EXCLUSIONARY PRICING WHEN SCALE MATTERS*

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We consider an incumbent firm and a more efficient entrant, both offering a network good to several asymmetric buyers, and both being able to price discriminate. The good has positive value to buyers only if the network size exceeds a certain threshold. The incumbent's installed base guarantees this critical size to the incumbent, while the entrant needs to attract enough 'new' buyers to meet this threshold. We show that price discrimination (in the various forms it may take) reduces the set of achievable socially efficient entry equilibria, and discuss the policy implications of this result.

I. INTRODUCTION

This paper deals with the exclusionary effects of price discrimination, which may take different forms. One such form which has recently received renewed attention is *rebates*, i.e. discounts applicable where a customer exceeds a specified target for sales in a defined period.

Under US case law, rebates are generally said to promote competition on the merits, and the (high) burden of demonstrating their anticompetitive effect is on

*We are indebted to two anonymous referees, the Editor Kai-Uwe Kühn, Claudio Calcagno, Daniel Cerquera, Claude Crampes, Joe Farrell, Carl Shapiro, Yossi Spiegel, Jeanine Thal, Hélder Vasconcelos, John Vickers, Christian Wey, and especially Chiara Fumagalli and Patrick Rey, for helpful comments and suggestions. We are also grateful to seminar participants at Hitotsubashi University, Tokyo; CORE, Université Catholique de Louvain; University of Vienna; University of Linz; CEPR Conference on Applied Industrial Organisation, Madeira; 2nd CSEF Symposium on Economics and Institutions, Capri; 1st CRESSE Conference on 'Abuse of Dominance', Corfu; CCP Workshop 2005, University of East Anglia; Kiel-Munich Workshop on Economics of Internet and Network Industries 2005; EMNet Conference 2005, Budapest; 2nd Workshop on Empirical IO, University of Innsbruck; European Economic Association Meeting 2006, Vienna; IDEI Conference on the Economics of the Software and Internet Industries 2007, Toulouse; EUI, Florence; RNIC Conference, ZEW Mannheim; Economics of ICT Conference, ENST, Paris, EARIE 2007, Valencia; ASSET 2007, Padova; and University of Bologna. The usual disclaimer applies.

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the plaintiff.[1] In the EU, instead, the European Commission and the Community Courts have systematically imposed large fines on dominant firms applying different forms of rebates.[2] The recent *Michelin II* judgment[3] has established that not only *individualized* discounts but also *standardized* quantity discounts (that is, rebates given to any buyer whose purchases exceed a predetermined number of units) are anticompetitive if used by a dominant firm.[4] The cases of explicit and implicit price discrimination we analyze in the paper are meant to reproduce the main features of individualized and standardized discounts.

In an industry exhibiting network effects, and where both firms can price-discriminate, we find that an incumbent firm having an established customer base can exclude a more efficient entrant that does not have a customer base yet. Under price discrimination, the incumbent might charge less than marginal costs to some crucial group of consumers (and make up the loss by charging monopoly price to the remaining buyers), thereby depriving the entrant of the critical mass of consumers it needs (in our model, network externalities imply that consumers will want to consume a network product only if demand has reached a critical threshold). As a result, price discrimination reduces the set of (socially efficient) achievable entry equilibrium: only very efficient entrants will be able to sell at equilibrium. We shall also show that the more targeted price discrimination the higher its exclusionary potential.

To give an example of the type of industry that we have in mind, consider the *Microsoft Licensing Case*.[5] Microsoft marketed its PC operating systems (Windows and MS-DOS) primarily through original equipment manufacturers ('OEMs'), which manufacture PCs. When discussing the substantial barriers to entry for potential rivals of Microsoft, the Complaint explicitly mentioned 'the difficulty in convincing OEMs to offer and promote a non-Microsoft PC operating system, particularly one with a small installed base'.

The US Department of Justice alleged that Microsoft designed its pricing policy to deter OEMs from entering into licensing agreements with competing operating system providers, thereby reinforcing the entry barriers raised by the network effects that are inherent in this industry.

Although it deals with pricing schemes rather than contracts, our paper is closely related to the literature on anticompetitive exclusive dealing. Segal and Whinston [2000] is probably the closest work to ours.[6] Building on Rasmusen et al. [1991], they show the exclusionary potential of exclusive contracts when the incumbent can discriminate on the compensatory offers it makes to buyers. Our study differs from theirs in several respects: (i) in their game the incumbent has a (first-mover) strategic advantage in that it is allowed to contract with buyers before entry occurs; (ii) if buyers accept the exclusivity offer of the incumbent, they commit to it and cannot renegotiate it even if entry occurs; (iii) buyers are symmetric and only linear pricing is considered. In our paper, instead, (i) the incumbent and the entrant choose price schedules simultaneously, (ii) buyers simply observe prices and decide which firm to buy from (therefore avoiding any problems related to assumptions on commitment and renegotiation); (iii) we explore the role of rebates and quantity discounts in a world where buyers differ in size. Yet, the mechanisms which lead to exclusion in the two papers are very similar: both papers present issues of buyers' miscoordination, and scale economies which are created by fixed costs in their model are created instead by network effects in ours.

Our paper is also related to the literature on divide-and-conquer strategies, in particular to Innes and Sexton [1993, 1994] and Segal [2003]. A major innovation of our work relative to theirs is that we allow the entrant to use the same discriminatory tools available to the incumbent.[7]

Armstrong and Vickers [1993] consider a situation where the incumbent has an uncontested turf (the 'sheltered segment ') and faces an entrant on a 'competitive segment '. They show that allowing the incumbent to price discriminate across these two segments will negatively affect entry. In our model, one can think of the installed base as the incumbent's sheltered segment, and of the new buyers as the competitive segment. However, in our setup, the buyers who bought in the past (i.e. those who constitute the installed base) do not buy again when the market opens for the new buyers. Therefore, there is no scope for exclusion through discrimination between old and new consumers. The exclusionary mechanism we study in our paper is based on price discrimination among different buyers *within* the competitive segment, rather than discrimination *between* the competitive and the sheltered segment. What makes it so hard for the entrant to prevail over the incumbent is the fact that the incumbent can break many entry equilibria by offering prices below cost to some of these new buyers, and recouping instantaneously all losses on the remaining buyers, whose demand is insufficient for the entrant to reach the critical size.

Finally, our paper is related to the literature on incompatible entry in network industries. The very nature of network effects provides a strong incumbency advantage, shielding dominant firms against competitors even in the absence of any anticompetitive conduct (Farrell and Klemperer [2006]). Crémer et al. [2000] show that an incumbent can strategically use compatibility decisions so as to deter entry.[8] More closely related to our paper, Jullien [2001] studies how an entrant can use divide-and-conquer strategies to induce buyers to coordinate on the entrant instead of the incumbent.

II. THE SETUP

Consider an industry composed of two firms, the incumbent I, and an entrant E. The incumbent supplies a network good, and has an installed consumer base of size $\beta_I > 0$. (The network good is durable: 'old' buyers will continue to consume it but no longer need to buy it.) I incurs constant marginal cost $c_I \in (0, 1)$ for each unit it produces of the network good.

The entrant can supply a competing network good at marginal cost $c_E \in [0, 1)$, with $c_E < c_I$, i.e. it is more cost-efficient than the incumbent. Since it has not been active in the market so far, it has installed base $\beta_E = 0$. To focus on the role of network externalities, we assume away any fixed costs of entry.

The good can be sold to m different 'new' buyers, indexed by $i = 1, \dots, m$. The buyers may differ in their (price-inelastic) demands: With total market size normalized to 1, denote buyer i's share in total demand by s_i, where $s_1 \leq s_2 \leq \ldots \leq s_m$ and $\sum_i s_i = 1$. Buyers cannot resell the good among each other, nor can they make side payments of any kind to each other. Whenever a buyer is indifferent between the two suppliers, we assume that it will source its requirements from one supplier only (i.e. it will not split orders among them).[9]

Define supplier k's network size Q_k as the firm's installed base plus its total sales to all 'new' buyers:

$$Q_k = \beta_k + s_1^k + \ldots + s_m^k$$

where k identifies the seller, $k = I, E$, and $s_i^k = s_i$ if buyer i sources from supplier k, and zero otherwise. Note that our definition of k's network size, Q_k, implies that only units which are actually consumed count towards firm k's network size. Thus, we rule out the possibility of supplier k artificially inflating its network size by selling (or giving away) some arbitrarily large quantity Q to a buyer i whose consumption potential is only $s_i < Q$.

Buyers exert positive consumption externalities on each other: If firm k's network size Q_k is below a certain threshold level $\bar{s}$, consumption of k's good gives zero value to its buyer. The goods produced by the two firms are incompatible, so that buyers of firm k do not exert network externalities on buyers of the rival network. Let the buyers' willingness to pay for a network good of sufficient size be $\bar{p}(Q_k) = 1$ if $Q_k \geq \bar{s}$, and zero otherwise. Thus, if both firms manage to reach the minimum size $\bar{s}$, then consumers will consider I's and E's networks as being of homogenous quality, even if $s_I \neq s_E$.

The assumption that a buyer's utility from consuming is positive only if the network in question reaches the threshold size $\bar{s}$ is designed to capture in an admittedly simple way the presence of network effects.[10] We make the following assumptions on the threshold size:
(i) $\beta_I \geq \bar{s}$: the incumbent has already reached the critical size with its sales to the 'old' buyers, while the entrant will have to attract enough 'new' buyers to reach $\bar{s}$;
(ii) $s_m < \bar{s}$, so that winning only one buyer's orders (even if it is the largest buyer) will not be sufficient for the entrant to reach the minimum network size;
(iii) $\bar{s} \leq 1$, so that the entrant will reach the minimum size for sure if it sells to all m new buyers.

These assumptions allow us to characterize the unique socially efficient allocation: Since the new generation of buyers is in itself sufficient to generate a network of size $\bar{s}$, and such a network gives the same utility as one that comprises both the old and the new generation, and since moreover the entrant is more cost-efficient ($c_E < c_I$), the social planner would want the entrant (and not the incumbent) to serve all buyers.

Let the unit prices offered by the two firms to buyer i be $p_k^i \in [0, 1]$, $k = I, E$. A buyer's consumer surplus is given by consumption value minus total expenditure, defined as:

$$CS^i\left(p_k^i, Q_k\right) = \begin{cases} \left(1 - p_k^i\right) s_i & \text{if } Q_k \geq \bar{s} \\ -p_k^i s_i & \text{otherwise} \end{cases} \tag{1}$$

Since all buyers have the same willingness-to-pay, $\bar{p} = 1$, even a monopolist who could price discriminate would optimally set a uniform price $p_i^m = 1$. Thus, discriminatory pricing can arise only as a result of strategic interaction.

The game: Play occurs in the following sequence: At time $t = 0$, the incumbent and the entrant simultaneously announce their prices, which will be binding at $t = 1$. At time $t = 1$, each of the m buyers decides whether to patronize the incumbent or the entrant. We also assume that offers are observable to everyone.

As for the prices that firms can offer in $t = 0$, we focus on the two extreme cases of uniform pricing and first degree price discrimination. We then briefly discuss other forms of price discrimination, such as implicit price discrimination (generalized discounts) and coupons.

III. EQUILIBRIUM SOLUTIONS

In line with Segal and Whinston [2000], who also analyze a model with scale effects and multiple buyers, we find that two types of pure-strategy Nash equilibria emerge in our game: an exclusionary (miscoordination) equilibrium where all buyers buy from the incumbent, and an entry equilibrium where all buyers buy from the entrant.[11]

We first state a general exclusion result which holds for any pricing regime (Section III(i)). Then, we study the role of miscoordination in sustaining such exclusionary equilibria, and how they are eliminated through buyer coordination. The following subsection analyzes entry equilibria under different pricing regimes (Section III(ii)). We then discuss other forms of price discrimination, and illustrate our findings with a simple example.

III(i). *Exclusionary equilibria*

Proposition 1. (Exclusionary equilibria) There always exist pure-strategy Nash equilibria where I serves all buyers. In such an equilibrium, I sets $\tilde{p}_I^i \in [0, 1]$ for all $i = 1, \ldots, m$, where $\sum_i s_i \tilde{p}_I^i \geq c_I$, E sets some $\tilde{p}_E^i \in [0, 1]$ such that $\tilde{p}_E^i \leq \tilde{p}_I^i$ for all $i = 1, \ldots, m$, and in all continuation equilibria where $\tilde{p}_E^i \leq \tilde{p}_I^i$, all buyers buy from I.
Proof: See Appendix.

The equilibria identified in Proposition 1 are all socially inefficient because the entrant could provide a good equivalent to the incumbent's at a lower cost (recall that the entrant can reach the minimum threshold size if it sells to all new buyers). Moreover, the incumbent will earn positive profits in some of these exclusionary equilibria. In fact, any incumbent profit from zero to the full monopoly rent can be sustained.

To understand Proposition 1, note that even if $p_E^i \leq p_I^i$ for all i, no buyer has an incentive to unilaterally deviate from I to E; with all other buyers buying from I, the entrant's network would be below the critical size (recall that no single buyer is sufficient for E to reach the minimum size), so that the entrant's good has zero value to such a deviating buyer. As long as buyers cannot coordinate on switching from I to E, I will continue to serve the entire market alone even if E offers much more attractive prices.

Continuation equilibria play a crucial role for the equilibrium at the firms' decision stage. Consider the candidate exclusionary equilibrium where $p_E^i = p_I^i = 1$ for all i and all buyers buy from the incumbent. This equilibrium is sustained by having that when $p_E^i \leq p_I^i$, the chosen continuation equilibria are those where all buyers will buy from the incumbent.[12] (As we shall see later, when $p_E^i \leq p_I^i$ there are also continuation equilibria where all buyers buy from the entrant). Otherwise, a deviation by the entrant could attract all the buyers, undermining the candidate equilibrium.

The example above represents an extreme case, in the sense that the underlying continuation equilibrium is the most favorable one for firm I. This equilibrium is by no means the only exclusionary equilibrium that can arise in our game. For instance, there are other equilibria where all buyers miscoordinate on the incumbent, but the latter can at most charge some price $\tilde{p}_I^i < p_I^m = 1$ to some or all i. Such an equilibrium is sustained by continuation equilibria where buyers buy from I as long as $p_E^i \leq p_I^i \leq \tilde{p}_I^i$, but would switch to E if p_I^i exceeded $\tilde{p}_I^i$. Thus, the structure of the continuation equilibria determines the level of equilibrium prices, which in turn determine the incumbent's equilibrium payoffs.

Finally, note that such exclusionary equilibria exist for any pricing regime, no matter if discriminatory or not.[13] The possibility of price discrimination only extends the range of sustainable prices and hence the range of possible rent distributions across buyers; in particular, some buyers may even be offered below-cost prices, $p_I^i < c_I$, which cannot happen under uniform pricing, where the lower bound on equilibrium prices is of course c_I. The driving force behind these equilibria is just that a unilateral deviation by a buyer - given that all others buy from the incumbent - is not sufficient to give the entrant the threshold size it needs.

If instead buyers can coordinate their supplier choice, the joint deviation of a *group* of buyers sufficiently large to generate critical mass for the entrant can disrupt any exclusionary equilibrium. In other words, if we apply the concept of coalition proofness[14] to the equilibria identified in Proposition 1, we find that all of these equilibria are eliminated.

Proposition 2. The exclusionary equilibria identified in Proposition 1 are not coalition proof.
Proof: See Appendix.

Intuitively, the exclusionary equilibria described in Proposition 1 all rely on buyers' miscoordination. If buyers could coordinate their choices, or equivalently if there existed only one buyer, these equilibria would no longer exist.

III(ii). *Entry equilibria*

In this Section, we look for those equilibria where the entrant serves all buyers. It turns out that these equilibria may not always exist, as their existence depends on the price regimes assumed. More precisely, Proposition 3 shows that entry equilibria always exist under uniform pricing, but they only exist for a subset of the total parameter space under first-degree price discrimination.

Proposition 3. (i) Under uniform pricing, an entry equilibrium in pure and undominated strategies exists for any $c_E < c_I$; it is characterized by: $\tilde{p}_E^i = \tilde{p}_I^i = c_I$ for all i, and all buyers buy from E whenever $p_E \leq p_I$.

(ii) Under first-degree price discrimination, a pure strategy entry equilibrium only exists for $c_E \leq \tilde{c}_I$ where $\tilde{c}_I \ll c_I$; when it exists, all buyers buy from E whenever $p_E^i \leq p_I^i$ for all i, and $\tilde{p}_E^i = \tilde{p}_I^i \leq c_I$ for all i, with $\tilde{p}_E^i = \tilde{p}_I^i < c_I$ for at least one i.

Proof: See Appendix.

Let us first consider the simpler case (i) where suppliers are constrained to charge the same price to every buyer, i.e. $p_k^i \leq p_k \forall i, k = I, E$. We have seen in Section III(i) that when $p_E \leq p_I$, there is an exclusionary equilibrium where all buyers buy from the incumbent. However, there is also an equilibrium at the supplier choice stage where all buyers buy from the entrant: The entrant reaches the critical size for sure, and no buyer has an incentive to deviate given that all others buy from the entrant, since it would pay a (weakly) higher price p_I for a product which is as good as the entrant's.

At the price setting stage of the game, the set of equilibria coincides with that of the Bertrand game with asymmetric costs: Any $p_E \in (c_E, c_I]$ can arise in equilibrium, provided I charges the same price as E so as to rule out an upward deviation by E. But as usual, $p_E = c_I$ is the only price supported by an equilibrium in undominated strategies. This equilibrium always exists, no matter how small the efficiency gap between E and I is, as long as $c_E < c_I$.[15]

Let us now turn to the case (ii) of first-degree price discrimination, i.e. the case where each firm can set a different price for each buyer. Unlike the uniform pricing case, entry equilibria do not necessarily exist when firms can price discriminate. To fix ideas, suppose that there are only two buyers, and start with the candidate entry equilibrium where both firms charge c_I and all buyers buy from the entrant (a natural candidate, as this was an entry equilibrium under uniform pricing). This equilibrium can be disrupted by the incumbent setting a price $c_I - \epsilon$ to buyer 1 (so as to deprive E of the critical size) and the monopoly price to the remaining buyer (buyer 2 on its own is not sufficient for E). Thus, the loss made on buyer 1 would be outweighed by the profits made on buyer 2. Indeed, under this deviation buyer 1 strictly prefers to buy from I, thus preventing the entrant from reaching the minimum size. Anticipating that for buyer 1 it is a dominant strategy to buy from the incumbent, buyer 2 will also prefer to buy from I rather than from the entrant, since it would derive zero utility from buying from E.

Suppose that to shield itself from this possible deviation, E sets a price which matches I's best offer to buyer 1, while continuing to charge c_I to buyer 2. Such a price profile cannot sustain an entry equilibrium either, because I could deviate again, by attracting buyer 2 with a price below c_I, while charging the monopoly price to buyer 1. Therefore, an entry equilibrium can exist only if it is immune to *all* the possible deviations. With two buyers, this means that both will pay a price strictly below c_I in equilibrium.

For the general case where $m \geq 2$, there are more than two coalitions (and possibly very many) which I can target to prevent the entrant from attaining the critical size. Their number and composition will then depend on the exact value of $\bar{s}$ and the size distribution of the buyers. For an entry equilibrium to exist for a general $m \geq 2$, E's equilibrium prices must be immune against deviations by all these possible coalitions.

To explore the *boundaries* of the parameter space where such equilibrium price vectors exist, we have to study the case which is most favorable to the entrant. This will be the case where the threshold value is very low (any two buyers are sufficient to reach $\bar{s}$), so that the incumbent will have to steal all but one buyer to prevent entry (i.e. coalitions must have at least $m-1$ buyers to break an entry equilibrium). This means that only one buyer will be left to be 'exploited' (i.e. who can be charged the monopoly price) under such a deviation, which is the minimum needed for I to offer below-cost prices to (some or all) the other buyers.

As we show in the Proof of Proposition 3, the candidate entry equilibrium prices which satisfy this condition can be characterized as

$$\hat{p}_E^i = 1 - \frac{1-c_I}{(m-1)\,s_i} \forall i$$

Note that $\hat{p}_E^i$ may exceed c_I; this will be the case for large buyers, i.e. whenever $s_i > 1/(m-1)$. In this case, the relevant upper bound for the equilibrium price offer by the entrant is of course c_I, as any $\hat{p}_E^i > c_I$ would immediately trigger undercutting by the incumbent on that particular buyer i. Therefore, the most general statement we can make about pricing patterns in entry equilibria with $m > 2$ buyers is that some buyers (at least one buyer), but not necessarily all buyers, will pay a price strictly below c_I, while some buyers (but not all) might pay exactly c_I.

Given that the *average price* paid in any entry equilibrium will be below c_I, this means that the entrant's profits will be lower than $c_I - c_E$. As we allow the minimum size to increase (so that E needs more and more buyers to reach $\bar{s}$), the ratio of 'targeted' to 'exploitable' buyers will change in favor of I, allowing I to make more and more aggressive price offers to any subgroup of buyers.

Then, equilibrium prices will fall below the upper bound identified by the most favorable case. In other words, E can no longer extract the total efficiency rent $c_I - c_E$ which it could appropriate under uniform pricing. Thus, for some parameters, namely c_E close to c_I, no entry equilibrium can be sustained under first-degree price discrimination where such equilibria would exist under uniform pricing.

Section III(iv) provides a simple example that characterizes entry equilibria under price discrimination. It will illustrate how the higher the efficiency gap $(c_I - c_E)$ the more likely entry equilibria will exist, and that at such equilibria prices are below c_I.

In parallel to our treatment of exclusionary equilibria, let us study whether the entry equilibria identified in Proposition 3 are coalition-proof.

Proposition 4. The entry equilibria identified in Proposition 3 are all coalition proof.
Proof: See Appendix.

This Proposition states that coalition-proofness does not eliminate any of the entry equilibria identified in Proposition 3.[16]

III(iii). *Other forms of price discrimination*

The case of first-degree price discrimination analyzed so far is a useful benchmark once we depart from a framework of uniform pricing. Of course, there are many other discriminatory schemes apart from first-degree price discrimination, each having different exclusionary effects, depending on how precisely they allow the incumbent to target individual buyers and/or orders to prevent the entrant from reaching the critical network size. Let us briefly discuss two such schemes which are of practical relevance:

(i) Implicit price discrimination (standardized rebates, or quantity discounts)

If firms cannot perfectly discriminate among buyers, they may resort to non-linear pricing to screen buyers by the quantities they buy. In this case, a buyer may want to order more or less than s_i to conceal its true type. To accommodate the case where buyer i acquires some quantity $q_i > s_i$ (where q_i is the quantity *acquired* by buyer i, and s_i is the maximum quantity i can *consume*), we have to allow for free disposal of excess units, i.e. a buyer who did not consume all the units it bought can dispose of the rest at no cost. We know from contract theory that one or more types of agents (i.e. buyers) will receive information rents if the price menu is to achieve self-sorting. Moreover, such self-sorting may even fail altogether, so that two or more types will bunch in the same contract. This makes quantity discounts a weaker instrument in targeting individual buyers compared to first-degree price discrimination. While the incumbent may still be able to break entry equilibria with quantity discounts, this can only occur in a subset of the parameter space where entry equilibria are broken under first-degree price discrimination. The example given in the next section will illustrate how first- and second-degree price discrimination differ in their exclusionary effects.[17]

(ii) Coupons

Firms may also want to set different prices for each unit they sell, even on units sold to the same buyer. This form of price discrimination can be achieved, for instance, through the use of coupons: suppose each coupon entitles the buyer who redeems it to a price reduction on one unit; then, the incumbent could issue an amount of coupons that is just sufficient to deprive the entrant of the critical size, and recover the losses made on these units by selling the remaining units at a monopoly price of 1. One may think that this form of price discrimination is perhaps more effective than first-degree price discrimination because the incumbent can reduce the quantity sold at a discount price to the necessary minimum of $\inf \{1 - \bar{s} + \epsilon | \, \epsilon > 0\} = 1 - \bar{s}$.

However, we will argue that such coupons are never more exclusionary (and sometimes less exclusionary) than first-degree price discrimination. Suppose the incumbent issues coupons which entitle the holders of these coupons to purchase a given quantity of the good at a discounted price $p_I^d < p_E$ (where p_E is the candidate entry equilibrium price). Assume that the coupons are not allocated randomly (i.e. the incumbent can target its coupons towards specific buyers). Let the total quantity available at the discounted price be $1 - \bar{s}$, i.e. such that the residual demand for E will fall below the minimum threshold if all buyers redeem their coupons. Suppose that all but one buyer bought all the discounted units they were offered by I. Will the last buyer also redeem all his coupons?

The last buyer understands that by purchasing all the remaining units from I, the entrant will not reach the critical mass of sales, so that the entrant's good has zero valuation to the buyer, while selling at a positive price. Buyer i then anticipates that he will have to purchase his remaining requirements from I at monopoly price 1. In other words, with q_i denoting the quantity offered to buyer i at the discounted price p_I^d, buyer i's total expenditure would then be $q_i p_I^d + (s_i - q_i)\, 1$. Then, buyer i would be better off buying just $q_i - \epsilon$ from I, and buying the rest, namely $s_i - q_i + \epsilon$, from E.[18] E would then attract just enough demand to reach the threshold size, and i's expenditure would be reduced to $(q_i - \epsilon)\, p_I^d + (s_i - q_i + \epsilon)\, p_E$. Thus, buyer i will undermine the incumbent's exclusionary strategy, preventing I from gaining the patronage needed to deprive E of the minimum size.

The only way for I to induce buyer i to buy a sufficient quantity from I (i.e. enough for E to lose critical mass) is by extending the discount price to all of i's demand, i.e. setting $q_i = s_i$. But this pricing strategy coincides with that of first-degree price discrimination, where each buyer is offered one flat price for all his requirements. In this sense, coupons cannot be more exclusionary than first-degree price discrimination.

If, in addition, we relax the assumption that I can perfectly target the coupons towards individual buyers, coupons will be even less effective than first-degree price discrimination. Recall that we ruled out side-payments or any other transactions among buyers. Thus, if one buyer happens to receive coupons for a quantity q in excess of this buyers demand, $q > s_i$, some of the coupons issued will simply remain unused, because buyer i cannot pass them on to some buyer j who received $q < s_j$. Whenever there is a chance that coupons end up in the wrong hands, the incumbent may end up selling less than the necessary $1 - \bar{s}$ units. Then, some entry equilibria may survive which could be broken under first-degree price discrimination (or with perfectly targeted coupons).

III(iv). *An example*

In this Section, we consider a simple example to illustrate how price discrimination may prevent entry equilibria from existing, and to compare the results under explicit and implicit price discrimination.

Throughout this Section, we keep the same assumptions as in the general model, but we restrict attention to the case where $s_1 = s_2 = k/2$ and $s_3 = 1-k$, with $k > 1 - k > k/2$. In other words, there are two small buyers whose individual demand is lower than the large buyer's, but whose total demand is higher than hers. (Note that this implies that $1/2 < k < 2/3$.) We also assume that $k < \bar{s} < 1 - k/2$. The first inequality says that selling only to the small buyers - and a fortiori only to the large buyer - would not allow the entrant to reach critical size; the second inequality says that the entrant would reach sufficient scale if it sold to the large buyer and one of the two small buyers. This is equivalent to saying that the incumbent would need to get either the large buyer or both small buyers to exclude the entrant: $k/2 \leq 1 - \bar{s} \leq 1 - k$.

Finally, in order to avoid the unnecessary complications of dealing with non-negative price constraints, we restrict attention to values where $c_I > k$ (of course we continue to assume that $c_E < c_I$).

(i) First degree (explicit) price discrimination

For an entry equilibrium to exist, we need to find a triple $(p_E^{S1}, p_E^{S2}, p_E^L)$ which is immune to deviations by the incumbent. Since the incumbent could block entry *either* (i) by selling to both small buyers through prices $p_I^{Si} < p_E^{Si}$, for $i = 1, 2$ (while serving the large buyer at monopoly price $p_M = 1$), *or* (ii) by selling to the large buyer at a price $p_I^L < p_E^L$ (while recouping losses by serving the small buyers at the monopoly price $p_M = 1$), at an entry equilibrium *all* of the entrant's prices must be such that no profitable undercutting by the incumbent could take place.

Let us analyze this problem formally. Under the possible deviations (i) and (ii) the incumbent's offers must satisfy $\pi_I \geq 0$:

$$\begin{aligned} (i) \quad kp_I^S + 1 - k &\geq c_I, \\ (ii) \quad (1-k)p_I^L + k &\geq c_I, \end{aligned}$$

where p_I^S denotes the average price paid to the small buyers, i.e. $p_I^S = \frac{1}{2}p_I^{S1} + \frac{1}{2}p_I^{S2}$. The incumbent's most aggressive price offers would therefore be respectively:

$$\underline{p}_I^{S(\text{expl})} = \tfrac{c_I-(1-k)}{k}; \underline{p}_I^{L(\text{expl})} = \tfrac{c_I-k}{1-k},$$

For an entry equilibrium to exist, the entrant must set prices which are immune to deviations, namely $p_E^{Si} \leq \underline{p}_I^S$, *and* $p_E^L \leq \underline{p}_I^L$; profit maximization for E requires strict equalities for these prices. Therefore, an entry equilibrium will exist if and only if $\pi_E(\underline{p}_I^S, \underline{p}_I^S, \underline{p}_I^L) = \underline{p}_I^S k + \underline{p}_I^L(1-k) - c_E \geq 0$. By substitution, an entry equilibrium exists if and only if $\pi_E(\underline{p}_I^S, \underline{p}_I^S, \underline{p}_I^L) = 2c_I - 1 - c_E \geq 0$, which leads to the following result.

Remark 1. (Explicit discrimination) An entry equilibrium in pure strategies exists if and only if $c_E \leq 2c_I - 1$. At such an equilibrium, firms E and I set prices $(p^{S1}, p^{S2}, p^L) = \left(\frac{c_I-(1-k)}{k} < c_I, \frac{c_I-(1-k)}{k} < c_I, \frac{c_I-k}{1-k} < c_I\right)$ and all three buyers buy from E.

(ii) Implicit (2nd degree) price discrimination

Suppose now that the firms are not able to target specific buyers, but have to rely on 2nd degree discrimination. In order to find the entry equilibrium prices, we have to follow the same logic as in the previous case, but in addition, we have to require that price offers satisfy a self-selection constraints. Consider for instance the incumbent's possible deviation where it sets the low price $\underline{p}_I^L$ to attract the large buyer, while charging $p_M = 1$ to the small buyers. The incumbent can make such an offer only if it satisfies the small buyers' incentive constraint (IC), i.e. if the latter do not prefer to buy $(1-k)$ units (of which they would use only $k/2$ units) at the price $\underline{p}_I^L$ rather than $k/2$ units at the monopoly price 1. Likewise for the case where the deviation targets the small buyers: such an offer must guarantee that the large buyer does not prefer to buy fewer units at the low price $\underline{p}_I^S$ intended for small buyers rather than $(1-k)$ units at the monopoly price.[19] Note that both firms have to set the same price for both small buyers, since prices can only condition on quantity sold here, which is of course the same for both small buyers.

Formally, therefore, the incumbent's offers must satisfy:

$$\begin{aligned}
(i') \quad k\underline{p}_I^S + (1-k)\overline{p}_I^L \quad &\geq \quad c_I, \text{ s.to: } (1-k)\left(1-\overline{p}_I^L\right) \geq \frac{k}{2}\left(1-\underline{p}_I^S\right); \overline{p}_I^L \leq 1 \\
(ii') \quad (1-k)\underline{p}_I^L + k\overline{p}_I^S \quad &\geq \quad c_I, \text{ s.to: } \frac{k}{2}\left(1-\overline{p}_I^S\right) \geq \frac{k}{2} - (1-k)\underline{p}_I^L;\ \overline{p}_I^S \leq 1.
\end{aligned}$$

Consider first (i'). It is straightforward to see that $\overline{p}_I^L = 1$ will never satisfy the IC of the large buyer (she would get zero surplus and would be better off pretending to be a small buyer). Therefore, the highest price that the incumbent can charge to the large buyer in a deviation would be:[20]

$$\overline{p}_I^L = 1 - \frac{1-\underline{p}_I^S}{1-k}\frac{k}{2}.$$

By substituting into (i') and solving we obtain the lowest price the incumbent could offer to small buyers:

$$\underline{p}_I^{S(impl)} = 1 - \frac{2(1-c_I)}{3k} > \underline{p}_I^{S(\text{expl})}.$$

Next, we need to consider (ii'). One can check that the prices $\underline{p}_I^L = \frac{c_I - k}{1-k}$, $\overline{p}_I^S = 1$ (i.e. the prices which apply under explicit discrimination) satisfy the IC of the small buyers as long as $c_I \geq 3k/2$. Else, the IC would not be satisfied, and the price intended for the small buyers must be reduced. By solving the IC with equality, one obtains:

$$\overline{p}_I^S = \frac{2(1-k)}{k}\underline{p}_I^L.$$

By substituting into (ii') and solving one obtains the best possible offer the incumbent can make to the large buyer:

$$\underline{p}_I^{L(impl)} = 1 - \frac{c_I}{3(1-k)} > \underline{p}_I^{L(\text{expl})}.$$

Clearly, the incumbent's offers in a deviation are (weakly) less aggressive under implicit than under explicit discrimination.

The final step is to check whether (i) the entrant can profitably set prices which are immune to deviations, and (ii) whether the candidate equilibrium prices are themselves incentive-compatible.

(i) The entrant breaks even under the candidate equilibrium prices if $\pi_E(\underline{p}_I^S, \underline{p}_I^S, \underline{p}_I^L) = \underline{p}_I^S k + \underline{p}_I^L(1-k) - c_E \geq 0$. Note that for the case of implicit price discrimination we have to consider two intervals:

- $c_I \geq 3k/2$. In this case, $\underline{p}_I^{S(impl)} = 1 - \frac{2(1-c_I)}{3k}$ and $\underline{p}_I^L = \frac{c_I-k}{1-k}$. By substitution, $\pi_E(\underline{p}_I^{S(impl}, \underline{p}_I^S, \underline{p}_I^L) = \frac{5c_I - 2}{3} - c_E \geq 0$.
- $c_I < 3k/2$. In this case, $\underline{p}_I^{S(impl)} = 1 - \frac{2(1-c_I)}{3k}$ and $\underline{p}_I^L = \frac{c_I}{3(1-k)}$. By substitution, $\pi_E(\underline{p}_I^{S(impl}, \underline{p}_I^S, \underline{p}_I^L) = c_I + k - \frac{2}{3} - c_E \geq 0$.

(ii) It is easily verified that both candidate price pairs $\left(\underline{p}_I^{S(impl)}, \underline{p}_I^L\right)$ always satisfy the ICs: By construction of $\underline{p}_I^L$, the small buyers prefer to buy quantity $k/2$ at price $\overline{p}_I^S = 1$ rather than $1-k$ at price $\underline{p}_I^L$, implying that they will also prefer $k/2$ at $\underline{p}_I^{S(impl)} < 1$ over $1-k$ at price $\underline{p}_I^L$; Analogously, by construction of $\underline{p}_I^S$, the large buyer prefers to buy quantity $1-k$ at price $\overline{p}_I^L > \underline{p}_I^L$ over buying $k/2$ at price $\underline{p}_I^{S(impl)}$, implying that it will also prefer $1-k$ at the respective

$\underline{p}_I^L$ over $k/2$ at price $\underline{p}_I^{S(impl)}$. Also note that our parameter restrictions imply $\underline{p}_I^{S(impl)} > \underline{p}_I^L$ for both candidate price pairs $\left(\underline{p}_I^{S(impl)}, \underline{p}_I^L\right)$; in other words, the equilibrium unit price is decreasing in quantity (as we would expect for a well-behaved quantity discount scheme).

These results can be summarized thus:

Remark 2. (Implicit discrimination) An entry equilibrium in pure strategies exists:

(i) For $c_I \geq 3k/2$, if and only if $c_E \leq (5c_I - 2)/3$. At such an equilibrium, firms E and I set prices $\left(1 - \frac{2(1-c_I)}{3k} < c_I, 1 - \frac{2(1-c_I)}{3k} < c_I, \frac{c_I - k}{1-k} < c_I\right)$ and all three buyers buy from E.

(ii) For $c_I < 3k/2$, if and only if $c_E \leq c_I + k - 2/3$. At such an equilibrium, firms E and I set prices $\left(1 - \frac{2(1-c_I)}{3k} < c_I, 1 - \frac{2(1-c_I)}{3k} < c_I, \frac{c_I}{3(1-k)} < c_I\right)$ and all three buyers buy from E.

Comparison: It is straightforward to check that entry occurs over a larger set of parameters under implicit than under explicit price discrimination. Obviously, this follows directly from the fact that under implicit discrimination the entrant's prices which are immune to the incumbent's deviation are higher.

IV. DISCUSSION OF RESULTS, AND POLICY ISSUES

In this Section, first (Section IV(i)) we take stock of the results obtained, in particular by comparing the price regimes we have studied so far; and then (Section IV(ii)) we discuss the possible policy implications that arise from these results.

IV(i). *Comparing price regimes*

The main point of our paper is that when there are network effects, an incumbent with an established customer base can outcompete a more efficient entrant by price discriminating, even if the entrant can resort to price discrimination as well and moves at the same time as the incumbent. The exclusionary mechanism at work relies on the fact that the incumbent can target certain subgroups of consumers with low prices so that sufficient scale is denied to the entrant.

The previous Section shows formally that when firms can price-discriminate, entry equilibria will only exist in a subset of the parameter space (more precisely, when the efficiency gap between the incumbent and the entrant is sufficiently large), whereas they would always exist under uniform pricing. If one looks only at the set of the possible Nash equilibria, one would conclude that under price discrimination there exists a range of parameters for which only a mis-coordination equilibrium would exist. If one prefers to rely on the refinement of Coalition-proof Nash equilibria, under price discrimination there would be a region in which no pure strategy coalition-proof Nash equilibrium exists.

The reader may wonder what kind of equilibrium can be sustained in such a region. If no pure strategy profile is immune to deviations by either incumbent or entrant, such an equilibrium will have to be in mixed strategies. While we do not fully characterize these mixed strategy equilibria here, we want to point out that in any such equilibrium, there is a strictly positive probability that the entrant will *not* serve the buyers. To see why, consider a very simple example with only two buyers, having demands s_1 and s_2. Note that any price pair $\left(\hat{p}_E^1, \hat{p}_E^2\right)$ in the support of the entrant's equilibrium mixed strategy must allow the entrant to break even: $\hat{p}_E^1 s_1 + \hat{p}_E^2 s_2 \geq c_E$. (Otherwise, the entrant could increase its expected profits by shifting probability mass away from such price pairs that yield negative profits.) If no pure-strategy entry equilibrium exists, then at least one of the two prices is above the lowest price that the incumbent could offer to that same buyer: e.g. $\hat{p}_E^1 > \tilde{p}_I^1$ where $\tilde{p}_I^1$ solves $\tilde{p}_I^1 s_1 + 1 \cdot s_2 = c_I$. Therefore, it must be a best reply for the incumbent in any such mixed strategy equilibrium to give positive probability to price pairs $\left(\hat{p}_I^1, 1\right)$ where $\hat{p}_I^1 \in \left[\tilde{p}_I^1, \hat{p}_E^1\right]$: In the event that the entrant plays $\left(\hat{p}_E^1, \hat{p}_E^2\right)$, the incumbent would outcompete E on buyer 1, and therefore also win buyer 2's orders, thus serving the entire market and making strictly positive profits.

Since the entrant produces at lower costs than the incumbent, consumers have inelastic demands, and both networks give the same utility to buyers, entry is always socially efficient in our model. By reducing the region in which entry equilibria can be sustained, price discrimination - whether explicit, implicit, or relying on price coupons - is welfare detrimental in our model.

Beyond this simple conclusion, a deeper comparison between the pricing regimes may be worth discussing. In particular, one may want to evaluate the welfare properties of the regimes in regions where the entry equilibrium exists under both uniform pricing and discriminatory pricing. In terms of our model, total surplus under the two regimes in regions where entry takes place is identical. However, under price discrimination equilibrium prices are lower than under uniform pricing, pointing to a possible trade-off between lower prices and achievable entry. If competition authorities gave more weight to consumer surplus than to total surplus in their objective function, then the policy implications of the paper might be more ambiguous.

Nevertheless, the fact that under price discrimination prices in an entry equilibrium (if it exists) are lower, *may* have some additional adverse consequences on entry, as they may discourage cost-reducing investment opportunities, as we discuss next.[21]

The (possible) investment effects of price discrimination:

Consider a variant of our model where the first stage (price choices) of the game is preceded by a stage where the entrant has to decide whether to carry out a cost-reducing investment or not. Absent the investment opportunity, the entrant has the same marginal cost c_I as the incumbent; by investing an amount f it would instead achieve a marginal cost $c_E = c_I - x$, with $x \in (0, c_I)$ and $f < x$ (which guarantees that the investment is socially efficient). To fix ideas, consider the specific example of Section III(iv) (but the same qualitative results hold in the general model). Given the investment decisions, the results of the pricing games are unchanged (f is a sunk cost).

Under uniform pricing, the entry equilibrium exists - given investment decisions - if $\pi_E = c_I - (c_I - x) \geq 0$, which always holds. Under explicit discrimination, the entry equilibrium exists - given investment decisions - if $\pi_E = 2c_I - 1 - (c_I - x) \geq 0$, or $x \geq 1 - c_I$.

Let us now look at the first stage of the game. Under uniform pricing, the investment (and therefore entry) will take place if and only if $\widehat{\pi}_E = x - f \geq 0$, which always holds. Under explicit discrimination, instead, the investment will take place if and only if $\widehat{\pi}_E = c_I - 1 + x - f \geq 0$, or $x \geq 1 - c_I + f$.

In other words, there are two effects which may negatively affect entry under explicit discrimination. One is the effect of the exclusionary mechanism at the heart of this paper; another one is that the expectation of lower equilibrium prices may further discourage efficient cost-reducing opportunities.

Note, however, that this effect may disappear if investment levels are endogenous and the price regimes do not change the marginal profits from the investments (rather than the absolute levels of profits as in the previous example with exogenous investment levels). Suppose that the entrant can choose its investment level x, at a fixed (but endogenous) sunk cost $x^2/2$. As before, assume that the entrant's cost are given by $c_I - x$.

At the second stage of the game, the conditions for an entry equilibrium - *given investment decisions* x - are the same as above: Under uniform pricing, entry exists if $\pi_E^u = x \geq 0$, which always holds. Under explicit discrimination, entry exists if $\pi_E^d = c_I - 1 + x \geq 0$. Note, however, that the marginal benefit from a unit of investment is precisely the same under the two regimes. Indeed, in the first stage of the game, investment levels are chosen respectively so as to $\max_x \widehat{\pi}_E^u = x - x^2/2$ and $\max_x \widehat{\pi}_E^d = c_I - 1 + x - x^2/2$. In both cases, the optimal investment will be $x^* = 1$, implying that there is no further investment distortion created by discriminatory pricing.

IV(ii). *Policy implications*

We have seen that price discrimination (whatever the actual form it takes) reduces the set of achievable socially efficient entry equilibria. Before drawing policy implications, though, we should bear in mind the context of our analysis. We analyze an industry where there is a dominant incumbent (when the entrant makes its offers, all 'old ' buyers are using the incumbent's network, so the incumbent's market share at the start of the game is 100%). Our policy conclusions cannot be generalized to situations where there is little asymmetry between competing suppliers. Rather than offering comments on the possible benefits of blanket prohibitions on price discrimination for all firms, we should therefore limit ourselves to discuss possible restrictions to the conduct of *dominant* firms.

In this perspective, there are two natural antitrust policy rules that one should consider. The first is that a dominant firm may not price discriminate.

The second is that a dominant firm may not sell at prices which are below marginal costs.

(i) Prohibiting a dominant firm from discriminating

As to the first rule, note that it should be applied to any form of price discrimination by the incumbent. Indeed, we have showed in Section III(iv) that even 2nd degree discrimination (which in the example amounts to quantity discounts - the unit price decreases with the number of units bought) can give the incumbent sufficient scale to deny entry. Still, as our results show, the more targeted price discrimination the higher its exclusionary potential (that is, the smaller the parameter space for which efficient entry can be achieved), giving some support to the fact that courts and antitrust authorities tend to regard individualized rebates by dominant firms with more suspicion than standardized rebates and quantity discounts, whenever they cannot be justified on efficiency grounds (e.g. savings on packaging and transaction costs, allowing for a larger production run). [22]

However, preventing dominant firms from price-discriminating may have detrimental effects we cannot account for in our model, where all consumers have the same valuation for the good. In a more general model with heterogeneous valuations, a firm may want to price discriminate even if it was an unchallenged monopolist (unlike in our paper), and - as is well known - price discrimination may well allow to reach consumers who would not otherwise buy, and turn out to be welfare beneficial. Accordingly, a policy rule aimed at prohibiting dominant firms from price discriminating may well have undesirable properties that admittedly we cannot fully evaluate within our model.

(ii) Prohibiting a dominant firm's below-cost prices

We would be more confident in supporting the second policy rule above, namely to prohibit a dominant firm from below-cost pricing (unless the standard pro-competitive justifications for below-cost pricing apply, as for instance in infant markets, or in the case of complementary products or two-sided markets). Such a rule would effectively eliminate the scope for the exclusionary mechanism highlighted in the paper: the incumbent can outcompete a more efficient rival only if it can price a certain threshold number of units below cost - while recouping losses made on such units by setting a high price on the remaining ones. If it could not sell below cost, it would therefore not be able to obtain orders at the expenses of a more efficient rival.

Note also that this policy rule does not coincide with a rule requiring the dominant firm not to make *overall* losses, but with one requiring it not to make losses on *any* (non-trivial) subset of the market. Indeed, as we have showed, the incumbent needs to sell only a certain threshold number of units to block entry; units beyond this threshold can be sold at monopoly prices, thereby giving overall positive profits. Proof that the incumbent is achieving positive profits in the market should accordingly not be accepted as evidence that there is no anticompetitive conduct.

This rule is in the spirit of *sacrifice tests* of anticompetitive effects, that are based on the analysis of the cost (the 'sacrifice') incurred by the dominant firm in order to implement the challenged conduct. In particular, it is consistent with the 'no economic sense' test, which consists of verifying whether the only reason why the defendant entails a sacrifice implementing the challenged strategy is to reduce competition. Note also that the 'no economic sense' test 'does not require a showing of that there is a period of time in which the defendant's profit are lower than they were before the exclusionary conduct was undertaken. The reduction in profits can be conceptual rather than temporal.' (Salop [2006]: 320) A dominant firm which sells below cost to some buyers while simultaneously recouping on other buyers would therefore be found positive under this test.

(iii) Interoperability

Another key feature of our model is the presence of network externalities and the assumption of incompatible networks, i.e. that the incumbent's pre-existing customer base does not exert any positive externality to the users of the entrant's network. A policy rule requiring interoperability between the incumbent's and the entrant's network would therefore solve the buyers' coordination problem at the root, and entry equilibria would always exist. Even less than perfect interoperability would work in the same direction by allowing buyers of the entrant to enjoy some of the network effects of the incumbent, and would enlarge the set of achievable entry equilibria.

Obviously, interoperability obligations may also have detrimental effects. For instance, they might conflict with intellectual property rights and accordingly have an ex ante disincentive effect. Further, in some cases they may discourage variety and innovations, as the entrant might find it more convenient to conform to the specifications of the incumbent's network rather than developing original but incompatible features. A complete discussion of the pros and cons of imposing compatibility is clearly beyond the scope of this paper, but our paper does suggest that when there exist strong asymmetries among an incumbent and entrants, interoperability obligations may be a way to avoid that those imbalances could have long term consequences (think for instance of imposing roaming obligations to telecom incumbents until new entrants have developed their own network).

(iv) Buyer power

Finally, our model crucially depends on some fragmentation of buyers: no buyer can command a sufficiently large number of orders to give the entrant's network a viable size. Clearly, the miscoordination problems - and accordingly the possible exclusionary effects - which are at the heart of our paper would be absent if there was sufficient buyer concentration. In terms of our model, it would be sufficient for $s_m > \overline{s}$ for exclusionary equilibria not to arise.

Furthermore, if buyers are fragmented (i.e., $s_m < \overline{s}$) but they can take joint decisions, miscoordination would not take place. Accordingly, agreements among buyers to establish a central purchasing agency, or to delegate their purchase decisions to an entity which sets up a common public procurement system, or any other device which allows to take joint decisions, would have procompetitive effects in industries such as the one described in this paper.

V. CONCLUSIONS

Our paper demonstrates the exclusionary potential of price discrimination and rebates in a model where - relative to the literature on exclusionary practices - the entrant is in a fairly good initial position: it is more efficient than the incumbent, it does not have to pay any set-up cost, it can approach buyers at the same time as the incumbent, and it can use the same pricing schemes. However, the incumbent does enjoy an incumbency advantage (when the game starts, its network has already reached the minimum threshold size to be viable, whereas the entrant's has not), and this turns out to be crucial.

We have showed that - if buyers are sufficiently fragmented and/or the threshold size is sufficiently high - both exclusionary equilibria and entry equilibria exist under uniform pricing, and that any form of price discrimination reduces the set of achievable (socially efficient) entry equilibria: while discrimination does not prevent miscoordination, it makes it easier for the incumbent to disrupt entry equilibria. This is done by a 'divide and rule' strategy where some buyers are offered a below-cost price, thereby depriving the entrant of the critical mass it needs, and allowing the incumbent to recover losses from the remaining buyers, who become captive to it. This suggests that there may be a rationale behind judges' findings that various forms of rebates and price discrimination may raise anticompetitive concerns.[23]

We have also showed that the more targeted the discounts the higher the potential for exclusion of the entrant, thereby lending some support to the view that individualised rebates should be treated with more caution than standardised rebates.

The possibility of exclusionary outcomes is intimately linked to the assumption that there is a very strong asymmetry between the customer base of the dominant incumbent and that of smaller and new rivals.[24] For this reason, the mechanism identified in our paper seems well suited to industries where entrants can challenge an incumbent firm only after the latter has developed a strong customer base; examples include industries that were recently liberalized or industries where a firm's dominant position is built upon intellectual property rights whose protection is about to expire.[25] In such industries, our model suggests that the dominant firm should be prohibited from selling below cost, and that interoperability obligations should be considered very seriously.

APPENDIX

Proof of Proposition 1 (Exclusionary equilibria): Consider the candidate equilibrium where $p_I^i = p_E^i = 1 \forall i$ and all buyers buy from I. Recall that $\bar{s} > s_m \geq \ldots \geq s_1$: none of the individual buyers alone is sufficient for E to reach the minimum size. Thus, no buyer $i = 1, \ldots, m$ will want to deviate and buy from E, even if $p_E^i = 0$, as E's product would have zero value for the deviating buyer. Firm I has no incentive to increase or decrease its price as it is getting the monopoly profits. Since in all continuation equilibria buyers will not switch to E no matter how low p_E^i is, E has no incentive to decrease its price either.

More generally, there exists a continuum of exclusionary equilibria with price vectors $\left(\tilde{p}_k^1, \ldots, \tilde{p}_k^m\right)$, $k = I, E$, $\tilde{p}_I^i \in [0,1]$, $\tilde{p}_E^i = \tilde{p}_I^i \forall i$, $\sum_{i=1}^{m} s_i \tilde{p}_I^i \geq c_I$, and buyers $i = 1, \ldots, m$ all buying from I. To sustain any such equilibrium, construct the appropriate continuation equilibria as follows: all buyers miscoordinate on I as long as $p_E^i \leq p_I^i \leq \tilde{p}_I^i$. As soon as I deviates to a $p_I^{i\prime} > \tilde{p}_I^i$ for some i, all buyers switch to E. The proof is analogous to the case of $p_I^i = p_E^i = 1 \forall i$. First, no buyer has an incentive to deviate unilaterally and buy from the entrant as the latter would not reach size $\bar{s}$. As long as firm I breaks even under the equilibrium prices, it has no incentive to increase its price to $p_I^{i\prime}$ if in the continuation equilibrium where $p_E^i < p_I^{i\prime}$ buyers would all buy from the entrant; firm E would have no incentive to change its prices provided in all continuation equilibria where $p_E^i < \tilde{p}_I^i$ all buyers buy from the incumbent.

The incumbent's equilibrium profits may therefore range from zero to full monopoly profits: the former is the case for all equilibrium price vectors where $\sum_{i=1}^{m} s_i \tilde{p}_I^i = c_I$, the latter is the maximum payoff corresponding to equilibrium prices $p_I^i = 1 \forall i. \square$

Proof of Proposition 2 (Coalition Proofness): Consider any candidate equilibrium where $\left(\tilde{p}_k^1, \ldots, \tilde{p}_k^m\right)$, $k = I, E$, $\tilde{p}_I^i \in [0,1]$, $\tilde{p}_E^i = \tilde{p}_I^i \forall i$ and all buyers buy from I. To sustain such an equilibrium, the continuation equilibria must be such that buyers miscoordinate on I as long as $p_E^i \leq \tilde{p}_I^i \forall i$. Consider the subset of price vectors where the inequality holds strictly, i.e. $p_E^i < p_I^i \forall i$. Suppose the grand coalition of buyers deviates to patronize the entrant instead: Since $\bar{s} \leq 1$, E would reach minimum size, i.e. $Q_E > \bar{s}$, and so the payoffs of all members of the buyer coalition would strictly improve:

$$CS^i\left(p_E^i, Q_E\right) = CS^i\left(p_E^i, Q_I \middle| Q_E > \bar{s}\right) > CS^i\left(p_I^i, Q_I\right) \forall i$$

where the last inequality follows from $p_E^i < p_I^i \forall i$. After switching to E, given that $p_E^i < p_I^i \forall i$, no individual buyer or subcoalition of the grand coalition of buyers can improve their payoffs relative to $CS^i\left(p_E^i, Q_E\right)$ by switching back to I (either unilaterally or multilaterally). Thus, we found at least one coalition having a self-enforcing and improving deviation from any continuation equilibrium where $p_E^i < p_I^i$ for all i and all buyers buy from I.

At the price setting stage of the game, this implies that it is no longer optimal for E to set $\tilde{p}_E^i = \tilde{p}_I^i \forall i$. By undercutting I slightly on all buyers, $p_E^{i\prime} = \tilde{p}_I^i - \epsilon \forall i$,

E can attract enough buyers to reach minimum size, $\sum_i s_i \geq \bar{s}$. Since I breaks even at the candidate equilibrium prices, i.e. $\sum_{i=1}^{m} s_i \tilde{p}_I^i \geq c_I$, and since $c_E < c_I$, there must exist an ϵ small enough such that E makes positive profits after the price cut:

$$\sum_i s_i p_E^{i\prime} = \sum_{i=1}^{m} s_i \tilde{p}_I^i - \epsilon > c_E$$

Thus, imposing coalition-proofness at the supplier choice stage of the game gives rise to a profitable deviation by E at the price setting stage of the game. This deviation, in turn, eliminates all exclusionary equilibria identified in Proposition 1. □

Proof of Proposition 3 (Entry Equilibria): (i) With all buyers buying from E at $p_E = c_I$, E's total sales are $1 \geq \bar{s}$: thus, E will reach the minimum size for sure. Since E's product has the same value to the buyers as I's, and the price is the same, no buyer has an incentive to deviate and buy from I. Firm I will not want to deviate either: To attract buyers, it would have to set $p_I < c_I$, i.e. sell at a loss; and increasing p_I above c_I will not attract any buyers under the appropriate continuation equilibria. Firm E has no incentive to change its price either: increasing p_E would imply losing the buyers to I, and decreasing p_E will just reduce profits.

Following the same logic, it is straightforward to show that there exists a continuum of entry equilibria with any price $p_E^j \in [c_E, c_I]$ and buyers $j = s, l$ all buying from E, sustained by the appropriate continuation equilibria. In those equilibria where $p_E = p_I < c_I$, the incumbent plays a dominated strategy; to sustain such an equilibrium, we must rule out the possibility that I makes positive sales, no matter how small, as otherwise the incumbent would be making losses; the latter is of course incompatible with equilibrium behavior because I could always avoid those losses by setting $p_I = c_I$. Our assumption that whenever buyers are indifferent between the two suppliers, they do not split orders, together with the appropriate continuation equilibria where all buyers (not just a subset) buy from E ensures that equilibria in dominated strategies exist. However, the unique equilibrium in undominated strategies is $p_E = c_I$.

Finally, note that there can be no equilibrium where E serves all buyers at a price $p_E > c_I$: In this case, I could profitably undercut E, and all buyers would switch to I. Since I's network has the required size even if none of the new buyers buys from I, it is rational for a single buyer to unilaterally deviate to I whenever $p_I < p_E$.

(ii) Consider a candidate equilibrium where $\left(\tilde{p}_k^1, \ldots, \tilde{p}_k^m\right)$, $k = I, E$, $\tilde{p}_E^i \in [0, c_I]$, $\tilde{p}_I^i = \tilde{p}_E^i \forall i$ and all buyers buy from E. For this to be an equilibrium, it must be immune to all deviations by the incumbent in which I sets $p_I^i = \tilde{p}_E^i - \varepsilon$ to a subset of buyers just large enough to deprive the entrant of the critical scale, and then charges monopoly price $p_I^j = 1$ $j \neq i$ to the remaining buyers.

Depending on the exact value of $\bar{s}$ and the size distribution of the buyers, there are many different ways in which the incumbent could design such a deviation. In particular, the exact number and identity of buyers needed to prevent entry will differ from case to case. With a very high $\bar{s}$, securing just one or two buyers may be sufficient for I to exclude E. Thus, to explore the boundaries of the parameter space where entry equilibria exist, we have to study the most favorable scenario for E, or equivalently, those equilibria that are hardest to break for I. The latter are characterized by $\bar{s} \leq s_1 + s_2$. This condition implies that any two buyers (even the smallest ones) are sufficient for E to reach minimum size; in turn, for I to break such an entry equilibrium, it must undercut E on at least $m-1$ buyers, and can charge the monopoly price to at most one buyer.

More specifically, denote the set of buyers by $B = \{1, \ldots, m\}$. With a total of m buyers, and $s_m < \bar{s}$, any subset $C_i = B \backslash i$ of buyers is sufficient for I to prevent E from reaching the threshold size. (If $\bar{s} \leq s_1 + s_2$, $C_i = B \backslash i$ is the smallest subset of buyers that can achieve exclusion; in general, smaller subsets may be sufficient.) There exist m such subsets, and a necessary (though not sufficient) condition for an entry equilibrium to exist is that none of the m possible deviations be profitable for I (where $p_I^i = \tilde{p}_E^i - \varepsilon$):

$$(2) \quad \begin{bmatrix} 1 & p_I^2 & \ldots & p_I^m \\ p_I^1 & 1 & \ldots & p_I^m \\ \vdots & & \ddots & \vdots \\ p_I^1 & p_I^2 & \ldots & 1 \end{bmatrix} \times \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_m \end{bmatrix} \leq \begin{bmatrix} c_I \\ c_I \\ \vdots \\ c_I \end{bmatrix}$$

We see immediately that $p_E^i = p_I^i = c_I \forall i$ does not satisfy condition (2): Since $c_I < 1$, we have that $1 \times s_i + \sum_{j \neq i} s_j \left(c_I - \epsilon\right) > \sum_{i=1}^{m} s_i c_I = c_I$ for any $i \in B$. This implies that if an entry equilibrium exists, then $\exists i \in B : \tilde{p}_E^i < c_I$. In fact, we can rewrite condition (2) to obtain an upper bound on the prices E can charge in an entry equilibrium, namely:

$$(3) \quad \begin{bmatrix} 1 & p_E^2 & \ldots & p_E^m \\ p_E^1 & 1 & \ldots & p_E^m \\ \vdots & & \ddots & \vdots \\ p_E^1 & p_E^2 & \ldots & 1 \end{bmatrix} \times \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_m \end{bmatrix} = \begin{bmatrix} c_I \\ c_I \\ \vdots \\ c_I \end{bmatrix}$$

Solving this system of m equations in m unknowns, we obtain:

$$\hat{p}_E^i = 1 - \frac{1 - c_I}{(m-1)\, s_i} \forall i$$

Note that two restrictions apply to $\hat{p}_E^i$, namely (i) $\hat{p}_E^i \geq 0$ (because we restrict the firm's strategy space to non-negative prices), and (ii) $\hat{p}_E^i \leq c_I$ (no buyer can be offered a price $\tilde{p}_E^i > c_I$ in equilibrium, because I would immediately undercut E on this individual buyer).

Regarding (i) $\hat{p}_E^i \geq 0$, note that if it is ever binding, this means that there is at least one buyer (the smallest one, and possibly others) who is offered $\tilde{p}_E^i = 0$

in equilibrium. Then, even if all other buyers could be charged as much as $\tilde{p}_E^j = c_I$, $j \neq i$, it is clear that E's break even constraint has become more stringent compared to the one under uniform pricing where $\tilde{p}_E^i = c_I \forall i$:

$$0 \times s_1 + \sum_{i>1} s_i c_I \geq c_E$$

can be written as:

$$c_E \leq (1 - s_1) c_I = \tilde{c}_I \ll c_I$$

As for (ii) $\hat{p}_E^i \leq c_I$, we have that

$$\hat{p}_E^i \leq c_I \Longleftrightarrow s_i \leq \frac{1}{m-1}$$

Thus, we have to distinguish two cases:

Case 1: $s_m \leq \frac{1}{m-1}$, so that $\hat{p}_E^i \leq c_I \forall i$. Then, the upper bound on E's equilibrium price to buyer i is given by $\hat{p}_E^i$. For the entrant to be able to break even under such prices, we must have:

$$\sum_{i=1}^{m} s_i \hat{p}_E^i \geq c_E$$

Inserting for $\hat{p}_E^i$ and rearranging, we obtain:

$$c_E \leq \frac{c_I m - 1}{m-1} = \tilde{c}_I' \ll c_I$$

Case 2: $s_m > \frac{1}{m-1}$. Then, for the largest buyer (and possibly some others) $\hat{p}_E^i$ violates $p_E^i \leq c_I$, so that only the smaller buyers will be offered prices below c_I. Let the first $\{1, \ldots, l\}$ buyers receive general prices p_E^i, while the remaining $\{l+1, \ldots, m\}$ buyers are charged c_I. Then, E's prices must solve

$$\begin{bmatrix} 1 & p_E^2 & \ldots & p_E^l & c_I & \ldots & c_I \\ p_E^1 & 1 & \ldots & p_E^l & c_I & \ldots & c_I \\ \vdots & & \ddots & \vdots & & & \vdots \\ p_E^1 & p_E^2 & \ldots & 1 & c_I & & c_I \\ p_E^1 & p_E^2 & \ldots & p_E^l & 1 & c_I & c_I \\ \vdots & & & \vdots & c_I & \ddots & \vdots \\ p_E^1 & p_E^2 & & p_E^l & c_I & c_I & 1 \end{bmatrix} \times \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_l \\ s_{l+1} \\ \vdots \\ s_m \end{bmatrix} \leq \begin{bmatrix} c_I \\ \\ \\ \vdots \\ \\ \\ c_I \end{bmatrix}$$

The first l equations imply that $\left(1 - p_E^i\right) s_i = \left(1 - p_E^j\right) s_j \forall i, j \in \{1, \ldots, l\}$. The following $m - l$ equations only differ by the identity of the buyer from the $\{l+1, \ldots, m\}$ group who is charged the monopoly price. The highest rent available for redistribution among the small buyers is of course generated by the largest of these buyer; in other words, if equation m holds with equality, the remaining inequalities from $l+1$ to $m-1$ are satisfied as well. Then, we can solve for E's prices as:

$$\hat{p}_E^i = 1 - \frac{1}{s_i l}(1 - c_I)\left(\sum_{i=1}^{l} s_i + s_m\right)$$

where l is implicitly defined by the inequalities: $p_E^l \leq c_I$ and $p_E^{l+1} > c_I$. It is easily verified that such an l always exists; $p_E^1 < c_I$ is implied by $s_1 < s_1 + s_m$, and $l = m - 1$ coincides with Case 1. Again, we have that at least 1 buyer will pay a price strictly below c_I. This will again raise the efficiency threshold for E:

$$\sum_{i=1}^{l} s_i \hat{p}_E^i + \sum_{i=l+1}^{m} s_i c_I \geq c_E$$

reduces to

$$c_E \leq c_I (1 + s_m) - s_m = \tilde{c}_I'' \ll c_I$$

This completes the proof.□

Proof of Proposition 4: Any Perfectly Coalition-Proof Nash Equilibrium must be a subgame-perfect equilibrium and must involve coalition-proof Nash equilibrium behavior in the continuation subgames following firm I's offer (see Segal and Whinston [2000], p. 299). By construction of the entry equilibria of Proposition 3, they are all immune against all possible price offers by the incumbent inducing a deviation by a sufficiently large subgroup of buyers to deprive the entrant of the minimum size. This is equivalent to ruling out improving and self-enforcing deviations by coalitions in the continuation subgames. To see that the entry equilibria are subgame-perfect, just note that there is only one proper subgame (the buyer-choice stage), and that all buyers buying from E unless any of them has a strict incentive to deviate to I is indeed a Nash equilibrium for any possible first-stage price offers.□

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Notes

[1] See Kobayashi [2005] for a review of the US case law on rebates.

[2] In a recent rebate case, the European Commission gave a fine of more than 1bn euro to Intel. For a review of the EU case law on rebates, see e.g. Gyselen [2003].

[3] Case T-203/01, Manufacture Française des pneumatiques Michelin v. Commission, Judgment of the Court of First Instance of 30 September 2003. See Motta [2009] for a detailed discussion of this case.

[4] The (almost) per se illegality of exclusive contracts, rebates and discriminatory prices by dominant firms has led to a hot debate on the EU policy towards abuse of dominance. See Gual et al. [2006] for a contribution to the debate.

[5] United States vs. Microsoft Corporation, District of Columbia 1994, http://www.justice.gov/atr/cases/ms_index_licensing.htm

[6] Bernheim and Whinston [1998] analyze the possible exclusionary effects of exclusive dealing when firms make simultaneous offers (as in our paper), but in *non-coincident markets*: first, exclusivity is offered to a buyer in a first market; afterwards, offers are made to a buyer in a second market. In their terminology, our paper is looking at *coincident market* effects, which makes our analysis closer to Aghion and Bolton [1987], Rasmusen et al. [1991], Segal and Whinston [2000] and Fumagalli and Motta [2006]. All these papers, however, study only

exclusive dealing arrangements and assume that the entrant can enter the market (if at all) only *after* the incumbent and the buyers have negotiated an exclusive contract.

[7] Innes and Sexton [1993, 1994] consider a very different contracting environment, strategic variables, and timing of the game. In particular, after the incumbent made its offers, they allow the buyers to contract with the entrant (or to enter themselves), so as to create countervailing power to the incumbent's.

[8] Where incompatibility could be overcome through multi-homing, Shapiro [1999] argues that incumbents can use exclusive dealing contracts to block multi-homing, thus excluding a technologically superior firm.

[9] This tie-breaking rule will be helpful when characterizing equilibrium outcomes. It can be rationalized by introducing a tiny seller-specific transaction cost, ϵ, which the buyer would have to pay twice if it purchased from both suppliers. Nonetheless, we do allow buyers to split orders when it is in their interest to do so, i.e. when splitting allows them to reduce the overall expenditure on the units they buy. One example where such splitting may arise is the case of coupons discussed in Section III(iii).

[10] It also has the advantage that the old generation of buyers can be ignored when studying welfare effects: since we assume that they have already attained the highest level of utility, new buyers' decisions will never affect old buyers' utility. Of course, this means that we cannot formalise here the possibility that entry may hurt the old generation of buyers, but this is a well-known effect which does not need to be emphasised again.

[11] Note that we rule out mixed strategies for now. We will briefly comment on them in Section IV.

[12] In this situation, the entrant is indifferent among all prices $p_E \geq 0$ it could charge, and might as well offer the monopoly price, which weakly dominates all other possible equilibrium prices.

[13] In a previous version of the paper we showed that if we relaxed the assumption of non-negative prices, then exclusionary equilibria may not exist, since the entrant could make a single buyer deviate - by subsidizing it - even if all others bought from the incumbent.

[14] A coalition-proof equilibrium is such that no coalition has a self-enforcing deviation making all its members better off; a deviation is self-enforcing if there is no further self-enforcing and improving deviation available to a proper subcoalition of players (see Bernheim et al [1987]).

[15] Moreover, when $p_E = p_I = c_I$, there are also equilibria (call them 'coexistence equilibria') where some buyers (in a sufficient number for the entrant to reach the critical size) buy from the entrant and the remaining buyers buy from the incumbent. However, Proposition 3 focuses

on the socially efficient equilibria where the inefficient incumbent does not make any sales. (We will briefly come back to this issue at the end of this section.)

[16] To be more precise, recall that there are also some 'coexistence equilibria' where both I and E make positive sales (though I's sales are small enough for E to reach minimum size). These equilibria are of course inefficient and, similar to fully exclusionary equilibria, can only be sustained by continuation equilibria where buyers would all switch to the incumbent whenever E tried to undercut I on the buyers served by I. Thus, they are eliminated by coalition-proofness in quite the same way as exclusionary equilibria.

[17] If both incumbent and entrant are forced to screen, as we shall assume in our example, then not only the incumbent's pricing will be less aggressive, but also the entrant's ability to respond to such aggressive offers will be restrained. It is therefore not apriori clear that implicit discrimination makes it harder for the incumbent to break entry equilibria. However, as our example demonstrates, the trade-off tilts in favor of the entrant.

[18] While we assumed that buyers will not split orders among suppliers when the latter *both offer the same price*, we have not ruled out the possibility of one buyer buying from both suppliers whenever prices differ across suppliers, as is the case here.

[19] Such a rebate scheme may appear as somewhat unorthodox, since buyers are 'rewarded' for buying little and 'penalized' for buying a lot. However, this is a deviation offer which will never be made in equilibrium.

[20] We implicitly ruled out the possibility that the large buyer buys the small quantity $k/2$ *twice*. For certain parameter values, this mimicking strategy gives a higher surplus to the large buyer than buying $k/2$ just once. In this case, the relevant incentive constraint reads $(1-k)\left(1-\overline{p}_I^L\right) \geq 1-k-k\underline{p}_I^S$. For the sake of brevity, we omit the full technical treatment here, which is very similar to the one presented above. We are grateful to an anonymous referee for pointing out this case.

[21] We are grateful to Kai-Uwe Kühn for bringing this effect to our attention.

[22] see for instance European Commission [2008]'s Guidance Paper on exclusionary conduct and cases referred therein. The European Commission and the Courts have treated individualised rebates far more harshly than standardised rebates; the two main precedents are Michelin I and Michelin II. See Michelin, OJ [1981] L/353/33, [1982] 1 CMLR 643 (paras. 37-42); on appeal, Case 322/81 NV Nederlandsche Banden-Industrie Michelin v Commission [1983] ECR 3461, [1985] 1 CMLR 282 (paras. 71-86). And PO-Michelin, OJ [2002] L143/1, [2002] 5 CMLR 388 (paras. 260-264); on appeal, Case T-203/01 Michelin v Commission [2003] ECR II-4071, [2004] 4 CMLR 923 (paras. 58-60).

[23] However, European judges in *Michelin II* completely overlooked efficiency defences which

might well have justified some of the rebate schemes used by Michelin. See Motta [2009].

[24] Note that a crucial assumption for the exclusionary mechanism at work is that the incumbent has 'old' customers that the entrant cannot contest, due for instance to large switching costs. If old buyers were not captive to the incumbent, it would lose its incumbency advantage and entry would always exist. More generally, we showed in the working paper version of this paper that the higher the incumbent's installed base the larger the set of parameters for which entry equilibria would not exist.

[25] Our model is based on scale effects on the demand side, but similar results and considerations would apply to industries characterized by supply-side scale economies and in which a dominant firm has a strong incumbency advantage.