}$	$F_E \geq \frac{1}{2}F_I$
I_l vs E_l		
None	<i>always</i>	
EOR	<i>always</i>	
BRR	<i>always</i>	
ILR	<i>always</i>	

Proposition 1 *All rules investigated fail to encourage sustainable competition in the market.*

Proof. By Lemmas 1 to 11 under all rules and all entry constellations entry is either blockaded, deterred or the incumbent exits when entry occurs. ■

In the field of competition policy the aim of encouraging competition is taken for granted. However, if the service level of the incumbent is taken as given, as it is in competition inquiries, the failure of the rules in this respect may not be a vice but a virtue (see below). The following proposition, however, is necessarily worrying.

Proposition 2 *If $F_E \geq \frac{9}{16}F_I$ and the incumbent is large, all rules do not lead to the selection of the most efficient operator and the incumbent earns monopoly profits.*

Proof. Follows from Table 3. ■

The standard problem in industries with predation is that a large incumbent’s threat of predation leads to entry barriers that allow the incumbent to earn monopoly profits. Our results show that all rules fail to make the threat of entry more effective unless the entrant is significantly more efficient than a large incumbent. In those cases where the entrant is more efficient the large incumbent will usually choose product proliferation in order to deter the more efficient entrant. This result supports the intuition that has been advanced in the context of the liberalised local bus industry in the U.K.:

“A good strategy for sole operators is [...] to provide the competitive equilibrium frequency, but to charge monopoly fares, or at least higher than competitive fares. This will provide both superprofits and a strong deterrent to entry” (Evans 1988, p. 299).

This prediction has not received much attention.⁸ From a welfare point of view the following proposition is the most important.

Proposition 3 *A first-best market structure cannot be implemented by any of the rules. The rules harm welfare relative to the unconstrained monopoly in two cases:*

1. *If $F_E \geq \frac{1}{2}F_I$, they protect inefficient small incumbents*
2. *If product proliferation is required to deter entry and profitable, all rules lead to welfare harming overbussing.*

⁸Evans himself chose, in his well received formal work, not to model entry and competition in this way. He used the standard free entry zero profit assumption in the Salop tradition.

Indeed, the rules improve welfare relative to the unconstrained monopoly only in the (unlikely) event that product proliferation is unprofitable for a large incumbent. Then a small entrant can enter and drive out the incumbent which he could not have done without the protection of the anti-predation rules.

Proof. In order to assess the welfare implications of the rules, we now, following Salop's analysis, identify the equilibrium in a regulated regime that aims at maximising net economic benefit.

In a regulated regime (RR) a benevolent social planner with full information minimizes total costs, i.e. the sum of fixed cost, nF , and rescheduling costs $v \left(2n \int_0^{1/2n} \tau \, d\tau \right) = \frac{v}{4n}$:

$$\min_n C = \frac{v}{4n} + nF.$$

The first order condition of this minimisation problem is

$$\frac{\delta C}{\delta n} = -\frac{v}{4n^2} + F = 0.$$

Hence, the optimal number of buses in a regulated regime is given by

$$n_r^* = \frac{1}{2} \sqrt{\frac{v}{F}}.$$

The social planner would always choose the most efficient firm. Thus, it follows from $\bar{n}_r < n_I^m < n^{ed}$ that no rule leads to a first-best result.

Now consider a large incumbent facing entry by a small entrant. In a no rules equilibrium the incumbent would remain unchallenged and earn monopoly profits. For blockaded entry the rules have no "bite" and this result does not change. If the rules lead to entry deterrence (product proliferation), the number of buses is increased and since there is no positive efficiency effect, it follows from $\bar{n}_r < n_I^m < n^{ed}$ that welfare is reduced.

Now suppose that the rules lead to entry. Then efficiency is improved since the incumbent will exit and the more efficient small entrant can enter.

■

Note that $\bar{n}_r = \frac{1}{2} \sqrt{\frac{v}{F}} < \bar{n}_m = \frac{1}{\sqrt{2}} \sqrt{\frac{v}{F}}$ implies that even a private profit maximizing monopolist would run, from a social planners point of view, too many buses, although less than in the competitive equilibrium. On first sight

this result seems counter-intuitive - why would the private monopolist not minimize costs. The reason is that the monopolist takes into account the fare increase that can be achieved if generalized costs are reduced by running more buses. However, this result does not generalize but depends crucially on the way demand is modelled (see below).

Now suppose entry occurs and the entrant stays in. We then have a positive welfare effect if $C^{rum} > C^{entry}$ or

$$\frac{v}{4n_I^m} + n_I^m F_I > \frac{v}{4n_I^m} + n_I^m F_I + \frac{v}{4n_I^m} + n_I^m F_E,$$

substituting $n_I^m = \sqrt{\frac{v}{2F_I}}$ we obtain

$$\frac{1}{2}F_I > F_E.$$

Compared to the regulated regime, entry could, of course, never improve welfare.

Since a social planner would want to set fares equal to marginal costs ($p_r = c$), the regulated regime would require subsidies to cover fixed cost determined by n_r^*F . However, given the unelastic demand in the model, mark-ups do not cause any welfare distortions as the decision to use the bus is not affected by the fare as long as the net utility gained from traveling is greater than the utility from spending money on the outside good (see 19). Hence, $p_r^* = u - \frac{v}{2n^*}$, or, using the optimal number of buses

$$p_r^* = u - \sqrt{vF}$$

Comparing the number of buses in the regulated and competitive regimes we have the excessive entry result as in Salop (1979):⁹

Limit pricing or entry reduce welfare, compared to the benchmark of a regulated regime (RR), $\bar{n}_r = \frac{1}{2}\sqrt{\frac{v}{F}} < n_I^m = \sqrt{\frac{v}{2F_I}} < n = 2n_I^m$.

This “overbussing” is due to the “business stealing” effect as firms do not take into account the negative externality they induce on other firms by

⁹Comparing fares we have:

$$\bar{p}_r = \bar{v} - \sqrt{vF} \neq \bar{p}_c = \sqrt{vF} + \hat{m}$$

running an additional bus (given that the buses are strategic substitutes)¹⁰. The finding of excessive entry is much more general than suggested by this restrictive model. Indeed, as Mankiw and Whinston (1986) have shown, unless compensated by other effects, entry will be excessive whenever post-entry competition is characterized by the following three conditions: first, aggregate output increases (price falls) when more firms enter; second, post-entry price is not below marginal cost and; third, entry of an additional firm causes sales of existing firms to fall (weakly). Standard Cournot-games satisfy these conditions.

However, given that buses are differentiated by departure times the negative externality due to business stealing may, in principle, be (over-) compensated by utility gains due to love for variety (frequency, reduced rescheduling). This effect is also apparent in the Salop model. Increasing frequency reduces rescheduling costs for passengers resulting in increasing utility. Given non-discriminatory pricing this utility gain is not fully captured by bus operators. Indeed, this effect has played a major role in transport economics as an argument for subsidies and regulation. However, due to the specific definition of technology and demand the business stealing effect always dominates the frequency effect in Salop's model.¹¹ This raises the question whether the model predicts over- or underbussing if more realistic specifications of demand are used. In applications of this model to the bus industry Evans (1987) employed constant elasticity demand functions based on previous empirical work in the bus industry and confirmed Salop's excessive entry result for the bus industry by evaluating equilibria numerically. He predicted a welfare loss of a competitive regime (based on the one bus firm, free-entry assumption, see Appendix F) compared to the regulated regime in the bus industry of 10 to 12 per cent over a wide range of parameter values. Taking into account that the number of buses is not a continuous function, welfare losses predicted are in the range of 20 to 24 percent. Note that this is due to both frequency and fares being higher than socially optimal.¹²

¹⁰Note that the Salop game involves Bertrand-Nash price setting, suggesting strategic complements. However, additional buses are strategic substitutes.

¹¹Technically, it would be easy to derive results where the externality dominates. Navon et al. (1995), for example, extend the Salop framework by introducing network externalities additionally to the utility gains from reduced transport costs. In this setting "underbussing" can be derived easily. In the original Salop framework overbussing occurs for all utility functions that are concave in distance (Salop 1979, p. 152).

¹²Ireland (1991) extended a model similar to Evans' by adding a vertical competition

Proposition 4 *If a large incumbent faces entry by a small entrant and the rules induce product proliferation or entry, they reduce consumer surplus compared to the unconstrained monopoly.*

Proof. Since the average consumer has to reschedule by $\frac{1}{4}n$, consumer surplus is $CS = u - p - \frac{v}{4n}$. In the unconstrained monopoly we have $n_I^m = \sqrt{\frac{v}{2F_I}}$ and $p_I^m = u - v\frac{1}{2n_I^m}$. Thus, $CS^{um} = u - \left(u - v\frac{1}{2\sqrt{\frac{v}{2F_I}}}\right) - \frac{v}{4\sqrt{\frac{v}{2F_I}}} = \frac{\sqrt{2}}{4} \frac{F_I v}{\sqrt{(vF_I)}}$. No rule leads to a duopoly. Hence, in all equilibria firms charge maximum prices compatible with full coverage. Thus, as long as there is no product proliferation or change of operator, consumer surplus does not change. Consider entry deterrence. Since $n_I^{ed} = \frac{1}{2}\sqrt{\frac{v}{F_E}}$ we have $CS^{ed} = u - \left(u - v\frac{1}{2\sqrt{\frac{v}{F_E}}}\right) - \frac{v}{4\sqrt{\frac{v}{F_E}}} = \frac{8}{45} \frac{F_E v}{\sqrt{(F_E v)}}$. Since entry deterrence occurs only if $F_E < F_I$, we have $CS^{ed} < CS^{um}$. Now consider the case when entry occurs and the incumbent exits. We then have $CS^{um}(F_I) > CS^{um}(F_E)$ since the entrant is more efficient, $F_I > F_E$, and will therefore increase the number of buses and the price. ■

Finally, it is worth remarking that all rules are not strategically robust since their effect on strategic behaviour is not taken into account. First, enforcement probabilities change the outcome of the game. Product proliferation will occur only if the probability of enforcement is high enough. Second, high cost entrants can strategically free-ride on the shelter provided by the rules. A small firm may enter for buyout. Under the BRR it is allowed to do so if its profits are zero, even if this implies that the ensuing (legal) competition by best-response undercutting leads to losses for both firms and overbussing. Third, rules lose effectiveness due to product proliferation.

component in order to capture (long term) intermodal competition with cars. This gives rise to another source of inefficiency in a deregulated bus market. Individual operators do not have an incentive to reduce prices in order to attract more passengers away from the higher quality car transport, as the bus vs car decision in the model depends on the average bus price. Both effects cause bus prices to be higher than what is socially optimal. Within the context of this model Ireland argues that deregulation must induce a decrease in bus operating costs of more than 36% in order to make the net effect of competition on welfare positive.

7 Alternative Entry Scenarios

For concreteness consider a typical transport service that operates throughout a day, with departure times evenly spread. Then there are a number of “focal” entry strategies. The entrant can choose full or small scale depending on whether he enters with the same or a lower number of buses (coaches, airplanes, trains, ferries) than the incumbent. Moreover, he can enter midway between the incumbent’s departure times, later than midway, or he can run exactly the same schedule as the incumbent. Note that if the entrant chooses departure times later than midway, the usual response is that the incumbent reschedules so that he has the advantage of running before the rival. In practice that has resulted in what was termed “chasing around the clock”. Given this response, there is no great difference to the strategy of entering in the middle other than that average profitability of both players will be lower (Oldale 1998).

In the following we discuss small scale entry and schedule matching entry.

7.1 Small Scale Entry

If fares on each bus are determined separately, small scale entry is much more difficult to deter than full scale entry. This has been pointed out by Judd (1985) who provides a simple example for illustration: Suppose the incumbent runs an hourly service at 8.00, 9.00, 10.00 etc. and the entrant chooses a departure time of 12.30 then “the multiproduct firm will have to choose between lowering prices on the 12:00 and 1:00 goods, which would cause loss of sales of the 11:00 and 2:00 goods, or keeping prices high and seeing sales of 12:00 and 1:00 fall substantially [...] Therefore, if exit costs are low and the local competition is intense, the multiproduct firm will possibly withdraw goods close to the entrant” (p. 163). The interesting point is that this will become more likely the higher the frequency of buses making entry deterrence a difficult exercise. This argument ignores, however, that the incumbent that accommodates small scale entry at one departure time will be worried about entry at other departure times. If fares are equal for all buses operated by one firm on a route the effect of local competition on prices of the neighbouring buses of the multiproduct firm will be smaller and pressure to remove buses lower. However, the minimum entry deterring number of buses will be larger since local price competition is softened as multiproduct firms hesitate to forego monopoly profits in the non-contested

markets.

Will the incumbent will prefer deterring to accommodating small scale entry? The result depends on the number of potential entrants considered. In case we consider only one potential entrant the incumbent faces a decision problem that differs from the one of an incumbent facing a mirroring entrant: if that small firm enters profits will be reduced only on the two neighbouring buses. However, if entry is to be deterred, prices on all buses have to be lowered. Hence, compared to the case of the mirroring entrant the costs of deterrence are the same but the benefits are lower. Hence, an incumbent that is large may (depending on parameter values) accommodate entry if the number of entrants is exogenously limited. If there are n_I or more potential small entrants the same result obtains as with a mirroring entrant.

7.2 Entry at Equal Times

After a schedule matching full-scale entry both firms provide a homogenous product. Thus, the ensuing Bertrand-Competition implies the following demand function.

$$q_i(p_i) = \begin{cases} 0 & \text{if } p_i > p_j \\ \frac{1}{n} & \text{if } p_i < p_j \\ \frac{1}{2n} & \text{if } p_i = p_j \end{cases}, i, j \in \{E, I\}, i \neq j. \quad (15)$$

Thus, undercutting is always a best-response until $p_i = p_j = 0$. Since best-responses are legal under all rules, the large firm will therefore be able to successfully drive out the small firm. Clearly, by eliminating product differentiation schedule matching entry is the most costly strategy that can be chosen. Clearly, with a number of passengers arriving randomly at a bus stop each operator would prefer to run just in front of the rival. In the British local bus industry a frequent change of service pattern has been observed where competition was fierce: “Chasing around the clock” was one way operators competed. In an empirical estimation large welfare losses have been attributed to network instabilities. Analysing the period from 1986 to 1989, White estimates consumer surplus losses due to instabilities of BPS 19m from lost trips and BPS 67m on remaining users for the metropolitan areas alone (White 1990, p. 326).

8 Avoiding ex-post investigations

Our analysis suggests that predation investigations do not perform well with regard to improving welfare. Moreover, predation investigations have potentially a number of additional disadvantages. They involve discretion and may therefore generate considerable business uncertainty. They are costly to pursue and divert management attention.

Freezing rules intend to avoid these investigations and build on the idea to make predatory behaviour more costly and thereby deter such behaviour. Baumol (1979) suggests this approach and it is still popular and of practical importance.

Definition 7 (Baumol Rule) *If an incumbent changes its policy as a response to entry and the entrant exits, the incumbent must maintain this policy for a specified period beginning at the date of exit (Baumol 1979).*

This rule has been recently suggested by Starkie in response to the approach of the U.S. Department of Transportation. He suggested to freeze the frequencies and capacities of incumbent airlines after the exit of a rival for a specified period (e.g. half a year). He is optimistic about the outcome: “The lock-in thus build in a response lag. This has the effect of inducing prices which one would expect to see in a competitive market” (Starkie 1999, S. 284).

British competition authorities also used this approach in the context of merger control in the local bus industry. Three mergers have been cleared on the basis of behavioural undertakings by the parties. According to the undertakings the firms would have to sustain any in response to entry reduced prices or increased frequency for one year (Caldaire-Bluebird, Stagecoach-Formia, Mid and West Kent).

Lemma 12 (Baumol Rule) *The Baumol Rule with midway entry has no impact on the strategic interaction of small and large firms.*

This stark result immediately follows from our definition of a large firm, where the reputation effect is assumed to play a prominent role. There is an incentive to predate irrespective of the number of periods since this has beneficial effects in the remaining markets.

Indeed our result may explain, why the undertakings given in the U.K.-merger cases did not lead to entry. Only in one case a firm gave the undertaking, not to reduce prices selectively on those routes where entry occurred.

This would then significantly affect the payoffs in case of predation. By A1 a small firm would then potentially be able to drive out a large firm. More generally, the Baumol Rule suffers from the same basic problem as the other anti-predation rules, it fails to link regulation to welfare.

A second freezing rule is used to encourage entry more directly.

Definition 8 (Williamson Rule) *The incumbent must not change its policy as a response to entry (Williamson 1977).*

The European Commission build on this logic in remedying potential anti-competitive effects of mergers and alliances in the airline industry. In the SAS-Lufthansa-alliance the firms had to give an undertaking not to increase the frequency on a route that faced entry. However, there were a number of exceptions from this rule (European Commission 1996). In the case of the KLM-Alitalia the undertakings were more strict and even required a reduction of frequency in case of entry: “For every daily return flight (“frequency”) introduced by a new entrant, the parties will reduce their own frequencies by one, up to a maximum of 40% of the frequencies they actually operate and provided that they can maintain a minimum number of frequencies on the routes to allow effective connection of their two networks (6 frequencies on Amsterdam-Milan and 4 on Amsterdam-Rome)” (European Commission 1999, S. 16). The merger was then not pursued.

Lemma 13 (Williamson Rule) *The Williamson Rule with midway entry has no impact on the strategic interaction between a large entrant and a small incumbent.*

Proof. As in the game with no rules, the large entrant can set arbitrarily low prices when entering the incumbent’s market. Thus by Remark 2 the entrant enters and drives out the small firm. ■

Lemma 14 (Williamson Rule) *In a game with a large incumbent, entry is blockaded if $F_E > \frac{1}{4} \frac{w^2}{v}$.*

Fixing the prices of the incumbent introduces a strong asymmetry to the advantage of the entrant. As a result product proliferation strategies fail whenever monopoly prices are high relative to the entrants cost. As a result incumbent’s have to revert to limit pricing strategies in order to deter entry.

Proof. A large entrant will only enter a market of a large incumbent if it can drive out the rival. However, a large incumbent prefers staying in the market to exiting as long as the former yields positive profits.

Suppose monopoly behaviour of the incumbent. Then the incumbent must maintain monopoly prices after entry and makes a loss if

$$\pi_I = n_I^m \left(p_I^m \left(\frac{p_E - p_I^m}{v} + \frac{1}{2n_I^m} \right) - F_I \right) < 0.$$

Suppose the entrant chooses a best-response price $p_E^{BR} = \frac{1}{2}p_I^m + \frac{1}{2}p^*$. Since $p_I^m = u - p^*$ we have $p_E^{BR} = \frac{1}{2}u$. Hence, the incumbent's profits are

$$\pi_I = n_I^m \left((u - p^*) \left(\frac{\frac{1}{2}u - (u - p^*)}{v} + \frac{1}{2n_I^m} \right) - F_I \right). \quad (16)$$

Note that π_I decreases in u : Making use of $p^* = \frac{v}{2n_I^m}$ we have $\frac{\partial \pi_I}{\partial u} = \frac{1}{4} - \frac{n}{v}u$. Since $u > v$ and $n_I^m \geq 1$ we have $\frac{\partial \pi_I}{\partial u} < 0$. Since $p_I^m = u - p^*$ we have $p_I^m \geq p^*$ only if $u \geq 2p^*$. (Note that if $p_I^m \leq p^*$ the incumbent will make a loss in the post-entry equilibrium if the entrant charges p^* . Since we are trying to identify positive profits for the incumbent, assuming $u \geq 2p^*$ is not restrictive, see 34.) With $\frac{\partial \pi_I}{\partial u} < 0$ maximum profits must be given at $u = 2p^*$. Substituting in the profit function yields

$$\pi_I = n_I^m \left(p^* \frac{1}{2n_I^m} - F_I \right) = \pi_I^*.$$

However, since we have shown earlier that $\pi_I^* < 0$ if $n = 2n_I^m$ setting a best-response price suffices to drive out the incumbent.

We now check under which conditions setting a best-response price is profitable for the entrant. From $\pi_E = n_I^m \left(p_E^{BR} \left(\frac{u - v \frac{1}{2n_I^m} - p_E^{BR}}{v} + \frac{1}{2n_I^m} \right) - F_E \right) \geq 0$ and $p_E^{BR} = \frac{1}{2}u$ we have

$$u \geq 2\sqrt{(F_E v)}$$

which is independent of F_I and satisfied whenever $F_E \leq \frac{1}{4} \frac{u^2}{v}$. ■

The freezing post-entry behaviour approach seems very simple and attractive on first sight. However, it involves a number of practical considerations: For how long and on which routes should the behaviour be frozen? Should one freeze prices and frequencies or one strategic variable alone? When should

the freezing period start: when the new behaviour occurred or on exit of the rival? How should one define the incumbent service (which amendments make an incumbent route a new route, should one use a corridor rather than a route)? Which behaviour should be frozen, the behaviour at the point when before entry was announced, after announcement but before entry, or after entry? What are exceptional market conditions that allow a firm to disregard the undertakings?

Altogether the freezing rules are either ineffective or they suffer from the same problems as the other rules, there is a regulatory first-mover advantage, the selection function of competition is not restored or even hindered, and there are negative welfare effects.

9 Conclusions

Is the purpose of competition policy to enhance competition? If we follow Bork (1978, p. 61) and others and incorporate welfare criteria into the definition of competition the simple answer to this simple question is yes. If we follow Stigler (1987) and define competition, in a more positive sense as “a rivalry between individuals (or groups or nations), and it arises whenever two or more parties strive for something that all cannot obtain,” the answer is may be. The relationship between competition and welfare has played an important role in the history of economic thought.¹³ The relationship between rules designed to promote competition and welfare seems to be less prominent. In this paper we pursued a first step in examining the performance of competition rules by a number of criteria. From our point of view the two most striking results are that

1. all rules fail to encourage sustained competition in the market and
2. all rules lead to a “regulatory first mover advantage” in the sense that even with rules an inefficient incumbent cannot be replaced by a more efficient entrant unless the difference in efficiency is extreme.

What has been neglected in previous research is that incumbents will choose a strategic response to the rules. Anticipating that the aggressiveness of their response to entry is curtailed by effective anti-competition rules, large

¹³Vickers (1995b) provides a survey.

incumbents will choose to crowd the product space, if this is necessary, in order to eliminate profitable (legal) entry opportunities for small entrants. So, anti-predation rules do achieve something. But is this welfare enhancing? In the context of the specific model presented here the answer is no. Product proliferation is detrimental to welfare and consumer surplus. We have presented some limited evidence that suggests that product proliferation is an issue in transport markets and is indeed detrimental to welfare on a significant scale.

Thus, one important normative implication of this paper is that making the threat of potential competition more effective need not be in the public interest. Competition authorities as well as economic research should move away from a simple “enhance competition” to a more sophisticated “enhance effective competition” approach, in which welfare criteria are explicitly considered (Vickers 1995a).

Establishing rules that build on welfare criteria seems one urgent need for future research.

Appendix

A Deriving demand

Let the ideal departure time of a passenger be $\tilde{\tau}$ (expressed, for instance, in minutes past the hour) and the actual departure time of a representative bus be τ_i then $\tau = |\tau_i - \tilde{\tau}|$ is the period of time that the preferred departure is later than the actual departure of this bus. Assuming that all passengers value a minute of rescheduling from the preferred departure time the same we have rescheduling cost with regard to a representative bus i of $v\tau$, where v is the value of a rescheduled unit of time.

There is a continuum of potential passengers with ideal departure times uniformly distributed around the circular schedule and normalized to 1. Hence, we can interpret τ as both the "distance" to the optimal departure time and the number of passengers that board during the time period τ .

Each potential passenger either makes one trip only or spends his money on an outside good. Denote the surplus from spending all income on the outside good by \tilde{s} , and fares of operator i running the representative bus by p_i then the consumers want to maximize:

$$\max_i U(\tau_i, \tilde{\tau}) - p_i \geq \tilde{s}. \quad (17)$$

Let \tilde{u} denote the utility (measured in units of the outside good) a passenger would gain if he got the ideal time of departure $\tilde{\tau}$ and the trip for free. Using the linear rescheduling cost model we can then specify total utility by:

$$U(\tau_i, \tilde{\tau}) = \tilde{u} - v|\tau_i - \tilde{\tau}| = \tilde{u} - v\tau, \quad \text{with } \tau = |\tau_i - \tilde{\tau}|. \quad (18)$$

Substituting $U(\tau_i, \tilde{\tau})$ in (17) by (18) and letting $u = \tilde{u} - \tilde{s}$ denote the maximum generalised cost (reservation price) passengers are prepared to incur before switching to the outside good we can write:

$$\max_i u - v\tau - p_i \geq 0. \quad (19)$$

B Sequential-move best-responses

We determine the sequential-move best-response function by backward induction. Note that we assume that both players stay in the market until

period T . Suppose that firm j is the firm to set prices in that period. Then period T profits of j are

$$\pi_{j,T} = p_{j,T} \left(\frac{p_{i,T-1} - p_{j,T}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_j \frac{n}{2},$$

the best response p_{jT} is given by

$$p_{j,T} = \frac{1}{2} \frac{p_{i,T-1}n + v}{n} = \frac{1}{2} p_{i,T-1} + \frac{v}{2n},$$

and maximum profits are

$$\pi_{j,T} = \frac{1}{8} \frac{p_i^2 n^2 + 2p_i n v + v^2 - 4F_j n^2 v}{n v}.$$

Now consider period $T - 1$. It is firm i 's turn to set prices. Profits of i are

$$\begin{aligned} \pi_{i,T-1} &= p_{i,T-1} \left(\frac{p_{j,T-2} - p_{i,T-1}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_i \frac{n}{2} \\ &\quad + p_{i,T-1} \left(\frac{p_{j,T} - p_{i,T-1}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_i \frac{n}{2} \\ &= p_{i,T-1} \left(\frac{p_{j,T-2} - p_{i,T-1}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_i \frac{n}{2} \\ &\quad + p_{i,T-1} \left(\frac{\left(\frac{1}{2} \frac{p_{i,T-1}n + v}{n} \right) - p_{i,T-1}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_i \frac{n}{2}, \end{aligned}$$

the best response $p_{i,T-1}$ is given by

$$\begin{aligned} p_{i,T-1} &= \frac{1}{6} \frac{2p_{j,T-2}n + 5v}{n} = \frac{1}{3} p_{j,T-2} + \frac{5}{6} \frac{v}{n} \\ &= .333 p_{j,T-2} + .833 \frac{v}{n}, \end{aligned}$$

and maximum profits are

$$\pi_{i,T-1} = \frac{1}{48} \frac{4p_{j,T-2}^2 n^2 + 20p_{j,T-2} n v + 25v^2 - 48F_i n^2 v}{n v}.$$

Now consider period $T - 2$. It is firm j 's turn to set prices. Profits of j are

$$\begin{aligned}
\pi_{j,T-2} &= p_{j,T-2} \left(\frac{p_{i,T-3} - p_{j,T-2}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{j,T-2} \left(\frac{p_{i,T-1} - p_{j,T-2}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad + p_{j,T} \left(\frac{p_{i,T-1} - p_{j,T}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_j \frac{3n}{2} \\
&= p_{j,T-2} \left(\frac{p_{i,T-3} - p_{j,T-2}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{j,T-2} \left(\frac{p_{i,T-1} - p_{j,T-2}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad + \left(\frac{1}{2} \frac{p_{i,T-1}n + v}{n} \right) \left(\frac{p_{i,T-1} - \left(\frac{1}{2} \frac{p_{i,T-1}n + v}{n} \right)}{v} + \frac{1}{n} \right) \frac{n}{2} - F_j \frac{3n}{2} \\
&= p_{j,T-2} \left(\frac{p_{i,T-3} - p_{j,T-2}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{j,T-2} \left(\frac{\left(\frac{1}{6} \frac{2p_{j,T-2}n + 5v}{n} \right) - p_{j,T-2}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad + \left(\frac{1}{2} \frac{\left(\frac{1}{6} \frac{2p_{j,T-2}n + 5v}{n} \right) n + v}{n} \right) \left(\frac{\frac{1}{6} \frac{2p_{j,T-2}n + 5v}{n} - \left(\frac{1}{2} \frac{\left(\frac{1}{6} \frac{2p_{j,T-2}n + 5v}{n} \right) n + v}{n} \right)}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad - F_j \frac{3n}{2},
\end{aligned}$$

the best response $p_{j,T-2}$ is given by

$$p_{j,T-2} = \frac{1}{118} \frac{36p_{i,T-3}n + 113v}{n} = \frac{18}{59}p_{i,T-3} + \frac{113}{118} \frac{v}{n} = .305p_{i,T-3} + .957 \frac{v}{n},$$

and maximum profits are

$$\pi_{j,T-2} = \frac{1}{472} \frac{36p_{i,T-3}^2 n^2 + 226vp_{i,T-3}n + 553v^2 - 708F_j n^2 v}{nv}.$$

Now consider period $T - 3$. It is firm i 's turn to set prices. Profits of i

are

$$\begin{aligned}
\pi_{i,T-3} &= p_{i,T-3} \left(\frac{p_{j,T-4} - p_{i,T-3}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{i,T-3} \left(\frac{p_{j,T-2} - p_{i,T-3}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad + p_{i,T-1} \left(\frac{p_{j,T-2} - p_{i,T-1}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{i,T-1} \left(\frac{p_{j,T} - p_{i,T-1}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_i \frac{4n}{2} \\
&= p_{i,T-3} \left(\frac{p_{j,T-4} - p_{i,T-3}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{i,T-3} \left(\frac{p_{j,T-2} - p_{i,T-3}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad - F_i \frac{2n}{2} + \frac{1}{48} \frac{4p_{j,T-2}^2 n^2 + 20p_{j,T-2} n v + 25v^2 - 48F_i n^2 v}{n v} \\
&= p_{i,T-3} \left(\frac{p_{j,T-4} - p_{i,T-3}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad + p_{i,T-3} \left(\frac{\frac{1}{118} \frac{36p_{i,T-3} n + 113v}{n} - p_{i,T-3}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_i \frac{2n}{2} \\
&\quad + \frac{1}{48} \frac{4 \left(\frac{1}{118} \frac{36p_{i,T-3} n + 113v}{n} \right)^2 n^2 + 20 \left(\frac{1}{118} \frac{36p_{i,T-3} n + 113v}{n} \right) n v + 25v^2 - 48F_i n^2 v}{n v},
\end{aligned}$$

the best response $p_{i,T-3}$ is given by

$$\begin{aligned}
p_{i,T-3} &= \frac{1}{23\,384} \frac{6962p_{j,T-4}n + 23\,039v}{n} = \frac{3481}{11\,692} p_{j,T-4} + \frac{23\,039}{23\,384} \frac{v}{n} \\
&= .297p_{j,T-4} + .985 \frac{v}{n},
\end{aligned}$$

and maximum profits are

$$\pi_{i,T-3} = \frac{1}{187\,072} \frac{13\,924p_{j,T-4}^2 n^2 + 92\,156p_{j,T-4} n v + 338\,857v^2 - 374\,144F_i n^2 v}{n v}.$$

Finally, consider period $T - 4$ profits. It is firm j 's turn to set prices. Profits of j are

$$\begin{aligned}
\pi_{j,T-4} &= p_{j,T-4} \left(\frac{p_{i,T-5} - p_{j,T-4}}{v} + \frac{1}{n} \right) \frac{n}{2} + p_{j,T-4} \left(\frac{p_{i,T-3} - p_{j,T-4}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad - F_j \frac{2n}{2} + \frac{1}{472} \frac{36p_{i,T-3}^2 n^2 + 226vp_{i,T-3}n + 553v^2 - 708F_j n^2 v}{nv} \\
&= p_{j,T-4} \left(\frac{p_{i,T-5} - p_{j,T-4}}{v} + \frac{1}{n} \right) \frac{n}{2} \\
&\quad + p_{j,T-4} \left(\frac{\frac{1}{23384} \frac{6962p_{j,T-4}n + 23039v}{n} - p_{j,T-4}}{v} + \frac{1}{n} \right) \frac{n}{2} - F_j \frac{2n}{2} \\
&\quad + \frac{1}{472nv} \left(36 \left(\frac{1}{23384} \frac{6962p_{j,T-4}n + 23039v}{n} \right)^2 n^2 \right. \\
&\quad \left. + 226v \left(\frac{1}{23384} \frac{6962p_{j,T-4}n + 23039v}{n} \right) n + 553v^2 - 708F_j n^2 v \right),
\end{aligned}$$

and the best response $p_{j,T-4}$ is given by

$$\begin{aligned}
p_{j,T-4} &= \frac{1}{461714930} \frac{136702864p_{i,T-5}n + 459300713v}{n} \\
&= \frac{68351432}{230857465} p_{i,T-5} + \frac{459300713}{461714930} \frac{v}{n} \\
&= .296p_{i,T-5} + .994 \frac{v}{n}.
\end{aligned}$$

Continuing backward this line of reasoning we obtain the best response function

$$p_{j,T-d} = .295p_{i,T-5} + .999 \frac{v}{n}, \text{ where } d \in \{7, 8, \dots, T-1\}$$

and

$$p_j = \frac{1}{3}p_i + \frac{v}{n}$$

$= p_j = .33333p_i + \frac{v}{n}$ is an approximation with a difference of

$$\Delta p_j = \left(\frac{1}{3} - .295 \right) p_i + (1 - .999) \frac{v}{n} = 3.8333 \times 10^{-2} p_i + .001 \frac{v}{n}.$$

C Unconstrained Monopolist

Consider a firm that has a local monopoly. It follows from (1) that the total number of passengers choosing to use the firm's buses rather than consume

the outside good is determined by

$$n_I q_{I,k}^m(p, n_I) = \begin{cases} 0 & \text{if } p > u \\ 1 & \text{if } p \leq u - \frac{v}{2n_I} \\ n_I 2^{\frac{u-p}{v}} & \text{if } p \in \left[u - \frac{v}{2n_I}, u \right] \end{cases}. \quad (20)$$

Suppose $p \in \left[u - \frac{v}{2n_I}, u \right]$, then a consumer will be indifferent between using a bus or not if

$$\begin{aligned} u &= p + v\tilde{\tau} \\ \tilde{\tau} &= \frac{u-p}{v}. \end{aligned}$$

Since $n_I q_{I,k}^m(p, n_I) = n_I 2\tilde{\tau}$ we get $n_I q_{I,k}^m(p, n_I) = n_I 2^{\frac{u-p}{v}}$.

Note that equation (20) also provides the maximum price compatible with full coverage for a given headway $\frac{1}{n_I}$. The highest price at which there is full coverage (demand = 1) is

$$p^{fc} = u - v \frac{1}{2n_I}. \quad (21)$$

If for a given p^{fc} the headway is increased further, the consumer located in the middle switches to the outside good.

Next we determine optimal pricing given the demand function $n_I q_i^m(p_i, n_I) = n_I 2^{\frac{u-p_i}{v}}$. For a given number of buses n_I the monopolist chooses prices to

$$\begin{aligned} \max_p \sum_{k=1}^{n_I} \pi_k(p, n_I) &= n_I \left(p \frac{u-p}{v} - F_I \right) \\ p &= p^* = \frac{u}{2}. \end{aligned}$$

Thus, there is no gap, $n_I q_{I,k}^m(p, n_I) = 1$, iff

$$\begin{aligned} p^* &\leq p^{fc} \\ u &\geq \frac{v}{n_I}. \end{aligned} \quad (22)$$

This must be always fulfilled since $u \geq v$ in order to have more than one consumer at zero prices. Thus, there is no gap ($u \geq \frac{v}{n_I}$).

Then a monopolist that is unconstrained by the threat of entry will solve the following maximization problem:

$$\max_{p,n} \sum_{k=1}^{n_I} \pi_k(p, n_I) = n_I \left(p \frac{1}{n_I} - F_I \right). \quad (23)$$

Substituting price in (23) by (21) and solving for the optimal number of buses in an unconstrained monopoly we have

$$n_I^m = \sqrt{\frac{v}{2F_I}}. \quad (24)$$

With (21) we also have

$$p_I^m = u - v \frac{1}{2\sqrt{\frac{v}{2F_I}}} \quad (25)$$

and profits are given by

$$\sum_{k=1}^n \pi_k(p, n_I) = n_I (ph - F_I) = u - \sqrt{2}\sqrt{(vF_I)}.$$

D Limit Pricing (Fixed Prices)

We derive optimal pricing and the number of buses that deter entry if post entry prices are fixed. We begin by determining the incumbent's profits at entry deterring prices. Making use of the condition that in equilibrium there should be no profitable entry opportunity we have

$$\sum_{i=1}^{n_E} \pi_E(p_E; n_I, p_I) = n_I \left(p_E \left(\frac{p_I - p_E}{v} + \frac{1}{2} \frac{1}{n_I} \right) - F_E \right) \leq 0. \quad (26)$$

The entrant will price his services so that his profits are maximized. Recall from Table 1 that the entrant's best-response function with respect to the incumbent's prices is: $p_E = \frac{v}{2} \left(\frac{1}{2n_I} + \frac{1}{v} p_I \right)$. Given this pricing behaviour together with the zero profit condition (26) we have

$$\left(\frac{v}{2} \left(\frac{1}{2n_I} + \frac{1}{v} p_I^{ed} \right) \right) \left(\frac{p_I^{ed} - \frac{v}{2} \left(\frac{1}{2n_I} + \frac{1}{v} p_I^{ed} \right)}{v} + \frac{1}{2} \frac{1}{n_I} \right) - F_E \leq 0,$$

or

$$p_I^{ed} \leq 2v \sqrt{\left(\frac{F_E}{v}\right)} - \frac{v}{2n_I}. \quad (27)$$

As long as customers do not switch to outside goods the incumbent will want to charge highest price that deters entry, $p_I = \min \{p^{fc}, p_I^{ed}\}$. Where $p^{fc} = u - \frac{v}{2n_I}$ by (21). Hence, $p_I = p_I^{ed} < p^{fc} = p_I^m$ whenever $u > 2\sqrt{(vF_E)}$ for all n_I .

Assuming that $p_I^{ed} < p_I^m$ we can use (27) with equality and solve the maximization problem of the incumbent in a deterrence equilibrium:

$$\max_{n_I} \sum_{i=1}^{n_I} \pi_I(n_I; p_I^{ed}) = n_I \left(p_I^{ed} \frac{1}{n_I} - F_I \right) = -\frac{v}{2n_I} + 2\sqrt{(F_E v)} - F_I n_I.$$

which yields¹⁴

$$\hat{n}_I(p_I^{ed}) = \sqrt{\frac{1}{2} \frac{v}{F_I}}. \quad (28)$$

Using (28) and (29) optimal prices are

$$\hat{p}_I^{ed} = 2v \sqrt{\left(\frac{F_E}{v}\right)} - \frac{v}{2\sqrt{\frac{1}{2} \frac{v}{F_I}}}. \quad (29)$$

Limit pricing yields positive profits for the incumbent if

$$\begin{aligned} \pi_I(\hat{n}_I; \hat{p}_I^{ed}) &\geq 0 \\ \hat{p}_I^{ed} \frac{1}{\hat{n}_I} - F_I &\geq 0 \\ F_E &\geq \frac{1}{2} F_I. \end{aligned}$$

¹⁴Note that again the optimal number of buses, given entry deterring pricing, is equal to the number of buses run by an unconstrained monopolist. It is because marginal revenue with respect to the number of buses is the same in both cases, i.e. the incumbent is effectively facing a demand function with the same slope as the monopoly demand function. Given the same cost per bus, F , the resulting optimum is equal.

E Proof of Lemma Entry Deterrence BRR

Proof. It follows from the proof of Lemma 3 that if $F_E < \frac{9}{16}F_I$, the high price entry strategy is profitable for the entrant, even if the incumbent chooses a best response.

Incumbent prefers product proliferation to duopoly

We can apply the same reasoning as in the proof of Lemma 2 in order to show that the incumbent prefers product proliferation to allowing entry, if product proliferation is a profitable strategy: First, choose any number of buses n_I that leaves a profitable entry opportunity and that leads to a post-entry equilibrium in which the incumbent earns a positive profit per bus $\pi_{I,k}^d > 0$. Then the incumbent earns $n_I\pi_{I,k}^d$ on the route whereas in case of proliferation he could have earned at least $2n_I\pi_{I,k}^m$. Clearly, for a given n_I $\pi_{I,k}^d \leq \pi_{I,k}^m$ and therefore $n_I\pi_{I,k}^d < 2n_I\pi_{I,k}^m$. Thus, the incumbent prefers product proliferation to allowing entry. Now choose any number of buses n_I that leaves a profitable entry opportunity and that leads to a post-entry equilibrium in which the incumbent does not earn positive profits per bus $\pi_I^d \leq 0$. Then the incumbent will choose product proliferation whenever the number of buses that deters entry yields positive profits per bus ($p_I(n_I^{ed})\frac{1}{n_I^{ed}} - F_I > 0$). Now suppose the number of buses that would deter entry is higher than the number of buses that the incumbent can run profitably. Then there is a profitable entry opportunity and the incumbent does not earn positive profits if entry occurs. Thus, it will exit on entry.

It remains to be shown (1) that product proliferation is profitable if $u > \frac{\sqrt{2}v(16F_E+9F_I)}{24\sqrt{(vF_E)}}$ and (2) that it is preferred to limit pricing.

Suppose $F_E < \frac{9}{16}F_I$ and consider high price entry. We show that the number of buses that deter high price entry is higher than the number of buses that deter entry if the entrant chooses to undercut the incumbent's response, i.e. we show that the high price entry strategy is the binding constraint for product proliferation. Using (10) and (11) product proliferation deters entry if $\frac{3}{4}\left(\frac{3}{4}\frac{v}{n_I}\right) - \frac{n_I}{2v}\left(\frac{3}{4}\frac{v}{n_I}\right)^2 - n_IF_E < 0$ or, ignoring the negative root,

$$\bar{n}_I^{ed} \geq \frac{3}{8F_E}\sqrt{2}\sqrt{(F_Ev)}. \quad (30)$$

Clearly in order to deter entry effectively the incumbent must choose

$$\max\{\bar{n}_I^{ed}, n_I^{ed}\}.$$

By (8) we have $n_I^{ed} \geq \frac{1}{2}\sqrt{\frac{v}{F_E}}$. Comparing n_I^{ed} and \bar{n}_I^{ed} we have

$$n_I^{ed} < \bar{n}_I^{ed}.$$

Product proliferation must be profitable

Now suppose the incumbent chooses \bar{n}_I^{ed} . When is this profitable? Optimal pricing of the incumbent is

$$p_I(\bar{n}_I^{ed}) = u - v \frac{1}{2\bar{n}_I} = u - \frac{2\sqrt{2}vF_E}{3\sqrt{(F_E v)}}. \quad (31)$$

This is profitable for the incumbent if $\pi_I(\bar{n}_I^{ed}) = p_I(\bar{n}_I^{ed}) - \bar{n}_I^{ed}F_I > 0$ or

$$\begin{aligned} u &> \frac{2\sqrt{2}vF_E}{3\sqrt{(F_E v)}} + \frac{3}{8F_E}\sqrt{2}\sqrt{(F_E v)}F_I \\ u &> \frac{\sqrt{2}v(16F_E + 9F_I)}{24\sqrt{(vF_E)}}. \end{aligned}$$

Incumbent prefers product proliferation to limit pricing

Now consider limit pricing. A limit pricing strategy makes entry unprofitable even if the entrant chooses a best-response. Since we have investigated this constellation already in the proof of Lemma 2 we can make use of the results derived in Appendix D: Optimal limit pricing yields

$$n_I(p_I^{ed}) = \sqrt{\frac{v}{2F_I}} \quad (32)$$

$$p_I^{ed} = 2v\sqrt{\frac{F_E}{v}} - \frac{v}{2n_I}. \quad (33)$$

It follows that product proliferation is better than limit pricing if

$$\begin{aligned} \pi_I(n_I^{ed}) = p_I(n_I^{ed}) - n_I^{ed}F_I &> p_I^{ed} - n_I(p_I^{ed})F_I = \pi_I(p_I^{ed}) \\ u - \frac{2\sqrt{2}vF_E}{3\sqrt{(F_E v)}} - \frac{3}{8F_E}\sqrt{2}\sqrt{(F_E v)}F_I &> 2v\sqrt{\frac{F_E}{v}} - \frac{v}{2\sqrt{\frac{v}{2F_I}}} - \sqrt{\frac{v}{2F_I}}F_I \\ u &> \frac{1}{24}v\frac{16F_E\sqrt{2} + 9\sqrt{2}F_I + 48F_E}{\sqrt{(F_E v)}} - \frac{v\sqrt{2}F_I}{\sqrt{(vF_I)}}. \end{aligned}$$

By (6) $p_I^m > p^*(2n_I^m)$ holds if and only if $u > 2p^*(2n_I^m)$. By Table 1 $p^* = \frac{v}{n}$. Thus, with (5) we have $p^*(2n_I^m) = \frac{\sqrt{2}}{2} \frac{vF_I}{\sqrt{(vF_I)}}$ and we must have

$$u > \sqrt{2} \frac{vF_I}{\sqrt{(vF_I)}}. \quad (34)$$

It follows from (34) that product proliferation is always better than limit pricing. ■

F Competitive market structure

As a benchmark we briefly present the solution to the model using the standard assumptions employed in the literature. Note that operators need to decide whether to enter, where to locate and which fare to take. The equilibrium concept is characterized by the following assumptions:

- A1 (relocation, one-bus-firms) Each firm operates one bus only and, on entry, this bus is rescheduled to equalize headways on the route.
- A2 (free-entry-zero-profits) Entry occurs until firms earn zero profits (neglecting the integer constraint).
- A3 (flexible pricing) Firms can adjust prices at any time.

Although the model is static the following story has been proposed to describe the construction of a timetable under free entry:

”What happens if as the timetable fills up [as a result of entry] there is an interval between two buses which is substantially more than the maximum? Then if the cost to an operator of altering its slot in the timetable is zero, it will pay for another operator to enter midway between the two existing buses and for them to shift further apart. This may induce other buses to move also, so that each bus ends by achieving a maximum interval. Such a process may be the means by which a timetable is achieved; but it is not a competitive equilibrium, since we have shown that all buses will be earning monopoly profits. Therefore it will still pay operators to introduce new buses into the schedule at a lower fare.

Then, through shunting, a new timetable with less than maximum intervals will be created, till a minimum frequency timetable is established in which no new bus entering could earn a positive profit. In this way, stable competitive [...] equilibrium is reached” (Foster and Golay 1986, p. 203).

Given the assumptions above we define the equilibrium concept:

Definition 9 *A symmetric active competition equilibrium (ACE) as in Salop (1979) is given by the number of buses n and the fares $p_i = p_{-i}$, $i = 1, 2, \dots, n$, that result if firms maximize profits according to the Bertrand-Nash assumption:*

$$p_{-i} = \arg \max_{p_i} \pi_i(p_i, p_{-i}) = p_i q_i(p_i, p_{-i}) - F \quad (35)$$

and earn zero profits in equilibrium:

$$\pi_i(p_i, p_{-i}) = p_i q_i(p_i, p_{-i}) - F = 0 \quad (36)$$

Where demand $q_i(p_i, p_{-i})$ being given by (2) and, due to relocation, equilibrium headway is equal around the circle, $h = \frac{1}{n}$.

Based on this definition of the standard circular city model by Salop adapted to the bus industry, we can now solve for equilibrium fares, passengers, and buses - \bar{p} , \bar{q} and \bar{n} . Note, that we ignore the constraint that the number of buses in equilibrium must be integers by assuming that n is continuous.¹⁵ The first-order condition for the Bertrand-Nash maximisation problem is

$$\frac{\delta \pi_i(p_i, p)}{\delta p_i} = \frac{p - 2p_i}{v} + h = 0.$$

Setting $p_{-i} = p_i = \bar{p}$ and solving for \bar{p} yields:

$$\bar{p} = hv = \frac{v}{n}. \quad (37)$$

Setting the profit function equal to zero (36) and substituting the equilibrium price (37) yields the number of buses in equilibrium

$$\bar{n}_c = \sqrt{\frac{v}{F}}. \quad (38)$$

¹⁵The implications of this assumption will be discussed below.

Making use of symmetry we know that in a covered market $q = \frac{1}{n}$. Hence, equation (38) also gives us the equilibrium number of passengers on each bus:

$$\bar{q}_c = \sqrt{\frac{F}{v}}.$$

Furthermore, with (38) we can also express the equilibrium fare as:

$$\bar{p}_c = \sqrt{vF}. \quad (39)$$

We have thus characterized a competitive equilibrium solution of the Salop-Model.¹⁶ We are now in a position to restrict parameter values in order to avoid kinked or monopoly equilibria. Note that the competitive equilibrium occurs for all optimal prices (weakly) below monopoly prices evaluated at the number of buses that obtains in the competitive equilibrium. Given the inverted monopoly demand function implied by (19) (and no restriction from neighbouring buses) we have $p_i^c \leq p_i = u - \frac{1}{2} \frac{v}{n^c}$. Substituting the equilibrium values identified in the next section we have:

$$u \geq \frac{3}{2} \sqrt{vF}. \quad (40)$$

We assume parameter values to be constrained by (40).^{17 18}

G Profitability of proliferation

The entrant stays out if

$$\sum_{k=1}^{n_E} \pi_{E,k}(p_I, p_E; n_I) = \sum_{k=1}^{n_E} (p_E q_{E,i}(p_I, p_E; n_I) - F_E) \leq 0 \quad (41)$$

¹⁶Note a peculiarity of the equilibrium: In equilibrium the fares are above marginal cost (see equation 39)- although by assumption firms make no profit. Hence, zero profits are, in the context of this model, no indication of market power if the latter is defined as pricing above marginal cost. This does not distort consumption as all passengers receive the same utility from the trip and each passenger is assumed to make one trip only.

¹⁷Note that this restriction excludes kinked equilibria which occur in the interval of $\hat{m} + \sqrt{2}\sqrt{(Fv)} < \bar{v} < \frac{3}{2}\sqrt{vF} + \hat{m}$ and monopoly equilibria that occur for parameter values $\bar{v} \leq \hat{m} + \sqrt{2}\sqrt{(Fv)}$.

¹⁸Note that the number of firms entering in competitive equilibrium is determined by the minimum efficient scale of production which in turn is determined by fix costs. If the latter are large relative to demand, the number of firms may reduce to one or zero and results may then fail to hold. We ignore these cases.

and enters otherwise.

By (??) we have $p_I^* = p_E^* = p^*$. Hence, we can write

$$\begin{aligned} p^* \left(\frac{1}{2n_I} \right) - F_E &\leq 0 \\ n_I^d &\geq \frac{p^*}{2F_E}. \end{aligned} \quad (42)$$

Using (??) we have the minimum number of buses that deter entry

$$n_I^d \geq \frac{1}{2} \sqrt{\frac{v}{F_E}}. \quad (43)$$

If entry is deterred, the incumbent's profits are given by the number of buses n_I that deter entry and fares p_I that maximize profits on the route

$$\max_{p_i, n} \sum_{i=1}^n \pi_i(p_i; n_I) = \sum_{i=1}^n (p_i q_i(p_i; n_I) - F_i), \quad (44)$$

where $q_i(p_i)$ is determined by (20) and n_I follows from (43). By (22) and (43) there will be no gap at the entry deterring number of buses iff $u \geq \frac{2vF_E}{\sqrt{vF_E}}$. Then the entry deterring number of buses does not yield positive profits for the incumbent if (see 23)

$$\begin{aligned} \sum_{k=1}^n \pi_{i,k}(p_i; n_I) &< 0 \\ p - n_I F_I &< 0 \\ u - v \frac{1}{2n_I} - n_I F_I &< 0 \\ \frac{u}{\frac{1}{2} \sqrt{\frac{v}{F_E}}} - \frac{v}{2 \left(\frac{1}{2} \sqrt{\frac{v}{F_E}} \right)^2} &< F_I \\ \frac{1}{2} \sqrt{(vF_E)} \frac{2F_E + F_I}{F_E} &< u. \end{aligned}$$

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