Exclusionary contracts and incentives to innovate

BY Simen A. Ulsaker

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Institutt for samfunnsøkonomi
Department of Economics

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Simen A. Ulsaker*

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Abstract

The article considers a situation where several firms have the opportunity to sell an identical product to a set of buyers, and where each seller can invest in R&D to develop a higher quality version of the product in question. If the sellers can offer exclusionary contracts prior to deciding how much to invest in R&D, every buyer will sign an exclusionary contract with the same seller in equilibrium. Since all buyers are locked to one seller, only this seller will have an incentive to invest in R&D. Whether or not banning exclusionary contracts increases the aggregate probability of successful innovation depends on the R&D technology. More specifically, banning exclusionary contracts will increase the aggregate probability of innovation and joint surplus of buyers and sellers only when the R&D technology exhibits sufficient diseconomies of scale.

*Telenor Research and Norwegian School of Economics. E-mail: simen.ulsaker@telenor.com. I would like to thank Lars Sørgard, Thibaud Vergé, Trond Olsen, Giancarlo Spagnolo and seminar participants at CREST (Paris) and CLEEN (Tilburg) for helpful comments.

1 Introduction

Why do firms innovate? The possibility of at least temporarily increasing their market power can be the prize that makes costly innovation worthwhile. Among the top 10 R&D spenders in 2018 we find technology companies such as Intel, Microsoft and Alphabet, and pharmaceutical firms such as Johnson & Johnson.[1] In innovative industries such as these, investment in R&D may lead to the development of technologies or products that gives the innovating firm a position as a market leader in a given segment. The present article considers the effect of allowing exclusionary contracts in such industries.

I follow a number of seminal articles by studying an innovation contest in which a number of firms may invests in R&D and where at most one firm can "win" (Fudenberg et al. 1983; Loury 1979). A natural interpretation is that patent protection gives the first innovator exclusive rights to market the innovation. In such a setting, I study the effect of allowing the sellers to offer exclusionary contracts to the buyers prior to deciding how much to invest in R&D.

In the model, several firms have the opportunity to sell an identical product to a set of buyers. Each seller has the opportunity to enter an innovation contest by investing in R&D. At most one firm will win the contest, and this firm will get the right to sell a higher quality version of the product in question. While a seller gains from winning the innovation contest, a buyer is indifferent about the outcome of the innovation contest. The reason is that regardless of whether there is innovation or not, the buyer will get a payoff equal to what she can get by buying the standard quality product at cost. In other words, the incremental gain from the use of the high quality version is entirely captured by the seller who wins the innovation contest.

I then consider the possibility of allowing the sellers to offer exclusionary contracts of the type considered by Rasmusen et al. (1991) and Segal and Whinston (2000) to the buyers, prior to deciding how much to invest in R&D. If a buyer accepts such a contract from a seller, it will be contractually prohibited from trading with other sellers. In equilibrium every buyer will sign an exclusionary contract with the same seller.

By signing exclusionary contracts with all buyers, one seller in effect becomes a monopolist in the innovation contest. As a consequence, this seller will increase its investment in R&D, while the incentive of the other sellers to invest in R&D is elimi-

[1] See https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html

nated. Whether or not the *aggregate* probability of successful innovation also increases will depend on the R&D technology. More specifically, banning exclusionary contracts will increase the aggregate probability of innovation when the R&D technology exhibits sufficient diseconomies of scale. However, banning exclusionary contracts may reduce joint surplus of the buyers and the sellers even when it increases the aggregate probability of succesfull innovation. Only when the efficiency gains from spreading the R&D technology across several firms is large enough will joint surplus increase when exclusionary contracts are banned.

The ability to offer exclusionary contract intensifies the competition for the buyers. As a consequence, the buyers benefit from the use of exclusionary contracts, while the ability to offer such contracts completely erodes the expected payoffs of the sellers. If the buyers are end-users, then consumer surplus is strictly increased by allowing exclusionary contracts. If on the other hand each buyer is local monopolist reselling the product in question, exclusionary contracts will increase the expected consumer surplus only if they increase the aggregate probability of innovation.

Most of the existing literature on exclusive dealing studies a situation in which an established incumbent is given a first-mover advantage by being able to offer contracts to one or several buyers before a potential rival seller enters the market. It is typically precisely this first-mover advantage that enables an incumbent to profitably exclude a more efficient entrant, often to the detriment of consumer and total surplus.[2] In this strand of the literature, the article that has most in common with the current one is Segal and Whinston (2007), which considers a dynamic setting.[3] In each period one seller is an incumbent, exclusively producing the leading quality version of a product. In addition, there is at least one potential rival who can invest in R&D. If a potential entrant innovates and acquires the exclusive rights to sell the next-generation version of the product, this firm enters the market in the current period and competes with

[2] The literature on exclusive dealing is rich. In addition to Rasmusen et al. (1991) and Segal and Whinston (2000), important contributions include Aghion and Bolton (1987) and Innes and Sexton (1994), who study the use of partially exclusionary contracts where the payment from a buyer to the incumbent is allowed to depend on whether the buyer buys from the entrant or not. Chen and Shaffer (2014) show how minimum-share requirements may be used to exclude a more efficient entrant, even in situations in which a fully exclusionary contract cannot. Fumagalli and Motta (2006) were among the first to study the use of exclusionary contracts when the buyers are downstream competitors, a strand of the literature that also includes Simpson and Wickelgren (2007) and Abito and Wright (2008).

[3] Another article that studies vertically differentiated sellers is Argenton (2010), which illustrates how an incumbent producer can use exclusionary contracts to profitably exclude a potential rival producing a higher quality product, when the buyers are two (undifferentiated) competing retailers.

the incumbent. In the next period it takes over the role as incumbent, and the old incumbent becomes a potential entrant. The authors consider the effect of allowing the current incumbent to write long-term (exclusionary) contracts with the buyers. In this setting, banning exclusionary contracts increases innovation and consumer surplus.[4]

In contrast to Segal and Whinston (2007), I assume that the sellers are ex-ante identical. Each seller has equal opportunity to try to distinguish itself from its rivals by investing in R&D. Further, the sellers have equal opportunity to offer exclusionary contracts. Whereas exclusionary contracts suppress innovation in Segal and Whinston (2007), the effect on the aggregate probability of innovation is ambiguous in the present article, and depends on the R&D technology. Moreover, exclusionary contracts enables more intense competition for the trade of the buyers in each period. As a consequence, the buyers are better off when exclusionary contracts are allowed, even when they suppress innovation.

In considering a situation where symmetric sellers are allowed to compete through offering exclusionary contracts the present article follows Mathewson and Winter (1987), who study a situation with two horizontally differentiated manufacturers and a large number of independent retailers, each a monopolist in its local marked. They find that the exclusionary contracts are used in equilibrium, and that they can have either anticompetitive or procompetitive effects. This result is qualified by O'Brien and Shaffer (1997) and Bernheim and Whinston (1998), who finds that if the manufacturers are allowed to offer nonlinear tariffs, they will no longer have an incentive to offer exclusionary contracts to a monopolist retailer, and that the efficient outcome where a monopolist retailer buys from both both manufacturers can be supported as an equilibrium. When the buyers in my model are interpreted as monopolist retailers, the use of exclusionary contracts in many situations reduce consumer surplus, total surplus or both. This is the case even though contracts are allowed to be nonlinear and information is complete.[5]

[4] In the main model of the article, the incumbent cannot invest in R&D. The authors also consider the use of long term contracts in a setting where also the incumbent is allowed to invest in R&D, and where the next best quality is always freely available to all potential producers. The main conclusions on the effect of exclusionary contracts carry over to this setting.

[5] Calzolari and Denicolò (2013) studies a similar setting, but assumes that a monopolist retailer has private information about its valuation of the products. The authors allow the sellers to offer menus of contracts, with both an exclusive and a non-exclusive option. In this setting, exclusionary contracts are used in equilibrium, even when nonlinear tariffs are allowed. However, while exclusionary contracts are offered (as an option), the buyer will buy from both sellers in many equilibria. In this setting, exclusionary contracts lead to more intense competition among the sellers, and thereby tend to lower prices and increase welfare.

The rest of the article is organized as follows. Section 2 presents the framework of the article, while section 3 supplies some preliminary results. The main analyses and results are contained in section 4. Effects on consumer surplus and total surplus are examined in Section 5. Section 6 considers a situation where the buyers are retailers. Section 7 concludes.

2 Framework

$N \geq 2$ sellers have the opportunity to supply a product to $M \geq 1$ buyers. Initially, every seller can offer identical versions of the product (the low quality version). However, each seller S_i can invest in R&D.[6] More precisely, let each S_i choose an R&D rate $\psi_i \in [0, 1]$ giving the probability at which it will make a discovery. The cost of R&D is given by the increasing and strictly convex function $c(\psi_i)$, where $c(0) = 0$.

If only one firm makes a discovery, this firm "wins" the innovation contest (i.e., is awarded a patent) and obtains the exclusive right to sell a high quality version of the product in question. If more than one firm makes a discovery, one firm will be chosen as the winner (more on this later).

Marginal cost of production is assumed to be constant and equal for both versions of the product, and is normalized to zero. Assume that a buyer will never want to buy positive quantities of both the low quality and the high quality version. Let $\pi(q, x)$ be the gross payoff of a buyer that buys x units of product type q, where $q = 0$ signifies the low version of the product and $q = 1$ signifies the high quality version. When only the low-quality product is available, the per buyer maximal gross surplus is given by $\max_x \pi(0, x) \equiv \Pi_0$. If the high quality is available, the maximized gross surplus is given by $\max_x \pi(1, x) \equiv \Pi_1$, where $\Pi_1 - \Pi_0 \equiv \Delta > 0$.

The following assumption implies that if there were only one seller in the industry, this seller would choose a strictly positive R&D rate.

Assumption 1. *$c'(0) < M\Delta$.*

Further, it will be assumed that as ψ approaches one, diseconomies of scale will eventually make further increases in the R&D rate prohibitively expensive.

Assumption 2. *$\lim_{\psi \to 1} c(\psi) = \infty$.*

[6] The modeling of the innovation process follows Segal and Whinston (2007) closely.

3 Preliminary analysis

This section considers the situation where the sellers are precluded from offering exclusionary contracts prior to the investment stage. More specifically, the interaction between the sellers and the buyers is modeled as follows.

Stage 1 Each S_i chooses a probability rate $\psi_i \in [0,1]$. The winner, if any, of the innovation contest obtains the right to sell the high quality version of the product.

Stage 2 Each seller S_i offers a two-part tariff (w_{ij}, f_{ij}) to each buyer B_j, consisting of a constant per-unit wholesale price, $w_{ij} \geq 0$, and a fixed fee, $f_{ij} \geq 0$. The buyers accept or reject each offer. The buyers order the desired quantities and payments are made according to accepted contracts.

The equilibrium concept used in this section and the next will be that of pure strategy subgame-perfect Nash equilibrium (hereafter equilibrium).

Let us first consider a situation in which no seller innovates. Then it is straightforward to see that every buyer must get the low-quality product at cost (i.e., for free) in any continuation equilibrium, giving each buyer a payoff of Π_0.

Lemma 1. *When no exclusionary contracts can be offered prior to the investment stage and no seller innovates, each buyer gets the product at marginal cost (equal to zero). Each buyer gets payoff equal to* Π_0*. Each seller gets a payoff of zero, gross of any R&D cost.*

Consider now a situation in which one seller, say S_i, won the innovation contest in Stage 1 after choosing the R&D rate ψ_i. It is easy to show that every buyer will buy from S_i in any continuation equilibrium, with $(w_{ij}, f_{ij}) = (0, \Delta)$ for each B_j. Further, the payoff of S_i will be $M\Delta - c(\psi_i)$, while the payoff of each buyer is again Π_0.

Lemma 2. *When no exclusionary contracts can be offered prior to the investment stage and* S_i *wins the innovation contest, every buyer will buy from* S_i *in all continuation equilibria. The payoff of* S_i *will be* $M\Delta - c(\psi_i)$*. The payoff of each buyer will be* Π_0*, while the payoff of the other sellers will be zero, gross of any R&D cost.*

We see from Lemma 1 and Lemma 2 that the equilibrium payoff of each buyer is the same, regardless of whether there is innovation or not: The winner of the innovation contest extracts the entire gain from the innovation.

Let us now turn to Stage 1 and the investment decision of the sellers. We will restrict attention to symmetric equilibria in which each of the N sellers chooses the same R&D rate, ψ. If only one seller makes a discovery, this seller will be awarded the patent. If several sellers makes a discovery, only one can be awarded the patent. Let $r(\psi, N)$ be the probability that a given seller is awarded the patent, conditional on it making a discovery, when the other sellers choose an R&D rate of ψ. Note that $r(0, N) = 1$, and assume that $r(\psi, N)$ is continuous in ψ and strictly decreasing in both arguments. Assume further that $r(\psi, N) > (1-\psi)^{N-1}$ for all $\psi \in (0, 1]$, where the right hand side of the inequality is the probability that no rival seller makes a discovery.[7]

Since the gain of winning the innovation contest is $M\Delta$, an equilibrium R&D rate ψ_N must satisfy the following condition.

$$\psi_N \in \arg\max_{\psi \in [0,1]} \{\psi r(\psi_N, N) M\Delta - c(\psi)\}.$$

The following lemma establishes that there is a unique and interior symmetric equilibrium.

Lemma 3. *When no exclusionary contracts can be offered prior to the investment stage, there is a unique symmetric equilibrium R&D rate $\psi_N \in (0, 1)$.*

Proof. Consider the best-response function $B(\psi_N, N) = \arg\max_{\psi \in [0,1]}\{\psi r(\psi_N, N) M\Delta - c(\psi)\}$. This function is single-valued, non-increasing and continuous in ψ_N (see the proof of Lemma $A1$ in Segal and Whinston (2007)). This means that the unique equilibrium is the fixed point of the function $B(\psi_N, N)$ on the $[0, 1]$ interval. Since $r(0, N) = 1$, Assumption 1 implies that $B(0) > 0$. Assumption 2 implies that $B(1) < 1$. It follows that the unique fixed point is interior. □

Since the equilibrium is interior and solves $\max_\psi\{\psi r(\psi_N, N) M\Delta - c(\psi)\}$, it will be implicitly defined by the following first order condition

[7] If the patent is awarded randomly to one of the sellers making a discovery, we have that

$$\begin{aligned} r(\psi, N) &= \sum_{k=0}^{N-1} \left(\frac{1}{k+1}\right) \binom{N-1}{k} \psi^k (1-\psi)^{N-1-k} \\ &= \frac{1-(1-\psi)^N}{\psi N} \end{aligned}$$

$$r(\psi_N, N)M\Delta - c'(\psi_N) = 0. \tag{1}$$

When every seller chooses the equilibrium R&D rate ψ_N, the expected payoff of each seller is $\psi_N r(\psi_N, N)M\Delta - c(\psi_N) \geq 0$. The following lemma sums up.

Lemma 4. *When no exclusionary contracts can be offered prior to the investment stage, each seller will get an expected payoff equal to* $\psi_N r(\psi_N, N)M\Delta - c(\psi_N) \geq 0$*, while each buyer gets a payoff equal to* Π_0*.*

As a preparation for the analysis in the following section, it will be useful to consider the effect of the number of sellers on the equilibrium R&D rate and on the aggregate probability of innovation. The equilibrium R&D rate is decreasing in the number of sellers.

Lemma 5. *The equilibrium per seller R&D rate* ψ_N *is decreasing in the number of sellers.*

Proof. Since the equilibrium value ψ_N is interior, it is given by the first order condition $r(\psi_N, N)M\Delta - c'(\psi_N) = 0$. The left hand side is strictly decreasing in both N and ψ_N. Suppose that we are in an equilibrium (i.e., the left hand side is zero). If N increases the left hand side becomes negative. In order to again make the left hand side equal to zero ψ_N must decrease. □

While the per seller R&D rate is decreasing in the number of sellers, the probability that at least one of the sellers successfully innovates may nevertheless be increasing in the number of sellers. This aggregate probability of innovation is given by $\phi(N) = 1 - (1 - \psi_N)^N$. The question is whether the R&D investment of an additional seller more than offsets the reduction in the investment of the existing sellers. Our assumptions are not such that we can give a general answer to this question.

A useful benchmark in what follows will be the equilibrium R&D rate of a monopolist seller. If there were only one seller, that is if $N = 1$, this seller would win the innovation contest if and only if it made a discovery, and the optimal rate of innovation would be given by

$$\psi_1 = \arg\max_{\psi \in [0,1]} \{\psi M\Delta - c(\psi)\}.$$

Our assumptions imply that ψ_1 will be implicitly defined by the first order condition $M\Delta - c'(\psi_1) = 0$.

4 Exclusionary contracts

In this section we add a Stage 0 before Stage 1 of the game specified in the previous section. In this stage, the sellers are allowed to offer the buyers (non-discriminatory) exclusionary contracts. The exclusionary contracts are offered simultaneously. As is common in the literature on exclusionary contracts, an exclusionary contract between a seller and a buyer cannot specify payments that are contingent on whether or not the buyer trades with a different seller at Stage 2.[8]

Specifically, an exclusionary contract between S_i and B_j makes it illegal for the buyer to buy from any other seller at Stage 2. In addition, the exclusionary contract can include a (possibly negative) upfront compensation y_i, paid by S_i to B_j. For simplicity, an exclusionary contract cannot include commitments on price. Given these assumptions, it is easy to verify that the following lemmas specify the equilibrium play in Stage 2.[9]

Lemma 6. *If B_j has signed an exclusionary contract with S_i it will buy from S_i using the two-part tariff $(0, \Pi_q)$, where $q \in \{0, 1\}$ is 0 if S_i sells the high quality product and 1 if S_i sells the high quality product.*

Lemma 7. *If B_j has not signed an exclusionary contract with any seller, it will buy from one of the sellers using the two-part tariff $(0, 0)$ if no seller offers the high quality product. If S_i sells the high quality product, B_j will buy from S_i using the two-part tariff $(0, \Delta)$.*

We will suppose that if a buyer is indifferent between signing an exclusionary contract and not signing any, it will sign.[10] The following proposition establishes that each buyer must sign an exclusionary contract with the same seller in any equilibrium, and that the buyers capture the entire expected surplus in the industry.

[8] Exclusionary contracts of this type is studied by among others Rasmusen et al. (1991), Segal and Whinston (2000) and Fumagalli and Motta (2006).

[9] The results in this section is not sensitive to the assumption that exclusionary contract cannot include price commitments. Firms payoffs and aggregate probability of innovation would be the same if we allowed the exclusionary contract to specify the price at which the buyer would be able to buy the low quality product, and/or the price at which it could buy the high quality product (if available from the seller in question).

[10] This tie-breaking rule is chosen solely for simplicity.

Proposition 1. *If exclusionary contracts can be offered prior to the R&D decisions, each buyer will sign an exclusionary contract with the same seller in any equilibrium. The equilibrium payoff of B_j will be $\Pi_0 + \psi_1 \Delta - (1/M)c(\psi_1) > \Pi_0$, while each seller gets an expected payoff equal to zero.*

Proof. Consider first the Stage 2 payoff of the buyers. By Lemma 7, a buyer that has not signed an exclusionary contract with any buyer will get a payoff equal to Π_0 regardless of whether there is successful innovation or not. A buyer that has signed an exclusionary contract will on the other hand by Lemma 6 get a Stage 2 payoff of zero.

Suppose that there exists an equilibrium in which a B_j rejects all exclusionary contract offers at Stage 0, and thus gets an equilibrium payoff equal to Π_0. Let $\bar{y}$ be the highest compensation offered at Stage 0. Since B_j chose to reject all offered exclusionary contracts, it must be the case that $\bar{y} < \Pi_0$ (we have assumed that indifferent buyers sign). It follows immediately that if B_j rejects all exclusionary contract offers, then all other buyers also reject all offers.

When no buyer signs an exclusionary contract in Stage 0, the continuation play will be as described in the previous section. The expected payoff of S_i will be $\psi_N r(\psi_N, N)M\Delta - c(\psi_N)$. Now let S_i deviate by offering an exclusionary contract with $y_i = \Pi_0$. Every buyer will accept this offer. Since following the deviation all buyers will be contractually prohibited from buying from the other sellers, these sellers will not invest in R&D. S_i will in Stage 2 get $M\Pi_0$ in revenue if it does not innovate, and $M\Pi_1$ in revenue if it innovates. The gain from innovation is thus $M\Delta$. In either case it pays a total amount of $M\Pi_0$ in upfront compensations. The expected profit of S_i following the deviation will therefore be given by

$$\max_{\psi}\{\psi M\Delta - c(\psi)\}.$$

Observe that S_i will choose an innovation rate equal to ψ_1, that is the innovation rate of a monopolist seller. To see that the deviation is profitable, note that the expected payoff of S_i after the deviation is

$$\begin{aligned}\psi_1 M\Delta - c(\psi_1) &\geq \psi_N M\Delta - c(\psi_N) \\ &> \psi_N r(\psi_N, N)M\Delta - c(\psi_N),\end{aligned}$$

where the first inequality comes from the optimality of ψ_1 and the second from the fact that $r(\psi_N, N) < 1$. We conclude that there cannot exist an equilibrium in which a retailer does not sign an exclusionary contract

Suppose now that in equilibrium more than one seller has had its offer accepted by at least one buyer at Stage 0. It must then be the case that two or more sellers have offered a compensation equal to $\bar{y} \geq \Pi_0$, where $\bar{y}$ again is the highest compensation offered in Stage 0. This cannot be an equilibrium, since by offering a slightly higher compensation, one of the sellers which had its exclusionary contract offer accepted would sign up all buyers. For small enough increase in compensation, this would increase this seller's expected payoff since it would reduce the R&D rate of the other sellers that offered $\bar{y}$ to zero.

We have now established that all buyers sign exclusionary contracts with one and the same seller in any equilibrium. All other sellers will have zero in payoff. The seller that has signed exclusionary contracts with the buyers, will then get an expected payoff equal to $M\Pi_0 + \psi_1 M\Delta - c(\psi_1) - M\bar{y}$. From this observation it is straightforward to see that $\bar{y} = \Pi_0 + \psi_1\Delta - (1/M)c(\psi_1)$ in equilibrium, which implies that the expected payoff of the seller that has signed exclusionary contracts with the buyers is zero. Otherwise one of the other sellers could offer a slightly higher compensation, sign exclusionary contracts with all buyer and obtain a strictly positive expected payoff. We conclude that the equilibrium payoffs must be as specified in the proposition. □

The intuition behind the Proposition 1 is simple. When no exclusionary contracts are signed, a seller that wins the innovation contest extracts the entire gain from upgrading from the low quality to the high quality version. Therefore, each buyer is willing to sign an exclusionary contract as long as it is guaranteed a payoff equal to Π_0. In the absence of exclusionary contracts, a seller gets a payoff (gross of the cost of R&D) equal to zero if it does not win the innovation contest, and $M\Delta$ if it wins. If it compensates each buyer with Π_0 in the exclusionary contract, a seller still gets a payoff (gross of cost of R&D) equal to zero if it does not innovate and $M\Delta$ if it innovates. However, signing exclusionary contracts with each buyer eliminates the rival sellers' incentives to invest in R&D. As a consequence, the seller in question has a higher probability of acquiring the patent (for a given R&D rate), and therefore a higher expected profit when it signs up the buyers on exclusionary contracts.

The ability to offer exclusionary contracts enables the sellers to compete more intensively for the buyers' trade. Absent exclusionary contracts, a seller that innovates will be able to extract rents from the buyers. As a consequence each seller is left with (weakly) positive expected payoff, even though they are ex-ante identical. Exclusionary contracts give the sellers an opportunity to offer the expected gain from innovation to the buyers. This intensifies the competition for the buyers to the extent that the buyers capture the entire expected payoff through the upfront compensations.

5 Consumer surplus, total surplus and aggregate probability of innovation

In contrast to what is often the case in the literature on exclusive dealing, it is the buyers that gain from the use of exclusionary contracts. If the buyers are end-consumers, allowing exclusionary contracts unambiguously increases consumer surplus and reduces firm profits. The effect of allowing exclusionary contracts on the joint surplus of the buyers and the sellers is however ambiguous. Let $JS(Z)$ be the joint surplus arising from investment in R&D when Z firms participate in the innovation contest. The joint surplus is given by

$$JS(Z) = \phi(Z)M\Delta - Zc(\psi_Z),$$

where $\phi(Z) = 1 - (1 - \psi_Z)^Z$ is the aggregate probability of successful innovation when Z firms choose the R&D rate ψ_Z.

When the buyers are end-consumers, the joint surplus is identical to the total surplus in the economy. Whether or not banning exclusionary contracts increases the joint surplus depends on the R&D technology.

Note first that when only one seller participates in the innovation contest, this seller will choose the socially optimal R&D rate (given that the number of participants being 1), since ψ_1 is implicitly defined by $M\Delta = c'(\psi_1)$. On the other hand, the following lemma establishes that when N firms participate in the innovation contest there is always excessive investment in R&D, in the sense that when the R&D rate is ψ_N a marginal reduction in this rate for all sellers increase joint surplus.

Lemma 8. *Absent exclusionary contracts, the equilibrium R&D rate ψ_N entails excessive investment in R&D in the sense that a marginal reduction in the per firm R&D rate increases the joint surplus of the sellers and the buyers.*

Proof. In equilibrium, the marginal effect of decreasing the R&D rate is given by

$$\begin{aligned}
\left.\frac{\partial JS}{\partial \psi}\right|_{\psi=\psi_N} &= N\left[M\Delta(1-\psi_N)^{N-1} - c'(\psi_N)\right] \\
&= N\left[M\Delta(1-\psi_N)^{N-1} - M\Delta r(\psi_N, N)\right] \text{ (By the optimality of } \psi_N) \\
&= NM\Delta\left[(1-\psi_N)^{N-1} - r(\psi_N, N)\right],
\end{aligned}$$

which is strictly negative since by assumption $r(\psi, N) > (1-\psi)^{N-1}$ for all $\psi \in (0, 1]$. $\square$

That there is over investment in R&D in equilibrium absent exclusionary contracts is intuitive. When a seller increases her R&D rate, the marginal effect on this seller's probability of winning the contest (which is what the seller cares about) is always higher than the marginal effect on the aggregate probability of innovation (which is what a social planner would care about), since part of the increase in the individual probability of winning comes at the expense of the rival sellers' probability of winning.[11]

In addition to the over investment arising when more than one seller is active in the innovation contest, one must also take into account the technological question regarding the most efficient way to do R&D in the industry. Because of the convexity of the cost function, it will always be cheaper to let $N \geq 2$ firms each choose an R&D rate equal to ψ/N than to let one firm choose ψ. However, when more than one seller invests in R&D one risks that more than one seller successfully innovates. This problem of potential duplication implies that the aggregate probability of innovation is strictly lower when N firms choose ψ/N than when one firm chooses ψ. If the cost of R&D is almost linear in the relevant range, it would be more efficient to only let one seller invest in R&D, even when a social planner could decide (symmetric) R&D rates for each active firm. If however the cost function is very convex, there could be significant gains from diversifying the innovation process across sellers.

Only when a social planner would prefer to spread the R&D investment across several sellers can banning exclusionary contracts increase joint surplus. Further, the potential efficiency gains from diversifying the R&D investment across the N firms must be sufficiently high to compensate for the over investment arising when more than one seller participates in the innovation contest.

[11] Similar results are found in several articles studying R&D competition, e.g. Loury (1979) and Dasgupta and Stiglitz (1980a,b).

As an illustration, consider the case where $M\Delta$ is normalized to 1, and the R&D technology is described by the cost function $c(\psi) = a\psi - b\ln(1-\psi)$, where $b > 0$ and $a + b \in [0, 1)$. The last term in the cost function ensures that as the R&D rate approaches 1, diminishing returns will eventually make further investments unprofitable. Further, assume that if several sellers make a discovery, the patent is awarded randomly to one of these firms. This implies that $r(\psi, N) = (1 - (1-\psi)^N)/\psi N$.

A measure of the convexity of the cost function is $\sigma(\psi) \equiv \frac{c''(\psi)}{c'(\psi)} = \frac{b}{a(1-\psi)^2 + b(1-\psi)} > 0$. This measure is decreasing in a, and is increasing (decreasing) in b whenever a is positive (negative): If a is positive, an increases in a or a decreases in b makes the (positive) linear term in the cost function more important, and as a consequence makes the cost function less convex.

If an aggregate probability ϕ is to be attained by letting Z sellers choose the same R&D rate, this rate is given by $1 - (1-\phi)^{1/Z}$. With the cost function considered, the cost K for a social planner of attaining the aggregate probability ϕ by imposing a symmetric R&D rate on Z sellers is then given by

$$
\begin{aligned}
K(\phi, Z) &= Z\left[c(1 - (1-\phi)^{\frac{1}{Z}})\right] \\
&= Z\left[a(1 - (1-\phi)^{\frac{1}{Z}}) - b\ln(1 - (1 - (1-\phi)^{\frac{1}{Z}}))\right] \\
&= Z\left[a(1 - (1-\phi)^{\frac{1}{Z}}) - \frac{b}{Z}\ln(1-\phi)\right] \\
&= Za(1 - (1-\phi)^{\frac{1}{Z}}) - b\ln(1-\phi)
\end{aligned}
$$

Note that when $a = 0$, K is independent of Z. That is, a given aggregate probability of innovation can be "produced" equally efficient regardless of the number of sellers sharing the investment in R&D. Further, treating Z as a continuous variable, we have that

$$
\frac{\partial K(\phi, Z)}{\partial Z} = \frac{a}{Z}(Z + \ln(1-\phi)(1-\phi)^{\frac{1}{Z}} - Z(1-\phi)^{\frac{1}{Z}}),
$$

which can be shown to have the same sign as a for $Z \geq 1$. That is, when $a > 0$, more firms sharing the R&D investment leads to higher cost of attaining a given aggregate probability level, whereas with $a < 0$ and the cost function is more convex, the opposite is true. Since banning exclusionary contracts always leads to over investment, it follows that banning exclusionary contracts can only increase joint surplus when $a < 0$ and there are potential cost savings from spreading the R&D activity across N firms.

Proposition 2. *Suppose $M\Delta$ is normalized to 1 and $c(\psi) = a\psi - b\ln(1-\psi)$, where $b > 0$, $a+b \in [0,1)$. Then, for any N, banning exclusionary contracts will decrease the joint surplus of the buyers and the sellers as long as $a \geq 0$.*

Another question is whether or not banning exclusionary contracts leads to a higher aggregate probability of innovation. When exclusionary contracts are allowed, every buyer signs an exclusionary contract with the same seller in equilibrium. Consequently, only one seller will invest in R&D and the probability of successful innovation is ψ_1. The seller that does invest in R&D will increase its R&D rate compared to when exclusionary contracts are not allowed, since $\psi_1 > \psi_N$. Whether or not this increase is sufficient to compensate for the discontinuation of the R&D activity of the other seller will depend on the R&D technology.

To consider the effect of banning exclusionary contracts on the aggregate probability of innovation, we restrict attention to $N = 2$. Now, when exclusionary contracts are allowed, only one firm will invest in R&D and the aggregate probability of innovation will be given by $1 = c'(\psi_1)$, implying that $\psi_1 = 1 - \frac{b}{1-a}$. When exclusionary contracts are not allowed, both firms will invest in R&D and the equilibrium per seller R&D rate will be implicitly given by $\frac{1-(1-\psi_2)^2}{2\psi_2} = c'(\psi_2)$, implying that $\psi_2 = \frac{3-2a-\sqrt{4a^2-4a+8b+1}}{2}$. Simple calculations imply that $\phi(2) \geq \phi(1) = \psi_1$ if and only if $a \leq 0.5$, which gives us the following proposition (See Appendix for details).

Proposition 3. *Suppose $M\Delta$ is normalized to 1, $N = 2$ and $c(\psi) = a\psi - b\ln(1-\psi)$, where $b > 0$, $a + b \in [0,1)$. Then, banning exclusionary contracts will increase the aggregate probability of innovation if and only if $a \leq 0.5$.*

Figure 1 plots the threshold that determines whether banning exclusionary contracts leads to higher aggregate probability of innovation and the threshold that determines whether banning exclusionary contracts increases the joint surplus of the buyers and the sellers when $N = 2$ (see Appendix for details). Banning exclusionary contracts increases the aggregate probability of innovation when $a \leq 0.5$, i.e., when the cost function is sufficiently convex. However, only to the left of the green dashed line does banning exclusionary contracts lead to an increase in the joint surplus of the sellers

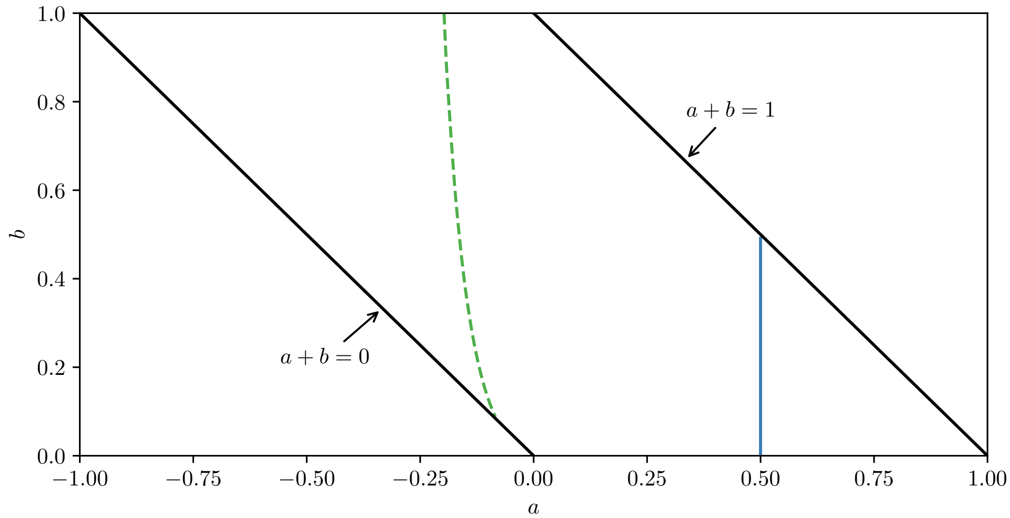

Figure 1: Critical combinations of a and b. In the area to the left (right) of the solid blue line, banning exclusionary contracts increases (decreases) aggregate probability of innovation. In the area to the left (right) of the dashed green line, banning exclusionary contracts increases (decreases) the joint surplus of the buyers and sellers.

and the buyers. In the area between the solid blue and the dashed green lines, banning exclusionary contracts increases the aggregate probability of innovation but still reduces the joint surplus of the buyers and the sellers.

6 Buyers are retailers

Suppose now that buyers are retailers, each a monopolist in a local market. Assume that each monopolist charges a single price in its market.[12] We know from the analysis above that the wholesale price will be equal to $c = 0$, regardless of whether exclusionary contracts are allowed or not, and that allowing exclusionary contracts may increase or decrease the probability of the high quality product being sold. We therefore conclude that as long as the end-consumers benefit when the high quality product is available, allowing exclusionary contracts increases consumer surplus if and only if $\phi(1) > \phi(N)$.

When the buyers are retailers, total surplus is no longer identical to the joint surplus of the buyers and sellers. Banning exclusionary contracts could then increase total surplus, even in situations in which it would decrease the joint payoffs of the buyers and

[12] If the monopolists could price discriminate perfectly, the analysis above would continue to hold.

sellers. When the buyers are retailers, a seller that has signed exclusionary contracts with all buyers no longer chooses the socially optimal R&D rate, since it disregards the effect of innovation on the consumer surplus. Further, it is no longer necessarily the case that there is over investment in R&D absent exclusionary contracts.

To consider the effect of banning exclusionary contracts on total surplus, let us again let $N = 2$ and $c(\psi) = a\psi - b\ln(1-\psi)$, where $b > 0$, $a + b \in [0, 1)$. Normalize M to 1, and let demand in each local market be given by $x = \frac{3}{2} + q - p$, where $q \in \{0, 1\}$ as before signifies the quality of the product. With this demand, the maximized gross profit is given by $\Pi_q^* = \frac{(3+2q)^2}{16}$, while consumer surplus is given by $CS(q) = \frac{(3+2q)^2}{32}$. This implies that $M\Delta = 1$, and that the gain in total surplus from successful innovation (gross of the cost of R&D) is $\frac{3}{2}$. Since $M\Delta = 1$, we know from Proposition 3 that banning exclusionary contracts reduces the aggregate probability of innovation, and consequently the consumer surplus, if and only if $a \leq 0.5$. The total surplus is however no longer identical to the joint surplus of the buyers and the sellers, and banning exclusionary contracts may increase total surplus even when it decreases the joint surplus of the buyers and the sellers. Critical combinations of a and b are given in Figure 2 (see Appendix for details).

As long as $a \leq 0.5$, banning exclusionary contracts increases the aggregate probability of innovation (and consumer surplus) but, as illustrated by Figure 2, total surplus may still decrease because exclusionary contracts prevent duplication of innovation. Only to the left of the dotted red line in Figure 2 does banning exclusionary contracts increase total surplus. Furthermore, only in the area to the left of dashed green line does banning exclusionary contracts increase the joint surplus of the sellers and buyers. In the area between the dashed green and the dotted red lines, banning exclusionary contracts increases total surplus even though it reduces the joint surplus of the buyers and sellers.

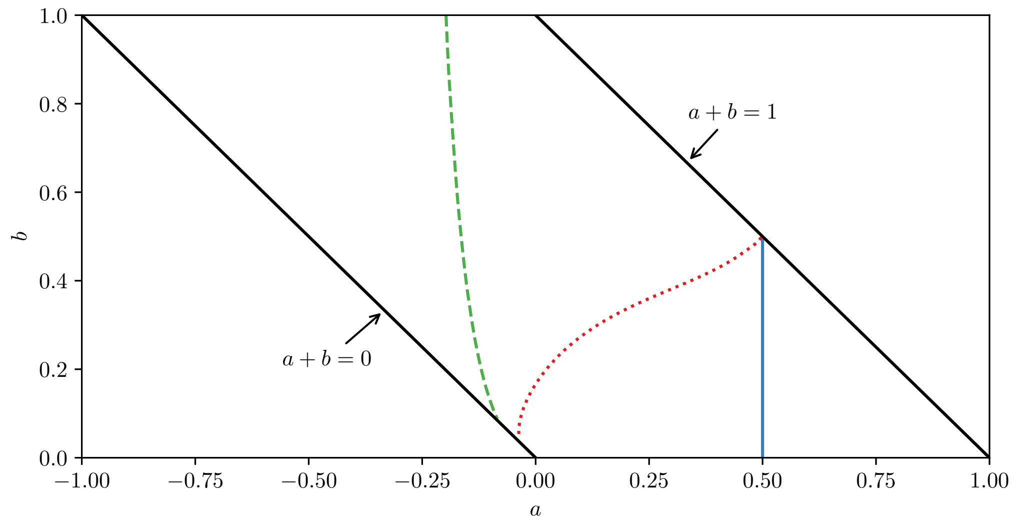

Figure 2: Critical combinations of a and b when buyers are monopolist retailers. In the area to the left (right) of the solid blue line, banning exclusionary contracts increases (decreases) aggregate probability of innovation. In the area to the left (right) of the dotted red line, banning exclusionary contracts increases (decreases) total surplus. In the area to the left (right) of the dashed green line, banning exclusionary contracts increases (decreases) the joint surplus of the buyers and sellers.

7 Conclusion

The article has illustrated how innovative industries may be prone to exclusion. In a setting with ex-ante identical sellers and perfect information, exclusion occurs in every equilibrium. As a consequence, only one seller will have an incentive to invest in R&D. Whether or not the aggregate probability of innovation is higher when exclusionary contracts are allowed depends on the R&D technology: Only when the R&D technology exhibits sufficient diseconomies of scale will the use of exclusionary contracts suppress innovation. The ability to offer exclusionary contracts makes the sellers compete more fiercely for the buyers. The buyers therefore gain from the use of exclusionary contracts. However, when buyers are retailers, exclusionary contracts may still decrease consumer surplus. This article thus illustrates that anti-competitive exclusion may occur even when all buyers are better off.

Appendix

This appendix contains calculations for the example where $M\Delta$ is normalized to 1, $N = 2$ and $c(\psi) = a\psi - b\ln(1-\psi)$, where $b > 0$, $a + b \in [0, 1)$.

When exclusionary contracts are allowed, only one firm will invest in R&D and the aggregate probability of innovation will be given by the following first order condition

$$\underbrace{1}_{r(\psi_1,1)M\Delta} = \underbrace{a + \frac{b}{1-\psi_1}}_{c'(\psi_1)}, \tag{2}$$

which implies that $\psi_1 = 1 - \frac{b}{1-a}$.

When exclusionary contracts are not allowed, both firms will invest in R&D and the equilibrium per seller R&D rate will be implicitly given by the following first order condition

$$\underbrace{\frac{1-(1-\psi_2)^2}{2\psi_2}}_{r(\psi_2,2)M\Delta} = \underbrace{a + \frac{b}{1-\psi_2}}_{c'(\psi_2)}$$

This equation has two solutions, but only the following gives positive values for ψ_2 in the relevant parameter ranges.

$$\psi_2 = \frac{3 - 2a - \sqrt{4a^2 - 4a + 8b + 1}}{2}.$$

Banning exclusionary contracts will increase the aggregate probability of innovation if and only if

$$\underbrace{1-(1-\psi_2)^2}_{\phi(2)} - \underbrace{\psi_1}_{\phi(1)} \geq 0,$$

which can be written as

$$\frac{2a-1}{2(a-1)}(3a-2b-2a^2-1+(1-a)\sqrt{4a^2-4a+8b+1}) \geq 0.$$

The first term in this expression is positive if and only if $\alpha \leq 0.5$. The second term is positive if and only if $4b(1-a-b) \geq 0$, which is true by assumption. It follows that the whole expression is true, and consequently that banning exclusionary contracts will increase the aggregate probability of innovation, if and only if $\alpha \leq 0.5$, which is what is stated in Proposition 3 and illustrated by the solid blue lines in Figures 1 and 2.

Let us now consider the joint surplus of the buyers and the sellers. The joint surplus from innovation when exclusionary contracts are allowed is

$$JS(1) = \underbrace{\psi_1}_{\phi(1)} - \underbrace{(a\psi_1 - b\ln(1-\psi_1))}_{c(\psi_1)},$$

while the joint surplus when exclusionary contracts are banned is given by

$$JS(2) = \underbrace{1-(1-\psi_2)^2}_{\phi(2)} - \underbrace{2(a\psi_2 - b\ln(1-\psi_2))}_{2c(\psi_2)}.$$

Banning exclusionary increases the joint surplus if and only if $JS(2) \geq JS(1)$, which can be written as

$$\frac{1}{2}(\sqrt{4a^2-4a+8b+1} + 4b\ln(a+\frac{1}{2}\sqrt{4a^2-4a+8b+1}-\frac{1}{2}) - 2b\ln(\frac{b}{1-a}) - 2b - 1) \geq 0.$$

This condition is represented by the dashed green line in Figures 1 and 2.

Finally, let us consider the total surplus when the buyers are monopolist retailers. The gross gain in total surplus from successful innovation is given by

$$\frac{(3+2)^2}{16} + \frac{(3+2)^2}{32} - (\frac{3^2}{16} + \frac{3^2}{32}) = \frac{3}{2}$$

The total surplus from innovation when exclusionary contracts are banned is then given by

$$TS(2) = \phi(2)\frac{3}{2} - 2c(\psi_2).$$

The total surplus from innovation when exclusionary contracts are allowed is given by

$$TS(1) = \phi(1)\frac{3}{2} - c(\psi_1).$$

Banning exclusionary contracts increases the total surplus if and only if $TS(2) \geq TS(1)$, which can be written as

$$\begin{aligned}\frac{1}{4(1-a)}\{&7a - 6b + 2a^2\sqrt{4a^2-4a+8b+1} + 3\sqrt{4a^2-4a+8b+1} - 4b\ln(\frac{b}{1-a}) + \\ &8b\ln(a + \frac{1}{2}\sqrt{4a^2-4a+8b+1} - \frac{1}{2}) - 5a\sqrt{4a^2-4a+8b+1} + 8ab - 8a^2 + 4a^3 + \\ &4ab\ln(\frac{b}{1-a}) - 8ab\ln(a + \frac{1}{2}\sqrt{4a^2-4a+8b+1} - \frac{1}{2}) - 3\} \geq 0.\end{aligned}$$

This condition is represented by the dotted red line in Figure 2.

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NORGES HANDELSHØYSKOLE
Norwegian School of Economics

Helleveien 30
NO-5045 Bergen
Norway

T +47 55 95 90 00
E nhh.postmottak@nhh.no
W www.nhh.no