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The Incentives for Takeover in Oligopoly

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ABSTRACT

The Incentives for Takeover in Oligopoly*

by Roman Inderst and Christian Wey

This paper presents a model of takeover incentives in an oligopolistic industry, which, in contrast to previous approaches, takes both insiders' and outsiders' gains from an increase in industry concentration into account. Our main application is to compare takeover incentives in a differentiated Cournot and Bertrand oligopoly model with linear demand and costs. We provide a complete analysis for arbitrary numbers of firms, complements and substitutes, and degrees of product differentiation. An increase in concentration is more likely under Cournot competition if products are complements and more likely under Bertrand competition if products are substitutes. Moreover, as products become closer substitutes, a takeover becomes more likely under Bertrand and less likely under Cournot competition.

Keywords: Merger, Takeover Bidding, Oligopoly

JEL Classification: D43, D44, L10, L41

ZUSAMMENFASSUNG

Übernahmeanreize im Oligopol

In dieser Arbeit wird ein Modell zur Analyse von Fusionsanreizen vorgestellt, in dem – im Gegensatz zu vorhergehenden Untersuchungen – sowohl die Gewinnzuwächse der an der Fusion beteiligten Firmen als auch die Gewinnveränderungen der Konkurrenzunternehmen die Übernahmewahrscheinlichkeit bestimmen. Die wichtigste Anwendung ist der Vergleich der Übernahmeanreize im Cournot- und Bertrand-Oligopol mit differenzierten Gütern und linearen Nachfrage- und Kostenfunktionen. Die Arbeit bietet eine vollständige Analyse für eine beliebige Anzahl von Unternehmen, komplementäre und substituierbare Güter und unterschiedliche Grade der Produktdifferenzierung. Eine Zunahme der Konzentration in einer Industrie ist wahrscheinlicher bei Cournot-Konkurrenz, wenn die Güter komplementär sind, und wahrscheinlicher bei Bertrand-Konkurrenz, wenn die Güter substituierbar sind. Des Weiteren steigt (sinkt) die Übernahmewahrscheinlichkeit mit zunehmender Substituierbarkeit der Güter bei Bertrand- (Cournot-) Konkurrenz.

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1 Introduction

Traditional analysis of takeover or merger incentives in oligopolistic industries focuses on conditions of stability. Essentially, this analysis asks whether insiders would be better off by staying independent instead of merging their businesses. This criterion is most explicit in axiomatic approaches on endogenous cartel formation (see, e.g., Selten (1973)) and ownership structures (see, e.g., Horn and Persson (2001)), and it is used in the seminal work of Salant, Switzer, and Reynolds (1983) and Davidson and Deneckere (1985) on exogenously proposed mergers. But it also drives the analysis of pure strategy equilibria in the simultaneous auction model of Kamien and Zang (1990).

One implication of the standard approach is that the outsiders' share of total industry gains that arise from concentration plays no role for predicting merger incentives. Besides neglecting potentially relevant information, which may prove useful for empirical studies, the stability approach yields rather extreme predictions. Most notably, Salant, Switzer, and Reynolds (1983) find that in the linear Cournot model with homogeneous products only a bilateral merger to monopoly is stable, while Davidson and Deneckere (1985) show for the linear Bertrand model with differentiated products that any bilateral merger is stable.¹ At the same time, however, outsiders gain more than insiders in both models. To our knowledge, the resulting *free-rider problem* due to the public good character of increasing industry concentration has not yet been fully incorporated in theoretical approaches dealing with merger incentives.

¹More recent literature has challenged these results by considering, e.g., cost savings (e.g., Perry and Porter (1985)), behavioral asymmetries (e.g., Levin (1990)), or more general demand conditions (e.g., Cheung (1992)).

Casual observations suggest that the public good nature of increased concentration and its implications for takeover strategies are important. For example, Stigler (1950) points out that *“the major difficulty in forming a merger is that it is more profitable to be outside a merger than to be a participant.”* A recent example is provided by the depressed semiconductor industry, where rumors of (further) consolidation among chipmakers tend to boost share prices of all market participants.² Illustrative are also reactions to the recent announcement of Japan’s Nippon Steel that it intends to tie-up its business with those of Sumitomo Metal Industries and Kobe Steel. Together with hopes of further mergers in the US this considerably boosted share prices for European steel makers. Interestingly, the head of the newly formed European steel maker Arcelor called for further mergers within the steel industry when commenting on the intentions to consolidate the Japanese steel industry.^{3,4}

To capture the free-rider problem and thereby incorporate both insiders’ and outsiders’ profits into the takeover prediction, we propose to model the takeover process as an auction in which a designated target optimally sets its reserve price. Under relatively standard symmetry restrictions on firms’ characteristics, we obtain a simple and intuitive prediction for the probability of takeover. This probability is only a function of the number of market participants and of the insiders’ share of total industry gains due to the increase in concentration. Typically, the takeover probability is less than one as,

²Financial Times UK, 4th December, 2001.

³Financial Times Europe, 13th December, 2001.

⁴A number of studies has reported abnormal stock returns for competitors, e.g., Eckbo (1985). However, the source of these positive rival returns is still disputed (see, e.g., Song and Walking (2000) for a recent account of the literature).

given the target's optimal reserve price, being an outsider will be more profitable than becoming an insider. Our major application is to provide a complete characterization of takeover incentives in the N -firm linear Cournot and Bertrand case.

More precisely, our analysis proceeds in two steps. Section 2 solves the takeover model and discusses the implied predictions. Amongst other things, our bidding game reveals an hitherto unexplored difference between fixed and marginal cost synergies. In contrast to marginal cost synergies, fixed cost synergies of any size never imply that a takeover will be successful with probability one. Consequently, from a welfare perspective it is likely that there are too few takeovers with fixed cost synergies.

Section 3 applies the takeover model to the study of the N -firm linear Bertrand and Cournot case. We find that an increase in concentration is more likely under Bertrand competition if goods are substitutes and more likely under Cournot competition if goods are complements. Moreover, we show that the probability of takeover is decreasing in the degree of substitutability between products under Cournot competition and increasing under Bertrand competition. Our analysis for the linear case therefore provides a complete picture how the mode of competition, the character of goods, and the differentiation of products affect market concentration. Despite the prominence of the linear model in the theoretical literature on industrial organization, such an analysis has, to our knowledge, not been undertaken so far.

Incidentally, in the course of our analysis, we also obtain a complete characterization of the stability condition with differentiated substitutes and complements in the linear model, which, to our knowledge, has also not been provided so far.

Finally, by linking the mode of competition and the likelihood of takeover we can

complement previous work on the welfare comparison of Bertrand and Cournot competition. This line of research was initiated by Singh and Vives (1984) and Vives (1985) (see also more recently Dastidar (1997), Qiu (1997), and Häckner (2000)). We argue that a comparison of total welfare must take into account the possibility of further concentration, which may counteract gains in consumer surplus arising from a more competitive mode of strategic interaction.

We are only aware of two recent papers by Molnar (2000) and Fridolfsson and Stenrek (2000) that also consider how insiders fare relatively to outsiders. However, both papers focus on unprofitable preemptive mergers and neither of them considers reserve price maximization nor makes the subsequent market interaction in form of Cournot or Bertrand competition explicit. As firms interact in the market, our model of takeover represents an auction with externalities. From this strand of the literature Jehiel and Moldovanu (2000a,b) are most closely related as they also consider downstream interaction among bidders. In contrast to our paper, these papers focus on the interdependency between allocative and informational externalities and on the optimal design of licence auctions, respectively.

2 The General Model

2.1 The Bidding Game

Consider an industry with $N > 2$ firms, indexed by $i \in I = \{1, \dots, N\}$, which produce symmetrically differentiated products and face the same cost conditions. If the N inde-

pendent firms compete in the market, they realize the same profit denoted by $\Pi^N > 0$. Let firm $i = 1$ be the target firm, which is exogenously picked.⁵ We assume that the target firm remains active in the market if there is no takeover, implying, for instance, that a financial investor or a firm operating in a different market would step in if intra-industry takeover fails. Suppose the takeover is successful. This reduces the number of independent firms to $N - 1$. If $N - 1$ firms compete in the market, the integrated firm, which controls multiple products, i.e., that of the target and the acquirer, realizes the profit Π_M^{N-1} . The $N - 2$ symmetric outsiders, which control a unitary product, realize Π_U^{N-1} . Denote $\pi_M = \Pi_M^{N-1} - 2\Pi^N$ and $\pi_U = \Pi_U^{N-1} - \Pi^N$. Total industry gains from an increase in concentration are then given by $\pi^* = \pi_M + (N - 2)\pi_U$. In the light of the following applications, we can restrict consideration to cases where, following takeover, total industry profits strictly increase.⁶

Assumption 1. *Industry profits strictly increase after takeover: $\pi^* > 0$.*

Note that this assumption implies, in particular, that either $\pi_U > 0$ or $\pi_M > 0$ must

⁵This can be explained, e.g., by generational handoffs of family-owned firms or unforeseen adverse shocks. For instance, the takeover of Camron Iron Works' by Cooper Industries in 1989 provides a well-documented example (see Kaplan, Mitchell, Wruck (1997)), in which a publicly traded company became a likely acquisition target after the family, which largely controlled the company, expressed its intention to sell. For broader empirical evidence on the characteristics of targets see Morck, Shleifer, and Vishny (1988).

⁶This condition rules out the case where $\pi_M < 0$ and $\pi_U < 0$ holds, for which we find multiple symmetric (bidding) equilibria. In these cases there is, however, always an equilibrium where no takeover takes place. If we select this equilibrium, which maximizes industry profits, Proposition 1 also extends to these cases.

hold strictly.

We now specify the takeover game as an auction in which the target can commit to a reserve price. This formulation incorporates two distinctive features of real-world takeovers for corporate control. Predominant takeover regulation in the United States encourages the board of directors to structure the sale of the firm's assets as an auction, while it is generally believed that the firm's board has considerable power in extracting rents from bidders. For instance, Cramton (1998) compares the various tactics employed by the target firm (most importantly the use of poison pills) to setting an (implicit) reserve price.⁷ While our proposed takeover game incorporates these features, our focus on the issue of a free-rider problem among competing firms leads us to abstract from the role of informational incompleteness or institutional details such as toeholds, minority shareholders, or participation costs.⁸

The takeover process involves two stages. In the first stage, the target commits to sell to the highest bidder if the respective price does not fall short of a reserve price B , which is chosen by the target. (We comment below on the outcome if the target can not commit.) In the second stage, buyers simultaneously submit bids. When analyzing the takeover game, we restrict attention to subgame perfect equilibria where bidders choose symmetric strategies and where ties are broken randomly. (We comment below on the justification of this requirement.) An outcome of the takeover game consists thus

⁷Comment and Schwert (1995) provide empirical evidence showing that such measures increase the expected takeover premium.

⁸The public good problem on which we focus is different from that analyzed in the finance literature, where the refusal of individual shareholders to tender their shares may frustrate a value enhancing takeover (see Grossman and Hart (1980)).

of a reserve price set by the target, the posted bids, and the selected acquirer (if any). Under the symmetry restriction we find a unique equilibrium. In what follows we are only interested in the industry's takeover probability, which we denote by ρ . We thus restrict the description of the equilibrium to ρ .

Proposition 1. *The takeover game has a unique equilibrium outcome where bidders use symmetric strategies. The takeover probability ρ is given as follows:*

(i) *If $\pi_M \leq 0$ then $\rho = 0$.*

(ii) *If $\pi_U \leq 0$ then $\rho = 1$.*

(iii) *If $\pi_M > 0$ and $\pi_U > 0$ then*

$$\rho = 1 - \left(1 - \frac{\pi_M}{\pi^*}\right)^{N-1}. \quad (1)$$

Proof. By Assumption 1, we only have to consider the following cases (i)-(iii) stated in the proposition. Assertion (i) is immediate because the merger is unprofitable. We can thus restrict consideration to the cases (ii) and (iii) where $\pi_M > 0$. Suppose that the target sets B such that

$$\Pi_M^{N-1} - \Pi_U^{N-1} \leq B \leq \Pi_M^{N-1} - \Pi^N, \quad (2)$$

implying by optimality that any serious bid will just match the reserve price B . As we restrict consideration to symmetric bidding strategies, denote by r the probability with which each firm $i > 1$ bids seriously. Given (2) this probability will be determined by an indifference requirement. To determine this indifference condition between posting the bid B and abstaining from putting in a serious bid, it proves to be more convenient to take a slightly different approach. If a firm is indifferent between these two strategies,

it is as well indifferent between abstaining from bidding and bidding seriously with probability r . In the first case the probability of takeover is just $1 - (1 - r)^{N-2}$. The firm's expected payoff from this strategy is then equal to

$$[1 - (1 - r)^{N-2}] \Pi_U^{N-1} + (1 - r)^{N-2} \Pi^N. \quad (3)$$

If the firm decides to bid with probability r , its expected payoff is determined as follows. From an ex-ante perspective, i.e., before the firm has rolled the dice to determine whether to bid seriously or not, takeover takes now place with probability $1 - (1 - r)^{N-1}$. Moreover, the firm expects to buy the target with probability $[1 - (1 - r)^{N-1}]/[N - 1]$.⁹ Hence, the expected payoff from mixing with probability r is equal to

$$[1 - (1 - r)^{N-1}] \left[\frac{1}{N - 1} (\Pi_M^{N-1} - B) + \frac{N - 2}{N - 1} \Pi_U^{N-1} \right] + (1 - r)^{N-1} \Pi^N. \quad (4)$$

Requiring now that (3) equals (4), we obtain the condition

$$B = \Pi_M^{N-1} - \Pi_U^{N-1} + (\Pi_U^{N-1} - \Pi^N)(N - 1) \frac{r(1 - r)^{N-2}}{1 - (1 - r)^{N-1}}. \quad (5)$$

Condition (5) determines for each B satisfying (2) a unique equilibrium bidding probability and vice versa. Substituting into the target's payoff, which we denote by Ω , we obtain

$$\begin{aligned} \Omega &= (1 - r)^{N-1} \Pi^N + (\Pi_U^{N-1} - \Pi^N)(N - 1)r(1 - r)^{N-2} \\ &\quad + [1 - (1 - r)^{N-1}] (\Pi_M^{N-1} - \Pi_U^{N-1}). \end{aligned}$$

⁹This expression is simply determined by the requirement that the sum of all firms' individual takeover probabilities must sum up to $1 - (1 - r)^{N-1}$. (Note that firms follow symmetric and uncorrelated strategies.)

Differentiating with respect to r yields

$$\Omega'(r) = (1-r)^{N-3}(N-1)[\pi_M - r\pi^*]. \quad (6)$$

By (6) Ω is strictly quasiconcave over $0 \leq r \leq 1$. We are now in the position to prove the assertion for the cases (ii) and (iii). Consider first case (iii), where $\pi_M > 0$ and $\pi_U > 0$, implying by (6) that Ω has a unique interior optimum at

$$r = \frac{\pi_M}{\pi^*}. \quad (7)$$

Substituting (7) into the probability of takeover yields (1). It remains to show that (2) must be satisfied. As $B > \Pi_M^{N-1} - \Pi^N$ implies $r = 0$ and as $r = 1$ holds for all $B < \Pi_M^{N-1} - \Pi_U^{N-1}$, these choices of B are not optimal for the target.

Turn next to case (ii), where $\pi_U \leq 0$. This implies by (6) that Ω is strictly increasing in r and obtains its maximum at the corner $r = 1$, so that $\rho = 1$. We can again exclude all choices $B > \Pi_M^{N-1} - \Pi^N$ and $B < \Pi_M^{N-1} - \Pi_U^{N-1}$. **Q.E.D.**

Proposition 1 states that the takeover probability is only a function of the number of firms and the share of total industry gains that is appropriated by the insiders. The takeover probability is equal to zero if only outsiders gain from concentration. It is equal to one only if outsiders will not gain at all. As demonstrated below, this is typically only the case if insiders enjoy synergies by which their marginal costs are reduced. Consider next the intermediate case, in which both insiders and outsiders gain. Regardless of the relative size of π_U and π_M , we find that the target sets the reserve price sufficiently high such that $0 < \pi_M - B < \pi_U$. While all firms benefit from a takeover, given this choice of the reserve price any bidder would prefer to stay an outsider rather than to win the

auction. In equilibrium each bidder randomizes over bidding the posted reserve price B or abstaining, e.g., by putting in an unacceptable offer. By (7) the probability with which each firm bids seriously is equal to the insiders' share of profits.

In what follows, we investigate how various factors influence the probability of takeover. By (1) this only amounts to analyzing how the insiders' share of total gains π_M/π^* change. In particular, we will consider the role of fixed and marginal cost savings in this section, while Section 3 considers the choice of Bertrand or Cournot competition, the substitutability or complementarity of goods, and the role of product differentiation in a linear model.

Before proceeding with the analysis, we comment on some aspects of our bidding game. Consider first the restriction to symmetric bidding equilibria. In the most interesting case when both insiders and outsiders benefit from concentration the bidding game has always multiple asymmetric equilibria where some firm(s) are made the primary acquirer(s) and the remaining firms abstain from bidding. In particular, there always exists an equilibrium where some firm $i \geq 2$ takes over the target and pays the price $\Pi_M^{N-1} - \Pi^N$. By selecting this equilibrium we obtain the extreme prediction that a takeover occurs with probability one and leaves the acquirer with zero gains. In particular, the profit differential π_U does not affect the outcome. Furthermore, coordination on asymmetric equilibria may be impossible if there are no explicit coordination

mechanisms or if players can neither negotiate efficiently nor write binding contracts.^{10,11}

It may be questioned whether the target can fully commit to a reserve price. In the absence of a reserve price exceeding Π^N , it generally holds in case (iii) that the probability of takeover is strictly higher than that in (1). In particular, the probability is always equal to one if the gains of insiders do not fall short of those of outsiders. As noted above, the optimal choice of the reserve price by the target *creates* a public good problem amongst bidders even if insiders gain more than outsiders, while otherwise the already existing public good problem becomes more aggravated.^{12,13}

Finally, as argued in the introduction, we feel that the route taken in this paper has the advantage of incorporating more information into the prediction of takeovers and therefore of the prevailing industry concentration. It may now be argued that as long as

¹⁰Similar symmetry restrictions are often invoked in the literature on war of attrition games (see for an overview Fudenberg and Tirole (1991)). It might be argued that the target can break the coordination problem by determining a “preferred” bidder. However, unless we introduce a different game, this communication does not alter the equilibrium set.

¹¹Harsanyi’s (1973) purification theorem provides a rationale for interpreting the symmetric mixed strategy equilibrium we select. From this perspective, we may interpret the mixed-strategy equilibrium of the complete-information bidding game as the limit of pure-strategy equilibria of slightly perturbed games of incomplete information where, for example, buyers have private information about their (statistically independent) payoffs in case of takeover.

¹²Formally, by substituting $B = \Pi^N$, the individual bidding probabilities r are obtained implicitly by equation (5) in case $\pi_M < \pi_U$ holds.

¹³The target may likewise lack the commitment not to sell in the future if the current bids fall short of its reserve price. If this is the case, an extension of our model would allow for repeated auctions, taking place with some delay. Delay may be costly as players discount future payoffs and as they obtain in the meantime the N -firm oligopoly profits (per period of time).

a takeover benefits insiders these gains should be realized, at least in the long run. In this respect our results present a short-run prediction of takeover activity. If the market is, however, constantly re-shaped by exogenous forces, prompting entry and exit, the public good effect underlying Proposition 1 may well have permanent implications for the prevailing degree of concentration.

2.2 Cost Synergies

While still confining ourselves to a reduced form for firms' profits, we can use Proposition 1 to investigate how cost synergies affect the takeover probabilities. This reveals a fundamental difference between fixed and marginal cost reductions.

Suppose first that the takeover decreases insiders' fixed costs, e.g., by reducing overhead expenditures. To express this in a parsimonious way, assume that integrating their business allows insiders to reap some windfall gain of $f \geq 0$. In a slight abuse of notation the profit differential of insiders is thus equal to $\pi_M + f$. As firms' strategies on the output market are not affected, the profit differential of outsiders remains unaffected. Under standard conditions, which, for instance, prevail in the linear case analyzed in the following section, outsiders are always positively affected by a higher concentration as long as the integrating firms do not enjoy a reduction in marginal costs. Given $\pi_U > 0$, we know from (1) that regardless of the size of f the takeover probability will always stay below one. As f becomes high, it is, however, very likely that the takeover increases welfare, even after taking into account a possible reduction in consumer rents. Hence, if fixed cost synergies are sufficiently high, it is likely that takeover occurs with

an inefficiently low probability.

In sharp contrast, if the integrated firm can reduce its marginal costs, this should affect outsiders negatively. Moreover, if this effect is sufficiently pronounced, outsiders may become strictly worse off compared to the status-quo. But given $\pi_U \leq 0$ we know from (1) that the takeover must occur with probability one.

3 Takeover Incentives under Bertrand and Cournot Competition

Suppose that a representative consumer's utility from consuming the quantity q_i of firm i 's product and paying the price p_i is given by

$$\alpha \sum_{i=1}^N q_i - \frac{1}{2} \left(\sum_{i=1}^N q_i^2 + 2\gamma \sum_{i=1, i \neq j}^N q_i q_j \right) - \sum_{i=1}^N q_i p_i.$$

This quadratic utility function has been widely used in oligopoly theory to compare Cournot and Bertrand competition (see, e.g., Singh and Vives (1984), Bester and Petrakis (1993), Qiu (1997), Häckner (2000)). Products are substitutes (complements) if γ is positive (negative). To ensure that the firms' problem stays strictly concave we have to assume $\gamma > 1/(1 - N)$. Moreover, Assumption 1 excludes the case $\gamma = 0$ where goods are fully independent and a takeover has no implications.¹⁴ From the first-order condition determining the optimal consumption of good i , we obtain the inverse demand

¹⁴With Bertrand competition Assumption 1 also rules out the case $\gamma = 1$ where industry profits are zero before and after the takeover.

for product i :

$$p_i = \alpha - q_i - \gamma \sum_{j \neq i} q_j, \text{ for } i, j \in I, i \neq j. \quad (8)$$

On the supply side we assume that firms can produce at constant marginal costs equal to c , with $\alpha > c \geq 0$.

3.1 Cournot Competition

Suppose first that firms compete in quantities. We relegate all derivations to the Appendix. If N independent firms compete, each realizes the payoff $\Pi^{N,C}$, which is given by

$$\Pi^{N,C} = \left(\frac{\alpha - c}{\gamma(N-1) + 2} \right)^2. \quad (9)$$

If takeover takes place, which reduces the number of independent firms to $N-1$, the profits of the integrated firm $\Pi_M^{N-1,C}$ and the profits of each outsider $\Pi_U^{N-1,C}$ are given by

$$\Pi_M^{N-1,C} = \frac{1 + \gamma}{2} \left(\frac{(\alpha - c)(2 - \gamma)}{2 + \gamma(N-1) - \gamma^2} \right)^2, \quad (10)$$

$$\Pi_U^{N-1,C} = \left(\frac{\alpha - c}{2 + \gamma(N-1) - \gamma^2} \right)^2. \quad (11)$$

Using (10) and (11) we can calculate the respective profit differentials $\pi_M^{N-1,C}$ and $\pi_U^{N-1,C}$.

It is straightforward that $\pi_U^{N-1,C} > 0$ holds for all γ , where we use $\gamma \neq 0$, i.e., outsiders always gain from a higher concentration of the industry. On the other side, it is well-known that in the case of substitutes $\pi_M^{N-1,C} < 0$ may hold, i.e., that the insiders' profits decrease.

With linear demand quantities are strategic substitutes in the sense of Bulow, Geanakoplos, and Klemperer (1985) if goods are substitutes. In other words, outsiders will optimally increase their supply in reaction to the expected reduction of the integrated firm's total output. This reduces the insiders' ability to reap the benefits from a higher concentration. This accommodation effect is relatively more pronounced the less differentiated the goods are, i.e., the higher $\gamma > 0$, and the smaller the integrated firm's share of total output, i.e., the higher the number of firms N . While insiders strictly lose if goods are complete substitutes, i.e., if $\gamma = 1$ holds, we find a threshold $\bar{\gamma}^C > 0$ such that also insiders gain if $\gamma < \bar{\gamma}^C$ holds. The range of parameters $\gamma > 0$ for which insiders gain shrinks as the market share of each individual firm becomes smaller with an increase in N .

If goods are complements, the firms' strategies become strategic complements in the case of Cournot competition with linear demand. As the integrated firm increases its output to internalize the positive externality on the demand of its own goods, the outside firms follow suit, creating a positive "feedback" effect for the insiders.

These observations are formalized in the following result.

Lemma 1. *In the case of Cournot competition the takeover implies the following changes in profits. Outsiders always gain, i.e., $\pi_U^C > 0$, while there exists a threshold $0 < \bar{\gamma}^C < 1$ such that insiders gain if and only if $\gamma < \bar{\gamma}^C$, i.e., $\pi_M^C > 0$ if $\gamma < \bar{\gamma}^C$, $\pi_M^C < 0$ if $\gamma > \bar{\gamma}^C$, and $\pi_M^C = 0$ if $\gamma = \bar{\gamma}^C$. Moreover, $\bar{\gamma}^C$ is strictly decreasing in N .*

Proof. See Appendix.

To provide an example for the threshold $\bar{\gamma}^C$, we obtain $\bar{\gamma}^C \approx 0.56$ if there are $N = 3$

firms in the market. Lemma 1 is of independent interest as it complements previous results on the profitability of a merger under Cournot competition with linear demand. To our knowledge, the literature has confined itself to noting that a bilateral merger, which does not lead to monopoly, can not be profitable if goods are complete substitutes. By Lemma 1 profitability can be achieved if goods are sufficiently differentiated. If we were to take a more standard approach asking whether a bilateral merger is stable, we could therefore conclude from Lemma 1 that this is the case if and only if $\gamma \leq \bar{\gamma}^C$ holds. Our takeover game, which takes into account also outsiders' profits, obtains less radical predictions. Substituting equilibrium profits into the takeover formula (1), we obtain the following result.

Proposition 2. *In the case of Cournot competition, the takeover probability ρ^C is strictly decreasing over $\gamma \leq \bar{\gamma}^C$ and satisfies $\rho^C = 0$ for all $\gamma \geq \bar{\gamma}^C$. Moreover, $\rho^C < 1$ holds everywhere.*

Proof. See Appendix.

As products become less complementary (over $\gamma < 0$) and more substitutable (over $\gamma > 0$), the takeover probability ρ^C decreases. Moreover, the takeover probability is always strictly smaller than one. This holds even though for values $\gamma < \bar{\gamma}^C$ the profits of the integrated firm exceed those realized if the takeover fails. It is worthwhile to recall that the underlying “public good” problem in the takeover process stems from two different sources. First, it can be shown that $\pi_U^{N-1,C} > \pi_M^{N-1,C}$, i.e., that outsiders' profits increase more than those of insiders. Second, we can show that $B > \Pi^{N,C}$, i.e., that the target requires a “bid premium”.

3.2 Bertrand Competition

Consider next the case of Bertrand competition in prices. We obtain from (8) the individual demand functions

$$q_i = \max \left\{ \frac{(\alpha - p_i)(\gamma(N-2) + 1) - \gamma(N-1)\alpha + \gamma \sum_{j \neq i} p_j}{(1-\gamma)(\gamma(N-1) + 1)}, 0 \right\}. \quad (12)$$

Solving for the unique equilibrium with N independent firms we obtain the individual profits

$$\Pi^{N,B} = \frac{(1-\gamma)(\gamma(N-2) + 1)}{(\gamma(N-1) + 1)} \left(\frac{\alpha - c}{\gamma(N-3) + 2} \right)^2, \quad (13)$$

while after a takeover insiders and outsiders realize the respective profits

$$\Pi_M^{N-1,B} = \frac{[(\gamma(N-3) + 1)(1-\gamma)(\gamma(2N-3) + 2)(\alpha - c)]^2}{2(\gamma(N-3) + 1) [(1-\gamma)(\gamma(N-1) + 1)] \Psi^2}, \quad (14)$$

$$\Pi_U^{N-1,B} = \frac{[(\gamma(N-2) + 1)(1-\gamma)(\gamma(N-2) + 1)(\alpha - c)]^2}{(\gamma(N-2) + 1) [(1-\gamma)(\gamma(N-1) + 1)] \Psi^2}, \quad (15)$$

with $\Psi = \gamma^2(N^2 - 5N + 5) + \gamma(3N - 7) + 2$.

With linear demand the case of Bertrand competition mirrors that of Cournot competition. If goods are substitutes prices are strategic complements, while if goods are complements prices are strategic substitutes. Hence, in contrast to the Cournot case, both insiders and outsiders cannot be worse off after a takeover if goods are substitutes. However, insiders may lose if goods are sufficiently complementary.

Lemma 2. *In the case of Bertrand competition the takeover implies the following changes in profits. Outsiders always gain, i.e., $\pi_U^B > 0$, while there exists a threshold $\bar{\gamma}^B < 0$ such that insiders only gain if and only if $\gamma > \bar{\gamma}^B$, i.e., $\pi_M^B > 0$ if $\gamma > \bar{\gamma}^B$, $\pi_M^B < 0$ if $\gamma < \bar{\gamma}^B$, and $\pi_M^B = 0$ if $\gamma = \bar{\gamma}^B$. Moreover, $\bar{\gamma}^B$ is strictly increasing in N .*

Proof. See Appendix.

To provide an example, we obtain $\bar{\gamma}^B \approx -0.36$ for $N = 3$. Lemma 2 again complements results in the literature on Bertrand competition, where, to our knowledge, only the case of integration under substitutes has received attention so far.

Substituting equilibrium profits (14) and (15) into the takeover formula (1), we obtain the following result.

Proposition 3. *In the case of Bertrand competition, the takeover probability ρ^C is strictly increasing over $\gamma \geq \bar{\gamma}^B$ and satisfies $\rho^B(\bar{\gamma}^C) = 0$ for all $\gamma \leq \bar{\gamma}^B$. Moreover, $\rho^B < 1$ holds everywhere.*

Proof. See Appendix.

By Proposition 3 the takeover probability ρ^B increases as products become less complementary (over $\gamma < 0$) and more substitutable (over $\gamma > 0$).

3.3 Comparison of Cournot and Bertrand Competition

Comparing Propositions 2 and 3 reveals that the case of Bertrand competition mirrors that of Cournot competition. In other words, while the insider's share of total gains decreases in γ under Cournot competition, it increases under Bertrand competition. Intuitively, the respective takeover probabilities ρ^C and ρ^B cross at $\gamma = 0$.¹⁵ Together with Propositions 2 and 3 this implies the following comparison.

¹⁵Using L'Hôpital's rule, we obtain for $\lim_{\gamma \rightarrow 0} \rho^B(\gamma)$ and $\lim_{\gamma \rightarrow 0} \rho^C(\gamma)$ the value $1 - \left(\frac{2(N-2)}{2N-3}\right)^{N-1}$.

It should be recalled that the case of $\gamma = 0$ is excluded by Assumption 1, which, however, is without consequences for this argument.

Proposition 4. *If goods are substitutes, i.e., if $\gamma > 0$, the takeover probability is strictly higher under Bertrand than under Cournot competition, i.e., $\rho^B > \rho^C$. The converse holds if goods are complements, i.e., if $\gamma < 0$.*

Proposition 4 formalizes an often expressed view on the interaction of market structure and conduct, whereby an increase in concentration is more likely under Bertrand competition if goods are substitutes and more likely under Cournot competition if goods are complements.

Figure 1 illustrates our results by showing the takeover probabilities under Cournot and Bertrand as a function of $\gamma \in (-0.5, 1)$ for the triopoly case. As already mentioned above, for $N = 3$ takeover is profitable for insiders under Bertrand if $\gamma \geq \bar{\gamma}^B \approx -0.36$ and under Cournot if $\gamma \leq \bar{\gamma}^C \approx 0.56$.

(Figure 1 about here!)

Besides appealing to the role of capacity constraints (a view famously formalized by Kreps and Scheinkman (1983)), one often thinks of Cournot and Bertrand competition as different forms of market conduct; i.e., as different degrees of toughness of competition in the final market.¹⁶ From this perspective Bertrand can be considered as the more competitive mode of market interaction because the resulting equilibrium prices are strictly lower than under Cournot competition. Proposition 4 can then be summarized as saying that more competition makes higher concentration more likely if goods are substitutes and less likely if goods are complements.

¹⁶One well-known formalization of this view can be obtained by a conjectural variation approach.

The last observation rises an interesting issue regarding the welfare comparison of Bertrand and Cournot competition. By reducing the prevailing prices for a given number of firms, Bertrand competition increases consumer rents and total welfare.¹⁷ If goods are substitutes, we know, however, from Proposition 4 that this benefit of Bertrand competition is mitigated by the higher propensity for takeover under this mode of competition. From this perspective an adequate comparison of welfare under different modes of conduct must take into account the implications on the prevailing concentration of the industry, which is itself an endogenous variable. If a more competitive mode of conduct makes higher concentration more likely, this should typically produce a countervailing effect on total welfare, which may more than outweigh lower prices for a *given* number of firms.

If goods are complements, a similar countervailing effect prevails as in the case with substitutes. By Proposition 4 takeover is now less likely under Bertrand competition. As welfare increases with concentration if goods are complements, this counteracts the gains from lower prices under Bertrand competition obtained for a *given* number of firms.

4 Conclusion

This paper introduces a framework to study takeover incentives, which, in contrast to most previous approaches, takes into account both insiders' and outsiders' gains from a higher concentration. We obtain a simple and intuitive prediction for the likelihood

¹⁷This holds for the linear specifications in Section 3. For more general results on prices and welfare see, e.g., Singh and Vives (1984), Vives (1985), and Okuguchi (1987).

of takeover, which is an increasing function of the insiders' share in total industry gains achieved by an increase in concentration.

Our main application to a linear model provides a complete characterization of takeover probabilities under Bertrand and Cournot competition, i.e., for an arbitrary number of firms, for complements and substitutes, and for differentiated and homogeneous goods. Under Cournot competition the insiders' share of total industry gains strictly decreases as goods become less complementary and more substitutable. The opposite holds under Bertrand competition. Our model predicts a higher probability for takeover under Bertrand competition if goods are substitutes and a lower probability if goods are complements. We argue that this counteracts any welfare gains under Bertrand competition due to lower prices for a given number of firms.

To conclude this paper, we return to the casual observations on the steel and semiconductor industry made in the introduction. Both industries are characterized by extreme cyclical movements in capacity utilization, prices, and profits. It may be an interesting empirical question whether consolidating activities in these and other industries are hampered by the addressed public good effect. Our prediction linking takeover and consolidation to the insiders' share of total gains may provide a useful tool in this analysis.

Appendix

Proof of Lemma 1

Derivation of profits

We first solve the Cournot equilibrium in more detail. Without a takeover the N independent firms set quantities to maximize $\Pi_i = (\alpha - c - q_i - \gamma \sum_{j \neq i} q_j)q_i$, which gives i 's reaction function

$$q_i = \max \left\{ \frac{\alpha - c - \gamma \sum_{j \neq i} q_j}{2}, 0 \right\}.$$

Solving the system of N best-response functions, we obtain a unique equilibrium where the symmetric quantities are given by

$$q^{N,C} = \frac{\alpha - c}{\gamma(N - 1) + 2}.$$

Substituting in Π_i we obtain (9). If the target is taken over by, say, firm $j \in I \setminus \{1\}$, the integrated firm's profit equals

$$\Pi_M = (\alpha - c - q_1 - \gamma q_j - \gamma \sum_{k \in I \setminus \{1,j\}} q_k)q_1 + (\alpha - c - q_j - \gamma q_1 - \gamma \sum_{k \in I \setminus \{1,j\}} q_k)q_j,$$

Solving for the reaction function, we obtain that the two quantities are set equal to

$$q_M = \max \left\{ \frac{\alpha - c - \gamma \sum_{k \in I \setminus \{1,j\}} q_k}{2(1 + \gamma)}, 0 \right\}.$$

For outsiders $k \in I \setminus \{1, j\}$, we obtain the reaction function

$$q_U = \max \left\{ \frac{\alpha - c - \gamma \sum_{i \neq k} q_i}{2}, 0 \right\}.$$

Solving for the unique equilibrium we obtain for the integrated firm and the outsiders the quantities

$$\begin{aligned} q_M^{N-1,C} &= \frac{(\alpha - c)(2 - \gamma)}{2(2 + \gamma(N - 1) - \gamma^2)}, \\ q_U^{N-1,C} &= \frac{\alpha - c}{2 + \gamma(N - 1) - \gamma^2}, \end{aligned}$$

which yield the profits (10) and (11).

Proof of the assertions

We are now in the position to prove Lemma 1. For the profit differential of outsiders, which is denoted by π_U^C in the Cournot case, it is immediate that $\pi_U^C > 0$ holds from $\gamma \in (1/(1 - N), 1]$.¹⁸ Calculating the equilibrium profit differential of the combined firm, we obtain that $\pi_M^C > 0$ holds if and only if

$$N^2\gamma^2(3 - \gamma) + N(4\gamma - 10\gamma^2 + 2\gamma^3) + 11\gamma^2 - \gamma^3 - 8\gamma - 4 < 0. \quad (16)$$

Condition (16) is quadratic in N , which suggests an indirect way to prove the assertion in Lemma 1. Solving the quadratic form we obtain two critical values

$$\begin{aligned} N_1 &= 1 + 2 \left(\frac{\sqrt{4 - \gamma^2(3 - \gamma)} - (1 - \gamma)}{\gamma(3 - \gamma)} \right), \\ N_2 &= 1 - 2 \left(\frac{\sqrt{4 - \gamma^2(3 - \gamma)} + (1 - \gamma)}{\gamma(3 - \gamma)} \right), \end{aligned} \quad (17)$$

such that (16) holds for $\gamma < 0$ if $N_1 \leq N \leq N_2$ and for $\gamma > 0$ if $N_2 \leq N \leq N_1$. We first show that the term in rectangular brackets in (17) is monotonic in γ . Calculating its derivative reveals that, regardless of the sign of γ , the sign of the derivative is determined

¹⁸For ease of exposition we neglect at this point and later on the fact that we excluded the case of independent demand where $\gamma = 0$.

by the expression $-\gamma^3 + \gamma^2 + 2\gamma - 12 - 2\sqrt{(\gamma + 1)(\gamma^2 - 2\gamma + 3)}$, which is strictly negative given $\gamma \in [-1, 1]$. By substituting $\gamma = -1$ it follows that $N_1 \leq 2$ and $N_2 \leq 2$. We show next that the only binding condition is $N \leq N_1$ for the case $\gamma > 0$. Consider first the case $\gamma < 0$ and the condition $N \leq N_2$. Transforming the requirement and using $\gamma(N - 1) > -1$, which holds by assumption, shows that it is surely satisfied in case $4\gamma^2 < 5 + \gamma$, which always holds. Note next that for $\gamma < 0$ the condition $N_1 \leq N$ follows directly as $N \geq 3$ and $N_1 \leq 2$. Turning to $\gamma > 0$ note similarly that $N \geq N_2$ holds from $N_2 \leq 2$. It thus remains to consider the condition $N \leq N_1$, where we already know that the threshold N_1 is strictly decreasing in γ . Moreover, for $\gamma \rightarrow 0$ it holds that $N_1 \rightarrow \infty$, while $N_1 = 1 + \sqrt{2} < 3$ holds for $\gamma = 1$. Combining the values for N_1 at the boundaries with the monotonicity of N_1 in γ proves the existence of the threshold $0 < \bar{\gamma}^C < 1$ and its monotonicity in N , as asserted in Lemma 1. **Q.E.D.**

Proof of Proposition 2

Denote the equilibrium probability with which a given firm bids the reserve price in the Cournot case by $r^C(\gamma, N)$. Note that, in contrast to the proof of Proposition 1, we now make the dependency on both γ and N explicit. By Proposition 1 and Lemma 1 we obtain $r^C(\gamma, N) > 0$ for all $\gamma < \bar{\gamma}^C(N)$ and $r^C(\gamma, N) = 0$ for all $\gamma \geq \bar{\gamma}^C(N)$, where we have written the threshold $\bar{\gamma}^C(N)$ explicitly as a function of N . Recall from Lemma 1 that $0 < \bar{\gamma}^C(N) < 1$ and that $\bar{\gamma}^C(N)$ is strictly decreasing in N . We show that for all N the probability $r^C(\gamma, N)$, and thus $\rho^C(\gamma, N)$, is strictly decreasing over $\gamma \in (1/(1 - N), \bar{\gamma}^C(N)]$. Substituting the respective profit differentials π_M^C and π_U^C into

(7) and differentiating yields

$$\frac{dr^C}{d\gamma} = \frac{-2(N-2)[\gamma(N-1)+2]\xi_1(\gamma, N)}{[\gamma^3(N-1)^2 - \gamma^2(3N^2 - 8N + 7) + 4\gamma(N^2 - 4N + 4) + 4(2N-3)]^2},$$

with

$$\xi_1(\gamma, N) = \gamma^3(N-1) - 2\gamma^2(2N^2 - 4N + 3) + 6\gamma(N^2 - 4N + 5) + 4(3N - 5).$$

As $\gamma(N-1) + 2 > 0$ follows from $\gamma > 1/(1-N)$, $dr^C/d\gamma < 0$ holds if $\xi_1(\gamma, N)$ is strictly positive over $\gamma \in (1/(1-N), \bar{\gamma}^C(N)]$. To show that this holds, we prove first that $\xi_1(\gamma, N)$ is strictly increasing in N over $N \geq 3$. We denote the derivative of ξ_1 with respect to N by $\xi_2(\gamma, N)$ and obtain

$$\xi_2(\gamma, N) = \gamma^3 - 8\gamma^2N + 8\gamma^2 + 12\gamma N - 24\gamma + 12. \quad (18)$$

Claim. *It holds that $\xi_2(\gamma, N) > 0$.*

Proof. Suppose first $\gamma > 0$, in which case $\xi_2 > 0$ holds if

$$N > \frac{-\gamma^3 - 8\gamma^2 + 24\gamma - 12}{4\gamma(3 - 2\gamma)}. \quad (19)$$

It is thus sufficient to show that the right-hand side of (19) is bounded from above by three. Setting the right-hand side of (19) lower than three reduces to $-\gamma^3 + 16\gamma^2 - 12\gamma - 12 < 0$. We show that the left-hand side of this inequality, which we denote by $\xi_3(\gamma)$, is strictly negative over the considered support $\gamma \in (0, 1)$. Differentiating ξ_3 yields $\xi_3'(\gamma) = -3\gamma^2 - 32\gamma + 12$, which is negative over $\gamma \in (0, (16 - 2\sqrt{55})/3)$ and positive over $\gamma \in ((16 - 2\sqrt{55})/3, 1]$, implying that $\xi_3(\gamma) < 0$ is surely satisfied in case it holds on the boundaries of the considered interval. (Observe that $(16 - 2\sqrt{55})/3 \approx 0.39$.) As we obtain $\xi_3(0) = -3$ and $\xi_3(1) = -9/4$, we have thus shown that $\xi_2 > 0$ holds for $\gamma > 0$.

Suppose next that $\gamma < 0$, where $\xi_2 > 0$ holds if

$$N < \frac{-\gamma^3 - 8\gamma^2 + 24\gamma - 12}{4\gamma(3 - 2\gamma)}. \quad (20)$$

It is thus sufficient to show that the right-hand side of (20) is bounded from below by three, which is again the case if $\xi_3(\gamma)$ is strictly negative over the considered support $\gamma \in [1/(1 - N), 0)$. (Observe that we use $\gamma < 0$ and $3 - 2\gamma > 0$ when transforming this requirement.) Using that $\xi_3' < 0$ for all $\gamma < 0$, $\xi_3(\gamma) < 0$ holds surely over the considered support if it holds at the lower boundary $1/(1 - N)$ or at some other value $\gamma < 1/(1 - N)$. Given $N \geq 3$ it is thus sufficient to consider $\gamma = -0.5$, where we obtain $\xi_3(-0.5) = -1$. This concludes the proof that $\xi_2 > 0$ holds also for $\gamma < 0$. **Q.E.D.**

Having shown that $\xi_2 > 0$ holds for all feasible values of γ , i.e., that $\xi_1(\gamma, N)$ is strictly increasing in N , it remains to show for the lower boundary $N = 3$ that $\xi_1(\gamma, 3) > 0$. We obtain for $\xi_1(\gamma, 3)$ the value $\xi_4(\gamma) = 2\gamma^3 - 18\gamma^2 + 12\gamma + 16$. We show first that $\xi_4(\gamma) > 0$ holds for all feasible values γ . By $N \geq 3$ it is sufficient to show $\xi_4(\gamma) > 0$ for all values $\gamma \in [-0.5, 1]$. From the derivative $\xi_4'(\gamma) = 6\gamma^2 - 36\gamma + 12$ we see that ξ_4 increases for $\gamma \in [-0.5, 3 - \sqrt{7})$ and decreases for $\gamma > 3 - \sqrt{7}$, where $3 - \sqrt{7} \approx 0.35$. Hence, $\xi_4(\gamma) > 0$ holds over the considered domain if it is satisfied at the boundaries, which holds by $\xi_4(-0.5) = 5.25$ and $\xi_4(1) = 12$.

Having shown that $\xi_1(\gamma, N) > 0$ holds for all N over the respective domain of γ , it follows that $dr^C/d\gamma < 0$, and thus $d\rho^C/d\gamma = (N - 1)(1 - r)^{N-2}[dr^C/d\gamma] < 0$, which completes the proof. **Q.E.D.**

Proof of Lemma 2

Derivation of profits

We first solve the Bertrand equilibrium in more detail. Summing over all N inverse demand functions we obtain

$$\sum_{i=1}^N q_i = \frac{N\alpha - \sum_{i=1}^N p_i}{1 + \gamma(N-1)}. \quad (21)$$

Substituting $\sum_{j \neq i} q_j = [\alpha - q_i - p_i]/\gamma$, this yields the demand functions (12). If no takeover takes place, we obtain the reaction functions

$$p_i = \max \left\{ \frac{\alpha + c}{2} - \frac{\gamma(\alpha(N-1) - \sum_{j \neq i} p_j)}{2(\gamma(N-2) + 1)}, 0 \right\}$$

and the unique (symmetric) equilibrium prices

$$p^{N,B} = \frac{\alpha(1-\gamma) + c(1 + \gamma(N-2))}{\gamma(N-3) + 2},$$

which give rise to (13). If $i = 1$ is taken over by j , we find that the integrated firm chooses symmetric prices given by the reaction function

$$p_M = \max \left\{ \frac{\alpha(1-\gamma) + c(\gamma(N-3) + 1) + \gamma \sum_{k \in I \setminus \{1,j\}} p_k}{2(\gamma(N-3) + 1)}, 0 \right\},$$

while for outsiders the reaction function of some $k \in I \setminus \{1, j\}$ equals

$$p_U = \max \left\{ \frac{\alpha + c}{2} - \frac{\gamma(\alpha(N-1) - \sum_{i \neq k} p_i)}{2(\gamma(N-2) + 1)}, 0 \right\}.$$

Solving for the unique price equilibrium, we obtain

$$\begin{aligned} p_M^{N-1,B} &= \frac{\alpha(1-\gamma)(\gamma(2N-3) + 2) + c(\gamma^2(2N^2 - 8N + 7) + \gamma(4N-9) + 2)}{2(\gamma^2(N^2 - 5N + 5) + \gamma(3N-7) + 2)}, \\ p_U^{N-1,B} &= \frac{\alpha(1-\gamma)(\gamma(N-2) + 1) + c(\gamma^2(N^2 - 4N + 3) + 2\gamma(N-2) + 1)}{\gamma^2(N^2 - 5N + 5) + \gamma(3N-7) + 2}, \end{aligned}$$

which give rise to (14) and (15).

Proof of a unique threshold $1/(1-N) < \bar{\gamma}^B < 0$

We are now in the position to prove Lemma 2. For the profit differential of outsiders, which is denoted by π_U^B in the Bertrand case, it is immediate that $\pi_U^B > 0$ holds from $\gamma \in (1/(1-N), 1)$. Substituting the respective profits, we obtain that $\pi_M^B > 0$ holds if

$$\frac{(1-\gamma)\phi_1(\gamma, N)}{(\gamma(N-1)+1)(\gamma(N-3)+2)^2(\gamma^2(N^2-5N+5)+\gamma(3N-7)+2)^2} > 0, \text{ with } (22)$$

$$\phi_1(\gamma, N) = \gamma^3(N(5N^2 - 33N + 67) - 43) + \gamma^2(N(17N - 70) + 69) + 16\gamma(N - 2) + 4$$

As $\gamma > 1/(1-N)$ holds by assumption, the sign of the left-hand side of (22) is determined by $\phi_1(\gamma, N)$.¹⁹ Observe first that $\phi_1(1/(1-N), N) = -2(N^2-2N-1)/(N-1)^3$ is negative for all N . This follows as the quadratic form $N^2 - 2N - 1$ has the two zeros $N = 1 - \sqrt{2}$ and $N = 1 + \sqrt{2}$, where $N = 1 + \sqrt{2} \approx 2.41$. On the other side, we obtain $\phi_1(0, N) = 4$. This implies existence of a threshold $\bar{\gamma}^B(N) < 0$ such that $\phi_1(\bar{\gamma}^B(N), N) = 0$. We show next that this is the only zero of ϕ_1 , which also implies $\phi_1(\gamma, N) < 0$ for $\gamma < \bar{\gamma}^B(N)$ and $\phi_1(\gamma, N) > 0$ for $\gamma > \bar{\gamma}^B(N)$.

Claim 1. $\phi_1(\gamma, N)$ has a unique zero.

Proof. Denoting $\phi_2(\gamma, N) = d\phi_1(\gamma, N)/d\gamma$, we obtain

$$\phi_2(\gamma, N) = \gamma^2(N(15N^2 - 99N + 201) - 129) + \gamma(34N^2 - 140N + 138) + 16N - 32. \quad (23)$$

We must now distinguish between $N = 3$ and $N \geq 4$. For $N = 3$ we obtain $\phi_2(\gamma, 3) = -12\gamma^2 + 24\gamma + 16$, which has the two zeros $\gamma = 1 - \sqrt{21}/3$ and $\gamma = 1 + \sqrt{21}/3$, where

¹⁹Note also that the denominator is always strictly positive. In particular, for $\gamma > 1/(1-N)$ it holds that $\gamma^2(N^2 - 5N + 5) + \gamma(3N - 7) + 2 > 0$.

$1 - \sqrt{21}/3 \approx -0.53$ and $1 + \sqrt{21}/3 \approx 2.53$. This implies $\phi_2(\gamma, 3) > 0$ for the relevant domain $\gamma \in (-0.5, 1)$ such that $\phi_1(\gamma, 3)$ is strictly increasing and has thus indeed a unique zero.

Suppose next $N \geq 4$ and note first that the factor multiplied by γ^2 in (23) is in this case positive. To see this, denote this factor by $\phi_3(N) = 15N^3 - 99N^2 + 201N - 129$, which has the derivative $\phi_3'(N) = 45N^2 - 198N + 201$. As $\phi_3'(N)$ has the two zeros $N = (33 - 2\sqrt{21})/15$ and $N = (33 + 2\sqrt{21})/15$, where $(33 + 2\sqrt{21})/15 \approx 2.81$, and as $\phi_3'(4) = 129$, this implies that $\phi_3'(N) > 0$ for all $N \geq 4$. Together with $\phi_3(4) = 51$ it then follows that $\phi_3(N) > 0$ for all $N \geq 4$. We next evaluate $\phi_2(1/(1 - N), N) = -(3N^3 - 11N^2 - 3N + 23)/(N - 1)^2$, which is negative for all $N \geq 4$. To see this, denote $\phi_4(N) = 3N^3 - 11N^2 - 3N + 23$, which has the derivative $\phi_4'(N) = 9N^2 - 22N - 3$. As $\phi_4'(N)$ has the two zeros $N = (11 - 2\sqrt{37})/9$ and $N = (11 + 2\sqrt{37})/9$, where $(11 + 2\sqrt{37})/9 \approx 2.57$, and as $\phi_4'(4) = 53$, this implies that $\phi_4'(N) > 0$ for all $N \geq 4$. Together with $\phi_4(4) = 27$ it then follows that $\phi_4(N) > 0$ for all $N \geq 4$. We can now determine the behavior of $\phi_2(\gamma, N)$ in γ for $N \geq 4$. As the factor multiplied by γ^2 , i.e., $\phi_3(N)$, is strictly positive and as we obtained for the left boundary $\phi_2(1/(1 - N), N) < 0$, the quadratic form implies that, as γ increases, ϕ_2 is first negative and then positive. As a consequence, $\phi_1(\gamma, N)$ first decreases and then increases in N . As we already noted that $\phi_1(1/(1 - N), N) < 0$, this implies that $\phi_1(\gamma, N)$ has indeed a unique zero also for $N \geq 4$. **Q.E.D.**

Proof that $\bar{\gamma}^B$ is increasing in N

To complete the proof of Lemma 2, we show that $\bar{\gamma}^B(N)$ is increasing in N . As the

threshold was defined as the unique zero of $\phi_1(\gamma, N) = 0$ over $\gamma \in [1/(N-1), 1]$, we can obtain monotonicity of $\bar{\gamma}^B(N)$ by implicit differentiation. For this purpose recall first from above that ϕ_1 cuts zero from below as we increase γ , i.e., that the derivative satisfies at this point $\phi_2(\bar{\gamma}^B(N), N) > 0$. Define next the derivative w.r.t. N as $\phi_5(\gamma, N) = d\phi_1(\gamma, N)/dN$. The asserted monotonicity of $\bar{\gamma}^B(N)$ follows then if $\phi_5(\bar{\gamma}^B(N), N) < 0$.²⁰

Claim 2. *It holds that $\phi_5(\bar{\gamma}^B(N), N) < 0$.*

Proof. Observe that

$$\phi_5(\gamma, N) = 15\gamma^3 N^2 + N(34\gamma^2 - 66\gamma^3) - 70\gamma^2 + 16\gamma + 67\gamma^3. \quad (24)$$

To show that $\phi_5(\bar{\gamma}^B(N), N) < 0$ we proceed indirectly and consider again the problem $\phi_1(\gamma, N) = 0$, where we now solve for N given some γ . Note that we can restrict consideration to the values γ where $\gamma = \bar{\gamma}^B(N)$ is feasible. We show first that this restricts the domain of γ to values $-0.4 < \gamma < 0$. To see this, recall first that we derived $1/(1-N) < \bar{\gamma}^B(N) < 0$, which implies the restriction for all $N \geq 4$. Moreover, for $N = 3$ we can show directly that $\bar{\gamma}^B(3) > -0.4$. The latter follows as $\phi_1(-0.4, 3) = -0.224$, while we have shown that $\phi_1(\gamma, 3)$ is strictly increasing in γ and has thus its zero to the right of $\gamma = -0.4$.

Note next that from $\gamma > 1/(1-N)$ the solution for $\phi_1(\gamma, N) = 0$ must satisfy $N < (\gamma - 1)/\gamma$. It holds that $\phi_1(\gamma, 0) = 4 + 69\gamma^2 - 32\gamma - 43\gamma^3$, which is strictly positive for all $\gamma \leq 0$, while we obtain at the upper boundary $\phi_1(\gamma, (\gamma-1)/\gamma) = 2\gamma(1-2\gamma^2)$, which is negative by $\gamma \in (-0.4, 0)$. We can thus already conclude that for given γ we obtain at least one zero denoted by $\bar{N}(\gamma)$, which satisfies $0 < \bar{N}(\gamma) < (\gamma - 1)/\gamma$. Moreover, at

²⁰Note that $d\bar{\gamma}^B(N)/dN = -\phi_5(\bar{\gamma}^B(N), N)/\phi_2(\bar{\gamma}^B(N), N)$, which shall be positive.

this zero it follows from the behavior of ϕ_1 at the boundaries $N = 0$ and $N = (\gamma - 1)/\gamma$ that ϕ_1 cuts zero from above, i.e., that $\phi_5(\gamma, \overline{N}(\gamma)) = 0$. If we can show that there is a unique zero for ϕ_1 in the feasible domain, it must follow that $\phi_5(\overline{\gamma}^B(N), N) < 0$.

For uniqueness note first that ϕ_5 is a quadratic form in N , where the factor multiplied by N^2 is negative. We obtain $\phi_5(\gamma, 0) = -70\gamma^2 + 16\gamma + 67\gamma^3$, which is strictly negative. At the upper boundary we obtain $\phi_5(\gamma, (\gamma - 1)/\gamma) = \gamma(16\gamma^2 - 3)$, which has the two zeros $-\sqrt{3}/4$ and $\sqrt{3}/4$, where $-\sqrt{3}/4 \approx -0.43$ is strictly smaller than the previously derived lower boundary -0.4 for γ . As we have shown above that $\phi_5(\gamma, 0) < 0$ and as $15\gamma^3 < 0$, which is the factor multiplied with N^2 in (24), it thus follows that $\phi_5(\gamma, N)$ is negative for low N and positive for high N . Together with the derived values for ϕ_1 at the boundaries $N = 0$ and $N = (\gamma - 1)/\gamma$ this implies that ϕ_1 has indeed a unique zero $\overline{N}(\gamma)$ at the considered domain. **Q.E.D.**

Proof of Proposition 3

Denote the equilibrium probability with which a given firm bids the reserve price in the Bertrand case by $r^B(\gamma, N)$ and recall that $r^B(\gamma, N) > 0$ for all $\gamma > \overline{\gamma}^B(N)$ and $r^B(\gamma, N) = 0$ for all $\gamma \leq \overline{\gamma}^B(N)$, where $1/(1 - N) < \overline{\gamma}^C(N) < 0$ and $\overline{\gamma}^C(N)$ is strictly increasing in N . We show that for all N the probability $r^B(\gamma, N)$, and thus $\rho^B(\gamma, N)$, is

strictly increasing over $\gamma \in [\bar{\gamma}^B(N), 1)$. Substituting π_M^B and π_U^B obtains

$$\begin{aligned} \frac{dr^B}{d\gamma} &= \frac{2(\gamma(N-3)+2)(N-2)}{[\psi_2(\gamma, N)]^2} \psi_1(\gamma, N), \text{ with} & (25) \\ \psi_1(\gamma, N) &= \gamma^3 [6N^4 - 48N^3 + 130N^2 - 143N + 53] \\ &\quad + \gamma^2 [24N^3 - 136N^2 + 236N - 126] + \gamma [30N^2 - 108N + 90] + 12N - 20, \\ \psi_2(\gamma, N) &= 45\gamma^3 + 85\gamma^3 N^2 + 4\gamma^3 N^4 - 31\gamma^3 N^3 - 101\gamma^3 N - 87\gamma^2 N^2 - 87\gamma^2 + 16\gamma^2 N^3 \\ &\quad + 152\gamma^2 N + 20\gamma N^2 - 68\gamma N + 56\gamma + 8N - 12. \end{aligned}$$

As $\gamma(N-3)+2 > 0$ follows from $\gamma > 1/(1-N)$, $dr^B/d\gamma > 0$ holds if $\psi_1(\gamma, N)$ is strictly positive over $\gamma \in (\bar{\gamma}^C(N), 1]$.²¹ In what follows, we will show that this holds also for the extended domain $\gamma \in [1/(1-N), 1]$. At the lower boundary we obtain $\psi_1(1/(1-N), N) = (3 - 3N + 2N^2)/(N-1)^3$, which is strictly positive for all $N \geq 3$. We show next that ψ_1 is strictly increasing over the considered domain, which completes the proof of Proposition 3.

Differentiating ψ_1 with respect to γ and rearranging terms we obtain

$$\begin{aligned} \psi_3(\gamma, N) &= d\psi_1(\gamma, N)/d\gamma = \gamma^2(18N^4 - 144N^3 + 390N^2 - 429N + 159) & (26) \\ &\quad + \gamma(48N^3 - 272N^2 + 472N - 252) + 30N^2 - 108N + 90. \end{aligned}$$

We analyze first the factor multiplied with γ^2 in (26), which we denote by $\psi_4(N) = 18N^4 - 144N^3 + 390N^2 - 429N + 159$. While it holds that $\psi_4(3) = -48$, we show that $\psi_4(N) > 0$ for all $N \geq 4$. For this purpose we repeatedly differentiate ψ_4 to obtain $\psi_4'(N) = 72N^3 - 432N^2 + 780N - 429$ and $\psi_4''(N) = 216N^2 - 864N + 780$. Note next

²¹It can be shown that $\psi_2(\gamma, N) \neq 0$ holds over the considered domain such that $dr^B/d\gamma$ is well defined.

that ψ_4'' has two zeros at $N = 2 - \frac{1}{6}\sqrt{14}$ and $N = 2 + \frac{1}{6}\sqrt{14}$, where $2 + \frac{1}{6}\sqrt{14} \approx 2.62$, implying that $\psi_4''(N) > 0$ for the considered domain $N \geq 4$. As $\psi_4'(4) = 387$ it follows that $\psi_4'(N) > 0$ holds as well for $N \geq 4$. Finally, as $\psi_4(4) = 75$, this implies that $\psi_4(N) > 0$ for all $N \geq 4$. We are now in the position to prove the monotonicity of ψ_1 .

Claim. *It holds that $\psi_3(\gamma, N) > 0$.*

Proof. Suppose first that $N = 3$ such that the factor multiplied with γ^2 in (26) is negative. Substituting $N = 3$ into (26) reveals that the respective quadratic form has two zeros at $\gamma = -3/4$ and $\gamma = 1$. As we can restrict consideration to $\gamma \geq -1/2$, it thus follows that $\psi_3(\gamma, 3) > 0$ holds over the considered domain of γ .

Suppose next that $N \geq 4$ such that the factor multiplied with γ^2 in (26) is positive. Again we can determine the zeros of the respective quadratic form in (26). We show that the zeros must also be smaller than $1/(1 - N)$, which completes the proof of the Claim. Observe first that $\psi_3(1/(1 - N), N) = (8N^3 - 18N^2 + 7N - 3)/(N - 1)^2$. The numerator of this expression equals 249 at $N = 4$, while it has the two zeros $N = (9 - \sqrt{39})/12$ and $N = (9 + \sqrt{39})/12$, where $(9 + \sqrt{39})/12 \approx 1.27$. This obtains $\psi_3(1/(1 - N), N) > 0$. Hence, if not both zeros of (26) lie to the left of $1/(1 - N)$, they must both lie to the right of $1/(1 - N)$, implying in particular that the vortex of the quadratic form lies to the right of $1/(1 - N)$, i.e., that

$$\frac{2}{3} \frac{12N^3 - 68N^2 + 118N - 63}{6N^4 - 48N^3 + 130N^2 - 143N + 53} < \frac{1}{1 - N}, \quad (27)$$

Note that the denominator on the left-hand side in (27) is just equal to $\psi_4(N)/3$, which was shown to be strictly positive for $N \geq 4$. With this information we can transform (27) to the condition that $\psi_5(N) = 6N^4 - 16N^3 - 18N^2 + 67N - 33 > 0$. To show that this

holds, calculate the derivatives $\psi'_5(N) = 24N^3 - 48N^2 - 36N + 67$ and $\psi''_5(N) = 72N^2 - 96N - 36$. Note next that $\psi''_5(N)$ has two zeros $N = (4 - \sqrt{34})/3$ and $N = (4 + \sqrt{34})/3$, where $(4 + \sqrt{34})/3 \approx 1.64$. As thus $\psi''_5(N) > 0$ for $N \geq 4$ and as $\psi'_5(4) = 691$, it holds that $\psi'_5(N) > 0$ for all $N \geq 4$. As finally $\psi_5(4) = 459$, this proves that $\psi_5(N) > 0$ for all $N \geq 0$. We have thus shown that (27) holds for all $N \geq 4$ and that therefore the zeros of (26) must lie to the left of $1/(1 - N)$, which completes the proof for $\psi_3(\gamma, N) > 0$.

Q.E.D.

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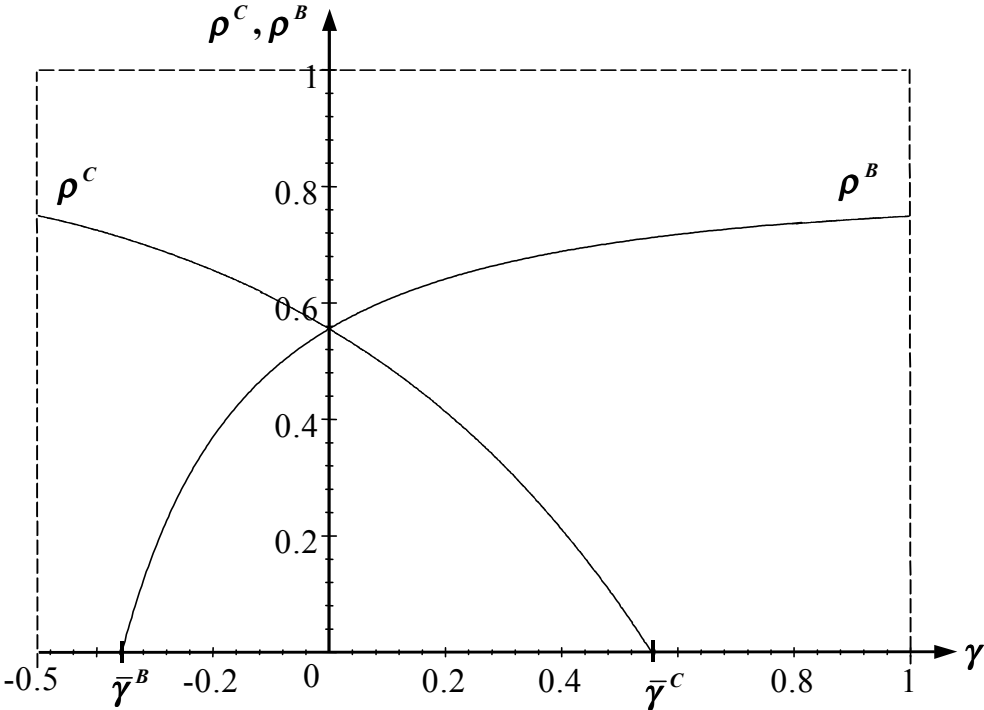
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Figure 1: Takeover Probabilities with Bertrand and Cournot ($N = 3$)



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