Similar bidders in takeover contests

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A R T I C L E   I N F O

A B S T R A C T

When bidders in a corporate takeover have related resources and post-acquisition strategies, their valuations of a target are likely to be interdependent. This paper analyzes sequential-entry takeover contests in which similar bidders have correlated private valuations. The level of similarity affects information content of bids and bidding competition. Our model predicts that expected acquisition prices and the probability of multiple-bidder contests are the highest for intermediately similar bidders. We test these predictions in laboratory experiments in which we control the similarity between bidders. The experimental data confirm the non-monotonic effects of similarity on prices and on the frequency of multiple-bidder contents.

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1. Introduction

Returns in mergers and acquisitions for acquirer and target not only depend on the value that is created, but also on acquisition premium that is paid. Empirical research indicates that, overall, acquisitions do create value (Andrade et al., 2001; Bargeron et al., 2008; Betton et al., 2008) but gains accrue mostly to targets. Acquiring firms' returns are, on average, close to zero and exhibit large variation (Stulz et al., 1990; Leeth and Borg, 2000; Fuller et al., 2002; Moeller et al., 2005). Taken together, the evidence suggests that acquisition prices are determinative for the division of takeover surplus.

The underlying causes of this variation in prices and returns have been subject to continuous scrutiny in the empirical literature. Surprisingly, the level of competition as measured by the number of bidders does not seem to explain this variation (Boone and Mulherin, 2008).[1] However, characteristics of buyers do appear to be successful in explaining returns.[2]

Guided by this evidence, we develop a model of takeover contests in which the characteristics of potential acquirers matter and affect the intensity of competition. We want to take into account that potential acquirers can be similar or dissimilar because they may have very similar or very unique resources, capabilities, and post-acquisition strategies. More

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[1] Boone and Mulherin (2008) use an extensive data set on potential bidders and control for the endogeneity between returns and the level of competition. Some earlier studies using less detailed data sets show either no significant relation (Kale et al., 2003; Betton et al., 2008) or mixed results (Schwert, 2000).

[2] Bidder size is responsible for a large portion of variation in returns (Moeller et al. 2004, 2005). Acquirers with more uncertain growth prospects gain less in acquisitions (Moeller et al., 2007). Furthermore, the premiums paid to targets depend significantly on the public status of acquirers and whether acquirers are operating firms or private equity funds (Bargeron et al., 2008). Among operating firms, acquirer returns depend on the strategic objectives of acquiring firms (such as vertical integration, horizontal integration, or diversification) (Walker, 2000).

specifically, we analyze a model of two potential bidders that may sequentially enter a takeover contest. If the bidders are similar, their private values of a target are correlated. After observing the initial bid, the second bidder may decide to pay an entry cost to learn its valuation and to participate in the contest. Entering takeover contests is costly since information on target value requires due diligence costs such as fees for consultants, lawyers and investment bankers. The first bidder may offer a high (preemptive) bid in an attempt to deter the competing firm from entering. Alternatively, a low (accommodating) offer by the first bidder may induce entry by the second bidder and start a competitive auction. The signaling effect of an opening offer depends critically on the similarity between bidders.

The interdependence of bidders' valuations has two opposing effects on contest participation. On the one hand, a bid from a bidder that is similar creates a greater informational externality and thereby encourages entry by a rival. On the other hand, if bidders are more closely related, the bidding contest is expected to be more competitive. The resulting high prices reduce expected payoffs from participation and thus discourage entry. We show that neither of the effects is dominant but their relative strengths depend on the level of similarity and radically affect bidding strategies, price, and bidders' participation. Our analysis provides several important new insights and implications.

First, conditional on observing a takeover, the probability of single-bidder acquisitions and multiple-bidder contests varies in similarity between potential bidders. Multiple-bidder contests are most likely between intermediately similar competitors, due to the strength of informational externalities of initial bids that attracts followers. Initial bids from very similar bidders promise an even higher expected target value, but also indicate a fierce bidding competition. As a result, single-bidder contests are expected mostly between dissimilar (when informational externalities are low) and very similar competitors (when potential competition is high).

Second, expected prices for targets demonstrate an inverted U-shape in the level of bidder similarity. This pattern applies for prices in both single-bidder acquisitions and in multiple-bidder contests. The initial bid embeds informational externalities that signal value, making it attractive for competitors to enter. In single-bidder acquisitions, this means that high preemptive bids are required to deter a competitor that shares some of the sources of value. However, if bidders become very similar, the competition effect on prices starts to dominate informational externalities, and deterrence is possible with a relatively low preemptive bid. When multiple-bidder contests occur, competitive bidding yields higher prices when rivals are more similar. However, when rivals are almost identical, the initial bidder will accommodate only if its valuation is low, but this means that the expected price in the contest will be low as well.

Third, our analysis indicates that in an environment with interdependent values, the similarity of potential bidders is an important measure of competition intensity. Targets' returns are higher in single-bidder acquisitions than in multiple-bidder contests for any given level of similarity because a premium is required to preempt a rival. However, this does not necessarily imply that empirical data should demonstrate higher target returns in single-bidder acquisitions. As discussed above, multiple-bidder contests are most likely at intermediate levels of similarity at which expected prices are the highest. Conversely, single-bidder acquisitions are most likely at very low and very high levels of similarity when expected prices are lower. This implies that, in a cross-section of acquisitions, the relation between the number of bidders and target returns may show either sign if the level of similarity is not controlled for.

The theoretical predictions of the model are difficult to test empirically using historical acquisition data because information about the identity of preempted bidders, and so their similarity with acquirers, is not readily observable by researchers. To overcome this difficulty, we employ a laboratory experiment with financially well-trained subjects. Relative to tests using field data where many relevant factors change simultaneously, controlled environments of laboratory experiments allow for clear comparative static tests. At the same time, laboratory experiments raise questions about external validity—is the behavior of students-subjects informative about investment strategies of firms? We believe that the experiment can inform us about the validity of our theory. First, the academic literature on takeovers shows that *individuals* play an important role in investment and acquisition decisions. CEOs, like all other people, have behavioral biases and these biases not only drive takeovers (Roll, 1986; Berkovitch and Narayanan, 1993), but also affect premiums paid in acquisition (Hayward and Hambrick, 1997; Malmendier and Tate, 2008; Levi et al., 2010). Second, human behavior often deviates from theoretical predictions even in simple auctions [see Kagel (1995) for a survey]. People in general demonstrate systematic biases that may intensify some predicted forces and weaken others. The aim of our experiment is to verify if people respond to the tradeoffs in our model. As such, a laboratory test is a first and important step to validate the relevance of our theoretical predictions to corporate environments.[3]

The experimental design replicates the model specification. Two groups of subjects play the roles of first or second bidder in an auction for a target. Their valuations are correlated with a correlation coefficient called "similarity level". The first bidder chooses his first bid and the second bidder can decide to enter or not depending on the first bid and the similarity level. In this way, we collect data about preemptive bidding behavior and conditional entry decisions.

The experimental results support the main insights of the model. Our first observation is that high first bids deter second bidders from entering in line with the preemption arguments. We then find that the frequency of multiple-bidder contests demonstrates a non-monotonic pattern in similarity levels. Furthermore, prices in both single- and multiple-bidder contents first increase in similarity and then decrease, as predicted by the theory.

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[3] Several other papers also use experiments to test corporate takeovers theories, e.g., Kale and Noe (1997), Weber and Camerer (2003), Croson et al. (2004), Gillette and Noe (2006), and Kogan and Morgan (2010).

This paper is related to the literature on sequential bidding in takeover contests initiated by Fishman (1988). With sequential entry, there is information externality from initial bids. Hence, a high first bid, which signals a high value of initial bidders for the target, can deter competition. Others have extended this model in various directions. Fishman (1989) shows that the medium of exchange can be a supplementary tool for preemption in addition to a high bid. Chowdhry and Nanda (1993) claim that issuing debt commits the bidder to overbidding, which can be preemptive. Burkart (1995), Singh (1998), Bulow et al. (1999), and Ravid and Spiegel (1999) study overbidding induced by toeholds. Hirshleifer and Png (1989), Daniel and Hirshleifer (1998) explore takeovers from the perspective of efficiency, and find that, although preemption reduces competition, it may raise expected social welfare if bidding is costly. Che and Lewis (2007) apply the preemption model to a policy analysis of lockups, and discuss how lockups affect competition levels and allocation efficiency. Bulow and Klemperer (2009) compare simultaneous auctions and sequential-entry takeover contests and rationalize the target's preference for auctions rather than for sequential bidding by showing how preemptive bids transfer surplus from sellers to buyers. The model presented here differs from all these papers in that it investigates the impact of similarity between bidders on equilibrium bids, participation, and returns by assuming private correlated values. Our experiment is the first direct test in a controlled environment of the underling model of sequential-entry takeover contrasts.

2. A model of takeover contests

2.1. Bidders and target values

Two potential bidders, firms A and B, compete to acquire a target.[4] The private values of the target for the two bidders are allowed to be interdependent. The valuation of firm i is denoted by v_i, $i = A, B$. Both valuations are drawn from normal distributions with equal means, v_0, standard deviations, σ, and are correlated with coefficient $\rho \geqslant 0$. f_i and F_i denote probability density and cumulative distribution functions of $\tilde{v}_i$. Below we use the notation $\tilde{v}_A$ and $\tilde{v}_B$ for the random values and v_A and v_B for their realizations to clarify the distinction. The bidders know the distributions of both values, but can observe the realizations of their own values only after conducting costly valuation and cannot directly observe the value realizations of the opponent. Target value without a takeover is equal to v_0. This means that uninformed bidders expect neither to create nor to destroy value in the takeover. The target accepts any offer at or above v_0.

We model the interdependence of values using non-negative correlation instead of the commonly-used affiliation, mostly because correlation is easier to understand for the subjects in our experiment.[5] It is important to understand how to interpret different levels of the correlation coefficient. The correlation between bidders' valuations reflects the degree of similarity of the rival bidders' resources, capabilities, and post-acquisition strategies. More specifically, we have the following examples in mind. Private equity funds often have very similar post-acquisition strategies and are therefore likely to face high correlation between valuations. For example, in leveraged buyouts, the added value is mainly generated by tax shields, high managerial participation, improved monitoring stemming from concentrated ownership and the disciplining effect of leverage. These value drivers are relatively homogeneous and can be obtained by a number of capable investors. Strategic buyers are more heterogeneous as they may have built up unique assets and are likely to create unique synergies that depend on the bidders' assets and resources and their match with the target. Clearly, in some such cases the correlation may be positive and high (e.g., two industry competitors competing for a horizontal merger with a third firm), but in other situations it can be much lower (e.g., an industry leader aiming at horizontal integration and industry consolidation competing against an industry supplier aiming at limiting bargaining power). Zero correlation can be expected if two bidders derive values from a completely different match of resources or industry forces, for example, a hostile bidder with an asset-stripping strategy and a strategic bidder valuing the target as a going concern.

2.2. Bidding and payoffs

We consider the following bidding contest. First, bidder A finds a potential target that is suitable for acquisition. Following Fishman (1989), we assume that there are few potential targets so that it is not profitable for acquirers to perform costly due diligence on random firms. Bidder A pays entry cost c_A to get informed about its private valuation v_A of the target. Next, if v_A exceeds the seller's reservation price, v_0, then bidder A places an initial offer b. If bidder A does not place a bid, the contest is over, as bidder B does not know the potential target. After observing b, bidder B decides whether to enter the contest and to learn its valuation v_B of the target. We denote bidder B's decision by $e_B \in \{0, 1\}$, where $e_B = 0$ indicates that bidder B does not enter the contest and $e_B = 1$ indicates that bidder B pays entry cost c_B and learns v_B. Finally, if bidder

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[4] Our focus on the single-bidder and two-bidder contests should be not seen as very limiting as few contests have more than two bidders. Bradley et al. (1988) report only eight instances of more than two public bidders in their sample of 286 contests. The number of *potential* bidders may be higher, but Boone and Mulherin (2008), who also identify potential bidders that did not publicly place a bid, provide evidence that our assumption is close to reality in most situations. They show that the average number of potential buyers (those signing confidentiality agreements to access non-public information about the target) is 3.14 (median 1), of private-bid bidders is 1.24 (median 1) and of public-bid bidders is 1.12 (median 1). The low numbers also indicate that it should be relatively easy for firms to identify other potential buyers.

[5] Note that affiliation is a subset of positive correlation.

B enters, the price is determined by an English auction. This means that the bidder with the highest valuation wins the auction and pays the value of the losing bidder.[6,7]

Entry is assumed to be costly. The entry costs of both bidders include due diligence costs required to learn the value of the target in acquisition. This includes fees to consultants and investment bankers but also other costs such as disclosure costs, financing fees, or opportunity cost of management time. In effect, we assume that a bidder can participate in the takeover contest only if it pays the entry cost. We simplify the analysis and assume that the entry cost of bidder A, c_A, is sufficiently low so that bidder A always performs due diligence if it identifies a potential target. Because the game is trivial if bidder A does not place a bid, this is with little loss of generality.

In the game after bidder A's entry, we derive equilibrium decisions of bidder A to place the initial bid and of bidder B to enter the takeover contest. This signaling game can have multiple equilibria. We focus on the perfect Bayesian equilibrium that is most profitable for bidder A. This is equivalent to selecting the perfect sequential equilibrium or the one satisfying the credibility refinement.[8]

With this game specification, we can determine the bidders' payoffs contingent on their valuations and actions. Denote by $\pi_i(v_A, v_B, b, e_B)$ the payoff of bidder i as a function of $v_A, v_B, b,$ and e_B. The payoff function of bidder A, if it places a bid, can be written as

$$\pi_A(v_A, v_B, b, 0) = v_A - b - c_A;$$
$$\pi_A(v_A, v_B, b, 1) = \begin{cases} v_A - b - c_A & \text{if } v_B \leqslant b \\ v_A - v_B - c_A & \text{if } b < v_B \leqslant v_A \\ -c_A & \text{if } v_B > v_A. \end{cases} \tag{1}$$

Upon winning the contest, bidder A receives the payoff equal to its valuation of the target v_A minus the price paid and minus the entry cost. The winning bidder pays the value of the losing bidder, so the price paid by winning bidder A if $b < v_B \leqslant v_A$ is v_B. Bidder A loses the contest if $v_B > v_A$ and its payoff is then just $-c_A$. Similarly, bidder B's payoffs are the following:

$$\pi_B(v_A, v_B, b, 0) = 0;$$
$$\pi_B(v_A, v_B, b, 1) = \begin{cases} -c_B & \text{if } v_B \leqslant v_A \\ v_B - v_A - c_B & \text{if } v_B > v_A. \end{cases} \tag{2}$$

2.3. Informational externalities and competition

We take a first look at the influence of bidder A's offer on bidder B's beliefs and payoff. An important observation is that the expected payoff may either increase or decrease in the level of similarity between the valuations. Intuition suggests that there are two effects due to correlated valuations. First, if valuations are dependent, then the second bidder can infer some information about its own value of the target from the first offer. Second, if both bidders enter the contest, the level of similarity will affect the competitiveness of the contest and the price paid by the winning bidder. We refer to the former effect as the informational externality effect and to the latter as the competition effect.

Suppose now that bidder A's strategy is fully revealing. From observing a bid b, bidder B can exactly infer the realization of bidder A's value v_A. In other words, we assume here that bidder A's strategy is separating and each valuation realization stipulates a different bid. Because v_A and v_B are correlated, information about the realization of v_A affects the posterior distribution of v_B. Given bidder A's value v_A, the posterior distribution of the value of bidder B is again normal with probability density function denoted by $f_{B|A}$. The expected value is updated to

$$\mu_{B|A} = E[v_B|v_A] = \rho v_A + (1 - \rho)v_0. \tag{3}$$

It follows from (3) that the informational externality effect of increasing ρ on bidder B's expected value is positive for all ρ as long as $v_A > v_0$. Because bidder A places a bid only if v_A exceeds v_0, the informational externality effect encourages bidder B to participate and bidder B is better off with a correlation with bidder A that is as high as possible.

The posterior standard deviation of v_B is updated to $\sigma_{B|A} = \sigma\sqrt{1 - \rho^2}$. It is the largest at $\rho = 0$ and decreases as the value of ρ increases. The posterior standard deviation is related to the competition effect and it works through the expected payoff that bidder B obtains from entering the contest. If bidder B knows the realization of v_A, this payoff is given by

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[6] English auction is also assumed to represent a sequential bidding contest in takeovers in other related studies (Fishman, 1988; Chowdhry and Jegadeesh, 1994; Burkart, 1995; Bulow et al., 1999; and Ravid and Spiegel, 1999; Che and Lewis, 2007). English auction in our model also ensures that the target is sold to the bidder with highest valuation. This is consistent with legal requirements on target management to solicit the highest tender price (see Che and Lewis, 2007).

[7] We note that in our setup a clock auction and an action allowing for jump bidding are equivalent; it is always a dominant strategy to bid up to one's value.

[8] The equilibrium selection follows Fishman (1988). See also Che and Lewis (2007) and Bulow and Klemperer (2009, footnotes 11 and 21) for more detailed discussions.

$$E\big[\pi_B(v_A, \tilde{v}_B, b, 1)\big] = - \int_{-\infty}^{v_A} c_B f_{B|A}(v)\, dv + \int_{v_A}^{\infty} (v - v_A - c_B) f_{B|A}(v)\, dv$$

$$= \sigma \sqrt{1 - \rho^2}\big[\phi(z_A) - z_A\big(1 - \Phi(z_A)\big)\big] - c_B, \tag{4}$$

where $z_A = (v_A - \mu_{B|A})/\sigma_{B|A}$, and ϕ and Φ denote probability density and cumulative distribution functions of the standard normal distribution.

To isolate the competition effect, we set $v_A = v_0$, at which the informational externality effect is absent. Taking the derivative of (4) with respect to ρ, we obtain

$$\frac{-\rho}{\sqrt{1 - \rho^2}} \frac{\sigma}{\sqrt{2\pi}}. \tag{5}$$

The sign of this expression—reflecting the competition effect of similarity—is negative if $\rho > 0$. When taking into account only the competition effect, bidder B prefers the correlation to be equal to zero. Intuitively, if both bidders enter the contest and their valuations are not dispersed, then they outbid each other to the point that the expected price paid by the winning bidder is close to its value. In other words, given the mean of its valuation, bidder B prefers to have the highest variance. The effect is caused by the convexity of bidder B's payoff function in its valuation of the target, so that a higher posterior variance $\sigma_{B|A}^2$ leads to higher expected payoffs.

With the assumption of this subsection that v_A is observable, neither the informational externality effect nor the competition effect dominates for all levels of similarity. The derivate of the expected payoff of bidder B from entering (given in (4)) with respect to ρ includes both effects and is given by

$$\frac{\sigma}{\sqrt{1 - \rho^2}}\big[-\rho\phi(z_A) + (1 - \rho)z_A\big(1 - \Phi(z_A)\big)\big]. \tag{6}$$

It is easy to establish that this expression is positive for relatively small positive ρ (the positive informational externality effect dominates the negative competition effect), and is negative for large positive ρ (the negative competition effect dominates the positive informational externality effect).

The preceding discussion clearly conveys the intuition for the two effects of similarity, but the separating strategy of bidder A that fully reveals its valuation cannot be sustained by an equilibrium (bidder A's with higher valuations have incentives to imitate those with lower valuations as long as it leads to the same actions of bidder B). The next section analyzes strategies of both bidders that can form equilibrium.

3. Bidders' strategies and equilibrium

3.1. Bidder A: to preempt or to accommodate

We restrict our attention to cut-off pure strategies in which bidder A with valuations within a certain set places a specified bid. These strategies have a clear interpretation in our bidding game: preemption and accommodation. With a preemptive bid, the expected payoff for the second bidder is sufficiently low so that it is deterred from entering. An accommodating bid does not attempt to limit participation of the follower. If bidder A preempts with a bid b, its expected payoff is given by

$$E\big[\pi_A(v_A, \tilde{v}_B, b, 0)\big] = v_A - b - c_A. \tag{7}$$

If bidder A accommodates, it cannot gain anything from bidding above the reservation value, so its bid is equal to v_0 and its expected payoff is

$$E\big[\pi_A(v_A, \tilde{v}_B, v_0, 1)\big] = \int_{-\infty}^{\infty} \pi_A(v_A, v, v_0, 1) f_{B|A}(v)\, dv = \int_{-\infty}^{v_0} (v_A - v_0 - c_A) f_{B|A}(v)\, dv$$

$$+ \int_{v_0}^{v_A} (v_A - v - c_A) f_{B|A}(v)\, dv + \int_{v_A}^{\infty} -c_A f_{B|A}(v)\, dv$$

$$= \sigma \sqrt{1 - \rho^2}\big[\phi(z_A) - \phi(z_0) + z_A\Phi(z_A) - z_0\Phi(z_0)\big] - c_A, \tag{8}$$

where $z_A = (v_A - \mu_{B|A})/\sigma_{B|A}$ and $z_0 = (v_0 - \mu_{B|A})/\sigma_{B|A}$.

Bidder A will be willing to preempt with a bid b if the expected payoff from preemption exceeds or equals the expected payoff from accommodation, that is if

$$V(v_A, b) \equiv E\big[\pi_A(v_A, \tilde{v}_B, b, 0)\big] - E\big[\pi_A(v_A, \tilde{v}_B, v_0, 1)\big] \geqslant 0. \tag{9}$$

Conversely, if $V(v_A, b) < 0$, then bidder A is better off with accommodation. Denote by $\bar{b}(v_A)$ the maximum bid that bidder A with value v_A is willing to offer to preempt bidder B. This means that with a bid at $\bar{b}(v_A)$, the condition in (9) holds in equality. Substituting (7) and (8) into (9), we obtain that

$$\bar{b}(v_A) = v_A - \sigma\sqrt{1 - \rho^2}\big[\phi(z_A) - \phi(z_0) + z_A\Phi(z_A) - z_0\Phi(z_0)\big]. \tag{10}$$

For a given preemptive bid b, bidder A's incentive for accommodation or preemption depends on the realized value of v_A. If $b \leqslant \bar{b}(v_A)$, then the expected payoff from preemption is larger than that from accommodation, and the opposite relation holds if $b > \bar{b}(v_A)$. In Appendix A we prove that the following result holds given that $\rho \geqslant 0$.

Lemma 1. $\bar{b}(v_A)$ increases in $v_A \geqslant v_0$.

The implication of the lemma is that for a given preemptive bid b, such that $b = \bar{b}(\underline{v})$, bidder A with valuation larger than or equal to $\underline{v}$ prefers to preempt rather than to accommodate. This observation justifies our focus on cut-off accommodation and preemption strategies of bidder A.

3.2. Bidder B: to participate or to stay out

We consider here bidder B's expected payoff when bidder A uses a cut-off strategy. Suppose a bid b is chosen if the realized valuation of bidder A lies in between some $\underline{v}$ and $\bar{v}$. Denote by $W(\underline{v}, \bar{v})$ bidder B's expected payoff if it decides to enter the contest (as long as bid b is lower than $\underline{v}$, which is the case in equilibrium, this value depends only on the implied valuations of bidder A, not on the bid itself). Then

$$W(\underline{v}, \bar{v}) = \frac{1}{F_A(\bar{v}) - F_A(\underline{v})} \int_{\underline{v}}^{\bar{v}} E\big[\pi_B(v_A, \tilde{v}_B, b, 1)\big] f_A(v_A)\, dv_A. \tag{11}$$

Bidder B is deterred by the set of bidder A with valuations in $(\underline{v}, \bar{v})$ if $W(\underline{v}, \bar{v}) \leqslant 0$. If this is the case, then bidder B's payoff from entering falls below its payoff from staying out, which is equal to zero.

From Section 3.1 we know that for $\rho \geqslant 0$, bidder A's incentives to preempt increase in its own valuation. Therefore bidder A uses a preemptive strategy if its valuations are above some $\underline{v}$. A preemptive strategy works only if it implies that bidder B does not enter, that is, that the expected payoff of bidder B from entering W is non-positive. The following lemma shows that the cheapest such strategies (with W equal to zero) are unique.

Lemma 2. There exists at most one $\underline{v} \geqslant v_0$ that solves $W(\underline{v}, \infty) = 0$.

Let us define v_L such that $W(v_L, \infty) = 0$. v_L is the lowest value such that information that $v_A \geqslant v_L$ deters bidder B from the contest.

The incentives of bidder B to enter are influenced by the informational externality and competition effects. If the negative effects of similarity dominate, bidder B may easily be deterred. In particular, in some cases, bidder B may be deterred by information that v_A exceeds the reservation value, $v_A \geqslant v_0$, inferred from observing bidder A placing *any* bid. The following lemma specifies when this is the case.

Lemma 3. Let $R = \sqrt{2\pi}c_B/\sigma$ and assume that $2R < 1$. If bidder B believes that $v_A \geqslant v_0$, then bidder B does not enter the contest whenever $\rho < \rho_1 = R - \sqrt{1 - 2R}$ or $\rho > \rho_2 = R + \sqrt{1 - 2R}$.

We assume from now on that $2R < 1$ to focus on interesting cases. If this condition is not satisfied, then bidder B does not participate after a bid from A for any possible value of ρ.[9] Lemma 3 states that if bidder B's only information is that bidder A's valuation exceeds the reservation price v_0, it may still be sufficient as a deterrent if the valuations are interdependent with a low correlation coefficient, $\rho < \rho_1$, or if the valuations are strongly positively correlated, $\rho > \rho_2$. Intuitively, a high value of v_A together with a low correlation promises a low expected value of v_B. For example, consider the extreme case with $\rho = -1$. Then $v_A > v_0$ implies $v_B < v_0$ and bidder B makes sure losses with any positive entry cost. On the other hand, a high value of v_A with a high correlation leaves little profit to be earned in the subsequent auction, because values of both bidders are expected to be similar. At the extreme point as $\rho = 1$, v_B is equal to v_A with probability one, and after entry the price paid is equal to the value, which leaves no profit. At very low and very high correlation, expected payoffs do not compensate the entry cost. We note that for positive c_B and $2R < 1$, both ρ_1 and ρ_2 are inside the domain for a correlation coefficient and are such that $-1 < \rho_1 < 0.5 < \rho_2 < 1$.

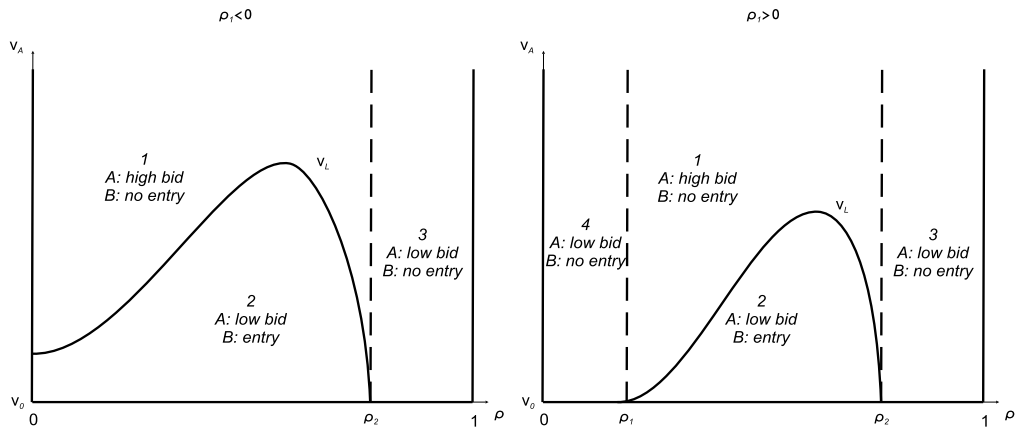[9] The condition is a result of the requirement that $W(v_0, \infty)$ is positive at least for some values of ρ.

Fig. 1. Equilibrium strategies in the bidding game (with bidder A participating) for various correlations ρ and bidder A's valuations v_A. The figure on the left presents the case of $\rho_1 \leqslant 0$ and the one on the right presents the case of $\rho_1 > 0$. Regions 1–4 specify qualitatively different strategy pairs.

3.3. Equilibrium

Equilibrium strategies consist of bidder A's initial bidding strategy b and bidder B's entry strategy e_B. In the previous subsections, we outlined the derivation of the strategies in the signaling equilibrium involving the most profitable outcome for bidder A. These strategies can be interpreted as accommodation with a bid at the reservation price that induces entry of the competitor and as preemption with a bid at a premium over the reservation price that deters the other contestant. In some cases, a deterring bid is placed that, while low at the reservation price, effectively deters the competitor.

For example, in the case of the preemptive outcome, the equilibrium is constructed as follows. We have shown that there is a threshold v_L such that bidder A with $v_A \geqslant v_L$ places a preemptive bid and deters bidder B. For this bid not to be imitated by bidder types with $v_A < v_L$, it must be at least $\bar{b}(v_L)$. Bidder A with valuations $v_A < v_L$ cannot match this bid and offers the lowest price v_0 which invites the second bidder. These results are gathered in the following proposition.[10]

Proposition 4. *In the game after bidder A enters, there exists equilibrium (b^*, e_B^*) in cut-off strategies with the following properties. If $v_A \geqslant v_0$, then bidder A places a bid and there are two cases.*

1. *If $0 \leqslant \rho < \rho_2$, then*

$$b^*(v_A) = \begin{cases} \bar{b}(v_L) & \text{if } v_A \geqslant v_L \\ v_0 & \text{if } v_0 \leqslant v_A < v_L, \end{cases}$$

$$e_B^*(b) = \begin{cases} 1 & \text{if } b < \bar{b}(v_L) \\ 0 & \text{if } b = \bar{b}(v_L). \end{cases}$$

2. *If $\rho \geqslant \rho_2$, then $b^*(v_A) = v_0$ and $e_B^*(b) = 0$.*

Fig. 1 presents how the equilibrium strategies depend on the level of correlation between the valuations. There are four possible scenarios depending on the correlation ρ and the first bidder's valuation v_A. In Region 1 at intermediate levels of correlation, bidder A preempts bidder B with a high bid. This happens for sufficiently high values v_A such that $v_A \geqslant v_L$. In Region 2 at intermediate levels of correlation and at low valuations (but above v_0), bidder A accommodates. With increasing correlation, the accommodation strategy is first supported by increasing valuations (preemption is difficult due to the informational externality effect). Then with increasing correlation, preemption becomes easier (due to the competition effect) and accommodation is used only by bidder A with relatively low values.[11] In Region 3, the bidders are so similar that it does not pay for bidder B to engage in a costly bidding contest. In Region 4, the bidders are so dissimilar that if the target is sufficiently attractive for the initial bidder to place a bid, then bidder B's expected payoff is too low to participate.

4. Model implications

Similarity between bidders generates the trade-off between the informational externality of the initial bid and competition intensity. The interaction of these two forces leads to a non-monotonic relationship of the correlation coefficient on

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[10] For transparency, Proposition 4 is stated for the case $\rho_1 < 0$. Using Lemma 3, it holds if $R < \sqrt{2} - 1$. The proposition can be adapted to the other case in the obvious way.

[11] See Appendix A for a proof that v_L is always non-monotonic in ρ, increasing for low correlation and decreasing for high correlation.
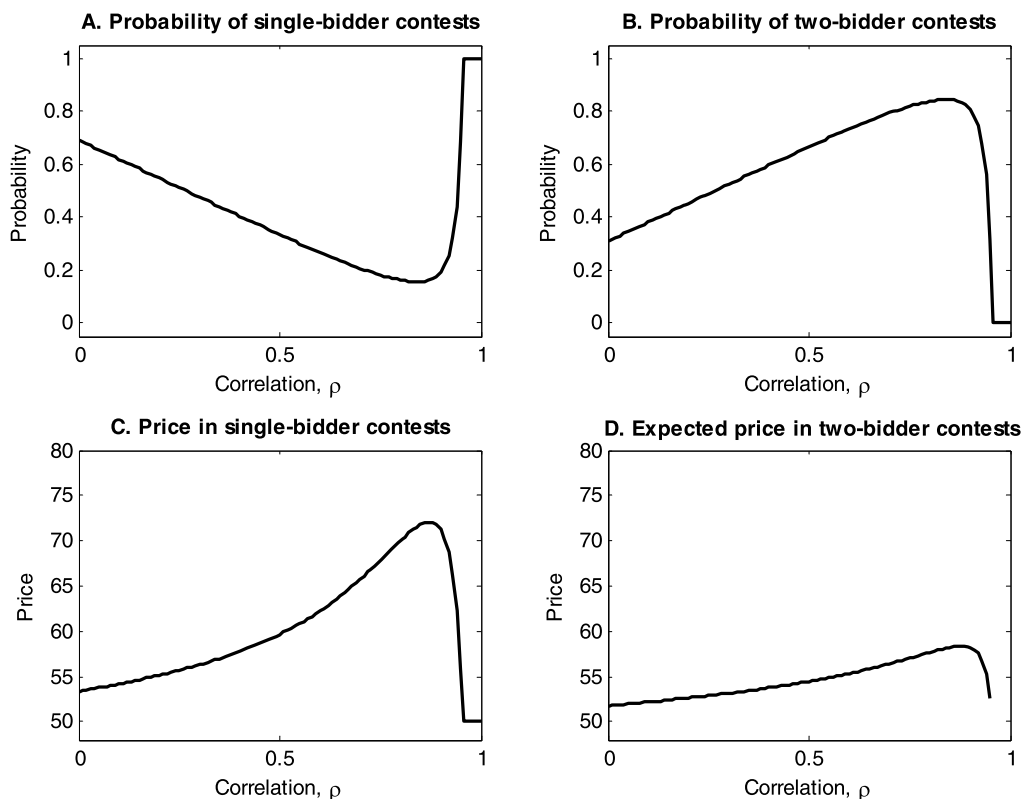
Fig. 2. Non-monotonic effects of correlation ρ. The figures present the probability of single-bidder contests (A), the probability of two-bidder contests (B), the price in single-bidder contests (C), and the expected price paid in a two-bidder contest (D) for different levels of the correlation coefficient between the bidders' valuations. All the values are calculated for $\sigma = 20$, $c_B = 2$, and $v_0 = 50$.

acquisition strategies and returns. Fig. 2 presents numerical comparative statics with respect to the correlation coefficient between bidders' valuations. Other exogenous parameters are set at $\sigma = 20$, $c_B = 2$, and $v_0 = 50$. These parameters are later used in our experiments. Figs. 2.A and 2.B present the probabilities of observing either a single-bidder contest or a multiple-bidder contest conditional on observing a takeover. The probability of single-bidder contests is non-monotonic and has a U-shape. The complementing probability of two-bidder contests is then also non-monotonic and has an inverted U-shape. The two-bidder contests are mostly observed at intermediate positive correlation. The intuition is that it is most difficult to deter the second bidder at these levels of correlation—the information externality is strong enough to attract followers and the post-entry competition is not yet to fierce—and only the highest valuations of the first bidder can serve as an effective deterrent.

Figs. 2.C and 2.D plot the expected prices paid for the target in single-bidders contest and multiple-bidder contests. Contingent on observing a single-bidder contest, the offered price has an inverted U-shape in bidder similarity. This non-monotonic effect is driven by the fact that low initial bids may deter competition if the potential competitors are very similar (post-entry bidding competition makes entry unattractive) or very dissimilar (the initial bid does not convey much of positive information to potential followers about their valuation of the target). Similarly, contingent on observing a two-bidder contest, the expected price paid by the winning bidder has an inverted U-shape in bidder similarity. The prices are the lowest for very similar and very dissimilar bidders because multiple-bidder contests arise in these cases only when bidders have low valuations for the target (the first bidder cannot afford to place relatively low preemptive bids).

The expected final price in two-bidder contests is lower that the preemptive bid in single-bidder acquisitions for any given correlation. This is because accommodating bids are offered by bidder A only when it has a relatively low valuation or when it expects weak competition. However, two-bidder contests are most likely when the expected prices in two-bidder contests are high, and single-bidder contests are most likely when the prices in single-bidder contests are low. This may explain why empirical evidence of the effects of competition measured by the number of bidders on target returns is inconclusive and frequently demonstrates a puzzling lack of any significant relation. The analysis indicates that the effect of the number of bidders should be controlled for the level of similarity.

Table 1
Theoretical predictions in the three treatments.
Single-bidder contests denotes the proportion of contests in which bidder B does not participate; *Price in single-bidder contests* denotes the level of the first bid that deters bidder B from entering (preemptive bid); *Price in two-bidder contests* denotes the average price in cases where bidder B enters; and *Preemption value* denotes the level of the first bidder valuation above which he decides to place a preemptive bid. The numbers are rounded to integer values.

Similarity treatment	Single-bidder contests[a]	Price in single-bidder contests	Price in two-bidder contests	Preemption value
Low	66%	53	51	58
Intermediate	30%	60	54	69
High	70%	56	53	58

[a] Based on the generated data used in this experiment. The predictions based on the exact theoretical distribution are 67%, 34%, and 67% for Low, Intermediate and High treatments, respectively.

5. The experimental setup

As discussed in the introduction, testing the model's predictions with historical field data is difficult because the identity of preempted bidders, and so their similarity with acquirers, is not observable to researchers. To address this problem and to offer a first test of the model's trade-offs, we use experimental data in which we can control the combinations of competing bidders and other characteristics of the environment. Specifically, we design a computerized laboratory experiment in which we recreate the exact setting of the model. In different treatments, we change only the level of interdependence between bidders' valuations and keep all other variables constant.

5.1. Treatments and hypotheses

The parameters in the experiment are chosen to replicate a takeover opportunity with uncertain value and with sufficient potential profits to make the investment attractive. The mean target value is set at $v_0 = 50$, the standard deviation of the bidders' valuation, σ, equals 20, and the entry cost, c, equals 2. When there is no rival, this parameter setting leads to an expected payoff of about 30 to a bidder if he or she enters. With competing bidders, the expected payoff of the initial bidder will vary depending on the intensity of competition and the strategies bidders adopt.

We set up three treatments that differ in the level of correlation between bidders' valuations. The correlations are 0, 0.5, and 0.95. These levels are sufficiently different to represent three typical takeover contests. In the low similarity treatment (with correlation equal to 0), bidders' valuations are independent. This is as in the standard Fishman (1988) model and we interpret this case as a contest between a strategic bidder and a financial bidder. The intermediate similarity treatment (with correlation equal to 0.5) represents the case of two strategic bidders. The high similarity treatment (with correlation equal to 0.95) represents the case in which bidders' valuation are highly dependent with each other as in bidding between two financial bidders.

The three treatments generate qualitatively distinctive equilibrium strategies. Table 1 reports the theoretical predictions for equilibrium strategies and outcomes. At low similarity, the minimum bid that can preempt bidder B is 53 and when bidder A's value is above 58, he chooses to offer this preemptive bid. This implies that single-bidder contests are expected in 66% of observed takeovers and that the average price in two-bidder contests is about 51. At intermediate similarity, bidder A makes a preemptive bid equal to 60 when his value is above 69 and the proportion of single-bidder contests is significantly lower at 30%, while prices in two-bidder contests are higher at 54. At high similarity, the proportion of single-bidder contests increases to 70%, bidder A will make a preemptive bid of 56 when his value is above 58, and the average price in two-bidder contests decreases slightly to 53. The model predicts a non-monotonic pattern in the proportion of single-bidder contests and acquisition prices. This leads to three testable hypotheses.[12]

Hypothesis 1. The proportion of single-bidder contests is higher in the low and high treatments than in the intermediate treatment.

Hypothesis 2. Acquisition prices in single-bidder contests in the low and high similarity treatments are lower than in the intermediate treatment.

Hypothesis 3. Acquisition prices in two-bidder contests in the low and high similarity treatments are lower than in the intermediate treatment.

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[12] We do not specify a separate hypothesis for preemption values. First, preemption values used by bidder A are not directly observable in the experiment. Second, in the theory, preemption values measure the same behavior as the proportion of single-bidder contests. The proportion of single-bidder contests is the proportion of bidder A's distribution that falls above preemption value.

5.2. Experiment implementation

We carried out the experiment in the Erasmus University Behavioural Lab with subjects that are master-level students in economics and finance. 36 subjects took part in the experiment in two identical sessions with different subjects: 20 in a first session and 16 in a second session.

In each session, the bidding game was repeated in 30 rounds. Additionally, the subjects first played six unpaid practice rounds to learn about the experimental setup and the game. Our experiment comprised 540 rounds in total. At the beginning of each session, participants were randomly assigned to play a role throughout the entire session: either "first bidder" or "second bidder". Each first bidder was randomly paired with a second bidder in each round to avoid learning bidder characteristics. This was aimed to facilitate the perception of a series of one-shot games.

The sequence of the game was as follows. At the beginning, both bidders were informed about the level of their similarity. The first bidder was assigned his or her valuation of the target and the entry fee was deducted from its account. Next, the first bidder submitted a bid. After observing the first bid and similarity level, the second bidder chose whether to enter or not. If he entered, the entry fee was deducted from his current account and his valuation of the target was revealed. Then the outcome of the auction was automatically determined by an English auction rule – the bidder with the highest valuation bought the target for the second highest bid.[13] If instead the second bidder chose not to enter, the game ended and the first bidder bought the target with his first bid.

Each bidder's valuation of the target was private information. The similarity level and the distribution of bidders' valuations were known to both bidders. It was also known that the target would not sell below a reservation price of 50. The first bidder's valuations were drawn from a normal distribution with a mean of 50 and a standard deviation of 20. The first bidder's observes only the realizations that are at or exceed the reservation value. In effect, the first bidder's valuations that are observed are truncated at 50, because otherwise no contest is initiated.[14] The values for the second bidder were drawn from a normal distribution with a mean of 50 and a standard deviation of 20. The second bidder's valuations were correlated with the normal distribution underlying the first bidder's valuation with a coefficient equal to the similarity level. To ensure that participants understood the distribution of bidders' valuations and their interdependent nature, numerical examples were given for different similarity levels.[15]

Each pair of bidders in each round was assigned with a new similarity level drawn from the set {0, 0.5, 0.95} with equal probability. To control for learning across different similarity levels, the sequence of similarity levels was selected randomly. The experimental sessions lasted about two hours and the final payoffs in the experiment were determined by the performance of the participants and by their roles. The accumulated payoffs were recorded by points they earned or lost, with a conversion rate of €1 for every 20 points. Because of the entry fee, the bidders that lost an auction incurred a net loss. To prevent bankruptcy, each bidder was given 60 initial points, which was just sufficient to cover the entire entry fee if he bid in every round. Furthermore, the second bidders were given an additional fixed payment of €5 to compensate for their disadvantaged initial position compared to the first bidders. The range of actual earnings paid to the first bidder was €5.90–17.00, with a mean of €9.00; the range of actual earnings paid to the second bidder was €7.70–10.90, with a mean of €9.00.[16]

6. Experimental results

We start with an overview of aggregate bidder behavior in different treatments. Table 2 presents descriptive statistics of the results. Panel A shows that the first bid in the single-bidder contests is higher than that in the two-bidder contests. The differences are highly significant in all treatments. We take this finding as reassurance that first bids can be preemptive and most subjects were responding sensibly within our experiment.

Panel B of Table 2 provides some support to the theoretical predictions for the proposed effects of similarity between bidders. The proportion of single-bidder contests is moderately lower in the intermediate similarity treatment compared to the low similarity treatment, while the percentage of single-bidder contests in the high similarity treatment is significantly higher than that in the intermediate treatment. The U-shape across the three treatments is in line with Hypothesis 1. The mean price paid in single-bidder contests is lower in the low treatment than in the intermediate treatment (significant at the 5% level), which is consistent with Hypothesis 2. The mean price paid in the high similarity treatment is higher than in the intermediate treatment, at odds with Hypothesis 2; the difference is, however, not significant. The mean prices paid

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[13] The second highest bid is defined as the second highest value in {the first bidder's valuation, the second bidder's valuation, the first bid}.

[14] Alternatively, we could have used a full non-truncated normal distribution and made subject to play rounds which involved no actions and provided no observations.

[15] The full experiment instructions can be found in the Online Appendix.

[16] The average payment level in our experiment is not very high. Experimental literature shows that subject performance can be affected by compensation levels (Smith and Walker, 1993; Gneezy and Rustichini, 2000). At a request of a referee, we conducted an additional experimental session with increased conversion rate between points and euro from 20:1 to 8:1. Sixteen subjects participated in this session and the payments range from €13.9 to €33.6 with an average of €22.3. Overall, the results are similar to the original sessions and confirm our hypotheses. One exception is the two-bidder-contest price in high similarity treatment which changes the sign (but is insignificant). It should be noted that the difference between two-bidder-contest prices in the high and intermediate treatment was quantitatively our weakest prediction (cf. Table 1). Because of the different compensation schemes, we do not pool the data of the high-payment and original sessions. The analysis of the additional data is available from the authors upon request.

Table 2
Descriptive statistics of the experimental results.
Statistics are calculated from 540 experimental observations. In Panel A, the data are split into two subgroups depending on the number of bidders active in the contest. Columns report the percentage of the two types of contests (*Proportion*) and the mean of the first bids (*First bid*) and prices across the three treatments. The last two columns present the difference in first bids across the two types of contests and t-statistics for differences between means. Panel B reports t-statistics for differences between means of the proportion of and prices paid in two types of contests across the three treatments. Parentheses report number of observations or standard errors.

Panel A: Statistics for each contest outcome							
Similarity treatment	Single-bidder contests		Two-bidder contests			First bid difference	
	Proportion	First bid [=Price]	Proportion	First bid	Price	Mean	t-stat
Low	27% (N = 48)	56 (0.93)	73% (N = 132)	52.48 (0.33)	55.97 (0.56)	3.52 (0.79)	4.47
Intermediate	22% (N = 39)	58.79 (1.28)	78% (N = 141)	53.81 (0.43)	57.82 (0.73)	4.99 (1.05)	4.73
High	39% (N = 70)	60.8 (1.42)	61% (N = 110)	56.04 (0.71)	61.78 (0.95)	4.76 (1.44)	3.31

Panel B: Differences between treatments						
Comparison pair	Proportion of single-bidder contests		Price in single-bidder contests		Price in two-bidder contests	
	Mean	t-stat	Mean	t-stat	Mean	t-stat
Low–Intermediate	5% (4.50%)	1.11	−2.79 (1.54)	−1.81	−1.85 (0.92)	−2.01
High–Intermediate	17% (4.80%)	3.56	2.01 (2.13)	0.94	3.96 (1.17)	3.38

in two-bidder contests exhibit similar pattern. Compared to the intermediate treatment, the low treatment is characterized with lower mean price, which confirms the prediction in Hypothesis 3, while the high treatment has the highest mean price, deviating from Hypothesis 3.

6.1. H1: proportion of single-bidder contests

The second bidder knows only the first bid and the similarity level before he decides whether to participate in the contest. To explain the binary participation decision in a regression analysis, we use these two variables as explanatory variables. Furthermore, considering that the participation decision may also be affected by individual characteristics, we adopt a random-effect probit regression with an individual specific term included in the disturbance. Specifically, we estimate the following model:

$$y_{jt}^* = \gamma_0 + \gamma_1 First\ Bid_t + \gamma_2 Low_t + \gamma_3 High_t + \eta_j + \varepsilon_{jt}$$

$$y_{jt} = \begin{cases} 1 & \text{if } y_{jt}^* \geq 0 \\ 0 & \text{if } y_{jt}^* < 0 \end{cases}$$

where y_{jt}^* is a latent variable, and y_{jt} is the observed participation decision of jth second bidder in round t (with 1 denoting non-participation and 0 participation). Variable $First\ Bid_t$ is the first bid of the first bidder in round t. Variables Low_t and $High_t$ are two dummies indicating the low similarity and the high similarity treatments, respectively. We take intermediate similarity as a reference treatment. If the proportion of single-bidder contests indeed exhibits a U-shape, both γ_2 and γ_3 are expected to be positive. Finally, η_j is an individual random effect of subject j and ε_{jt} is a residual error term; both are assumed to be normally distributed with a mean zero.

Estimation results are presented in Table 3. The positive sign of the coefficient of First Bid confirms that the probability of successful preemption is increasing in the first bid. Furthermore, the positive signs of the coefficients of Low and High indicate that the probabilities of being preempted in the low and high similarity treatments are higher than in the intermediate similarity treatment. All the estimates of γ are significantly positive. Therefore, the response of the second bidder is consistent with Hypothesis 1. It seems that the second bidders respond to the tradeoff between similarity effects. Low information externality in the low similarity treatment apparently discourages the second bidder from entering. The strong competition effect in the high similarity treatment can also be discouraging. On the contrary, the second bidder is less likely to be preempted in the intermediate treatment because the information externality is relatively large while the competition is not very high.

Table 3
Random-effects probit regression on the proportion of single-bidder contests.

Regression is done on all experimental data, with a sample size equal to 540. The dependent variable takes a value 1 if the second bidder does not participate in the contest and 0 otherwise. *First Bid* is the first bid of the first bidder. *Low* and *High* are dummies for the similarity treatments. The second column reports estimated coefficients and standard errors. The third column reports predicted signs and t-statistics.

Variable	γ estimate (std. err.)	Predicted sign (t-stat)
First Bid	0.06 (0.01)	H_0: $\gamma_1 > 0$ (6.53)
Low	0.31 (0.17)	H_0: $\gamma_2 > 0$ (1.86)
High	0.52 (0.16)	H_0: $\gamma_3 > 0$ (3.19)
Constant	-4.55 (0.61)	–

Table 4
Linear regression on prices in single-bidder contests.

Only data in single-bidder contests are included, with a sample size equal to 157 observations. The dependent variable is the price paid for the target in single-bidder contests. *Low* and *High* are dummies for the similarity treatments. *Inverse Mills ratio* is estimated based on regression outcomes in Table 3, and is negative if the second bidder enters and positive otherwise. The second column reports estimated coefficients and the third column reports standard errors.

Variable	β estimate (std. err.)	Predicted sign (t-stat)
Low	-5.42 (0.36)	H_0: $\beta_1 < 0$ (−14.87)
High	-8.41 (0.37)	H_0: $\beta_2 < 0$ (−22.8)
Inverse Mills ratio	-24.54 (0.35)	
Constant	92.56 (0.56)	

6.2. H2: prices in single-bidder contests

If the second bidder is preempted, prices in single-bidder contests are equal to the first bidder's preemptive bids; if the second bidder enters, prices in two-bidder contests are equal to the highest among bidders' valuations. That is, the determination of final price essentially switches between two pricing regimes depending the successfulness of preemption:

$$Price_{ijt} = \begin{cases} Price1_{ijt} = \beta' X_t + v_{ij} + \epsilon_{ijt} & \text{if } \gamma' Z_t + \eta_j + \varepsilon_{ijt} \geqslant 0 \\ Price2_{ijt} = \theta' X_t + v'_{ij} + \epsilon'_{ijt} & \text{if } \gamma' Z_t + \eta_j + \varepsilon_{ijt} < 0 \end{cases}$$

where X_t is the vector of explanatory variables in round t, v_{ij} (v'_{ij}) is a random effect of the group consisting of ith first bidder and jth second bidder assumed normal with a mean of 0. Z_t is a vector of explanatory variables in the model of participation of from Section 6.1. Due to the correlation between the second bidder's participation decision and the price formation, estimation of coefficients (β and θ) can be biased because $E(\epsilon_{ijt}|\gamma' Z_t + \eta_j + \varepsilon_{ijt} \geqslant 0) \neq 0$, and $E(\epsilon_{ijt}|\gamma' Z_t + \eta_j + \varepsilon_{ijt} < 0) \neq 0$.

To eliminate this selection bias, we apply the Heckman two-step estimation method (Heckman, 1979; Li and Prabhala, 2007). The first step is to conduct a probit regression on the preemption outcomes to estimate γ, which is already done in the previous section. Denote the inverse Mills ratio by λ_{jt}. $\lambda_{jt} = \phi(\hat{\gamma}' Z_t)/\Phi(\hat{\gamma}' Z_t)$ in single-bidder contests, and $\lambda_{jt} = -\phi(\hat{\gamma}' Z_t)/[1 - \Phi(\hat{\gamma}' Z_t)]$ in two-bidder contests. The second step is to introduce the inverse Mills ratio as a regressor and run a panel data regression to control for individual effect and time varying error:

$$Price1_{ijt} = \beta_0 + \beta_1 Low_t + \beta_2 High_t + \beta_3 \lambda_{jt} + v_{ij} + \epsilon_{ijt}.$$

According to Hypothesis 2, the intermediate treatment should facilitate the highest prices in single-bidder contests. That is, both β_1 and β_2 are expected to be negative. The estimation results are reported in Table 4. Both β_1 and β_2 are significantly negative. The first bids in preempted contests exhibit non-monotonic pattern, as Hypothesis 2 predicted, with the intermediate treatment yielding the highest price. The experiment outcome, therefore, confirms the comparative statics prediction of Hypothesis 2 across different similarity treatments.

Table 5
Linear regression on prices in two-bidder contests.
Only data in two-bidder contests are analyzed, which include 383 observations. The dependent variable is the price paid for the target in two-bidder contests. *Low* and *High* are dummies for the similarity treatments. *Inverse Mills ratio* is estimated based on regression outcomes in Table 3, and is negative if the second bidder enters and positive otherwise. The second column reports estimated coefficients and standard errors. The third column reports predicted signs and t-statistics.

Variable	θ estimate (std. err.)	Predicted sign (t-stat)
Low	−3.67 (0.86)	H_0: $\theta_1 < 0$ (−4.28)
High	−3.13 (1.06)	H_0: $\theta_2 < 0$ (−2.95)
Inverse Mills ratio	−24.08 (1.92)	–
Constant	51.40 (0.81)	

6.3. H3: prices in two-bidder contests

The next step is to check prices in two-bidder contests. According to Hypothesis 3, the intermediate treatment boasts the highest average price compared to low and high treatments. To test it, we run a similar self-selection regression as above, but the dependent variable changes to prices in two-bidder contests and we use only observations with two-bidder contests. The regression equation is as follows:

$$Price2_{ijt} = \theta_0 + \theta_1 Low_t + \theta_2 High_t + \theta_3 \lambda_{jt} + v'_{ij} + \epsilon_{ijt}$$

$Price2_{ijt}$ denotes prices in two-bidder contests, and Low_t and $High_t$ are two similarity indicators. Again, we control a random effect of group ij, v'_{ij}, assumed to be normal with a mean of 0.

As Hypothesis 3 predicts that prices in two-bidder contests in the low and high treatments are lower than in the intermediate treatment, both θ_1 and θ_2 are expected to be negative. Regression results in Table 5 provide confirmative evidence to this prediction. Both θ_1 and θ_1 are significantly negative. Again, non-monotonic pattern in prices is supported in two-bidder contests. In addition, coefficients of inverse Mills ratio are both significant at 1% level in Table 4 and Table 5, which indicate the self-selection effect plays a role in determining prices.

6.4. Dynamic session-effects

There are two sessions in our experiment. Observations across subjects of a given session might be more correlated than observations across subjects from different sessions. One possible source of the higher correlation can be that subjects adjust their strategy according to the feedbacks from their previous actions. For example, a successful low bid in a previous round can make the first bidder more likely to submit a low bid in the following round, and a successful entry decision can induce the second bidder to enter. If this is the case, there can be some interdependence between observations within one session, which is referred to as "dynamic session-effects" in experimental economics (Fréchette, 2012).[17]

Ignoring dynamic session-effects can bias the variance computation of estimators, resulting in incorrect conclusion on accepting or rejecting null hypothesis. To mitigate this problem, we employ two solutions suggested by Fréchette (2012), one by clustering, and the other by identifying a possible source of interdependence among observations.

Because interdependence between observations is within sessions, one simple solution is to cluster standard errors at the session level. Table 6 presents the new estimates with clustering. All of our previous findings hold with the new regression outcomes. Both the proportion of single-bidder contests and the acquisition prices follow a non-monotonic pattern, consistent with all the hypotheses. However, because clustering of standard errors places no restriction on the correlation structure of the residuals within a cluster, the limited number of clusters in our experiment can result in an underestimation of the variance.[18] As an alternative, we cluster standard errors at both subject and period (that is, round number) level. The two-dimension clustering produces similar results, confirming that acquisition prices and entry decisions change non-monotonically in the level of similarity.[19]

Compared to clustering, modeling the source of dynamic session-effects in regression is less robust but more efficient. Following Aoyagi and Fréchette (2009) and Rojas (2012), we modify the previous regressions in several ways to capture the characteristics of dynamic session-effects. The first modification is to assume the individual random effect η_j follows

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[17] The discussion on dynamic session-effects is inspired by a comment from an anonymous referee.
[18] See Cameron et al. (2008) and Petersen (2009) for a more recent discussion on clustered errors.
[19] For the sake of brevity, we report the estimate by 2D clustering in Table B.1 in Appendix B.

Table 6
Regression outcomes with clustering at the session level.
Standard errors are clustered at the session level. First Bid is the first bid of the first bidder. Low and High are dummies for the similarity treatments. Inverse Mills ratio is estimated based on regression outcomes on the proportion of single-bidder contests, and is negative if the second bidder enters and positive otherwise. For each estimate, we report estimated coefficients and predicted sign. Standard errors and t-statistics are listed in parentheses.

Variable	Proportion of single-bidder contests		Price in single-bidder contests		Price in two-bidder contests	
	γ estimate (std. err.)	Predicted sign (t-stat)	β estimate (std. err.)	Predicted sign (t-stat)	θ estimate (std. err.)	Predicted sign (t-stat)
First Bid	0.05 (0.00)	H_0: $\gamma_1 > 0$ (20.76)				
Low	0.25 (0.18)	H_0: $\gamma_2 > 0$ (1.39)	−5.57 (0.01)	H_0: $\beta_1 < 0$ (−681.50)	−4.18 (0.14)	H_0: $\theta_1 < 0$ (−29.31)
High	0.39 (0.10)	H_0: $\gamma_3 > 0$ (3.71)	−8.16 (0.08)	H_0: $\beta_2 < 0$ (−104.05)	−3.47 (0.21)	H_0: $\theta_2 < 0$ (−16.80)
Inverse Mills ratio			−31.69 (0.38)	(−83.76)	−30.32 (0.43)	(−69.70)
Constant	−3.52 (0.27)	(−12.81)	98.37 (0.54)	(181.97)	47.35 (0.08)	(629.49)
N	540		157		383	

an independent normal distribution $N(\psi_\eta \varsigma_j, \sigma_\eta)$. ς_j is equal to the entry choice of second bidder j in the first round of each similarity treatment, which serves as a proxy for bidder j's tendency to enter. ψ_η and σ_η are common parameters across subjects and can be estimated from the data. Similarly, v_{ij} and v'_{ij} follow independent normal distributions $N(\psi_v \tau_{ij}, \sigma_v)$ and $N(\psi'_v \tau'_{ij}, \sigma'_v)$, respectively. $\tau_{ij}(\tau'_{ij})$ is set to be equal to the first acquisition price in single-bidder contests (two-bidder contests) in a paired bidder group in each similarity treatment. This specification is introduced to deal with the initial-conditions problem (Chamberlain, 1980; Heckman, 1981; Wooldridge, 2002). Moreover, we add two variables, namely *Successful entry in the previous round*, and *Successful first bid in the previous round*, to reflect the idea that previous successful experience can influence consequent decision-making. Variable *Period* is introduced to see whether there is evolution of bidding outcomes over time, and variable *First Round* is added to check what's in common in subjects' first action.

New estimates are presented in Table 7. Most of our findings remain under the new specification, except that θ_2 (two-bidder-contest price in the high treatment relative to the intermediate treatment) becomes insignificantly positive. Considering that the difference in acquisition prices in two-bidder contests between the intermediate and high similarity treatments was quantitatively our weakest prediction,[20] the weakest significance of θ_2 is not unexpected.

With regards to the dynamic session-effects, significant estimates of ψ indicate that initial outcome has a persistent influence on subsequent decisions. A successful entry decision in the previous round is more important than a successful first bid in the previous round, as the coefficients of the former are all significant while the coefficients of the later are not significant at all. There is no evidence of evolution of bidding over time as all of the coefficients of *Period* are not significant. In addition, insignificant coefficients of *First Round* suggest that bidders do not behave differently in the first round from what they do in other rounds.

In sum, the new estimates in Table 7 indicate the existence of dynamic session-effects and show that the hypotheses of non-monotonic entry and bidding cannot be rejected after controlling for these effects.

7. Conclusions

This paper has shown that interdependence (or similarity) in bidders' private valuations has significant effects on the strategies and outcomes in sequential-entry takeover contests. With interdependent valuations, the initial bid not only conveys information about the first bidder's valuation but also about other potential bidders' valuations. Besides this information externality, similarity levels indicate the intensity of bidding competition if both bidders enter the contest. The information externality and the intensity of competition determine the chances of preemption and equilibrium acquisition prices. Our theory for takeover contests predicts that the information externality effect dominates at low levels of similarity and the competition effect dominates at high levels of similarly. The interplay of these two forces generates a non-monotonic effect of similarity: the proportion of multiple-bidder versus single-bidder contests and the level of acquisition prices are the highest at intermediate levels of similarity.

To verify whether these predictions hold, we carried out a controlled laboratory experiment. Subjects participated in three treatments that differed in the level of interdependence between valuations. The comparative statics prediction with respect to the proportion of single-bidder contests and acquisition prices are strongly supported by the data, indicating that subjects reacted strategically to the effects of information externality and competition intensity in the way predicted by our model. Our findings on the differences between takeover contests with different similarity levels between bidders can be summarized as follows. Contests between dissimilar potential acquirers (e.g., a strategic bidder against a financial bidder)

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[20] The predicted price in two-bidder contests in the intermediate treatment is 54, while it is 53 for the high treatment.

Table 7

Regressions incorporating potential sources of dynamic session-effects.

Additional regressions to investigate potential dynamic session-effect in the experiment. *First Bid* is the first bid of the first bidder. *Low* and *High* are dummies for the similarity treatments. *Inverse Mills ratio* is estimated based on regression outcomes on the proportion of single-bidder contests, and is negative if the second bidder enters and positive otherwise. If the first bidder buys the target in most recent round where the similarity level is the same as the current round, *Successful first bid in previous round* is equal to the first bid in that round and 0 otherwise. If the second bidder buys the target in the most recent round where the similarity level is the same as the current round, *Successful entry in previous round* is equal to 1 and 0 otherwise. *First round* is an indicator which takes value of 1 if the round is the first round in that session and 0 otherwise. For each estimate, we report estimated coefficients and predicted sign. Standard errors and t-statistics are listed in parentheses.

Variable	Proportion of single-bidder contests		Price in single-bidder contests		Price in two-bidder contests	
	γ estimate (std. err.)	Predicted sign (t-stat)	β estimate (std. err.)	Predicted sign (t-stat)	θ estimate (std. err.)	Predicted sign (t-stat)
First Bid	0.06 (0.01)	H_0: $\gamma_1 > 0$ (6.11)				
Low	0.27 (0.17)	H_0: $\gamma_2 > 0$ (1.54)	−2.43 (1.08)	H_0: $\beta_1 < 0$ (−2.25)	−1.83 (0.93)	H_0: $\theta_1 < 0$ (−1.97)
High	0.29 (0.17)	H_0: $\gamma_3 > 0$ (1.68)	−4.73 (1.12)	H_0: $\beta_2 < 0$ (−4.24)	0.53 (1.05)	H_0: $\theta_2 < 0$ (0.51)
Inverse Mills ratio			−16.76 (1.19)	– (−14.09)	−11.83 (1.73)	– (−6.83)
Period	0.01 (0.01)	– (0.70)	0.00 (0.05)	– (−0.01)	0.01 (0.05)	– (0.27)
Successful entry in previous round	−0.37 (0.18)	– (−2.05)	7.62 (1.36)	– (5.60)	2.80 (0.98)	– (2.86)
Successful first bid in previous round			0.01 (0.02)	– (0.62)	−0.02 (0.02)	– (−1.02)
First Round	−0.06 (0.44)	– (−0.13)	0.67 (2.29)	– (0.29)	1.55 (2.40)	– (0.65)
Constant	−4.77 (0.66)	– (−7.23)	64.56 (4.93)	– (13.10)	39.44 (3.73)	– (10.59)
ψ	−0.88 (0.16)	– (−5.49)	0.23 (0.07)	– (3.16)	0.25 (0.06)	– (4.16)
ρ	0.30		0.15		0.00	
N	540		157		383	

have low prices and are relatively often single-bidder contests. Contests between intermediately similar bidders (e.g., two strategic bidders) generate high prices and are frequently competitive with two bidders placing bids. Contests in which potential acquirers are very similar (e.g., two financial bidders) have low prices and are seldom with more than one bidder.

In conclusion, this paper reveals a strong influence of bidders' similarity on takeover strategies. The theory and the experiment imply that, in addition to the number of bidders, the similarity in bidders' characteristics is an important measure of competition intensity which should be accounted for in empirical studies of returns in takeovers.

Acknowledgments

Appendix A. Proofs

Proof of Lemma 1. Taking the derivative of (10) with respect to v_A we obtain

$$\bar{b}'(v_A) = 1 - \Phi(z_0) - (1-\rho)\big(\Phi(z_A) - \Phi(z_0)\big)$$
$$\geqslant 1 - \Phi(z_0) - \big(\Phi(z_A) - \Phi(z_0)\big) = 1 - \Phi(z_A) \geqslant 0. \tag{A.1}$$

In the first inequality we use that $z_A \geqslant z_0$ and $\rho \geqslant 0$.   □

Proof of Lemma 2. Let $\underline{v} \in \{v : W(v, \infty) = 0\}$. We will show that $\underline{v}$ is unique if it exists. By (11) $W(\underline{v}, \infty) = 0$ is equivalent to

$$\int_{\underline{v}}^{\infty} E\big[\pi_B(v_A, \tilde{v}_B, b, 1)\big] f(v_A)\, dv_A = 0. \tag{A.2}$$

Note that $E[\pi_B(v_A, \tilde{v}_B, b, 1)]$ (given in (4)) is negative for large v_A, $E[\pi_B(\infty, \tilde{v}_B, b, 1)] = -c_B < 0$. Since $f(v_A)$ is always positive, $E[\pi_B(v_A, \tilde{v}_B, b, 1)]$ must be positive for some $v_A \geqslant \underline{v}$, for the root $\underline{v}$ in (A.2) to exist. Because $E[\pi_B(v_A, \tilde{v}_B, b, 1)]$ is decreasing in v_A:

$$\frac{\partial E[\pi_B(v_A, \tilde{v}_B, b, 1)]}{\partial v_A} = \sigma\sqrt{1-\rho^2}\left[-z_A f(z_A) - 1 + \Phi(z_A) + z_A f(z_A)\right]\frac{dz_A}{dv_A}$$

$$= \sigma\sqrt{1-\rho^2}\left[\Phi(z_A) - 1\right]\frac{(1-\rho)}{\sigma_{B|A}} \leqslant 0,$$

it must be then that

$$E[\pi_B(\underline{v}, \tilde{v}_B, b, 1)] > 0. \tag{A.3}$$

Suppose now that $\underline{v}$ exists so that (A.3) holds. Then the derivative of $W(v, \infty)$ with respect to v evaluated at $\underline{v}$ is negative:

$$\begin{aligned}
\frac{d}{dv}W(v, \infty)\bigg|_{v=\underline{v}} &= \frac{f(\underline{v})}{(1-F(\underline{v}))^2}\int_{\underline{v}}^{\infty}E[\pi_B(v_A, \tilde{v}_B, b, 1)]f(v_A)\,dv_A - \frac{f(\underline{v})}{1-F(\underline{v})}E[\pi_B(\underline{v}, \tilde{v}_B, b, 1)] \\
&= \frac{f(\underline{v})}{1-F(\underline{v})}\left(W(\underline{v}, \infty) - E[\pi_B(\underline{v}, \tilde{v}_B, b, 1)]\right) \\
&= -\frac{f(\underline{v})}{1-F(\underline{v})}E[\pi_B(\underline{v}, \tilde{v}_B, b, 1)] \\
&< 0.
\end{aligned}$$

Since $W(v, \infty)$ is a continuous function, it follows that it must have at most one root. Therefore the solution to $W(\underline{v}, \infty) = 0$ is unique if it exists. $\quad\square$

Proof of Lemma 3. We will use the following integrals for some constants m, n, and h:

$$\int_m^n \phi(hx)\phi(x)\,dx = \frac{\Phi(Hn) - \Phi(Hm)}{H\sqrt{2\pi}},$$

$$\int_m^n x\Phi(hx)\phi(x)\,dx = \frac{h}{H\sqrt{2\pi}}\left(\Phi(Hn) - \Phi(Hm)\right) + \phi(m)\Phi(hm) - \phi(n)\Phi(hm), \tag{A.4}$$

where $H = \sqrt{1+h^2}$. Then

$$\begin{aligned}
W(\underline{v}, \bar{v}) &= \frac{1}{F_A(\bar{v}) - F_A(\underline{v})}\int_{\underline{v}}^{\bar{v}}E[\pi_B(v_A, \tilde{v}_B, b, 1)]f_A(v_A)\,dv_A \\
&= \frac{1}{F_A(\bar{v}) - F_A(\underline{v})}\int_{\underline{v}}^{\bar{v}}\left[\sigma\sqrt{1-\rho^2}\left(\phi(z_A) - z_A(1-\Phi(z_A))\right) - c_B\right]f_A(v_A)\,dv_A \\
&= \frac{\sigma - \sigma\rho}{\Phi(\bar{y}) - \Phi(\underline{y})}\left[\frac{H}{h\sqrt{2\pi}}\left(\Phi(H\bar{y}) - \Phi(H\underline{y})\right) - \phi(\underline{y})\left(1-\Phi(h\underline{y})\right) + \phi(\bar{y})\left(1-\Phi(h\bar{y})\right)\right] - c_B, \tag{A.5}
\end{aligned}$$

where $\underline{y} = (\underline{v} - v_0)/\sigma$, $\bar{y} = (\bar{v} - v_0)/\sigma$, $h = (1-\rho)/\sqrt{1-\rho^2}$ and $H = \sqrt{1+h^2}$. In the second line of (A.5) we use (4) and the third line follows from (A.4).

If bidder A's valuation is above v_0, then bidder B's expected payoff from entering is equal to

$$W(v_0, \infty) = \frac{1}{\sqrt{2\pi}}\left[\sigma\sqrt{2(1-\rho)} - \sigma(1-\rho)\right] - c_B.$$

The expression follows from (A.5). Bidder B does not enter if $W(v_0, \infty) \leqslant 0$. Solving this quadratic inequality for ρ, yields ρ_1 and ρ_2 given in the proposition. They exist and are distinct under the assumption that $2R < 1$. $\quad\square$

Proof of the non-monotonic shape of v_L in ρ. We show that v_L increases in ρ at low ρ and decreases in ρ at high ρ. Since v_L is defined by $W(v_L, \infty) = 0$, we have that $dv_L/d\rho = -\partial W/\partial\rho/\partial W/\partial v_L$. As shown in the proof of Lemma 2, $\partial W/\partial v_L$ is negative, so $dv_L/d\rho$ has the same sign as $\partial W/\partial\rho$. Differentiating (A.5), we obtain

$$\frac{\partial W(v_L, \infty)}{\partial\rho} = \frac{-\sigma}{1 - \Phi(y_L)} \left[\frac{H}{2h\sqrt{2\pi}} \big(1 - \Phi(Hy_L)\big) - \phi(y_L)\big(1 - \Phi(hy_L)\big) \right], \tag{A.6}$$

where $y_L = (v_L - v_0)/\sigma$.

Suppose first that $\rho_1 \geqslant 0$. Then the lowest ρ that supports preemption is ρ_1. At $\rho = \rho_1$, $v_L = v_0$ and so $y_L = 0$. We have

$$\frac{\partial W(v_0, \infty)}{\partial\rho}\bigg|_{\rho=\rho_1} = \frac{\sigma}{\sqrt{2\pi}} \frac{\sqrt{2(1-\rho_1)} - 1}{\sqrt{2(1-\rho_1)}} > 0.$$

The inequality holds because $\rho_1 < 0.5$ and thus $2(1 - \rho_1) > 1$.

Suppose next that $\rho_1 < 0$. Then preemption is possible at $\rho = 0$. At $\rho = 0$, $v_L > v_0$ and so $v_L > 0$. When $\rho = 0$, $h = 1$ and $H = \sqrt{2}$, and (A.6) becomes

$$\frac{\partial W(v_L, \infty)}{\partial\rho}\bigg|_{\rho=0} = \frac{\sigma}{1 - \Phi(y_L)} \left[\phi(y_L)\big(1 - \Phi(y_L)\big) - \frac{1}{2\sqrt{\pi}}\big(1 - \Phi(\sqrt{2}y_L)\big) \right]$$

which has the same sign as $G(y_L)$, where

$$G(y_L) = \phi(y_L)\big(1 - \Phi(y_L)\big) - \frac{1}{2\sqrt{\pi}}\big(1 - \Phi(\sqrt{2}y_L)\big).$$

Because $y_L > 0$,

$$G'(y_L) = -y_L\phi(y_L)\big(1 - \Phi(y_L)\big) - \phi^2(y_L) + \frac{\phi(\sqrt{2}y)}{\sqrt{2\pi}} = -y_L\phi(y_L)\big(1 - \Phi(y_L)\big) < 0.$$

In addition, $G(0) = 1/(2\sqrt{2\pi}) - 1/(4\sqrt{\pi}) > 0$ and $G(\infty) \to 0^+$. It follows that the sign of function $G(y_L)$ is always positive, which means that $\partial W/\partial\rho|_{\rho=0}$ is positive. The signs of the derivatives at $\rho = \rho_1$ (if $\rho_1 \geqslant 0$) and $\rho = 0$ (if $\rho_1 < 0$) show that the preemptive value first increases in similarity level.

The highest ρ that supports preemption is ρ_2. At $\rho = \rho_2$,

$$\frac{\partial W(v_0, \infty)}{\partial\rho}\bigg|_{\rho=\rho_2} = \frac{\sigma}{\sqrt{2\pi}} \frac{\sqrt{2(1-\rho_2)} - 1}{\sqrt{2(1-\rho_2)}} < 0.$$

The sign is negative because $2(1 - \rho_1) > 1$. This shows that the preemptive value v_L decreases in ρ at high ρ. □

Appendix B. 2-D clustering

Table B.1
Regression outcomes by 2-dimension clustering
This table reports regression outcomes with clustering standard errors at both subject and period level. *First Bid* is the first bid of the first bidder. *Low* and *High* are dummies for the similarity treatments. *Inverse Mills ratio* is estimated based on regression outcomes on the proportion of single-bidder contests, and is negative if the second bidder enters and positive otherwise. For each estimate, we report estimated coefficients and predicted sign. Standard errors and t-statistics are listed in parentheses.

Variable	Proportion of single-bidder contests		Price in single-bidder contests		Price in two-bidder contests	
	γ estimate (std. err.)	Predicted sign (t-stat)	β estimate (std. err.)	Predicted sign (t-stat)	θ estimate (std. err.)	Predicted sign (t-stat)
First Bid	0.05 (0.01)	H_0: $\gamma_1 > 0$ (4.58)				
Low	0.25 (0.16)	H_0: $\gamma_2 > 0$ (1.55)	−5.57 (0.15)	H_0: $\beta_1 < 0$ (−36.20)	−4.18 (0.88)	H_0: $\theta_1 < 0$ (−4.77)
High	0.39 (0.28)	H_0: $\gamma_3 > 0$ (1.38)	−8.16 (0.24)	H_0: $\beta_2 < 0$ (−34.24)	−3.47 (2.26)	H_0: $\theta_2 < 0$ (−1.53)
Inverse Mills ratio			−31.69 (0.81)	(−39.33)	−30.32 (2.75)	(−11.01)
Constant	−3.52 (0.61)	(−5.77)	98.37 (0.96)	(102.62)	47.35 (1.09)	(43.26)
N	540		157		383	

Appendix C. Supplementary material

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.geb.2013.08.010.

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