Journal of Economic Behavior & Organization
Vol. 47 (2002) 451–462

JOURNAL OF Economic Behavior & Organization

www.elsevier.com/locate/econbase

Why competition may drive up prices

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Abstract

We show that the expected price of an incumbent firm may increase in response to increasing competition as it may become more profitable to exploit a rather immobile fraction of consumers instead of capturing a larger but more contested segment of the market. To derive this result, we consider two approaches of modelling the degree of competition. First, in a duopolistic setting competition is said to be more intense if the entrant's product becomes more attractive to the mobile fraction of buyers. In this case we find that all buyers, i.e. both the mobile and the immobile fraction, may lose if the market becomes more competitive. Secondly, in a model with two entrants competition is said to become intense if entrants serve an overlapping segment of the market for mobile buyers. © 2002 Published by Elsevier Science B.V.

JEL classification: D13

Keywords: Switching costs; Imperfect competition

1. Introduction

We consider competition between an incumbent firm and new entrants. It is assumed that the customer base of the incumbent firm contains two fractions. One segment is perfectly immobile and can only shop at the incumbent, while the other segment may also turn to one of the entrants. We show how an increase in competition for the mobile fraction of buyers may hurt all customers and particularly the fraction locked-in with the incumbent. These results are derived under two different notions of competition which may play a role for the policy formation of a regulator.

In the first approach, we suppose that the incumbent faces a single entrant. Firms engage in Bertrand competition. While the former monopolist may serve the whole market, the entrant can only provide services to a strict subset of buyers. Furthermore, the mobile fraction of buyers, who may shop at both firms, incurs an additional cost (of substitution) if it patronizes the entrant. Our main result is that the incumbent's expected price is U-shaped

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PII: S0167-2681(01)00213-X

in the cost of substitution of the mobile fraction. As a low cost of substitution makes the entrant's offer more competitive, it becomes less attractive for the incumbent to capture the whole market. Note that the incumbent has always the option to focus on his locked-in fraction of customers. Interestingly, we find that also mobile consumers may fare worse if their costs of substitution decrease.

In the second variant we allow for two entrants. While the incumbent can still cover the whole market, each entrant serves again only a strict subset. The entrants' market segments may now be disjunct or overlapping. One might conjecture that entrants intend to avoid head-on competition in overlapping segments, while a regulator may want to stimulate competition by requiring that all market participants cover a minimum size implying overlapping segments. We show that this policy hurts the fraction of buyers who are still locked-in with the incumbent. Increasing competition for mobile customers makes the exploitation of the locked-in fraction more attractive for the incumbent.

The possibility that a loyal share of costumers induces an incumbent to price less aggressively has already achieved some attention in the literature.[1] Fudenberg and Tirole (1984) call it the 'fat cat' effect, which becomes particularly instructive in multiperiod models with switching costs and overlapping generations of buyers (see Padilla, 1995 and To, 1996 for recent overviews).[2] It has also been applied to answer questions relating to endogenous price leadership (Deneckere et al., 1992), new market entry in an open oligopoly (see the references in Klemperer, 1995), or the role of promotional strategies (Narasimhan, 1988; Caminal and Matutes, 1990). In light of this literature, we think that the contribution of our first approach, where we consider a single entrant, is as follows. We are not aware of any results similar to our comparative statics on the costs of substitution where we show that expected prices change in a U-shaped form. This applies as well to our possibly surprising results that a decrease in these costs may hurt *all* buyers.

The rest of this paper is organized as follows. Section 2 considers the model where a single entrant faces the incumbent who has the advantage of a locked-in fraction of buyers. In Section 3, we introduce a second entrant and analyze the impact of overlapping market coverage. Section 4 concludes.

2. Varying the costs of substitution

Envisage a market with two firms indexed by $i \in I = \{1, 2\}$. We call firm $i = 1$ the incumbent and firm $i = 2$ the entrant. Both firms produce a homogenous good at constant marginal costs normalized to zero. We restrict attention to a static model where the market operates for one period. In this period firms face a unit measure of buyers who demand at most a single unit of the good. All customers have the same reservation value $r > 0$. Firms compete by simultaneously quoting a pair of prices. We assume that buyers are made up

[1] Instead of 'loyalty' as used in Rosenthal (1982), we may also speak of 'buyer lock-in' (Nilssen, 1997), 'switching costs' (Klemperer, 1995), or 'costs of substitution' (von Weizsäcker, 1984). At this point we should also mention work by Schulz (1995), who argues that increasing the substitutability between products may lead to higher prices. In contrast to our model, his result is driven by an increase in aggregate demand, which is endogenous as potential buyers must incur information costs before deciding which good to purchase.

[2] Their analysis is similar to that in Bulow et al. (1985).

by two fractions denoted by A and B with respective masses $\alpha \in (0, 1)$ and $\beta = 1 - \alpha$. A buyer of type A has only access to the product of the incumbent. The fraction B may patronize both firms, but buyers incur a cost of substitution c with $0 \leq c < r$ if they turn to the entrant. Hence, the willingness to pay reduces to $r - c$ if a mobile customer purchases at $i = 2$. Below we will propose some examples and interpretations.

Consumers of type A shop at the incumbent if his price does not exceed r, while the incumbent can only attract a member of fraction B if his price does not exceed that of the entrant by more than c. We apply the deterministic tie-breaking rule that consumers of type B choose the incumbent in case of indifference between the two firms. Though our main result for low values of c would still hold with a random tie-breaking rule, we have to choose this specification to ensure existence of an equilibrium for high values of c, for which all buyers are served by the incumbent.

Our equilibrium concept is that of a Nash equilibrium in possibly mixed strategies. In any equilibrium the incumbent will only charge prices in the interval $P = [c, r]$ as the entrant will never quote negative prices. Without loss of generality we can restrict the entrant's price to the interval $[0, r - c]$ as prices above $r - c$ will not attract any customer. The exposition of the further arguments is now heavily abbreviated if the entrant's strategy space consists out of 'gross prices' including the costs of substitution c. We denote the respective gross prices for firms $i = 1, 2$ by p_i, where $p_1 \in P$ and $p_2 \in P$.

For low values of c we find a (unique) equilibrium in mixed strategies, while the equilibrium is in pure strategies for high c, where only the incumbent trades. To save notation, we generally denote the firms' strategies as (possibly degenerate) distribution functions F_i for $i \in I$ with respective supports $S \subseteq P$. (Recall that the support is the smallest closed set with probability one.) Define $F_i^-(p) = \sup_{\tilde{p}<p} F_i(\tilde{p})$ such that F_i has an atom at p if $F_i(p) - F_i^-(p) > 0$. If $S_i \subset P$ holds strictly, the distribution can be extended over the whole interval P in an obvious way. The expected profit of firm i from charging a gross price p while the other firm plays according to F_j equals

$$\Pi_1(p, F_2) = p(\alpha + \beta(1 - F_2^-(p))), \qquad \Pi_2(p, F_1) = (p - c)\beta(1 - F_1(p)). \quad (1)$$

We will suppress the distribution F_j as an argument of Π_i whenever this does not lead to confusion. A pair of distributions (F_1^*, F_2^*) with respective supports (S_1^*, S_2^*) constitutes a (Nash) equilibrium if it satisfies the following requirements for both $i \in I$:

$$\Pi_i(\check{p}, F_j^*) = \Pi_i(\hat{p}, F_j^*) = \Pi_i^*, \quad \text{for all } \check{p}, \hat{p} \in S_i^*,$$

$$\Pi_i(p, F_j^*) \leq \Pi_i^*, \quad \text{for all } p \notin S_i^*.$$

We solve next for an equilibrium of the game. In a first step boundaries on the equilibrium supports (S_1^*, S_2^*) are determined. It can further be shown that supports must be connected and that distributions can only have an atom at the upper boundary of the respective support. With these preliminary results we can next derive the equilibrium distribution functions from the Nash conditions. Readers who are familiar with these steps may skip to the characterization of equilibria in Proposition 1.

Denote now the boundaries of the supports by $p_i^{\mathrm{o}} = \max S_i$ and $p_i^{\mathrm{u}} = \min S_i$. Recall that we consider gross prices. Lemma 1 derives first characteristics for an equilibrium.

Lemma 1. *In any equilibrium it holds that* $p_1^{\mathrm{u}} = p_2^{\mathrm{u}} = p^{\mathrm{u}}$. *For* $p^{\mathrm{u}} > c$ *we obtain* $\Pi_2^* = (p^{\mathrm{u}} - c)\beta$ *and* $\Pi_1^* = p^{\mathrm{u}}$, *while for* $p^{\mathrm{u}} = c$ *it holds that* $p_1^{\mathrm{o}} = p^{\mathrm{u}}$ *and* $\Pi_2^* = 0$.

Proof. For $p_1^{\mathrm{u}} < p_2^{\mathrm{u}}$ it follows from (1) that $\Pi_1(p) > \Pi_1(p_1^{\mathrm{u}})$ for $p \in (p_1^{\mathrm{u}}, p_2^{\mathrm{u}})$. As the same argument applies for $i = 2$ in case $p_2^{\mathrm{u}} < p_1^{\mathrm{u}}$, we obtain $p_1^{\mathrm{u}} = p_2^{\mathrm{u}} = p^{\mathrm{u}}$. This implies $\Pi_1^* = \Pi_1(p^{\mathrm{u}}) = p^{\mathrm{u}}$. If F_i^* has for $p^{\mathrm{u}} > c$ an atom at p^{u}, there exists $p \in (c, p^{\mathrm{u}})$ with $\Pi_2^* = \Pi_2(p^{\mathrm{u}}) < \Pi_2(p)$. Without an atom we obtain $\Pi_2^* = (p^{\mathrm{u}} - c)\beta > 0$. As $\Pi_2^* = 0$ follows from $p^{\mathrm{u}} = c$, we obtain in this case $p_1^{\mathrm{o}} = p^{\mathrm{u}}$ as otherwise the entrant could strictly improve by choosing a price $p \in (p^{\mathrm{u}}, p_1^{\mathrm{o}})$ to realize $(p - c)\beta(1 - F_1^*(p)) > 0$. □

Lemma 1 distinguishes between equilibria where the lower boundary of the supports is equal or different to the cost of substitution c. For $p^{\mathrm{u}} > c$ an equilibrium has the following characteristics.

Lemma 2. *In an equilibrium with* $p^{\mathrm{u}} > c$ *it holds that* $S_1^* = S_2^* = [\alpha r, r]$. F_2^* *has no atom, and* F_1^* *has no atom at prices* $p < r$.

Proof. We abbreviate the formal argument as it is analogous to that in Narasimhan (1988) or Padilla (1992). First, strategies will not simultaneously put an atom on a price $\bar{p}$ as the entrant earns strictly more from a marginally lower price. (Recall that we can restrict consideration to prices $\bar{p} \geq p^{\mathrm{u}} > c$.) And if only F_1^* has an atom at $\bar{p} < r$, the discontinuity in Π_2 induces the entrant to shift all mass away from a sufficiently small interval $p \in [(\bar{p}, \bar{p}+\varepsilon)]$.[3] But this implies $\Pi_1(p) > \Pi_1(\bar{p}) = \Pi_1^*$ for $p \in (\bar{p}, \bar{p}+\varepsilon)$. Similarly, if F_2^* had an atom at $\bar{p} < r$, the incumbent would not put positive probability on $p \in (\bar{p}, \bar{p}+\varepsilon)$. This argument also implies $p_1^{\mathrm{o}} = p_2^{\mathrm{o}} = p^{\mathrm{o}}$, as $p_1^{\mathrm{o}} > p_2^{\mathrm{o}}$ would induce $i = 1$ to withdraw all probability mass from $(p \in [p_2^{\mathrm{o}}, p_1^{\mathrm{o}})$ such that $\Pi_2(p_2^{\mathrm{o}}) < \Pi_2(p)$ for $p \in (p_2^{\mathrm{o}}, p_1^{\mathrm{o}})$. (The same argument applies for $p_1^{\mathrm{o}} < p_2^{\mathrm{o}}$.) With no atom at $p < r$, $p_1^{\mathrm{o}} = r$ follows for $i = 1$ as otherwise $\Pi_1(p) > \Pi_1(p_1^{\mathrm{o}})$ holds for $p = r$. But then $\Pi_2^* > 0$ implies that F_2^* has no atom at r, which yields $\Pi_1^* = \Pi_1(r) = \alpha r$ and thus $p^{\mathrm{u}} = \alpha r$. To prove that the supports are connected, suppose to the contrary that firm i puts zero mass on an interval $p \in (\check{p}, \hat{p}) \in [\alpha r, r]$ and choose this interval as large as possible. (This uses the closedness of the support.) Without atoms at $p < r$ this cannot be optimal, as it induces j to withdraw all probability mass from $p \in (\check{p}, \hat{p}-\varepsilon)$, which then implies $\Pi_1(p) > \Pi_1(\check{p}) = \Pi_1^*$ $(i = 1)$ or $\Pi_2(p) > \Pi_2(\check{p}) = \Pi_2^*$ $(i = 2)$ for $p \in (\check{p}, \hat{p} - \varepsilon)$. □

As supports are equal to $S_1^* = S_2^* = [\alpha r, r]$ for $p^{\mathrm{u}} > c$ due to Lemma 1, we obtain for all $p \in [\alpha r, r]$ the requirements

$$\Pi_1(p) = p(\alpha + \beta(1 - F_2^*(p))) = \Pi_1^* = \alpha r,$$

$$\Pi_2(p) = (p - c)\beta(1 - F_1^*(p)) = \Pi_2^* = (\alpha r - c)\beta, \tag{2}$$

[3] As the number of atoms is countable, we can choose $\varepsilon > 0$ to rule out atoms over $p \in \bar{P} = (\bar{p} - \varepsilon, \bar{p} + \varepsilon)\backslash\{\bar{p}\}$, which makes $\Pi_2(p)$ continuous for $p \in \bar{P}$ such that the discontinuity at $\bar{p}$ assures $\Pi_2(\bar{p} - \tau) > \Pi(p)$ for $p \in [\bar{p}, \bar{p} + \varepsilon]$ and a sufficiently small value $\tau > 0$.

which transform to

$$F_2^*(p) = 1 - \frac{\alpha(r-p)}{\beta p}, \qquad F_1^*(p) = 1 - \frac{\alpha r - c}{p - c}. \tag{3}$$

Note that F_1^* has an atom at $p = r$ of size $(\alpha r - c)/(r - c)$. Recall that we consider gross prices where the costs of substitution c is added to the (net) price charged by firm $i = 2$. The net price $\tilde{p}$ of the entrant is distributed over $[\alpha r - c, r - c]$ according to the distribution function $(\tilde{p} + c - \alpha r)/(\beta(\tilde{p} + c))$.

So far we restricted attention to an equilibrium candidate satisfying $p^{\mathrm{u}} > c$. From Lemmas 1 and 2 we obtain in this case $\Pi_1^* = p^{\mathrm{u}} = \alpha r$. As the incumbent can always focus on the immobile fraction A and realize the profit αr by charging the monopoly price r, it must hold from optimality that $p^{\mathrm{u}} \geq \alpha r$. Hence, we can exclude the existence of an equilibrium with $p^{\mathrm{u}} > c$ in case the costs of substitution satisfies $c \geq \alpha r$, while $p^{\mathrm{u}} > c$ must hold in any equilibrium in case $c < \alpha r$. We are now in the position to fully characterize the set of equilibria.

Proposition 1. *Equilibria are characterized as follows*:

1. *for $c < \alpha r$ the equilibrium distributions of gross prices (F_1^*, F_2^*) are uniquely characterized by* (3) *with the support $S_1^* = S_2^* = [\alpha r, r]$;*
2. *for $c \geq \alpha r$ there exists an equilibrium in pure strategies where both firms choose the gross price $p_i = c$ with probability one. As a consequence, all buyers purchase at the incumbent. There is no equilibrium where the incumbent chooses a different strategy.*

Proof. Recall that $p^{\mathrm{u}} > c$ is implied by $c < \alpha r$. For this case we already derived a unique equilibrium candidate with $S_1^* = S_2^* = [\alpha r, r]$ and (F_1^*, F_2^*) satisfying (3). Though an offer $p \in [0, \alpha r]$ would allow a firm to capture the whole contested segment B, the realized profit is strictly smaller than $\Pi_1^* = \alpha r$ and $\Pi_2^* = (\alpha r - c)\beta$. This ensures that the specified mixed strategies constitute an equilibrium. For $c \geq \alpha r$ it is straightforward that the strategies of assertion (ii) constitute an equilibrium, while from Lemma 1 F_1^* must be concentrated on c. □

We now analyze how expected equilibrium prices change in c. Denote the expected price of the incumbent by $p_1^{\mathrm{E}}(c)$. As the incumbent's strategy is unique for all levels of c, this function is well defined. For the entrant's gross price we define a function $p_2^{\mathrm{E}}(c)$ which is calculated from the unique equilibrium distribution $F_2^*(p)$ if $c < \alpha r$. For $c \geq \alpha r$ we set the gross price equal to $p_2^{\mathrm{E}}(c) = c$. The expected net price for the entrant is calculated by $\tilde{p}_2^{\mathrm{E}}(c) = p_2^{\mathrm{E}}(c) - c$. For $c \geq \alpha r$ the incumbent charges c and attracts all customers, while for $c < \alpha r$ the expected price $p_1^{\mathrm{E}}(c)$ is derived by

$$p_1^{\mathrm{E}}(c) = (\alpha r - c)\left(\int_{\alpha r}^{r} \frac{p}{(p-c)^2}\,\mathrm{d}p + \frac{r}{r-c}\right),$$

which transforms to

$$p_1^{\mathrm{E}}(c) = (\alpha r - c)\ln\frac{r-c}{\alpha r - c} + \alpha r.$$

This expression is intuitive. The expected price strictly exceeds αr for all $c \in [0, \alpha r]$. Differentiating $p_1^{\mathrm{E}}(c)$ for fixed c with respect to α yields the derivative $r\ln(r-c)/(\alpha r-c) > 0$. The larger the locked-in fraction of buyers, the less willing is the incumbent to engage in price competition for the mobile fraction. Note that from $\lim_{c\to\alpha r} p_1^{\mathrm{E}}(c) = \alpha r$ the function $p_1^{\mathrm{E}}(c)$ is everywhere continuous. Differentiating $p_1^{\mathrm{E}}(c)$ for $c \in [0, \alpha r]$ yields

$$\frac{\mathrm{d}p_1^{\mathrm{E}}}{\mathrm{d}c} = \ln\frac{\alpha r - c}{r - c} + \frac{r\beta}{r - c},$$

which is strictly negative.[4] While for $c > \alpha r$ the incumbent reacts to a decrease in c by adjusting his price downwards to still capture the whole market, the sign of the reaction is reversed for $c < \alpha r$. Defending the whole market becomes increasingly expensive as c decreases. We derive next the entrant's expected price for $c < \alpha r$. As F_2^* is independent of c, the expected gross price $p_2^{\mathrm{E}}(c)$ remains constant such that the net price $\tilde{p}_2^{\mathrm{E}}(c) = p_2^{\mathrm{E}}(c) - c$ is strictly decreasing in c. Precisely, we obtain

$$\tilde{p}_2^{\mathrm{E}}(c) = \int_{\alpha r - c}^{r-c} p\frac{\alpha r}{\beta(p+c)^2}\,\mathrm{d}p = -\frac{\alpha}{\beta} r\ln\alpha - c.$$

Though mixed strategies do not lend themselves to an easy interpretation, we feel that our results have some intuitive appeal. Recall that the incumbent has always the option to exploit the locked-in segment of buyers. As the contested market segment becomes more competitive, he becomes more inclined to exploit the locked-in segment.

Denote next the expected price of a type A customer by $p_{\mathrm{A}}^{\mathrm{E}}(c)$, which must necessarily be equal to the expected price of the incumbent $p_1^{\mathrm{E}}(c)$. In contrast, a mobile buyer may shop at either firm. To calculate consumer welfare, we must consider gross prices. For $c < \alpha r$ the gross price paid by a type B buyer is continuously distributed according to the distribution function $M(p) = 1 - (1 - F_1^*(p))(1 - F_2^*(p))$, which from (3) transforms to

$$M(p) = 1 - \frac{\alpha r - c}{p - c}\frac{\alpha(r - p)}{\beta p}.$$

Note that $M(p)$ is distributed over $[\alpha r, r]$ for all values of c. Moreover, we obtain$[\mathrm{d}M(p)/\mathrm{d}c] > 0$ for $p > \alpha r$. Hence, if we choose two cost levels $\check{c}, \hat{c}$ with $\check{c} < \hat{c} < \alpha r$, the distribution of the gross price incurred by a mobile buyer for a cost of substitution $\check{c}$ strictly dominates the distribution for $\hat{c}$ in the sense of first-order stochastic dominance. This implies that a mobile buyer's expected gross price is strictly decreasing in c for $c < \alpha r$. Precisely, if we denote the expected gross price by $p_{\mathrm{B}}^{\mathrm{E}}(c)$, we obtain for $c < \alpha r$

$$p_{\mathrm{B}}^{\mathrm{E}}(c) = \alpha r + \frac{\alpha(\alpha r - c)}{\beta c}\left[(r - c)\ln\left(\frac{r - c}{\alpha r - c}\right) - r\ln\left(\frac{r}{\alpha r}\right)\right],$$

which has a continuous derivative $(\mathrm{d}p_{\mathrm{B}}^{\mathrm{E}})/(\mathrm{d}c)$ on $p \in (0, \alpha r)$.[5] As $p_{\mathrm{B}}^{\mathrm{E}}(c)$ is equal to c for $c \geq \alpha r$, the function is everywhere continuous. For $c = 0$ we obtain $p_{\mathrm{B}}^{E}(0) =$

[4] To see this, note that the (right-side) derivative at $c = 0$ equals $(\mathrm{d}p_1^{\mathrm{E}})/(\mathrm{d}c)|_{c=0} = \beta - \ln\alpha < 0$, while $[(\mathrm{d}^2 p_1^{\mathrm{E}})/(\mathrm{d}c^2)] < 0$. The strict monotonicity is also immediate by differentiating F_1^* with respect to c and arguing with first-order stochastic dominance.

[5] We obtain $\mathrm{d}p_{\mathrm{B}}^{\mathrm{E}}/\mathrm{d}c = \alpha/(\beta c^2)[cr\beta + c^2\ln[(r-c)/(\alpha r - c)] - \alpha r^2\ln[(\alpha[(r-c)/(\alpha r - c))]]$.

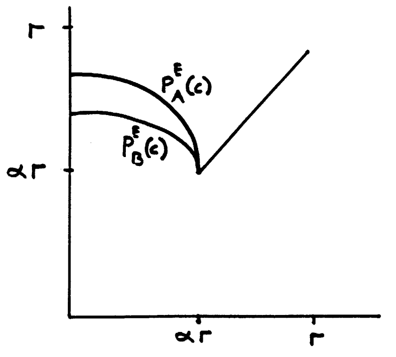

Fig. 1. Expected gross purchasing prices.

$\alpha r(2 + (\alpha/\beta)\ln\alpha)$, which has the intuitive limits $\lim_{\alpha\to 0} p^{\mathrm{E}}_{\mathrm{B}}(0) = 0$ and $\lim_{\alpha\to 1} p^{\mathrm{E}}_{\mathrm{B}}(0) = r$.

To summarize results, we can conclude that for small costs of substitution $c \leq \alpha r$ a decrease in c increases the expected gross prices for all buyers. In other words, consumer welfare must strictly decrease if costs of substitution are lower.

Proposition 2. *The expected price of a locked-in buyer* $p^{\mathrm{E}}_{\mathrm{A}}(c)$ *and the expected gross price of a mobile buyer* $p^{\mathrm{E}}_{\mathrm{B}}(c)$ *exhibit the following characteristics: They are continuous in* c, *equal to* c *for* $c \in [\alpha r, r]$, *and strictly decreasing for* $c \in [0, \alpha r]$.

Recall at this point that the downwards sloping segment of the curve in Fig. 1 stems from the mixed strategy equilibrium for low c, while the upwards sloping segment is created by the pure strategy equilibrium for high c, where the incumbent captures the whole market.

We conclude this section with some interpretations of Proposition 2. For a first example, consider the case of the mailing business where after deregulation a single entrant offers services to private customers. The entrant is constrained it two ways. First, it should be prohibitively expensive to ensure full market coverage, which will always leave some fraction α to the incumbent. Second, when starting operations, the service network in the covered area may not be very tight. For instance, dispatching private mail may still be more comfortable with the former monopolist. This is captured by the costs of substitution c.[6] As time passes, we may suppose that the service network improves such that c decreases. Our comparative statics suggest, however, that competition need not necessarily become more effective over time. Indeed, this result may be cautiously linked to some empirical findings. As competitors catch up over time, an incumbent firm may choose to focus on its (rather immobile or loyal) core segment of customers instead of facing competition on the whole market. For instance, it has been observed in the pharmaceutical industry that competition by generic drugs after the expiry of a patent may lead to a price increase by the former patent holder (see Scherer, 1993). Moreover, after deregulation prices for a range of

[6] Hence, in this interpretation the goods offered by the incumbent and the entrant are vertically differentiated for buyers who have access to both firms.

products or services often increase. Typically, this is explained by previous cross-subsidization (see, e.g. Harris and Kraft, 1997).

For another example, suppose that c can be chosen by a regulator. For instance, a former monopolistic phone company is told to charge a (maximum) additional fee c to customers who use a competing firm for certain services. [7] A fraction of customers may stick with the incumbent regardless of his price as they are simply not aware of the alternative service. Observe that in the one-shot setting it is realistic to assume that the incumbent cannot identify the different market segments, which precludes price discrimination. A regulator interested in consumer welfare would be advised not to lower c below αr. Increasing the degree of (potential) competition even further may induce the incumbent to focus more on his locked-in segment. [8]

3. Competition between entrants

We now introduce a second entrant with the index $i = 3$ ($I = \{1, 2, 3\}$). All buyers have still access to the incumbent's product, but only a fraction $\gamma_i \in (0, 1)$ can also shop at firm $i = 2, 3$. For simplicity we now assume that there are no costs of substitution, i.e. that buyers are willing to pay r regardless of which firm offers the product ($c = 0$). We denote the measure of buyers with access to both entrants by δ such that $\beta_i = \gamma_i - \delta$ equals the mass of buyers for which only the incumbent and the firm $i \in \{2, 3\}$ compete. The fraction of buyers locked-in with the incumbent becomes $\alpha = 1 - \gamma_2 - \gamma_3 + \delta$. We assume $\alpha > 0$ and $\beta_i > 0$. Moreover, we restrict consideration to the symmetric case where $\beta_1 = \beta_2 = \beta$.

We compare now the case where entrants serve disjunct segments ($\delta = 0$) with the case where segments are overlapping ($\delta > 0$). A regulator may intend to increase competition by requiring firms to serve overlapping segments. For instance, this may be achieved by prescribing a minimum size of market coverage or the coverage of a core segment. While this may stimulate competition among entrants, we show that it has a detrimental effect on buyers who are still locked-in with the incumbent.

We extend the notation from Section 2 in an obvious way. If firms choose the distributions F_i ($i \in I$) and if these distributions have no atom, we obtain the following payoff functions:

$$\begin{aligned} \Pi_1(p, F_2, F_3) &= p(\alpha + \beta(1 - F_2(p))) + \beta(1 - F_3(p)) + \delta(1 - F_2(p))(1 - F_3(p)), \\ \Pi_2(p, F_1, F_3) &= p(1 - F_1(p))(\beta + \delta(1 - F_3(p))), \\ \Pi_3(p, F_1, F_2) &= p(1 - F_1(p))(\beta + \delta(1 - F_2(p))). \end{aligned} \tag{4}$$

We can again restrict prices to the interval $[0, r]$. Recall that Section 2 applied a deterministic tie-breaking rule in favor of the incumbent to ensure existence of an equilibrium for $c \geq \alpha r$, where only the incumbent trades. With $c = 0$ this is no longer necessary. Though our results

[7] We do not address any issues of (strategic) access pricing, which are covered in a recent strand of literature (see Armstrong and Vickers, 1998).

[8] Of course, we have completely ruled out any dynamic issues. This has the advantage that we can interpret c both as a switching cost (away from the incumbent) and, more generally, as an indicator of vertical product differentiation. In a multi-period model, these two interpretations would clearly give rise to different results.

are independent of the specific tie-breaking rule, it is convenient to assume now a symmetric (random) tie-breaking.

It turns out that equilibrium strategies with overlapping segments become quite complicated. We, therefore, refrain from explicitly deriving an equilibrium. Theorem 5 of Dasgupta and Maskin (1986) allows to conclude that an equilibrium in mixed strategies exists.[9] The following lemma states some characteristics which any equilibrium must exhibit regardless of whether $\delta = 0$ or $\delta > 0$ applies. The proof is in the Appendix A.

Lemma 3. *Any equilibrium for the model with two entrants, $\alpha > 0$, $\beta_1 = \beta_2 = \beta > 0$, and zero costs of substitution, has the following characteristics.*

1. *F_1^* has no atoms at $p < r$.*
2. *$S_2^* = S_3^*$ and $F_2^* = F_3^*$, where F_i^* has no atoms and S_i^* is convex for $i = 2, 3$.*
3. *With $p_i^{\mathrm{u}} = \min S_i^*$ and $p_i^{\mathrm{o}} = \max S_i^*$ it holds that $p_2^{\mathrm{u}} = p_3^{\mathrm{u}} \leq p_1^{\mathrm{u}}$ and $p_i^{\mathrm{o}} = r$ for $i \in I$, which implies $\Pi_1^* = \alpha r$.*

Select now for both cases with $\delta = 0$ and $\delta > 0$ an equilibrium. We can now prove that locked-in customers are strictly worse off if the entrants' segments are overlapping.

Proposition 3. *Take two values $\delta = 0$ and $\delta > 0$, and select for any choice an equilibrium of the model analyzed in Lemma 3. Then the expected price of the incumbent is strictly higher in the equilibrium chosen for $\delta = 0$ than in the equilibrium chosen for $\delta > 0$.*

Proof. Denote $\beta_i = \bar{\beta}$ for $\delta = 0$ and $\beta_i = \beta = \bar{\beta} - 1/2\delta$ for $\delta > 0$ with $i \in \{2, 3\}$. We select for each case an equilibrium denoted by distributions F_i^0 over S_i^0 for $\delta = 0$, and analogously by F_i^δ and S_i^δ for $\delta > 0$.

Take first $\delta = 0$. Recall from Lemma 3 that $p_1^{\mathrm{u}} \geq p^{\mathrm{u}} = p_2^{\mathrm{u}} = p_3^{\mathrm{u}}$. Note now that $p_1^{\mathrm{u}} > p^{\mathrm{u}}$ would imply $\Pi_2(p) > \Pi_2(p^{\mathrm{u}}) = \Pi_2^*$ for all $p \in (p^{\mathrm{u}}, p_1^{\mathrm{u}})$ as entrants do not compete with each other by $\delta = 0$. From $\Pi_1^* = \alpha r$ we then obtain $p^{\mathrm{u}} = \alpha r$.

Turn next to $\delta > 0$. From now on all notations regarding boundaries of the supports and profits refer to this case. We distinguish between two subcases. Suppose first $p_1^{\mathrm{u}} = p^{\mathrm{u}}$, which again implies $p^{\mathrm{u}} = \alpha r$ and thus $\Pi_2^* = \Pi_3^* = \alpha r(\beta + \delta)$. Using continuity of the distributions from Lemma 3, we obtain from (4) for $p \in [\alpha r, r]$

$$p(1 - F_1^\delta(p))(\beta + \delta(1 - F_2^\delta(p))) = \alpha r(\beta + \delta),$$
$$p(1 - F_1^0(p))\bar{\beta} = \alpha r\bar{\beta},$$

such that $F_1^0(p) > F_1^\delta(p)$ holds strictly on $p \in (\alpha r, r)$ given $F_2^\delta(p) > 0$. Hence, $F_1^\delta(p)$ strictly dominates $F_1^0(p)$ in the sense of first-order stochastic dominance, which proves the assertion if $p_1^{\mathrm{u}} = p^{\mathrm{u}}$. Assume next $p_1^{\mathrm{u}} > p^{\mathrm{u}}$. Substitution into (4) yields $p_1^{\mathrm{u}} > \alpha r$ to ensure $\Pi_1(p_1^{\mathrm{u}}) = \Pi_1^* = \alpha r$. This implies $F_1^0(p) > F_1^\delta(p)$ for all $p \in [\alpha r, p_1^{\mathrm{u}}]$. Recall now that all distributions are continuous for $p < r$. Hence, if $F_1^\delta(p)$ does not strictly dominate

[9] With random tie-breaking a player's profit is lower semi-continuous in his own strategy. If the tie-breaking rule was deterministic favoring the incumbent, we could still apply their theorem as the incumbent's profit is 'weakly' lower-semicontinuous according to their Definition 6. (Use $\lambda = 0$ for $i = 1$ in this definition.)

$F_1^0(p)$ in the sense of first-order stochastic dominance, there must exist a price $\bar{p}$ with $\alpha r < p_1^{\mathrm{u}} < \bar{p} < r$ and $F_1^\delta(\bar{p}) = F_1^0(\bar{p})$. We show that this cannot be the case. Note that S_2^δ and S_2^0 are convex by Lemma 3 and that $\bar{p}$ is strictly above the lower boundary of the support in both cases. Substitution into (4) for $\delta = 0$ yields $\bar{p}(1 - F_1^0(\bar{p}))\bar{\beta} = \alpha r\bar{\beta}$, which from $F_1^\delta(\bar{p}) = F_1^0(\bar{p})$ transforms to $\bar{p}(1-F_1^\delta(\bar{p})) = \alpha r$. An entrant must realize his equilibrium profit for $\delta > 0$ both at $\bar{p}$ and at $p_1^{\mathrm{u}} > p^{\mathrm{u}}$. This implies

$$\Pi_2^* = \bar{p}(1 - F_1^\delta(\bar{p}))(\beta + \delta(1 - F_3^\delta)(\bar{p})) = \alpha r(\beta + \delta(1 - F_3^\delta)(\bar{p})),$$
$$\Pi_2^* = p_1^{\mathrm{u}}(\beta + \delta(1 - F_3^\delta(p_1^{\mathrm{u}})),$$

which cannot hold simultaneously from $p_1^{\mathrm{u}} > \alpha r$ and $F_3^\delta(p_1^{\mathrm{u}}) < F_3^\delta(\bar{p})$ with $p_1^{\mathrm{u}} < \bar{p}$. We have thus proved for any choices of equilibria under $\delta = 0$ and $\delta > 0$ that it holds for the respective distribution functions for the incumbent's price F_1^0 and F_1^δ that F_1^δ strictly dominates F_1^0 in the sense of first-order stochastic dominance. This proves the assertion in Proposition 3. □

By Proposition 3 the locked-in fraction of buyers is strictly better off if the entrants cover non-overlapping segments. From their perspective a regulator should thus not require entrants to serve, for instance, a core segment of the market in order to stimulate competition. It may now be asked which market structure emerges if entrants are allowed to choose freely their respective market coverage. Our conjecture would be that they might indeed opt for non-overlapping segments to stifle competition. Solving the respective entry game is, however, beyond the scope of this paper.

4. Conclusion

This paper analyzes price competition in a market where an incumbent enjoys the advantage of having a locked-in fraction of buyers. We study how prices react to an increase in competition. In a first model we consider the case of a single entrant whose product is also less attractive to the mobile fraction of buyers. We investigate how equilibrium prices change if the entrant's product becomes more attractive. We find that in this case all buyers, i.e. both the locked-in and the mobile fraction, may become worse off. In a second model we consider two entrants and distinguish between the case where entrants serve overlapping segments of the market or where their coverage is non-overlapping. We find that the fraction of buyers locked-in with the incumbent is worse off if competition between entrants is more intense as they serve overlapping segments. In both models, an increase in competition for the mobile fraction of buyers may induce the incumbent to focus more on the locked-in segment, which may rise expected prices for all buyers.

In the current analysis we have taken many parameters as exogenously given. For instance, in the second model we only compared market structures where entrants' segments were overlapping or disjunct. As already suggested in the previous section, we should be interested in the equilibrium market structure arising if entrants can freely choose their market coverage. Similarly, allowing for free entry to study the number of entrants would be a worthwhile exercise. Regarding the first model of duopolistic competition, we should endogenize the "costs of substitution" (c) between the entrant's and the incumbent's product offered to the mobile fraction of buyers. As indicated in Section 2, these costs may change over time as the entrant improves his service quality by extending facilities or by simply moving up his learning curve. The speed of this switch could represent a strategic variable for the entrant.

Acknowledgements

Work on this paper was supported by a grant from 'Studienstiftung des Deutschen Volkes' and from Sonderforschungsbereich 504 at the University of Mannheim. I thank an anonymous referee for making valuable suggestions which improved the exhibition of results.

Appendix A. Proof of Lemma 3

As all steps are analogous to the two-firm case, we only sketch the formal arguments. As $p_1^{\rm u} \geq \alpha r$ holds from optimality, $\beta > 0$ implies $\Pi_i^* > 0$ and, therefore, $p_i^{\rm u} > 0$ for $i \in I$. We argue next that $F_i^*(p)$ has no atom at any $p < r$ for $i \in I$, which implies assertion (i) for $i = 1$.

Take now $\delta > 0$. If i had an atom at $\bar{p}$, both F_j^* with $j \neq i$ would put zero mass on a sufficiently small interval $p \in (\bar{p}, \bar{p} + \varepsilon)$. But then $\Pi_i(p) > \Pi_i(\bar{p}) = \Pi_i^*$ must hold for $p \in (\bar{p}, \bar{p} + \varepsilon)$. This argument extends directly to $\delta > 0$ and thus proves assertion (i). The argument also implies that only one firm can have an atom at $p = r$, which from $\Pi_i^* > 0$ can only be the incumbent. Hence, F_i^* has no atom for $i \in \{2, 3\}$. If $p^{\rm u} = \min_{i \in I} p_i^{\rm u}$ was only attained by one firm i, $\Pi_i(\min_{j \neq i} p_j^{\rm u}) > \Pi_i(p_i^{\rm u})$ would hold as $\min_{j \neq i} p_j^{\rm u} < r$ (F_2^*, F_3^* have no atoms). Suppose $p_3^{\rm u} > p_1^{\rm u} = p_2^{\rm u} = p^{\rm u}$. With $p_3^{\rm u} < r$ we obtain

$$\Pi_3^* = \Pi_3(p_3^{\rm u}) = p_3^{\rm u}(1 - F_1^*(p_3^{\rm u}))(\beta + \delta(1 - F_2^*(p_3^{\rm u}))) \geq \Pi_3(p^{\rm u}) = p^{\rm u}(\beta + \delta),$$

which implies

$$\Pi_2(p_3^{\rm u}) = p_3^{\rm u}(1 - F_1^*(p_3^{\rm u}))(\beta + \delta) \geq p^{\rm u}(\beta + \delta)\frac{\beta + \delta}{\beta + \delta}(1 - F_2^*(p_3^{\rm u})) > \beta + \delta = \Pi_2^*,$$

where we used $F_2^*(p_3^{\rm u}) > 0$ from $p^{\rm u} < p_3^{\rm u}$. As the argument is symmetric (in fact, it does not even require $\beta_2 = \beta_3$), we obtain $p_2^{\rm u} = p_3^{\rm u} = p^{\rm u} \geq p_1^{\rm u}$ and thus $\Pi_2^* = \Pi_3^* = p^{\rm u}(\beta + \delta)$. We show next that his implies identical strategies for the entrants. We argue to a contradiction and assume existence of some $\bar{p} \in (p^{\rm u}, r)$, where $0 < F_i^*(\bar{p}) < 1$ and $F_2^*(\bar{p}) \neq F_3^*(\bar{p})$. Suppose without loss of generality $F_2^*(\bar{p}) < F_3^*(\bar{p})$, which implies

$$\begin{aligned}\Pi_2(\bar{p}) &= \bar{p}(1 - F_1^*(\bar{p}))(\beta + \delta(1 - F_3^*(\bar{p}))) \\ &< \bar{p}(1 - F_1^*(\bar{p}))(\beta + \delta(1 - F_2^*(\bar{p}))) = \Pi_3(\bar{p}).\end{aligned}$$

With $\Pi_3(\bar{p}) \leq \Pi_3^* = \Pi_2^*$ we obtain $\bar{p} \notin S_2^*$. Similarly, at $\hat{p} = \min_{p \in S_2^* \cap [\bar{p}, r]} p < r$, which uses the closedness of S_2^*, we still have $\Pi_2(\hat{p}) < \Pi_3(\hat{p}) \leq \Pi_3^* = \Pi_2^*$ such that $F_2^*(r) = 1$ cannot be obtained. Hence, we must indeed have symmetry with $F_2^* = F_3^*$ and $S_2^* = S_3^*$.

If S_2^* is now not connected, it would contain an interval $[\check{p}, \hat{p}]$ with $F_2^*(\hat{p}) - F_2^*(\check{p}) = 0$, where we use that F_2^* has no atoms. We choose this interval as large as possible, where closedness of S_2^* ensures that the maximum is attained. By optimality F_1^* has no mass on $[\check{p}, \hat{p}]$, which implies $\Pi_2(p) > \Pi_2(\check{p}) = \Pi_2^*$ for any $p \in (\check{p}, \hat{p})$. We have thus proved assertion (ii). For assertion (iii) we have already proved $p_2^{\mathrm{u}} = p_3^{\mathrm{u}} \leq p_1^{\mathrm{u}}$. With $p^{\mathrm{o}} = \max_{i \in I} p_i^{\mathrm{o}}$ it follows that $p^0 = r$ as there are no atoms at $p < r$. This implies $p_1^{\mathrm{o}} = r$ to ensure $\Pi_2^* = \Pi_3^* > 0$. Otherwise, from $p_2^{\mathrm{o}} = p_3^{\mathrm{o}} < p_1^{\mathrm{o}}$ the incumbent would put zero mass on $p \in [p_2^{\mathrm{o}}, r]$ such that $\Pi_2(p) > \Pi_2(p_2^{\mathrm{o}})$ for $p \in (p_2^{\mathrm{o}}, r)$. (Recall that there are no atoms at $p < r$.) Finally, this also implies $\Pi_1^* = \alpha r$.

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