Takeover Auctions with Information Externalities

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Abstract

The acquisition of a target firm with unknown costs seems to be a standard application of a reverse auction. Using this example, this paper shows that no mechanism that allows an investor to acquire a low-cost firm under incomplete information exists. Acquiring a high-cost firm through a *separating* auction is possible, but implies adverse selection. Furthermore, it relies substantially on the commitment not to acquire the low-cost firm even if it will have been more profitable ex post. The paper also considers a *pooling* auction in which the two target firms quote the same price. This setup avoids adverse selection, serves as a commitment device that avoids ex-post opportunistic behavior, and generates a higher expected payoff for the investor than a separating auction.

Keywords: Takeover; Auction; Externality; Incomplete Information; Commitment

JEL Classification: D44; D82

1 Introduction

After auction theory has made so much progress in the last decades, it seems to be a common view that private sales under incomplete information are in most cases strategically equivalent to a standard auction format. Standard auction models, however, do not allow for any further interaction among bidders once the auction is over. Typically, in such models, auctions with symmetric bidders are efficient, such that the agent who has the highest valuation wins the auction; see Janssen and Karamychev (2009), Janssen and Moldovanu (2004), and Myerson (1981).[1] Furthermore, auction theory assumes commitment to the rules of the auction although manipulation of rules is frequently observed (e.g., shill bidding in Internet auctions, accepting subsequent offers after an auction closes in corporate acquisitions, or re-auctioning unsold items in real-estate sales).[2] If ex-ante commitment to a particular allocation mechanism is not ex-post credible, the bidders anticipate some ex-post modification of the auction and adjust their bids accordingly. In such a case, the seller (or the buyer if it is a reverse auction)[3] mostly bears the cost, since the auction generates smaller rents; see Hoppe *et al.* (2006), Janssen and Karamychev (2010), and Jehiel and Moldovanu (2006).

The innovation of this paper is that it looks at commitment and post-auction interaction at the same time. For this purpose, we use a topical example: a private (foreign) firm wants to acquire one out of two target firms with unknown costs.[4] The two firms quote acquisition prices, and firms compete by quantities after the auction. An auction setup may generate information externalities because it allows the investor to update her beliefs about the (non-acquired) future rival. In this framework we show that there is no mechanism that will allow the investor to acquire the low-cost firm. She will be able to acquire the high-cost firm in a *separating* reverse auction, but this has the cost of adverse selection. Furthermore, commitment that the high-cost firm is selected is crucial as the scope of a reverse auction that separates different types is very small without commitment due to potential opportunistic behavior of the investor in post-

[1] See Klemperer (1999; 2004) and Krishna (2002) for reviews of the literature on auction theory.

[2] For more information on these examples, and on some anecdotal evidence, see McAdams and Schwarz (2006; 2007), Vartiainen (2013), and Skreta (2013).

[3] In reverse auctions (procurement auctions, subcontracting, etc.) a buyer asks potential sellers to quote prices for a particular contract.

[4] Mergers and acquisitions have been the driving force of international integration and have increased substantially over the last decades. However, not all mergers and acquisitions are successful (see e.g., Gugler *et al.*, 2003), indicating asymmetric information.

auction interactions. Alternatively, the investor can run a *pooling* auction in which she expects all target firms to quote the same price. Our novel result is that such a pooling auction will always be viable, and that the investor can do better with a pooling compared to a separating auction. The reason is that the pooling auction also serves as a commitment not to learn future types, and thus can avoid opportunistic behavior. Furthermore, the pooling auction does not imply adverse selection as the investor will have a chance to acquire the low-cost firm.

Our paper is, mostly, related to the two strands of the recent auction literature: (i) (non-)commitment in auctions, and (ii) auctions with externalities. Commitment issues in auctions are scrutinized recently by several papers. McAdams and Schwarz (2007) is, for example, one that formally introduces the lack of commitment, such that the seller, after having observed the bids, cannot commit not to ask for another round of bids. Vartiainen (2013), in his model, allows for both the seller and the bidders not to commit to the auction rules, and he assumes that all actions are publicly observable. Skreta (2013) is one in which the seller can re-auction the good if it has not been sold. The seller in her model discounts the future, and thus the lack of commitment is costly for the seller. All three papers essentially have a set-up where an auction mechanism is followed by another auction-like mechanism if commitment is not feasible. Our paper differs from these studies since the auction stage in our model is followed by product market competition and there are both informational and allocative interdependencies as in Jehiel and Moldovanu (2000), relating our study to the literature on auctions with externalities.

Jehiel and Moldovanu (2000) focus on downstream externalities: they employ a second-price sealed-bid auction and model both the sale of a cost-reducing innovation to firms (which leads to negative externalities) and a merger between two out of three firms competing in the same industry (which leads to positive externalities). They show the existence of a separating equilibrium in the presence of negative externalities, and no separating equilibrium but pooling equilibria in the presence of positive externalities. In their model, only firms, bidding in the auction, are exposed to externalities, and, although the information structure is incomplete ex ante (at the auction stage), there is complete information ex post (at the product-market competition stage). In our study, however, all agents are exposed to externalities, which are mainly information externalities and depend on characteristics that are not observable. More importantly, we relax their assumption that all private information is revealed after the auction, and we focus on the perfect Bayesian equilibrium concept.

We allow for the possibility that the prices quoted in the takeover auction may serve as signals that influence beliefs on the intensity of competition in the product market. This approach is similar to Goeree (2003). He considers an auction setup in which bidders with incomplete information compete for a cost-reducing patent. All bidders, the winner and the losers, then compete in an aftermarket. He shows that bidders signal their private information via the winning bid, and this puts an upward bias on the equilibrium bidding strategies. Another study that includes aftermarket competition in the analysis is one by Janssen and Karamychev (2010). They focus on auctioning of multiple licenses and on the winning firms that compete in the aftermarket. They show that the auction mechanism does not always choose the most cost-efficient firms. Our main contribution, relative to the articles mentioned above, is that we look at the scope for (credible) commitment to a particular takeover procedure in an auction model that features a post-auction strategic (product market) competition and information externalities.

The rest of the paper is organized as follows. Section 2 introduces the Cournot duopoly model under incomplete information, shows that no mechanism that allows an investor to acquire the low-cost firm exists, and solves the model for a symmetric, fully-separating equilibrium in strictly decreasing bidding strategies when the investor commits to acquire the high-cost firm. Section 3 scrutinizes the implications of information externalities on commitment and discusses the scope of a separating auction without commitment. Section 4 develops a pooling auction and compares the investor's best outcome with the separating auction. Finally, Section 5 concludes. For convenience, we have relegated most of the proofs and technical details to the Appendix.

2 The auction model

The model considers a market which is served by two potential target firms, labeled 1 and 2. Consumers in this market have quasi-linear preferences which lead to the inverse demand function $p = a - (q_i + q_j)$, $i \neq j$ and $i, j = \{1, 2\}$, where p denotes the equilibrium price, and q_i and q_j are the respective outputs of the two firms, producing homogeneous goods. The production costs are private information of the firms. Both firms draw their marginal production cost (independently) from the uniform distribution $F(c) = c$; hence, the marginal costs are distributed over the support $[0, 1]$.

Without any acquisition, the two firms were to compete in a Cournot duopoly, and would produce at the level maximizing their expected profits $\Pi_i = (a - q_i - E_i(q_j) - c_i)q_i$, $i \neq j$ and $i, j = \{1, 2\}$, where $E_i(q_j)$ is firm i's expectation of firm j's output. Firms do not know each other's marginal production cost, but they can correctly anticipate each other's optimal behavior. We can derive the optimal outputs as a function of firm-specific marginal production costs and expected costs:

$$q_i = \frac{2a - E_j(c_i) + 2E_i(c_j) - 3c_i}{6}, \quad i \neq j \text{ and } i, j = \{1, 2\}. \tag{1}$$

We will assume throughout the paper that $a > 2$ which guarantees that outputs are positive even if $E_j(c_i) = c_i = 1$ and $E_i(c_j) = 0$, $i \neq j$. In equation (1), c_i is firm i's realized marginal production cost, and $E_i(c_j)$ is firm i's expectation of firm j's marginal production cost. Firms update their beliefs on each other's marginal production cost with any relevant information that is revealed before they make their output decisions. If no further information is revealed until the two firms make their output decisions, then $E_i(c_j) = E_j(c_i) = 1/2$. From equation (1), we can derive the expected profits:

$$\pi(c_i) = \left(\frac{2a - E_j(c_i) + 2E_i(c_j) - 3c_i}{6}\right)^2, \quad i \neq j \text{ and } i, j = \{1, 2\}. \tag{2}$$

Equation (2) shows that a firm's expected profit is positively related to its expectation of its rival's cost, and is negatively related to the rival firm's expectation of its own cost. Any information that reveals, before the firms make their output decisions, that the rival is a low-cost firm leads the other firm to update its beliefs, such that $E_i(c_j)$ becomes smaller, and hence decreases the firm's expected profits and increases the rival firm's expected profits, ceteris paribus. Similarly, if the firm signals that it is a low-cost firm, the rival updates its beliefs, such that $E_j(c_i)$ becomes smaller, which increases the firm's expected profits, and decreases the rival's expected profits, ceteris paribus.

The acquiring firm is an investor who considers the acquisition of one of the two target firms to enter the market. The investor may realize two different forms of acquisition gains: (i) access to technologies, management skills, intangible assets etc., and (ii) combining its own (complementary) assets with those of the target firm for competition in the target firm's market. The first gain is fixed and independent of the cost realization of the target firm, whereas the second gain depends on the target firm's cost realization. Let $v^i(c_i, c_j)$, $i \neq j$ and $i, j = \{1, 2\}$, denote the investor's aggregate operating profit after having acquired a target firm of cost-type c_i and competing against type c_j. Superscript i represents the firm that is acquired by the investor. The investor's ex-post aggregate payoff (excluding the cost of acquisition) consists of the fixed benefit Γ

and the operating profit $v^i(c_i, c_j)$, and is equal to

$$\Gamma + v^i(c_i, c_j) \text{ where } v^i(c_i, c_j) = \left(\frac{2a - E_j(c_i) + 2E_i(c_j) - 3\gamma c_i}{6}\right)^2. \tag{3}$$

We assume that Γ is sufficiently high such that the investor will always prefer to acquire a firm, so as to enter the market. The fixed benefit could also be adjusted by the inclusion of other entry options (e.g., greenfield investment). Our results would remain qualitatively the same, if the investor had to choose simultaneously between the acquisition of a local firm and greenfield investment.[5] Empirical evidence suggests that such decisions are indeed made simultaneously, especially given a long lead time that greenfield investments generally require; see, for example, Raff *et al.* (2012).

If the investor acquires a firm, the acquired firm's marginal cost will decline to γc_i, $i = \{1, 2\}$, where $\gamma \in [0, 1]$ measures the cost-saving effect of the acquisition, and is common knowledge. We can consider γ as the investor's contribution to the ex-post productivity of the acquired firm: combining complementary assets of the investor and the acquired firm generates efficiency gains. Therefore, $\gamma = 0$ implies that the investor's assets are substantially efficient, dominating the acquired firm's assets: the investor successfully carries over her technology to the acquired firm. Similarly, $\gamma = 1$ implies that the acquisition of a firm generates no efficiency gains:[6] the acquired firm's technology is used.

Which type of firm should be targeted by the investor? Suppose that the investor learns the cost types such that $c_i < c_j$, $i \neq j$ and $i, j = \{1, 2\}$. From an ex-post perspective, it is obvious from equation (3) that

$$v^i(c_i, c_j) - v^j(c_i, c_j) = \left(\frac{2a - 4\gamma c_i + 2c_j}{6}\right)^2 - \left(\frac{2a - 4\gamma c_j + 2c_i}{6}\right)^2 > 0, \tag{4}$$

for any $c_i < c_j$, $i \neq j$ and $i, j = \{1, 2\}$. Consequently, if the cost of acquiring either firm (the acquisition prices) were the same, and if the investor were free to choose

[5] Scrutinizing the optimal entry mode when different options for foreign market entry are available is beyond the scope of this study; see Koska (2014) for a model that employs a second-price, sealed-bid, takeover auction, and looks at an investor's choice between firm acquisition and greenfield investment.

[6] Efficiency gains play an important role in the profitability of mergers and acquisitions: firms may benefit from a merger, provided sufficient efficiency gains are generated as in Perry and Porter (1985). Without efficiency gains, firms may not benefit from a merger if they compete in a market of strategic substitutes in the sense of Bulow *et al.* (1985) due to the *merger paradox*; see, for example, Salant *et al.* (1983), and Farrell and Shapiro (1990). Convex demand (Hennessy, 2000), product differentiation (Lommerud and Sorgard, 1997) and competition in a market of strategic complements (Deneckere and Davidson, 1985) can overcome the merger paradox. The merger paradox does not apply here as the investor stays out of the market and earns zero profit if no acquisition takes place.

any target firm, she would always select the low-cost firm. We will see later that this incentive may lead to serious complications if ex-ante commitment to select a certain type is not possible.

Suppose that the investor can commit to a certain allocation and transfer scheme that includes which type of firm she would prefer to acquire. Not surprisingly, we find a clear ex-ante preference of the investor under asymmetric information, but we also conclude that this is not a viable option.

Proposition 1 *The expected operating profit of the investor, acquiring the low-cost firm and competing against the high-cost firm, is larger than the expected operating profit of the investor, acquiring the high-cost firm and competing against the low-cost firm. However, there is no implementable mechanism that allows the investor to select the low-cost firm under asymmetric information.*

Proof: See Appendix A.1.

The reason is that the compensation for a low-cost firm should increase with its high productivity, but this allows the high-cost firm to mimic the low-cost firm without any cost. Proposition 1 shows that any separating equilibrium must imply that the investor acquires the high-cost firm, and consequently, the best an auction setup can achieve is to target the high-cost firm. In such an environment, the cost-saving effect has important implications for the extent of business-stealing by the rival firm. When $\gamma = 0$, the marginal production cost of the acquired firm does not play a role in the profitability of the investor, as far as the operating profits are concerned. In such a situation, the business-stealing effect is relatively small, and so is the potential rival's expected profits from competing against the investor. If, however, $\gamma \neq 0$, the acquired firm's marginal production cost affects the extent of business-stealing. Acquiring a high-cost firm leads to a higher marginal production cost, such that the investor loses business to the rival (low-cost) firm not only because the cost-saving effect is smaller ($\gamma > 0$), but also because the acquired firm's marginal production cost is higher, such that γc_i is higher.

The "quality of a match" that is determined by the size of the ex-post marginal cost is the potential target firms' private information. The investor can distinguish between different qualities of the match by running a sealed-bid auction in the first stage of the game. This type of allocation is common in *reverse auctions* to which the auction process in this paper is theoretically analogous. In our model, the investor's cost of entering a foreign market is auctioned, such that the two potential targets are the bidders and quote prices, and the buyer (the investor) pays one of the two prices to enter the market.[7] The acquisition prices quoted in the auction determine the investor's market entry cost, and are not disclosed after the auction. Our results do not change qualitatively if bids are (honestly) disclosed.[8] However, we find this setup more compelling, also because the investor would always claim that the winning firm was just as productive as the losing firm unless she could credibly prove it.

After acquisition prices have been quoted, the investor acquires one of the two target firms.[9] Finally, the investor and the non-acquired firm update their beliefs on each other's productivity, and compete in a Cournot duopoly. The following condition specifies whether or not the auction will be similar to a first-price auction.

Condition 1 *If the investor decides to acquire a firm via a separating takeover auction, she will commit to acquire the firm quoting the lowest acquisition price. Should the firms quote the same price, the investor will randomly choose one to acquire.*

In what follows, we will develop the auction outcome if Condition 1 holds, and will then scrutinize whether the same outcome can be achieved without Condition 1. Let ϕ_i denote firm i's quoted price that is monotonic and strictly increasing in firm i's productivity (i.e., strictly decreasing in its marginal production cost), an assumption that we have to confirm later. The higher is the firm's marginal cost, the smaller is the quoted price. If Condition 1 is fulfilled, firm i will win the auction by quoting $\phi_i < \phi_j$, and will be paid ϕ_i. We denote by Ψ_i the probability that firm i wins the auction (that is, the probability that $\phi_i < \phi_j$). By the same token, the other firm wins the auction with complementary probability $(1 - \Psi_i)$ (that is, the probability that $\phi_i > \phi_j$). If firm j wins the auction, firm i will have to compete against the investor in a Cournot duopoly, and its profit follows from equation (2), where $E_j(c_i) = \Psi_i(\phi_i)$ and $E_i(c_j) = \gamma(1 + \Psi_i(\phi_i))/2$. Firm i's probability to win the auction $\Psi_i(\phi_i)$

[7]Formally, we consider a perfect Bayesian equilibrium. We do not consider a potential repetition of an auction as in Skreta (2013). A well-known complication in these setups is the ratchet effect; see Freixas *et al.* (1985), and Laffont and Tirole (1988).

[8]The results are available upon request.

[9]We set up the model such that the investor is not allowed to acquire both firms. The reason is that local competition authorities would not permit the foreign firm to gain monopoly power.

is determined by firm i's productivity signal. Provided Condition 1 is fulfilled, if the investor acquires firm j, firm i updates its belief about firm j's productivity such that $E_i(c_j) = \gamma \int_{\Psi_i}^{1} (c_j/(1-\Psi_i))dc_j = \gamma (1+\Psi_i)/2$, since the investor would have acquired firm j only if firm j had quoted a lower price, that is, only if firm j's cost signal had been higher than that of firm i. By the same token, in equilibrium, $E_j(c_i) = \Psi_i(\phi_i)$, since the investor, acquiring firm j, observes the bid of the other firm, and so can invert the bidding function. If the firms bid according to their true productivity, then $E_j(c_i) = c_i$. Firm i's expected profit, denoted $\hat{\pi}^a(c_i)$ where superscript a stands for the auction outcome, is thus equal to

$$\hat{\pi}^a(c_i) = \Psi_i(\phi_i)\phi_i + (1-\Psi_i(\phi_i))\left(\frac{2a - \Psi_i(\phi_i) + \gamma(1+\Psi_i(\phi_i)) - 3c_i}{6}\right)^2, \quad (5)$$

where $\Psi_i(\phi_i)$ coincides with the inverse of the price function. The price function $\phi_i(\Psi_i)$ specifies firm i's price demand, where Ψ_i represents firm i's signal. Incentive compatibility requires $\phi_i(\Psi_i) \equiv \phi_i(\Psi_i = c_i)$,[10] and we find:

Proposition 2 *When Condition 1 is fulfilled, the auction stage of the game has a symmetric, fully-separating equilibrium in strictly decreasing bidding strategies. In equilibrium, firm i quotes*

$$\begin{aligned} \phi^*(c_i, \gamma) &\equiv \phi^*(c_i, \gamma = 0) + \gamma \Delta(c_i, \gamma), \text{ where} \quad (6)\\ \phi^*(c_i, \gamma = 0) &= \left(\frac{2a^2 + 2a + 4c_i^2 - 5ac_i - 2c_i}{18}\right) \text{ and}\\ \Delta(c_i, \gamma) &= \left(\frac{2 + 4ac_i - 6c_i^2 - (1 - c_i - c_i^2)\gamma}{36}\right). \end{aligned}$$

Proof: See Appendix A.2.

The following remarks are in order. Provided Condition 1 is fulfilled, it is individually rational for both firms to quote prices that are a function of their private information (the size of the ex-post marginal cost); see Appendix A.2. The reason is simple. Firms' expected profits, when they participate in the auction, are larger than those when they stay away from the auction. Also a firm can increase the probability of winning the auction (insofar as Condition 1 is fulfilled) simply by pretending to be a higher-cost firm, and thus by quoting a lower price. This, however, will not maximize the firm's expected profits as the quoted price will be the firm's profit in case of winning the

[10] In contrast to Jehiel and Moldovanu (2000) and Koska (2014), we do not assume revelation of firms' private information after the auction and before product market interactions occur.

auction. Similarly, a firm can pretend to be a lower-cost firm by quoting a higher price, but this will not maximize expected profits either, as the probability of winning the auction is inversely related to the quoted price. The profit-maximizing strategy is, thus, to quote a price that signals true productivity. Therefore, the outcome of the auction reveals valuable information that will affect future interactions (i.e., product market competition).

Proposition 2 shows that in a larger market (a is bigger) firms quote higher prices in equilibrium, as they expect a higher profit: it will be, ceteris paribus, more costly to enter a larger market by acquiring a firm. By the same token, for any given market size $a > 2$ and the cost-saving effect $\gamma \in [0,1]$, it will be more costly to acquire a lower-cost firm, such that $\partial\phi_i^*(c_i,\gamma)/\partial c_i < 0$: a lower marginal production cost enables the firm to steal more business from the investor (in case if it competes against the investor) and thus to realize a higher profit in expected terms. Moreover, the quoted prices increase with the cost-saving effect, such that $\partial\phi_i^*(c_i,\gamma)/\partial\gamma > 0$ for all $a > 2$ and c_i, $\gamma \in [0,1]$. Firms quote relatively small prices, $\phi_i^*(c_i,\gamma=0)$, when there is not much room for business-stealing (i.e., when $\gamma = 0$). As the cost-saving effect gets smaller (such that $\gamma \neq 0$ increases), firms anticipate that the acquired firm will produce with a larger marginal cost, which leads them to expect larger business-stealing (larger expected profits) when competing against the investor. Therefore, they quote higher prices, $\phi_i^*(c_i,\gamma>0)$ (see equation (6), given by Proposition 2), such that they compensate for the increase in their outside profits; see equation (5).

Finally, we are able to compute the investor's ex-ante expected profits net of fixed gains. Let $c_{(1)}$ and $c_{(2)}$ denote the signals that are rearranged in ascending order: $c_{(1)}$ is the lowest-cost signal, and $c_{(2)}$ is the highest-cost signal, such that $c_{(1)} < c_{(2)}$. Given the uniform distribution $F(c) = c$, we can write the highest-order statistics, denoted $F_1(c)$, such that $F_1(c) = F(c)^2 = c^2$. The investor's ex-ante expected profit from a separating takeover auction (which follows Condition 1), denoted by $\hat{V}^a$, is equal to

$$\begin{aligned}\hat{V}^a &= \int_0^1 \left(\int_0^{c_{(2)}} v^{(2)}(c_{(1)},c_{(2)})dF(c_{(1)}) - \phi^*(c_{(2)})\right) dF_1(c_{(2)}) + \Gamma \\ &= \int_0^1 2c_{(2)} \left(\int_0^{c_{(2)}} \frac{v^{(2)}(c_{(1)},c_{(2)})}{c_{(2)}} dc_{(1)} - \phi^*(c_{(2)})\right) dc_{(2)} + \Gamma \\ &= \frac{64a(2-5\gamma)+\gamma(181\gamma-72)-16}{864} + \Gamma, \end{aligned} \tag{7}$$

where $v^{(2)}(c_{(1)},c_{(2)})$, derived from equation (3), denotes the investor's operating profit after having acquired the high-cost firm, and $\phi^*(c_{(2)})$ is derived from equation (6).

Note carefully that the variable gains from the acquisition of a firm can be negative: the auction includes the possibility to acquire a *lemon* and to compete against a strong (high-productivity) rival. Since we are not interested in the role of the investor's participation constraint in this paper, we assume that the fixed gains Γ are sufficiently large and make any firm acquisition worthwhile. However, any separating auction relies crucially on Condition 1, and the following section shows that a lack of commitment may jeopardize the whole acquisition process when it is set up as a separating takeover auction.

3 Information externalities

In the preceding section, we have scrutinized the outcome of a separating takeover auction when Condition 1 is fulfilled. We have shown that the outcome of the auction signals firms' private information, which generates information externalities. In this section, we show that the takeover procedure via such a separating auction is prone to ex-post opportunistic behavior, which is exacerbated by information externalities. Therefore, we highlight the importance of commitment, given by Condition 1, in the presence of information externalities. Without commitment, the investor may find it profitable ex post to acquire the low-cost firm, as we could already see from equation (4). This incentive depends on the level of business-stealing which is determined by market size, the size of the ex-post marginal production cost, and on the difference in quoted acquisition prices. We will show that the investor will want to continue to acquire the high-cost firm only in a sufficiently large market, especially when there is sufficiently large cost-saving.

Suppose that the investor were free to select any firm for acquisition, and she would pick firm i. Let $V^i(c_i, c_j)$ denote the investor's ex-post profit after having acquired firm i and when competing against firm j:

$$V^i(c_i, c_j) = \left(\frac{2a - \gamma(1 + c_j)/2 + 2c_j - 3\gamma c_i}{6}\right)^2 - \phi^*(c_i) + \Gamma; \quad i \neq j \in \{1, 2\}. \tag{8}$$

The first expression of the RHS is derived from equation (3) and represents the investor's operating profit after having acquired firm i, where $\gamma(1 + c_j)/2$ corresponds to $E_j(c_i)$ in equation (3), the non-acquired firm's ex-post expectation of the acquired firm's marginal cost. The investor's market entry cost, which is equivalent to the acquired firm's quoted price, $\phi^*(c_i)$, is given by equation (6) (Proposition 2), and Γ is the fixed benefit. The investor, after having received the quoted prices, correctly anticipates the rival's (the non-acquired firm's) realized marginal production cost, simply by solving the same problem backwards: c_j in equation (8) corresponds to $E_i(c_j)$ in equation (3). In contrast, the non-acquired firm, learning only that the other firm has been acquired, updates its belief about the size of the ex-post marginal cost (i.e., $E_j(c_i) = \gamma(1+c_j)/2$). It is clear from equations (6) and (8) that (i) higher cost-saving (lower γ) leads to not only higher operating profits, but also smaller market entry costs; (ii) the impact of cost-saving on the investor's profit is accentuated in a larger market; and (iii) acquiring a high-cost firm – larger c_i in equation (8) – increases the size of the ex-post marginal cost (and so decreases the investor's operating profits), while decreasing the investor's market entry costs. We are now ready to scrutinize the role of Condition 1. We define:

Definition 1 *A separating takeover auction is self-enforcing, if it is optimal ex post for the investor to select the firm that quotes the lower acquisition price, given that both firms follow the bidding strategy, given by Proposition 2.*

A separating takeover auction will be self-enforcing only if the investor's profit $V^i(c_i, c_j)$, $i \neq j \in \{1, 2\}$, given by equation (8), in the case of acquiring the firm quoting a lower price is larger than the profit she could have earned by acquiring the other firm. So, when does a separating takeover auction work without Condition 1? We find:

Proposition 3 *For any given market size $a > 2$ and firms' cost draws $c_i, c_j \in [0, 1]$, i, $j = \{1, 2\}$, and for the threshold of cost-saving, denoted $\widetilde{\gamma} \simeq 0.32$:*

1. *If $\gamma \geq \widetilde{\gamma}$, the separating takeover auction is never self-enforcing, so it does not work without Condition 1.*
2. *If $\gamma < \widetilde{\gamma}$,*
   (a) *the separating takeover auction can be self-enforcing only for some values of c_i, c_j if $a < 10$ and/or γ is sufficiently large, but it does not work without Condition 1 as the cost realizations c_i, c_j are not known ex ante;*
   (b) *the separating takeover auction is self-enforcing for all $c_i, c_j \in [0, 1]$ if $a > 10$ and γ is sufficiently small, so it works even without Condition 1.*

Proof: See Appendix A.3.

Proposition 3 demonstrates that the investor will always want to select the high-cost firm if and only if cost-saving is substantial (γ is sufficiently small) and the market is sufficiently large. The intuition is as follows. If cost-saving is sufficiently large, the size of the ex-post marginal cost (γc_i) will be sufficiently low (even after having acquired the high-cost firm). A sufficiently low ex-post marginal cost does not allow for substantial business-stealing, while decreasing the investor's market entry costs significantly. In a sufficiently large market, these effects are accentuated, such that the decrease in market entry costs dominates the business-stealing effect: the investor would have to pay significantly larger market entry costs so as to decrease (relatively small) business stealing by the rival. If, however, the market is sufficiently small, such that $a < 10$, the target firms will believe that the investor's incentive to decrease business-stealing dominates her incentive to decrease the market entry cost, irrespective of cost-saving.

Thus, Proposition 3 suggests that both a sufficiently large market and sufficiently high cost-saving are necessary in order to ensure the firms that a separating takeover auction can be run without Condition 1. An interesting implication of Proposition 3 is that a sufficiently small business-stealing effect can serve as a signal in a takeover procedure under information externalities, such that it alleviates information externalities and, thus, provides the target firms with assurance that Condition 1 is not required to ensure that the separating auction is run according to the standard rules. We illustrate these results in Figure 1, which shows the set of parameter values of market size (a) and cost-saving ($\gamma < \widetilde{\gamma}$) for which the investor's commitment (i) is not self-enforcing for any given c_i, $c_j \in [0, 1]$ in Region I, (ii) may or may not be self-enforcing for a given c_i and c_j in Region II, or (iii) is self-enforcing for any given c_i, $c_j \in [0, 1]$ in Region III.

Region III is the only region in Figure 1 that the target firms can make sure the investor will have no incentive to select the low-cost firm also without binding commitment. In this region, both market size is sufficiently large and cost-saving is sufficiently high. In Regions I and II, the target firms anticipate that a separating takeover auction is not self-enforcing. In Region II, for example, the investor wants to acquire the lower-cost firm (which quotes a higher price) if the average industry marginal cost before the acquisition of a firm takes place, $C/2 = \left(\sum_{i=1}^{2} c_i\right)/2$, is sufficiently large such that $C > \widetilde{C}$. Although a separating takeover auction can be self-enforcing if $C < \widetilde{C}$, the firms do not know the average industry marginal cost at the time of the auction. If the target firms anticipate that there is a conflict between the investor's ex-ante commitment to a particular allocation mechanism and her objective of maximizing ex-post profits after having seen the quoted prices, they will no longer follow the bidding

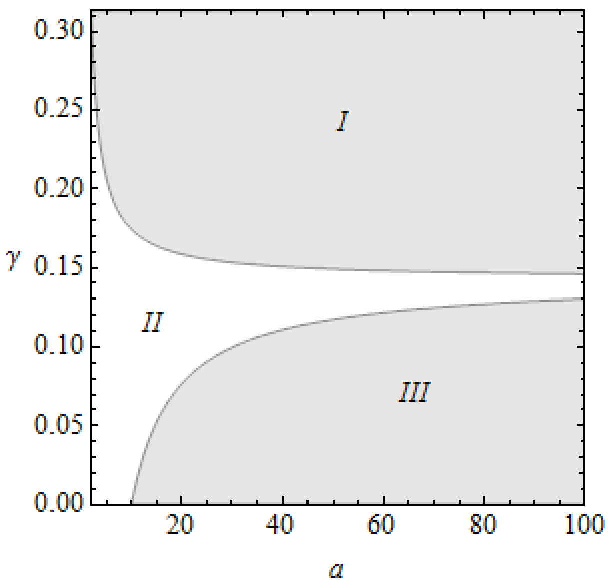

Figure 1: The scope of self-enforcing auctions

strategy, given by Proposition 2. An optimal response for all types of firms is, then, to quote the highest price that the lowest-cost firm would have quoted. Such bidding behavior will be consistent with beliefs on the investor's ex-post allocative decision: expecting the investor to acquire a firm that quotes a higher price leads the target firms to quote the highest possible price, which will increase not only their profits (the acquisition price), but also the probability of winning the auction. Consequently, the takeover procedure is no longer strategically equivalent to a first-price auction, nor does it lead to symmetric and fully-separating equilibrium in strictly decreasing bidding strategies. In such a situation, a separating equilibrium cannot exist without Condition 1: all firms would quote the same acquisition price $\phi(0)$. This would also be inconsistent with the investor's belief structure that the quoted price truthfully reveals the type. However, it does not mean that there is no pooling equilibrium in which both firms will quote the same price. This possibility is scrutinized in the next section.

4 A pooling takeover auction

An alternative auction setup is given if the investor expects both firms to quote the same acquisition price, irrespective of their cost-types. In order to scrutinize this possibility, we have to be more explicit about the investor's belief structure. In standard auctions, the belief structure does not play a critical role: bidders reveal their types, but this is inconsequential. In the previous sections, however, the belief structure has been consequential: there is no direct revelation of the cost-types, but the quoted prices in the takeover auction convey information, and the firms update their beliefs about their future rival. Furthermore, this has been a potential source of time inconsistency: the investor may want to accept the higher acquisition price, making the separating auction setup vulnerable to ex-post opportunistic behavior.

If, however, an equilibrium exists in the pooling auction, then the investor, in equilibrium, will not be able to update her beliefs but will continue to use her priors to evaluate the expected outcomes. While there is no room for a pooling equilibrium in standard auctions, we show that it plays an important role in our setup. If the investor believes that all types will quote the same acquisition price, she will not be able to use the auction as an update device. In this sense, a pooling auction setup serves as a commitment device to avoid ex-post opportunistic behavior. A delicate issue in pooling equilibria is the specification of out-of-equilibrium beliefs that will support the equilibrium. Here, we will assume that the investor is able to convince both target firms that she will believe that any firm not accepting the acquisition price she has in mind will be thought of being the highest-cost firm. The idea is that the investor sets up an auction and, prior to running it, communicates to the target firms which offer she will expect and accept, and that any firm deviating from this will be considered as the highest-cost firm.

In particular, assume that a pooling equilibrium exists in which both firms quote an acquisition price Φ^*. The investor forms beliefs as follows: (i) if any firm quotes Φ^*, the investor believes that this firm's marginal production cost is uniformly distributed between 0 and 1; (ii) if any firm quotes an acquisition price $\Phi \neq \Phi^*$, the investor believes that this firm has the highest marginal cost, such that it is equal to 1. If a pooling equilibrium exists, the investor's expected profit from firm acquisition via a pooling auction, denoted $\hat{V}^p(\Phi^*)$ where superscript p stands for pooling, is given by

$$\begin{aligned}\hat{V}^p(\Phi^*) &= \int_0^1 \left(\frac{2a - \gamma/2 + 1 - 3\gamma c}{6}\right)^2 dc - \Phi^* + \Gamma \\ &= \frac{(2a + 1 - 2\gamma)^2}{36} + \frac{\gamma^2}{48} - \Phi^* + \Gamma. \qquad (9)\end{aligned}$$

Both target firms quote the same price Φ^*. Therefore, the investor randomizes when selecting one of the target firms, which do not look different for her. Each target firm's expected profit from a pooling auction, denoted $\hat{\pi}^p(c_i)$, $i = \{1, 2\}$, is thus given by

$$\hat{\pi}^p(c_i) = \frac{1}{2}\Phi^* + \frac{1}{2}\left(\frac{2a - 1/2 + \gamma - 3c_i}{6}\right)^2. \tag{10}$$

Note that the acquisition of a firm is profitable for the investor: fixed benefits from firm acquisition (Γ) are sufficiently large. Therefore, any pooling equilibrium supported by the belief structure has to fulfill the condition that no firm has an incentive to quote a different acquisition price.

If any firm quotes a higher price than Φ^*, the investor will never select this firm, but will update her beliefs, such that after the acquisition of the other firm, she will have received the good news that the rival has the highest cost. This specifies a lower bound for the acquisition price: if Φ^* price is too low, a target firm might find it more profitable not to quote it and lose the auction even if this leads the investor to believe that the firm has the highest cost. If, however, any firm quotes a lower acquisition price than Φ^*, this lower price will be accepted by the investor only if it undercuts Φ^* substantially: the investor believes that the defecting firm is of highest cost-type, which increases the expected operating profit from the acquisition of the rival firm and decreases the operating profit from the acquisition of the defecting firm. This defection option puts an upper bound on Φ^*: if Φ^* is very large, it is relatively costless to undercut the candidate pooling acquisition price. Appendix A.4 has the details of the defection options and proves that

Proposition 4 *Pooling equilibria exist: each target firm quotes the same acquisition price* $\Phi^* \in [\underline{\Phi}, \overline{\Phi}]$ *where*

$$\overline{\Phi} = \frac{(2a + 2 - 2\gamma)^2}{18} + \frac{\gamma^2}{24} - \frac{(2a - 7\gamma/2 + 1)^2}{18} + \frac{(2a - 7/2 + \gamma)^2}{36},$$

$$\underline{\Phi} = \frac{(2a - 1 + \gamma)^2}{18} - \frac{(2a - 1/2 + \gamma)^2}{36}.$$

Proof: See Appendix A.4.

Let us consider the "best" pooling outcome from the investor's perspective, that is, $\Phi^* = \underline{\Phi}$. Substituting $\Phi^* = \underline{\Phi}$ into equation (9) gives the investor's "best" expected payoff in a pooling auction:

$$\begin{aligned} \hat{V}^p(\Phi^* = \underline{\Phi}) &= \frac{(2a + 1 - 2\gamma)^2}{36} + \frac{\gamma^2}{48} - \underline{\Phi} + \Gamma \\ &= \frac{1}{144}(8a(5 - 6\gamma) + (1 + 3\gamma)(5\gamma - 3)) + \Gamma. \end{aligned} \tag{11}$$

How does the outcome of the pooling auction compare to that of the separating auction?

Proposition 5 *The best pooling equilibrium for the investor has a higher expected payoff than the separating (auction) equilibrium.*

Proof: See Appendix A.5.

This is a strong result: we find that the investor can always do better with a pooling auction. The pooling auction allows her to commit not to exploit information revealed during the auction. On the one hand, the pooling auction will serve as a commitment device against opportunistic behavior which jeopardizes the separating takeover auction. On the other hand, the separating takeover auction can only be run such that the investor will select the high-cost firm, but the pooling auction avoids adverse selection. This is an important difference to a model in which the investor makes take-it-or-leave-it acquisition offers to target firms (see e.g., Koska and Stähler, 2014) as these offers made by the investor may discriminate against low cost-types. With a pooling auction in which the target firms are expected to quote identical acquisition prices, the investor will have a chance to acquire the more profitable (low-cost) target firm.

5 Concluding remarks

Our paper has brought together two different strands of the recent auction literature: (i) auctions with post-auction strategic interactions among agents, and (ii) auctions without enforceable commitment. We have shown that a separating auction procedure for firm acquisition will imply adverse selection. Furthermore, commitment issues along with information externalities, due to post-auction interaction, may make the takeover procedure via a separating auction not work. However, a pooling auction will work and can even yield a higher expected payoff for the investor.

Appendix

A.1 Proof of Proposition 1

Recall that $c_{(1)}$ and $c_{(2)}$ are the signals that are rearranged in ascending order: $c_{(1)} < c_{(2)}$. If the design is given, such that the investor acquires the low-cost firm and competes against the high-cost firm, then the investor's ex-ante expected operating profit from acquiring the low-cost firm, denoted $\hat{v}^{(1)}(c_{(1)}, c_{(2)})$, is equal to

$$\begin{aligned}
\hat{v}^{(1)}(c_{(1)}, c_{(2)}) &= \int_0^1 \left(\int_{c_{(1)}}^1 v^{(1)}(c_{(1)}, c_{(2)}) dF(c_{(2)}) \right) dF_2(c_{(1)}) \\
&= \int_0^1 2(1 - c_{(1)}) \left(\int_{c_{(1)}}^1 \frac{\left(2a - \gamma c_{(2)}/2 + 2c_{(2)} - 3\gamma c_{(1)}\right)^2}{36(1 - c_{(1)})} dc_{(2)} \right) dc_{(1)} \\
&= \frac{1}{864} \left(96a^2 + 128a(1 - \gamma) + 57\gamma^2 - 96\gamma + 48\right),
\end{aligned}$$

where $v^{(1)}(c_{(1)}, c_{(2)})$ is derived from equation (3), and denotes the investor's operating profit after having acquired the low-cost firm. $F_2(c)$ is the lowest-order statistics, and given the uniform distribution $F(c) = c$, we can show that $F_2(c) = 2F(c) - F(c)^2 = c(2 - c)$. If, however, the design is given, such that the investor acquires the high-cost firm and competes against the low-cost firm, then the investor's ex-ante expected operating profit from acquiring the high-cost firm, denoted $\hat{v}^{(2)}(c_{(1)}, c_{(2)})$, is equal to

$$\begin{aligned}
\hat{v}^{(2)}(c_{(1)}, c_{(2)}) &= \int_0^1 \left(\int_0^{c_{(2)}} v^{(2)}(c_{(1)}, c_{(2)}) dF(c_{(1)}) \right) dF_1(c_{(2)}) \\
&= \int_0^1 2c_{(2)} \left(\int_0^{c_{(2)}} \frac{\left(2a - \gamma(1 + c_{(1)})/2 + 2c_{(1)} - 3\gamma c_{(2)}\right)^2}{36c_{(2)}} dc_{(1)} \right) dc_{(2)} \\
&= \frac{1}{864} \left(96a^2 + 64a(1 - 4\gamma) + \gamma(185\gamma - 96) + 16\right),
\end{aligned}$$

where $v^{(2)}(c_{(1)}, c_{(2)})$ is derived from equation (3), and denotes the investor's operating profit after having acquired the high-cost firm. $F_1(c) = F(c)^2 = c^2$ is the highest-order statistics. We are now ready to show that

$$\hat{v}^{(1)}(c_{(1)}, c_{(2)}) - \hat{v}^{(2)}(c_{(1)}, c_{(2)}) = \frac{1}{27}(2\gamma + 1)(2a - 2\gamma + 1) > 0,$$

which proves the first part of Proposition 1. In the second part of Proposition 1, it is noted that, as to realize $\hat{v}^{(1)}(c_{(1)}, c_{(2)})$, no implementable design that leads to truthful revelation exists. We do the proof by contradiction: we assume that there is a design in which the investor learns the types. In such a design, for all possible cost realizations, the low-cost firm is selected and the other firm learns - by not being selected - that the acquired firm has a lower cost. If such a design exists, using the Revelation Principle, we can confine the analysis to a design in which each target firm will send the investor a cost signal that should reveal, in equilibrium, the firm's realized (true) cost. In an implementable design, each target firm truthfully reports its cost-type to the investor. Suppose that a target firm of type c sends cost signal $\tilde{c}$ to the investor. The target firm's expected profit is then given by

$$\tilde{c}\left(\frac{2a - \tilde{c} + \gamma\tilde{c} - 3c}{6}\right)^2 + T(\tilde{c})$$

where the expression in brackets, derived from equation (2), is the firm's profit when it competes against the lower-cost (acquired) firm, and $T(\tilde{c})$ is the transfer from the investor to the target firm that signals type $\tilde{c}$. If the target firm sends cost signal $\tilde{c}$, the probability of being a higher-cost firm (that is, the probability of the other firm being a lower-cost firm) is exactly equal to $\tilde{c}$: with probability $\tilde{c}$, the firm will not be selected and will realize the profit of a firm competing against a lower-cost firm. At the same time, the firm that is not selected learns that the selected firm has a lower cost than $\tilde{c}$, so the expected ex-post marginal cost of the selected firm - which corresponds to $E_i(c_j)$ in equation (2) - is equal to $\tilde{c}\gamma/2$. Consider now any two different types $c', c'' \in [0,1]$. If a design exists, it must be incentive compatible, such that neither type has an incentive to mimic the other type:

$$IC' = c'\left(\frac{2a + c'\gamma - 4c'}{6}\right)^2 + T(c') - \left(c''\left(\frac{2a - c'' + c''\gamma - 3c'}{6}\right)^2 + T(c'')\right) \geq 0,$$

$$IC'' = c''\left(\frac{2a + c''\gamma - 4c''}{6}\right)^2 + T(c'') - \left(c'\left(\frac{2a - c' + c'\gamma - 3c''}{6}\right)^2 + T(c')\right) \geq 0.$$

Adding up these two inequalities should also be positive. However, we can show that

$$IC' + IC'' = -\frac{1}{12}(c' - c'')^2(4a - (5 - 2\gamma)(c' + c''))$$

is definitely negative for sufficiently low cost realizations (and/or for a sufficiently large a). Consequently, any implementable design in which the target firms will truthfully report their cost-types and the low-cost firm will be selected for acquisition will not exist, proving the second part of Proposition 1. Note that Appendix A.2 shows that a mechanism (designed as an auction) will exist if the investor can commit to select the high-cost firm. In that case, the transfer, denoted by T in this section, is equivalent to the expected profit when the firm is selected for acquisition, that is, the probability of being selected times the quoted acquisition price.

A.2 A separating takeover auction with commitment

Incentive compatibility

Consider the two different types - as defined by private (marginal cost) information - $c', c'' \in [0,1]$. A separating takeover auction must be incentive compatible, such that neither type has an incentive to mimic the other type:

$$\begin{aligned} IC' = \; & c'\phi' + (1-c')\left(\frac{2a+\gamma(1+c')-4c'}{6}\right)^2 \\ & -\left(c''\phi'' + (1-c'')\left(\frac{2a-c''+\gamma(1+c'')-3c'}{6}\right)^2\right) \geq 0, \end{aligned} \tag{A.1}$$

$$\begin{aligned} IC'' = \; & c''\phi'' + (1-c'')\left(\frac{2a+\gamma(1+c'')-4c''}{6}\right)^2 \\ & -\left(c'\phi' + (1-c')\left(\frac{2a-c'+\gamma(1+c')-3c''}{6}\right)^2\right) \geq 0. \end{aligned} \tag{A.2}$$

Adding up the two inequalities, given by equations (A.1) and (A.2), leads to

$$IC' + IC'' = \frac{1}{12}(c'-c'')^2(4a-(5-2\gamma)(c'+c'')+2),$$

which is clearly positive for any $c', c'', \gamma \in [0,1]$, given $a > 2$. Hence, the sufficient condition for incentive compatibility is fulfilled.

Optimal bids and individual rationality

Firm i has to quote a price that maximizes the expected profit given by equation (5). We simplify the notation by expressing equations without subscript i. The first-order condition, $\partial\pi(\phi)/\partial\phi = 0$, is equal to

$$\Psi(\phi) + \frac{\partial\Psi(\phi)}{\partial\phi}\left(\begin{array}{l} \phi - \left(\dfrac{2a-\Psi(\phi)+\gamma(1+\Psi(\phi))-3c}{6}\right)^2 \\ -(1-\Psi(\phi))(1-\gamma)\left(\dfrac{2a-\Psi(\phi)+\gamma(1+\Psi(\phi))-3c}{18}\right) \end{array}\right) = 0.$$

We assume that both firms follow the same strategy $\phi(c)$, which is strictly decreasing in a firm's marginal cost and has a well-defined inverse function. In equilibrium, the inverse of a firm's price function is equal to the firm's marginal cost.

Substituting $c \equiv \Psi(\phi(c))$ into the first-order condition gives

$$\Psi(\phi) + \frac{\partial \Psi(\phi)}{\partial \phi} \left(\begin{array}{c} \phi - \left(\frac{2a + \gamma(1 + \Psi(\phi)) - 4\Psi(\phi)}{6} \right)^2 \\ -(1 - \Psi(\phi))(1 - \gamma) \left(\frac{2a + \gamma(1 + \Psi(\phi)) - 4\Psi(\phi)}{18} \right) \end{array} \right) = 0, \quad \text{(A.3)}$$

where $\Psi\left(\overline{\phi}\right) \equiv 0$ such that $\overline{\phi} \equiv (2a+\gamma)^2/36 + (2a+\gamma)/18$. Note that $\overline{\phi}$ is the maximum price that the most efficient firm quotes in equilibrium. We can use equation (A.3) to characterize the firms' quoted prices in equilibrium. Rewriting equation (A.3) as a differential equation,

$$-\phi'(c) = \frac{1}{c} \left(\begin{array}{c} \phi(c) - \left(\frac{2a + \gamma(1 + c) - 4c}{6} \right)^2 \\ -(1 - c)(1 - \gamma) \left(\frac{2a + \gamma(1 + c) - 4c}{18} \right) \end{array} \right),$$

and, by including the boundary condition $\phi(0) = (2a + \gamma)^2/36 + (2a + \gamma)/18$, solving for $\phi(c)$ gives the optimal price function:

$$\phi^*(c, \gamma) = \underbrace{\frac{(2a^2 + 2a + 4c^2 - 5ac - 2c)}{18}}_{\phi^*(c, \gamma = 0)} + \underbrace{\gamma \frac{(2 + 4ac - 6c^2 - (1 - c - c^2)\gamma)}{36}}_{\gamma \Delta(c, \gamma)}.$$

Individual rationality is guaranteed: a firm's expected profit when it participates in the auction, $c\phi^*(c, \gamma) + (1 - c)(2a + (1 + c)\gamma - 4c)^2/36$, is larger than its expected profit when it stays away from the auction, $(2a - (1/2) + \gamma - 3c)^2/36$. A firm can manipulate the post-auction market game by participating in the auction, and by pretending to be the lowest-cost firm ($c'' = 0$ or $c' = 0$ in equations (A.1) and (A.2), respectively) which of course leads to a larger expected outside profit, $(2a + \gamma - 3c)^2/36$. Even in this case, $c\phi^*(c, \gamma) + (1 - c)(2a + (1 + c)\gamma - 4c)^2/36 > (2a + \gamma - 3c)^2/36$, provided $a > 2$.

A.3 Proof of Proposition 3

Recall that $V^i(c_i, c_j)$, $i \neq j \in \{1, 2\}$, given by equation (8), denotes the investor's expected profit after having acquired firm i and when competing against firm j. Firms quote prices $\phi^*(c_i)$, $i \in \{1, 2\}$, in equilibrium, following the price function, given by Proposition 2. The investor's commitment on acquiring the higher-cost firm is credible only if the investor acquires firm i when firm i's quoted price is less than the price quoted by the other firm.

Let us suppose that firm i's marginal cost is larger than that of firm j, such that $c_i > c_j$, $i \neq j \in \{1,2\}$, implying firm i and firm j will quote prices in equilibrium such that $\phi^*(c_i) < \phi^*(c_j)$, $i \neq j \in \{1,2\}$. We need to prove that $V^i(c_i, c_j) > V^j(c_i, c_j)$, $i \neq j \in \{1,2\}$, that is, the investor will acquire firm i in such a situation, even without binding commitment, which makes the auction self-enforcing. Equation (A.4) gives the difference between $V^i(c_i, c_j)$ and $V^j(c_i, c_j)$:

$$V^i(c_i, c_j) - V^j(c_i, c_j) = \frac{1}{144}(c_i - c_j)(\alpha + \beta C); \quad i \neq j \in \{1,2\}, \tag{A.4}$$

where $C = c_i + c_j$, $\alpha = 16 + 8a + 8\gamma - 56a\gamma + 6\gamma^2$, and $\beta = -48 + \gamma(32 + 31\gamma)$.

Equation (A.4) shows that $V^i(c_i, c_j) > V^j(c_i, c_j)$ only if $(\alpha + \beta C) > 0$, given $c_i > c_j$. We can see that $\partial(\alpha + \beta C)/\partial C < 0$ if $\gamma < 0.831$. Let us start from the case $\gamma > 0.831$, so $\partial(\alpha + \beta C)/\partial C > 0$. It is obvious that $V^i(c_i, c_j) - V^j(c_i, c_j) = 0$ if $C = \widetilde{C}$, where $\widetilde{C} = -\alpha/\beta$. Also, it is straightforward to show that $\widetilde{C} > 2$ for any given $a > 2$, and for $\gamma \in [0.831, 1]$. Therefore, for all $c_i \in [0,1]$, $i = \{1,2\}$, $C < \widetilde{C}$, implying that $V^i(c_i, c_j) - V^j(c_i, c_j) < 0$. The investor's profit will be larger if she acquires the lower-cost firm. So the investor's commitment is not credible given that γ is sufficiently large such that $\gamma > 0.831$. If, however, $\gamma < 0.831$, then $\partial(\alpha + \beta C)/\partial C < 0$. In this case, we can see that $\widetilde{C} < 0 < C$ for all $c_i \in [0,1]$, $i = \{1,2\}$, for any given $a > 2$, and for $\gamma \in [0.313, 0.831]$. Consequently, the investor fails to commit credibly on acquiring the higher-cost firm when $\gamma \in [0.313, 0.831]$, or rather, when $\gamma \in [0.313, 1]$.

As for $\gamma \in [0, 0.313]$ at which $\partial(\alpha + \beta C)/\partial C < 0$, we find that $\widetilde{C} < 0 < C$. The investor fails to commit credibly on acquiring the higher-cost firm, especially for some constellations of parameter values of a and γ (Region I in Figure 1). Similarly, we find that $\widetilde{C} > 2 > C$ in Region III, illustrated by Figure 1, so the auction is self-enforcing in this region. As is illustrated by Figure 1, $\widetilde{C} \in [0,2]$ in Region II: the investor's ex post behavior depends on the value of C. In Region II, the investor wants to acquire the lower-cost firm if the average industry marginal cost before the acquisition of a firm takes place, $C/2$, is sufficiently large, such that $C > \widetilde{C}$. Although a separating takeover auction can be self-enforcing if $C < \widetilde{C}$, the firms do not know the average industry marginal cost at the time of the auction. Consequently, a separating takeover auction does not work in Region II.

A.4 Proof of Proposition 4

Suppose that a target firm quotes a higher acquisition price $\Phi' > \Phi^*$. This higher acquisition price will make sure that this target firm will not be selected. The reason is simple. First, the acquisition price is higher; and second, the investor believes now that it will face a weak rival after having acquired the other firm. The expected profit of the target firm quoting Φ', denoted $\hat{\pi}^{p\prime}(c_i)$, and that of the target firm quoting Φ^*, denoted $\hat{\pi}^p(c_i)$ and given by equation (10), are compared in equation (A.5):

$$\hat{\pi}^{p\prime}(c_i) = \left(\frac{2a - 1 + \gamma - 3c_i}{6}\right)^2 \leq \hat{\pi}^p(c_i) = \frac{1}{2}\Phi^* + \frac{1}{2}\left(\frac{2a - 1/2 + \gamma - 3c_i}{6}\right)^2$$

$$\Leftrightarrow \Phi^* \geq \frac{(2a - 1 + \gamma - 3c_i)^2}{18} - \frac{(2a - 1/2 + \gamma - 3c_i)^2}{36}, \quad \text{(A.5)}$$

where the inequalities are the condition that this defection option is not be profitable. This defection option should not be profitable for any cost-type. To determine the relevant condition, we define

$$\Lambda(c_i) \equiv \frac{(2a - 1 + \gamma - 3c_i)^2}{18} - \frac{(2a - 1/2 + \gamma - 3c_i)^2}{36},$$

where $d\Lambda/dc_i = -(4a - 6c + 2\gamma - 3)/12$ and $d^2\Lambda/dc_i^2 = 1/2$, showing that $\Lambda(c_i)$ is convex in c_i. Thus, the maximum of Λ is either $\Lambda(0)$ or $\Lambda(1)$. We can show that

$$\Lambda(0) - \Lambda(1) = \frac{1}{6}(2a + \gamma - 3) > 0,$$

because $a > 2$. Thus, we find that the condition given by equation (A.5) holds for all cost-types if it is satisfied for the most productive firm, $c_i = 0$:

$$\Phi^* \geq \frac{(2a - 1 + \gamma)^2}{18} - \frac{(2a - 1/2 + \gamma)^2}{36}. \quad \text{(A.6)}$$

Now suppose that the target firm quotes a lower acquisition price $\Phi'' < \Phi^*$. The investor has the option to accept this lower offer, but at the same time she updates her beliefs, such that she assumes that this is now a target firm with the highest marginal production cost, which is equal to 1. A remark on the rival firm is in order when this lower bid is accepted by the investor. Since bids are not revealed, the firm that is not selected by the investor will not be able to learn whether or not the winning bid was a deviation; therefore it will continue to assume that the firm that is selected by the investor has an expected cost realization of 1/2, which leads to the expected ex-post marginal cost of the acquired firm $\gamma/2$. Therefore, the investor's expected payoff from accepting the lower offer, denoted $\hat{V}^{p\prime\prime}(\Phi'')$, is equal to

$$\hat{V}^{p\prime\prime}(\Phi'') = \left(\frac{2a - 7\gamma/2 + 1}{6}\right)^2 - \Phi'' + \Gamma,$$

which we can compare with her expected payoff from rejecting Φ'' (in which case she will update her beliefs accordingly) and accepting Φ^*, denoted $\hat{V}^{p''}(\Phi^*)$ and given by

$$\hat{V}^{p''}(\Phi^*) = \int_0^1 \left(\frac{2a - \gamma/2 + 2 - 3\gamma c}{6}\right)^2 dc - \Phi^* + \Gamma = \frac{(2a + 2 - 2\gamma)^2}{36} + \frac{\gamma^2}{48} - \Phi^* + \Gamma.$$

A lower offer makes sense only if it will be accepted by the investor. Otherwise, the target firm loses, not only because the lower offer is declined, but also it will be considered as the highest-cost firm by the investor. The investor will accept the lower offer Φ'' if $\hat{V}^{p''}(\Phi'') > \hat{V}^{p''}(\Phi^*)$ which is the case when

$$\Phi'' < \Phi^* - \left(\frac{(2a + 2 - 2\gamma)^2}{36} + \frac{\gamma^2}{48} - \frac{(2a - 7\gamma/2 + 1)^2}{36}\right).$$

At the same time, Φ'' must be large enough to make the defecting firm better off such that $\Phi'' > \hat{\pi}^p(c_i)$, where $\hat{\pi}^p(c_i)$ is given by equation (10). Thus, we conclude that no target firm of any cost-type has an incentive to quote a lower acquisition price if

$$\begin{aligned}
\hat{\pi}^p(c_i = 1) &= \frac{1}{2}\Phi^* + \frac{1}{2}\left(\frac{2a - 7/2 + \gamma}{6}\right)^2 \\
&\geq \Phi^* - \left(\frac{(2a + 2 - 2\gamma)^2}{36} + \frac{\gamma^2}{48} - \frac{(2a - 7\gamma/2 + 1)^2}{36}\right) \\
\Leftrightarrow \Phi^* &\leq \frac{(2a + 2 - 2\gamma)^2}{18} + \frac{\gamma^2}{24} - \frac{(2a - 7\gamma/2 + 1)^2}{18} + \frac{(2a - 7/2 + \gamma)^2}{36}. \qquad \text{(A.7)}
\end{aligned}$$

Note that $\hat{\pi}^p(c_i)$, given by equation (10), increases with a decrease in c_i. Therefore, if the acquisition price that would be accepted by the investor (Φ'') is too small even for the least productive target firm, such that $\hat{\pi}^p(c_i = 1) > \Phi''$, then it is not profitable for any firm to deviate. In summary, we can use the two conditions that are given by equations (A.6) and (A.7), respectively, to show that a pooling equilibrium exists if these two conditions

$$\begin{aligned}
\Phi^* &\leq \frac{(2a + 2 - 2\gamma)^2}{18} + \frac{\gamma^2}{24} - \frac{(2a - 7\gamma/2 + 1)^2}{18} + \frac{(2a - 7/2 + \gamma)^2}{36} \equiv \overline{\Phi}, \\
\Phi^* &\geq \frac{(2a - 1 + \gamma)^2}{18} - \frac{(2a - 1/2 + \gamma)^2}{36} \equiv \underline{\Phi}
\end{aligned}$$

hold at the same time, where $\overline{\Phi} - \underline{\Phi} = (2\gamma(4a - 5\gamma - 2) + 11)/24 > 0$ for any $\gamma \in [0, 1]$ and $a > 2$. This completes the proof that pooling equilibria exist, such that each target firm quotes the same acquisition price $\Phi^* \in [\underline{\Phi}, \overline{\Phi}]$.

A.5 Proof of Proposition 5

The difference between equations (11) and (7) is equal to

$$\frac{1}{864}\left(16a(7+2\gamma)-2+\gamma(48-91\gamma)\right)>0,$$

for any $\gamma \in [0,1]$ and $a > 2$.

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