UNIVERSITEIT GENT

FACULTEIT ECONOMIE
EN BEDRIJFSKUNDE

HOVENIERSBERG 24
B-9000 GENT
Tel. : 32 - (0)9 – 264.34.61
Fax. : 32 - (0)9 – 264.35.92

WORKING PAPER

Acquisitions as a real options bidding game

Han T.J. Smit[1]

Ward A. van den Berg [2]

Wouter De Maeseneire[3]

January 2005

2005/289

[1] Erasmus University Rotterdam
[2] Erasmus University Rotterdam
[3] Erasmus University Rotterdam and Ghent University. Wouter De Maeseneire is Aspirant of the Fund for Scientific Research-Flanders (FWO-Vlaanderen) and greatly acknowledges financial support from the Fund. Corresponding author: Wouter De Maeseneire, P.O. Box 1738, NL-3000 DR Rotterdam, The Netherlands, Tel: +31 10 408 23 68, Fax: +31 10 408 91 65, email: wouter.demaeseneire@ugent.be. We would like to thank Michael Fishman, Enrico Perotti and the participants of the 2004 Corporate Finance Day, Ghent University. The usual disclaimer applies.

D/2005/7012/07

Abstract

This paper uses a unified treatment of real options and game theory to examine the occurrence of bidding contests within a competitive environment of imperfect information and asymmetric bidders. Competing potential buyers may sequentially perform due diligence and incur costs (option premium) to become informed about their firm-specific target value (underlying value) before making a bid (exercise price). The first player's bid reveals a signal on its own and the rival's target value, thereby affecting the value of the rival's option to bid on the target and the probability of a bidding contest. We find that bidding contests are more likely to take place between moderately correlated buyers, whereas rather diverse or just very similar buyers are less likely to compete.

Acquisitions are known to have sometimes a beneficial and occasionally a very detrimental impact on a corporation's performance. Empirical research on this topic indicates that, on average, acquisitions create value but most of this added value is reflected in the acquisition price. However, the resulting low acquirer returns exhibit substantial variation. In bidding contests in particular, heterogeneity between rival bidders and information asymmetry between them determine the acquisition premium (Bradley, Desai, and Kim (1988); Fishman (1988)). The real options-game model presented here examines the bidding process, the likelihood of a bidding contest and the expected value appropriation for the acquirer. The implications of the model are built on signaling by heterogeneous[i] players. The information about target value that is revealed to a rival by a bid depends on the (dis)similarity of resources of the rival bidders. The bidding strategy, the likelihood of a bidding contest and the expected acquisition price are determined by new and less obvious parameters such as volatility and correlation between bidders' resources.

Firms often invest aggressively in due diligence before making acquisitions. Early, detailed, and rigorous transaction screening yield a significant advantage in placing a successful bid to many deals or avoid that the other deals are being taken too far through the process. The due diligence investment of an interested bidder can in this sense be considered as the purchase of a real option on the target's value. The due diligence costs (option premium) a potential buyer needs to incur reveals the target value (underlying value) and are thus a prerequisite before making a bid (exercise price). A potentially interested bidder will only perform due diligence and incur the associated cost if this is justified by the real option value. The opportunity to bid on a target, however, is not an exclusive but rather a shared option, where the acquisition price is determined by competition between potential buyers.

The specific acquirer's assets, resources and capabilities and their fit with those of the potential target determine the actual value for each potential buyer (Barney (1986)). A public opening bid might reveal an attractive takeover target for rivals and provokes closer scrutiny of the target by other bidders. The extent to which an opening bid affects an uninformed rival's beliefs concerning its target value and its expected gains from the acquisition depends on the bidders' resources. For instance, a high bid indicates a high value for the initial bidder and a similar rival is likely to assign a high value to the target as well, whereas this bid would give no indication on the value for an unrelated rival.

Fishman (1988) and Hirshleifer and Png (1989) also relate the expected gains in a bidding contest to the costs associated with acquiring information. Fishman (1988) offers the interesting insight that the price of a target in a bidding contest may exhibit a jump when some contestants have imperfect and costly information. We contribute insights from option theory to Fishman's model and show that uncertainty and correlation between bidders determine the information revealed by the opening bid. Our model builds on Fishman (1988) and presents a two player setting, where the initial bidder may decide to make a pre-emptive or an accommodating bid after performing due diligence. When the bid provides an accommodating signal, the second bidder invests in due diligence and an English auction[ii] unfolds. However, when the initial bidder has offered a pre-emptive bid, the costs of due diligence are higher than the second bidder's option value on the target. The rival will abstain from entering a bidding contest and the first bidder acquires the target at the pre-emptive bid.

Our model provides several novel implications that can in principle be tested. In contrast to common beliefs, value appropriation is not strictly decreasing with the level of relatedness between bidders (correlation) but follows a U-shaped form. The opening bid provides a double signal to the rival. When correlation is high (bidders are similar), the opening bid signals high target value for the rival, inducing him to invest in due diligence and potentially join in a bidding contest. However, at the same time, due to the great similarity, acquisition prices will be high and value creation will be bid away in the contest, making the second player less inclined to invest in due diligence. When rival bidders are different (correlation is low) the second player is less likely to invest as well, since the bid signals low target value. As a consequence, both very low and very high levels of correlation enhance the ability to make a pre-emptive bid and increase the initial bidder's value appropriation. Intermediate levels of correlation may result in a bidding contest and low value appropriation. Furthermore, value appropriation increases in case of higher uncertainty and higher expected value for the initial bidder. Greater uncertainty to the second bidder increases the likeliness of a bidding contest and reduces the value appropriation.

The remainder of the article is as follows. In Section II, we provide a brief review of background literature on bidder heterogeneity and information asymmetry to support the economic fundamentals of our model. In Section III, we present our real option-game model. The model's results are discussed in Section IV, and Section V elaborates upon the model's implications. Section VI summarizes this paper and its main findings.

II. Literature on Value Appropriation in Acquisitions: Heterogeneity and Imperfect Information

From empirical research it is clear that acquisitions may create value, but there is substantial variation in how this value is split up between target and acquirer.[iii] A successful tender offer increases the combined value of the target and acquiring firm by about 7 to 10% on average (Bradley, Desai, and Kim (1988); Seth (1990); Stulz, Walkling, and Song (1990)). Further evidence suggests that acquiring firms on average earn a return close to zero, though there is tremendous variation in these returns (e.g., Berkovitch and Narayanan (1993)). The underlying causes of this variation in acquisition returns have enjoyed continuous attention in the empirical literature. However, further theoretical development explaining the variation in value appropriation is desirable (Fuller, Netter, and Stegemoller (2002)).

Recently, several articles have used real options and games to explain the occurrence and returns of mergers (Smith and Triantis (1994), and Smit (2001)). Lambrecht (2004) shows that firms have an incentive to merge in periods of economic expansion when mergers are motivated by economies of scale, which provides a rationale for the procyclicality of merger waves. Morellec and Zhdanov (2004) have developed a model that is consistent with the general empirical observation that target shareholders' returns are larger than returns to bidding shareholders and that returns to bidding shareholders can be negative if there is competition for the target acquisition.

The existence of *information asymmetry* between rival bidders has a significant influence on competition for deals and the size of the acquisition premium (Barney (1988)). For instance, a *buyer's initial stake (toehold)* results in a financial and strategic advantage and to higher bidder returns (e.g., Grossman and Hart (1981); Shleifer and Vishny (1986); Franks and Harris (1989); Stulz, Walkling, and Song (1990)). In addition, those returns could be attributed to the information advantage provided by the initial shareholding (Burkart (1995)). Bradley, Desai, and Kim (1988) have shown that bidder returns were higher before the acceptance of the 1968 Williams Act, which requires a bidder to disclose private information about the target. A larger part of the value creation goes to the acquirer when buying a *private firm or a subsidiary* rather than a public firm. In addition to the lack of liquidity, this can be explained in part by limited information that is available, higher information costs for rivals, and consequently lower competition for the target. This is consistent with the findings of Fuller, Netter, and Stegemoller (2002), who show that acquirer returns are more positive for larger *non-public targets* and more negative for larger public firms. In our model, information on the idiosyncratic target value is acquired at a cost, such as consultancy and banker fees related to due diligence, but essentially creates an option to acquire the target. We show that a bid may reveal part of this information to potential rival bidders, and that the information revealed depends critically on the heterogeneity between bidders (correlation).

Heterogeneity as a result of the specific match between the target's and the acquirer's resources creates the ability of a buyer to avoid bidding away all the value creation through high takeover prices (Chatterjee (1986,1992); Barney (1988)). The target will have different values for heterogeneous buyers. Capron and Pistre (2002), for example, show that acquirers earn abnormal returns only when they can transfer their own unique resources to the target, which prevents the competitive bidding process from fully unfolding.[iv] Parenting advantage (Campbell, Goold, and Alexander (1995)), complementary resources (Harrison, Hitt, Hoskisson, and Ireland (2001)) and absorptive capacity (Zahra and George (2002)) might be considered as partly inimitable valuable resources and are therefore important factors in explaining the appropriation of value creation in acquisitions.

In our model, we analyze the effect of heterogeneity on the information signaled to rivals by the opening bid, and we develop implications for the likelihood of bidding contests to occur.

III. Option and Game Model

In this section we develop our real option-game model in which players sequentially retrieve information on the target value and we determine the optimal Bayesian Nash equilibrium under an accommodating or deterrent bidding strategy.

A. Assumptions of the Option-Game Model

We assume a two-player setting of the bidding game. Contests with more than two bidders seldom occur.[v] In our model, Player A is the first to investigate the target value at time $t = 0$; at $t = 1$, Player A is informed about its target value and offers its initial takeover bid. Player B observes this public bid and can infer some information on the target value for both itself and the rival, enabling him to better assess the expected acquisition price and real option value obtained by performing due diligence. Player B will only invest in due diligence if the option value to bid on the target exceeds the costs of due diligence, *I*.[vi] If Player B decides to invest in due diligence, the target becomes the subject of a bidding contest between informed players at $t = 2$. The winning bidder's value appropriation is contingent on its rival's value (= acquisition price). If Player B does not invest in due diligence, Player A acquires the target at its binding opening bid.

We assume that common beliefs about expected target values, uncertainty around those values, and correlation between rivals' target values are available to all participants in the game. The decisions are based on those common beliefs and observed players' actions. We denote the present or expected value of the uncertain target value by $V_A(0) = E_0(V_A(2))$ and $V_B(0) = E_0(V_B(2))$ for Players A and B respectively.[vii] The volatility or uncertainty can be different for both players and reflects the extent to which the actual value can deviate from the expected value; it is given by σ_A and σ_B. The correlation between bidders' target values is denoted by ρ.

The information search period has been standardized to one.[viii] In the due diligence process small pieces of information on the acquisition value emerge, gradually reducing uncertainty, until at the end of the search the player knows its private actual target value, denoted by $V_A^* = V_A(2)$ and $V_B^* = V_B(2)$ for Players A and B, respectively. We assume a risk-neutral world, in which the resolution of uncertainty about the actual target value during the process of information search is represented by the geometric Brownian motion in Eq. (1). [ix]

$$dV_i(t) = V_i(t)\sigma_i dZ_i(t) \quad for\ i = A, B \tag{1}$$

The Brownian motions of the actual target values, $Z_A(t)$ and $Z_B(t)$[x], are correlated by a factor ρ, with $-1 \leq \rho \leq 1$. The correlation reflects the degree of uniqueness of the rival bidders' resources and capabilities. When ρ equals 0, the two prospective buyers do not share any resources or capabilities that contribute value in the acquisition. For increasing values of ρ a larger proportion of value creation in the acquisition results from similar capabilities and resources, and competition would become more intense in a bidding contest. For instance, tax shields in management buyouts can be obtained by many investors and stem from similar resources, whereas improving operations requires idiosyncratic capabilities (Kaplan (1989)). For $\rho = 1$, competitors are identical in their value creation competences and a bidding contest would transfer all value creation to the present shareholders. In case of negative correlation, a resource of the target or acquirer that has greater value to one player than initially expected will likely have a lower value for the competitor. An example would be the case of an inefficient business unit of a target that is making huge losses. If one player cannot perform the required restructuring, while the rival bidder is an expert in transforming inefficient businesses into successful ones, this would result in negative correlation between the rival bidders' value of this resource.

Finally, we assume -similar to most tender offer literature (e.g., Bradley, Desai, and Kim (1988); Burkart (1995))- that managers of bidding firms seek to maximize their shareholders' wealth, that there are no transaction costs in bidding, that offers cannot be withdrawn (binding bids) and that all takeover bids are public information. Furthermore, we assume that a player who does not know its actual target value will never enter a bidding contest solely on the basis of common knowledge.[xi] Any bid must exceed the seller's reservation price, *RES*, which is the price at which current owners are willing to sell their stake in the target. It is assumed to be equal to the target's stand-alone value, or to the financial market value in the case of a listed firm. We do not consider free-rider problems, as did Grossman and Hart (1980), and assume that current owners are rather passive in the transaction.

B. Option Value for Second Bidder

At t = 1, Player A has conducted due diligence and has offered a bid, b_A, thereby signaling its value to Player B who is contemplating investment in due diligence. The real option for Player B to bid on the target resembles the exchange option of Margrabe (1978), as the uncertain target value to Player A (= price) is exchanged for the uncertain target value to Player B, but it also incorporates the information offered by Player A's initial bid, b_A. Player A's bid provides a lower bound to Player A's target value distribution, V'_A, which is at least as large as the bid.[xii] Furthermore, correlation between the players' target values determines the bid's impact on Player B's update of its target value and uncertainty. When firms are similar, a high bid indicates a high value for Player A and therefore a high value for Player B is more likely as well. At time 1 the value of Player B's option to bid on the target is given by Eq. (2), where we take the truncation of the price distribution into account, or $V_A^* > V'_A$.[xiii]

$$C(1) = E_Q\big(\max(V_B(2) - V_A(2), 0) \mid V'_A\big) \tag{2}$$

To obtain a closed form solution for the option value of Eq. (2), we first examine the impact of the opening bid b_A on Player B's beliefs on the target's value distribution for both players. At time 1 Player A has complete knowledge on its target value. Player B can infer some information on Player A's value, as the lognormal distribution of the value at time 1 is now truncated by the lower bound V'_A. The paths of the Brownian motion $Z_A(t)$ that attain a value at $t = 2$ below $k = \left(\ln(V_A') - \ln(E(V_A)) + \frac{1}{2}\sigma_A^2\right)/\sigma_A$ are not feasible anymore. Hence, the expected target value of Player A conditional on its implied bid, $E_1(V_A(2) \mid V_A')$, is given by the truncated expectation in Eq. (3).

$$E_1(V_A(2) \mid V_A') = V_A(0)N(\sigma_A - k)/N(-k) \tag{3}$$

Thus, Player A's bid results in an upwards update of Player B's beliefs about Player A's expected target value. Moreover, when rivals' target values are correlated, the bid reveals that certain due diligence outcomes on the value of the shared resources are not feasible. This affects Player B's expected target value, as some values of $Z_B(t)$ are more likely to occur if the lower paths of $Z_A(t)$ have not been attained. In case of positive correlation Player B's expected target value will increase by a bid of Player A, while the update is downwards for negative correlation. Eq. (4) provides Player B's updated expected target value after observing Player A's bid.

$$E_1(V_B(2) \mid V_A') = V_B(0)N(\rho\sigma_B - k)/N(-k) \tag{4}$$

If $\sigma_A > \rho\sigma_B$ Player A's bid has a larger impact on the expected value to Player A than to Player B. Player B's shared resources are not sufficiently valuable to overcome the unique value creation that Player A might realize.

Player B's option value to bid on the target can now be expressed in terms conditional on the lower bound on Player A's value revealed by its initial bid.[xiv,xv]

$$C(1) = E_1(V_B(1) \mid V_A')M(d_1, d_2, \rho_1)/N(d_2) - E_1(V_A(1) \mid V_A')M(e_1, e_2, \rho_1)/N(e_2) \tag{5}$$

The parameters[xvi] of the standard bivariate and univariate normal distribution functions *M* and *N* are given by

$$d_1 = \frac{\ln(E(V_B)) - \ln(E(V_A)) + \frac{1}{2}\sigma_{B/A}^2}{\sigma_{B/A}} \qquad d_2 = \frac{\ln(E(V_A)) - \ln(V_A') + \rho\sigma_A\sigma_B - \frac{1}{2}\sigma_A^2}{\sigma_A}$$

$$e_1 = \frac{\ln(E(V_B)) - \ln(E(V_A)) - \frac{1}{2}\sigma_{B/A}^2}{\sigma_{B/A}} \qquad e_2 = \frac{\ln(E(V_A)) - \ln(V_A') + \frac{1}{2}\sigma_A^2}{\sigma_A}$$

The variance of the ratio $V_B(1)/V_A(1)$ is given by $\sigma_{B/A}^2 = \sigma_A^2 + \sigma_B^2 - 2\rho\sigma_A\sigma_B$, while the correlation between the ratio $V_B(1)/V_A(1)$ and the variable $V_A(1)$ is given by $\rho_1 = (\rho\sigma_B - \sigma_A)/\sigma_{B/A}$.

Let us consider some properties of this option. For a bid close to zero, or when no bid is offered, the option value collapses to the Margrabe simple exchange option given by $V_B(0)N(d_1) - V_A(0)N(e_1)$. For very low bids, the signal provided by Player A's implied bid is weak and does not much alter Player B's beliefs about its own or Player A's expected target value. For higher bids, the influence on option value depends on uncertainty and correlation, which both affect the probability of a successful takeover and the updated value for the players. For very high bids ($\lim V_A' \to \infty$) the option can take one of two values. If $\rho\sigma_B < \sigma_A$, the option value converges to zero. A high bid increases the expected target value to Player A by far more than to Player B, and Player B will surely lose in a bidding contest. On the other hand, if $\rho\sigma_B > \sigma_A$, a high bid indicates an even larger value for Player B than for Player A and Player B would certainly win a bidding contest. The option value will then become infinitely large.

C. Pre-emption or Accommodating Competition

Player A must deliberate at time 1 whether to quote a high pre-emptive bid or a lower bid that allows the rival to enter a bidding contest. The gains from quoting a pre-emptive bid are known in advance, while the option value of an accommodating bid strategy depends on the unknown target value to Player B. For which level a bid acts pre-emptive depends on the value of the alternative of offering an accommodating bid, which we will consider first.

After due diligence, Player A knows its own target value $V_A(2) = V_A^*$ and can update its beliefs about Player B's target value based on their common resources and capabilities. The value of this shared component in the Brownian motions $Z_A(t)$ and $Z_B(t)$ is thus known to Player A, who is informed about the realization of $Z_A^*(2) = l = \left(\ln(V_A^*) - \ln(E(V_A)) + \tfrac{1}{2}\sigma_A^2\right)/\sigma_A$. Hence, Player A knows the probability distribution of Player B's target value conditional on $V_A(2) = V_A^*$, and the updated expected value equals

$$E_1(V_B(2) \mid V_A^*) = V_B(0)\varphi(l - \sigma_B \rho)/\varphi(l) \tag{6}$$

where $\varphi(x)$ is the standard normal probability density function evaluated at *x*, where $-\infty < x < \infty$. If Player A's value is smaller than expected, $V_A(0)$, it is more likely that Player B's value is also smaller than initially expected, $V_B(0)$, under positive correlation. The variance in the geometric Brownian motion that describes Player B's possible values is therefore reduced as well and is given by

$$dV_B(t) = \sqrt{(1-\rho^2)}\sigma_B V_B(t) dZ_{B|A}(t) \tag{7}$$

The Brownian motion $Z_{B|A}(t)$ is independent of $Z_A(t)$. Player A will make a pre-emptive bid only if the expected payoff from preventing Player B from participating in a bidding contest outweighs the higher purchase price. The value of quoting a low bid and facing competition from Player B is given by the option

$$D(1) = E_Q(\max(V_A^* - \max(V_B(2), b_A), 0)) \tag{8}$$

The minimum acquisition price equals the initial bid, b_A. A competitor will enter the bidding contest if its target value is higher than this opening bid. When Player A values the target higher than Player B, it acquires the target at a price $V_B(2)$; otherwise, Player B acquires the target and Player A's payoff is zero. The present value of this option at t = 1 is given in closed form by

$$D(1, V_A^*) = V_A^* N(d_1) - E_1(V_B(2) \mid V_A^*)\big(N(e_1) - N(e_2)\big) - b_A N(f_1) \tag{9}$$

where the parameters are given by

$$d_1 = \frac{\ln(V_A^*) - \ln(E_0(V_B(1) \mid V_A^*)) + \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B}$$

$$e_1 = \frac{\ln(V_A^*) - \ln(E_0(V_B(1) \mid V_A^*)) - \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B} \qquad e_2 = \frac{\ln(b_A) - \ln(E_0(V_B(1) \mid V_A^*)) - \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B}$$

$$f_1 = \frac{\ln(b_A) - \ln(E_0(V_B(1) \mid V_A^*)) + \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B}$$

Player A's option value under an accommodating bid strategy is decreasing in the level of the bid b_A. In a bidding contest, the likelihood of a successful acquisition depends only on Player B's target value, which is not affected by a higher or lower bid. A higher bid only increases the average acquisition price, as the opportunity to acquire the target at the rival's value, which may be lower than the bid, has been forestalled. In an accommodating bid strategy, Player A therefore has an incentive to offer an opening bid as low as possible and will hence offer a bid equal to the reservation price.

Player B can obtain the option to bid by investing in due diligence at costs I. Player A can avoid a bidding contest when it has the opportunity to offer a pre-emptive bid that results in a Player B's option value that is smaller than the information costs. Player A will follow a pre-emptive bid strategy if the pre-emptive bid is lower than the expected purchase price in a bidding contest. If Player A offers the pre-emptive bid, Player B infers that the value of pre-emption exceeds the value of accommodation for the actual target value of Player A. The lower bound on Player A's target value distribution is therefore not given by the pre-emptive bid, $\widetilde{b}_A$, itself, but by the implied pre-emptive bid, b_A^{imp}, at which the value of accommodation equals the value of pre-emption. At this implied pre-emptive bid, Player B's option value to bid on the target equals the due diligence costs.

$$b_A^{imp} = \inf\{b_A : C(0, b_A) < I\} \tag{10}$$

The pre-emptive bid itself is the difference between the implied pre-emptive bid and the value of the option to accommodate at a target value equal to this implied pre-emptive bid.

$$\widetilde{b}_A = b_A^{imp} - D(1, b_A^{imp}) \tag{11}$$

To summarize, Player A may choose a pre-emptive bid and receive the certain payoff, $V_A^* - \widetilde{b}_A$, or the option value under an accommodating bid strategy, $D(1, V_A^*)$ dependent on its actual target value, V_A^*. There are three equilibrium regions. If Player A's target value is below the pre-emptive bid ($V_A^* < \widetilde{b}_A$), it accommodates. For target values between the pre-emptive and the implied pre-emptive bid ($\widetilde{b}_A < V_A^* < b_A^{imp}$) accommodating is preferred as well, despite the fact that its value exceeds the pre-emptive bid. From a certain threshold, $V_A^* > b_A^{imp}$, offering a pre-emptive bid yields a higher payoff than accommodating competition.

The pre-emptive bid depends on the uncertainty of and correlation between bidders. If $-1 < \rho < \sigma_A / \sigma_B$, a pre-emptive bid exists since Player B's option value decreases in Player A's bid and will thus become smaller than the information costs. If $\rho\sigma_B > \sigma_A$, the option value increases in the initial bid and pre-emption is impossible, except in the special case where the reservation price is already deterrent. The pre-emptive bid decreases in due diligence costs, as the implied pre-emptive bid decreases more than the value of the option under an accommodating strategy.

Finally, if Player A accommodates a double signal is provided to Player B: i) Player A's target value is at least as large as the reservation price (= accommodating bid); and ii) an accommodating bid implies that Player A could not offer a high pre-emptive bid and Player A's actual value is consequently lower than the threshold level b_A^{imp}. In the Appendix Eq. (A.17), this cap on Player A's value is accounted for in Player B's option. Player B's option value increases due to the cap on Player A's value.

IV. Results of the Model

In this section we discuss the initial bidder's decision between the alternative strategies -offering a high pre-emptive or a low accommodating bid- and examine Player A's expected value appropriation. In our analysis, we focus on the impact of correlation and uncertainty about actual target value.

A. Pre-emptive Bidding: Option Value for Player B

Player B will invest in due diligence after observing Player A's bid when its option value exceeds the information costs. Player A knows the parameter values of this option and can offer a pre-emptive bid to deter Player B from entering the bidding contest.

Fig. 1 shows the influence of Player A's implied bid (=lower bound on its value distribution) on Player B's real option value to bid on the target under various parameter settings. As noted, in the special case where Player A has offered no bid or a bid equal to zero the option collapses to the Margrabe exchange option. In this case, Player B's option value decreases in the level of correlation. In line with conventional wisdom, higher correlation decreases total uncertainty about the difference in values that both bidders assign to the target (ratio of value and price). In general, heterogeneity between bidders' resources -measured in our context by correlation- leaves room for appropriation of value in competitive bidding.

[Insert Figure 1]

However, when acknowledging the signaling effect of Player A's implied bid on price and value for Player B, the option value of Player B becomes a non-linear function of the implied bid, and the impact of correlation on option value becomes more complex. At high correlation levels the implied bid has a limited impact on the option value: the likely acquisition price increases, but so does the expected target value. However, at low or even negative levels of correlation the bid signals a low target value, and the non-linearity becomes more apparent.

The comparative static analysis presented in Fig. 1 shows three types of curvatures, depending on the correlation: strictly increasing, strictly decreasing and initially increasing but later decreasing. First, when $\rho < 0$, the option value is strictly decreasing in the level of the implied bid. A higher bid reduces the expected value for Player B, while its beliefs about the acquisition price (i.e., the expectation of Player A's value) increase. Second, when $0 < \rho < \sigma_A / \sigma_B$ the option value is (often marginally) increasing for a low implied bid[xvii] and is decreasing for higher bids. In this case, the total uncertainty for Player A is higher than Player B's uncertainty on the shared target resources. Consequently, a higher bid increases Player B's conditional expected value (since $\rho > 0$), but Player B's belief of the acquisition price increases by an even larger amount (since $\rho\sigma_B < \sigma_A$; e.g., the curves in Panels D and F for $\rho = 0.9$ and in Panel C for $\rho = 0.6$). Third, when $\rho\sigma_B > \sigma_A$ the option value is strictly increasing in the level of the bid. When the uncertainty surrounding the shared resources faced by Player B is higher than the total uncertainty faced by Player A, a higher bid reveals information for Player B that increases its expected target value by more than the expected price. An example is shown in Panel C for the case $\rho = 0.9$.

In the base case of Panel A, the target's (unconditional) expected value for both players equals 100 and uncertainty around this expectation is 0.3 ($\sigma_i = 0.3$). By offering an implied pre-emptive bid, P^A, Player A can deter Player B from bidding because the information costs exceed Player B's option value. Due to non-linearity the S-shaped option value functions for different correlation levels intersect. Whether higher correlation facilitates or hinders pre-emptive bidding therefore depends on the option value function vis-à-vis the level of information costs, *I*. When a low pre-emptive bid is sufficient (e.g., high costs) the effect on price exceeds the signal on value and higher correlation has a negative effect on the option value and the pre-emptive bid. When a high pre-emptive bid is required (e.g., low costs) the effect on value dominates the effect on price and higher correlation has a positive effect on option value, driving the pre-emptive bid upward.

Panel B shows that higher uncertainty for Player A ($\sigma_A = 0.4$) amplifies the S-shaped form of the option value function relative to the base case. Player B's acquisition price is more uncertain than its target value. Similar to Margrabe's exchange option, higher uncertainty about the acquisition price would increase option value, since it increases the volatility in the difference between players' actual target values. Interestingly, the bid's signaling effect on price is stronger than in the base case, while its effect on Player B's value has not been altered, thereby reducing option value. When a low pre-emptive bid is sufficient, the increased price uncertainty dominates the larger acquisition price and the option value rises. In cases where Player A has to make a high pre-emptive bid, the increased price uncertainty is dominated by the larger acquisition price and option value decreases. For instance in the example of Panel B, the implied pre-emptive bid is lower as compared to the base case of Panel A (for $\rho = 0.3$, from P^A to P^B).

Panel C shows the effect of higher uncertainty for Player B ($\sigma_B = 0.4$) on option value. In this situation target value is more uncertain than target price. Now, the bid conveys a more significant adjustment in Player B's expected value. In general[xviii], the option value and the pre-emptive bid rise (for $\rho = 0.3$, from P^A to P^C). Pre-emptive bidding may even become impossible when $\rho\sigma_B > \sigma_A$.

Panel D shows the case of higher uncertainty for both players (to $\sigma_i = 0.4$) and thus combines the effects of the two previous panels. More uncertainty about resources and capabilities increases the attractiveness of conducting due diligence, as a greater potential is to be explored. With some exceptions, the option values in Panel D are shifted upward relative to Panel A, increasing the implied pre-emptive bid (for $\rho = 0.3$, from P^A to P^D).

Panels E and F show the influence of expected target value on option value. A higher expected value of Player A (Panel E) reduces the bid's signaling function. In general, the option value and required pre-emptive bid will be lower (for $\rho = 0.3$, from P^A to P^E).[xix] Higher expected value to Player B (Panel F) increases its option value and the implied pre-emptive bid (for $\rho = 0.3$, from P^A to P^F).

B. Accommodation: Option Value for Player A in a Bidding Contest

The value of accommodating competition depends on Player A's actual target value and its update on Player B's expected target value (= expected acquisition price). Player A will accommodate when this strategy is more valuable than pre-emption. Accommodating competition may result in a lower acquisition price and hence larger value appropriation, but Player A faces the risk of paying more or even losing the contest.

Fig. 2 shows Player A's real option value as a function of its actual target value when competition is accommodated. In the numerical example we set the reservation price equal to 80. If Player A's actual value, V_A^*, equals the reservation price, the option value is zero, and the option value increases for higher actual target. The shared resources (correlation between the players' target values) are an important factor for the shape of the function. The impact of correlation depends on the initially expected value for Player A and the actual target value which is private information of Player A. When Player A's actual value is lower than initially expected (100 in our example) and correlation is positive, Player B's value -and hence the acquisition price for Player A- is likely to be smaller. When actual target value is higher than initially expected, the effect of correlation on the acquisition price update is opposite. Player A's option value therefore increases in the correlation level at low actual values due to lower acquisition prices, while it decreases in correlation for large actual target values due to higher acquisition prices (as can be best viewed in Panels C and E of Fig. 2).[xx]

[Insert Figure 2]

Panel B shows the option value when the uncertainty faced by Player A is higher than for Player B.[xxi] Player A's negative or positive update on the expected acquisition price is smaller. As can be observed from Panel A and B differences in option values due to correlation are therefore smaller under higher uncertainty to Player A.

Panel C depicts the case where uncertainty on Player B's value (or the acquisition price) is higher. As usual, higher price uncertainty increases option value, but it has also an effect on the updated expected acquisition price. Player A's update will be larger, which may reinforce or offset the option value increase due to the larger uncertainty. When the actual target value is lower than expected, the downwards update on the acquisition price will be larger under positive correlation, raising option value. When the actual target value is higher than expected, the option value will decrease under positive correlation, partially or totally offsetting the increase due to larger uncertainty. An extreme example is given by the option value curve for $\rho = 0.9$, where the option value converges to zero for large actual target values. The effect of higher uncertainty to Player B on its option value are opposite for negative correlation.

In Panel D uncertainty to both players is increased and the results of previous two cases might reinforce or offset each other. In Panel E a larger expected value to Player A increases option value for positive correlation and reduces it for negative correlation. A higher expected value to Player B (Panel F) reduces the option value in any case.

C. Deliberation of Player A: Pre-emption or Accommodation

At t = 1 Player A deliberates between making a pre-emptive bid or a lower bid that allows the rival to participate in a bidding contest. The gains from a pre-emptive bid are certain, $V_A^* - \widetilde{b}_A$. The value of allowing the competitor to enter the contest equals $D(1)$ from

Eq. (9). For low target values, $V_A^* < \widetilde{b}_A$, Player A finds it optimal to place a low bid and accommodate competition, which is represented by the smooth line in Fig. 3. For values $\widetilde{b}_A < V_A^* < b_A^{imp}$ Player A makes a profit when offering the pre-emptive bid, but the value of accommodation is higher, as can be observed in Fig. 3. he value of offering the pre-emptive bid, $V_A^* - \widetilde{b}_A$ (represented by the thin dotted line), is less than the value of accommodating competition. The level of the pre-emptive bid $\widetilde{b}_A$ is given by the value where the diagonal dotted line crosses the X-axis. The pre-emptive bid is offered for $V_A^* > b_A^{imp}$, when pre-emption yields a higher return than accommodation. The implied pre-emptive bid is represented by the vertical dotted line.

[Insert Figure 3]

Panel A, the base case, shows for each actual target value the expected value appropriation for Player A. Due to non-linearities in option value for Player B, a correlation level exists above which the pre-emptive bid no longer increases but instead decreases in correlation.[xxii] The pre-emptive bid shifts right in correlation, but from a certain threshold level it shifts left again, as can be best viewed in Panel B. This can be explained if we revisit Fig. 1. When the option value intersects the cost line, the pre-emptive bid can fall in the low cost region (correlation increases the pre-emptive bid) or high cost region (correlation decreases the pre-emptive bid). When correlation is very high and the opening bid is equal to the reservation price, Player B's option to bid on the target may be less valuable than the due diligence costs. Player A can then appropriate all value creation and no bid premium is offered (e.g., the curve $\rho = 0.9$ in Panels A, B and E).

When competition is accommodated, the results from Section IV.B Player A's option value apply. For high actual target values the option value to accommodate competition decreases in correlation (see Fig. 2). This reinforces the effect of larger correlation on offering a pre-emptive bid for high target values: not only the pre-emptive bid decreases but also the alternative of accommodation is less valuable.

In Panel B (higher uncertainty for Player A) we observe lower pre-emptive bids. As the pre-emption lines shift to the left, the first bidder appropriates a higher proportion of value. The high or low cost regions are a function of information cost vis-à-vis option value. Increased uncertainty to Player A shifts the minimum of the U-shaped value appropriation function to a lower correlation level.[xxiii]

Panel C of Fig. 1 shows that it is more difficult to deter competition under higher uncertainty for Player B. As Player B's option value increases, the pre-emptive bid shifts to the right. As can be confirmed from Section IV.B, the value of the accommodation option is higher for low target values and it might even exceed the value of pre-emption in the base case.

Panel D again unites the previous both cases. The value of Player B's option to bid on the target increases in uncertainty, raising the pre-emptive bid. A higher uncertainty to both players also results in a higher value of the accommodation option. For high actual target values, the value appropriation will be less than in the base case where pre-emption occurs. However, for smaller actual target values, the value of the option to accommodate competition will be more valuable than in the base case where a pre-emptive bid is offered or competition is accommodated. The increased uncertainty to both players shifts the minimum of the U-shaped value appropriation function to a higher correlation.

A higher expected value to Player A (Panel E) facilitates offering a pre-emptive bid and raises the value of the option to accommodate competition under positive correlation, so value appropriation will be larger. A larger expected target value to Player B (Panel F) reduces Player A's expected value appropriation. The pre-emptive bid will be higher, and the option to accommodate competition becomes less valuable.

To summarize, the value appropriation by the initial bidder decreases with a higher rival option value to bid on the target or lower information costs, resulting in higher pre-emptive bids, or with a lower value of accommodating competition. For high target values, value appropriation takes a U-shaped function in correlation. It initially decreases until correlation reaches a certain level; from that level on, value appropriation rises with correlation.

V. Discussion of the Model Results and Model Extensions

The value of a target depends on its resources and the related and complementary resources of the potential acquirer. Potential acquirers differ in their resource base and part of the value created in the acquisition is unique. The uncertainty around the expected value and the correlation between potential bidders are determined by the match between the resources of the target and potential acquirers. The degree of correlation and (asymmetric) uncertainty depends on the proportion of shared and unique resources of acquirers. When the initial bidder controls more unique, potentially valuable resources (rather than shared resources) its expected target value is likely to be higher and correlation lower. Part of the value creation in the acquisition cannot be replicated by rivals. In many cases unique resources increase uncertainty about target value (e.g., the acquirer possesses a unique technology with an uncertain match with the target). It is hard for outsiders to make inferences on the value of these unique resources in relation to the target. Likewise, the holder of unique resources has a more complicated task to assess the use and value of its unique resources within the target. Of course, there are situations in which the addition of unique resources to a player's bundle of resources may reduce the uncertainty about its target value. For instance, a high quality (unique) distribution channel that can be used for the target's products may decrease uncertainty.

From finance and strategy literature, it is known that firms need unique, idiosyncratic skills to generate abnormal returns in acquisitions, since for common resources competition drives up the takeover price and, as a consequence, value appropriation is low or non-existent. Imperfect and costly information might change this result. In order to compete for the target, a rival must incur due diligence costs that it expects to recover. The initial bidder, who is informed about its target value, therefore has a strategic competitive advantage, as it can affect the rival's beliefs about expected gains from the acquisition. A key feature of our model lies in the opening bid, which contains a signal on both the initial bidder's and the rival's target value. The ability of the first bidder to influence the later entrant's behavior by setting the appropriate opening bid depends on the degree of relatedness between bidders and the bidders' uncertainty.

The extent to which value-creating capabilities in the acquisition are shared or, on the contrary unique, has a sophisticated effect on value appropriation. When the first bidder offers the opening bid, the second bidder updates its own expected value of the acquisition in a potential bidding contest. The impact of this update depends on correlation between the bidders. On one hand, the rival's expected target value increases in the level of correlation and on the other hand, the acquisition price in the contest will also be closer to its target value. A certain tradeoff in both effects exists, in which bidding contests are most likely when there is an intermediate level of correlation. For low correlation, the opening bid reveals only a high acquisition price, not a higher target value to the rival. High correlation implies that both players' target values are closer to each other and that value creation will be bid away in a contest. For intermediate correlation, the opening bid provides an upwards update on target value, while leaving room for favorable due diligence outcome on the acquisition price and for value appropriation.

Larger asymmetries in uncertainty between players can strengthen or weaken the signal of the opening bid. Increased asymmetric uncertainty can therefore offset the increase in option value as caused in general by higher uncertainty. When a player's target value is surrounded by larger uncertainty, this player has more power in the first stage of the bidding game in which players decide on investing in due diligence.

Our model provides a number of interesting new implications. The likelihood of bidding contests to occur depends on correlation. A bidding contest between players operating in different industries is not very likely as correlation is low. Similarly, we do not expect bidding contests between rivals who possess different experience/skills, when one bidder is a strategic buyer and the other a financial investor, or when one bidder is aiming for a vertical acquisition while the other is pursuing a horizontal acquisition. Likewise, a bidding contest is not likely to take place between similar firms within an industry, as the due diligence costs are too high as compared with the potential gains. The highest probability of a bidding contest occurs when rivals are characterized by intermediate correlation (e.g., financial bidders who pursue different strategies for the target, strategic bidders in the same sector that differ in their resource base, a high cost-high quality vs. low cost player). Thus, we expect bidding contests to unfold when the target is under scrutiny of several players that differ in some aspects but are not completely different.

The likelihood of bidding contests depends also on the uncertainty both players face. When the second bidder is more uncertain about its target value, the option to perform due diligence is more valuable, lowering value appropriation for the initial bidder. On the other hand, if the second bidder has higher uncertainty about the acquisition price (=initial bidder's target value) and observes a high opening bid as well, he is less induced to retrieve information, resulting in higher value appropriation for the initial bidder. We expect that a bidding contest is less likely to unfold and that the initial bidder captures the highest amount of value appropriation when the initial bidder is a young firm[xxiv] or operates in a different sector than the target (high uncertainty about its target value). Bidding contests are also less likely when potential rival bidders are larger, mature firms (low uncertainty due to experience in matching resources) or when information costs are high (e.g., the target is a complex firm to value).

A typical young firm is less likely to experience a rival bidder but is more likely to join a bidding contest as a second player, as the first bidder's offer triggers his interest. As a consequence, outsiders are the main opponents within bidding contests. An outsider, more uncertain about its value and to a lesser extent correlated with the first bidder, may show up in the takeover battle. Within bidding contests, we expect that initial bidders will be those with high expected value and considerable uncertainty, while we expect rival bidders also to be faced with high uncertainty and to be related to some extent with the first (not too little, but neither too much).

The timing of the rival bidder's decision to invest in due diligence is exogenous in our model. However, our results do not change when we consider endogenous timing, because firms are inclined to invest sequentially in order to optimally use the revelation of information. To show this, consider the possible timing game presented in a matrix in Fig. 4. *(i, ii)* When firms invest sequentially the value of the first entrant is given by F_i, and the value of the second to enter the bidding contest by S_i. *(iii)* When both players decide to invest simultaneously in due diligence, there is no information revelation and the payoff is given by the value of the Margrabe exchange option N_i minus the due diligence costs. *(iv)* When both rivals defer, the game is repeated in the next period (D_i).

[Insert Figure 4]

Simultaneous investment in due diligence (N_A, N_B) is not a Nash equilibrium. In order to benefit from the information revealed by a bid it is always preferred that the rivals invest sequentially and thereby potentially avoid unnecessary due diligence investment of the second player in the game ($S_i > N_i$). Dependent on the actual payoffs, the three other cells constitute an equilibrium. Firms will invest sequentially when $F_i > D_i$.. A coordination problem arises in a symmetrical game when there are two equilibria, in which one player invests and the other player waits. However, asymmetry in the payoffs might facilitate solving the coordination game by finding a unique Nash equilibrium or at least a focal point. Note that due to the opportunity to offer a pre-emptive bid Fi is larger than N_i.

The value of waiting, D_i, depends on additional uncertainty besides the incomplete information in our model. The actual target value may change as developments in the economy or business environment create new opportunities for the employment of the combined target's and acquirer's resources. Over time not only the target's reservation price, and potential rival bidders' expected value, but also uncertainty itself and correlation may evolve. When the game is repeated in the next period the firms may defer until a sequential revelation equilibrium results. Endogenous timing will therefore result in sequential investment and will not affect the main results of our model.

VI. Conclusions

In this paper we use a real options-game model that examines the bidding process, the likelihood of a bidding contest and the expected value appropriation for the acquirer. We focus on the role of information asymmetry and on heterogeneity in the rival bidders' resource base. A firm's capabilities and resources, combined with those of the target, determine its expected target value, uncertainty around it, and the correlation with rivals' target values. In our model, an uninformed bidder may acquire the option to bid on the target by performing due diligence. A potentially interested buyer will only become an informed bidder when its option value exceeds the due diligence costs. The initial bidder can affect the rival's option value since the opening bid provides a signal on its own and on the rival's target value. The first bidder may therefore choose a strategy to bid high and pre-empt rivals, or to bid low and accommodate competition, when pre-emption is too costly.

By considering a bidding contest as a sequential option game within a resource-based perspective of bidders, our model introduces the roles of uncertainty and correlation for the likelihood of a bidding contest and value appropriation. The extent to which value-creating capabilities in the takeover are shared between rival bidders (correlation) has a U-shaped effect on value appropriation. Very high levels and very low levels of correlation lead to a rise in value appropriation due to pre-emption, under imperfect information. At intermediate levels of correlation a bidding contest may occur and value appropriation is lower. The magnitude and sign of the bidding signal further depends on the uncertainty both players face.

Our model could be further expanded by including bidding costs, examining the endogenous timing of making a bid and determining endogenously which player offers the opening bid. Under uncertainty, rivals may defer investment until major macroeconomic uncertainties are resolved.

Appendix

A. Derivation of Player B's option to bid

Before any due diligence Players A and B share common beliefs on the target value for each of them, both given by a lognormal distribution or the solution of a geometric Brownian motion from Eq. (1) at $t = 1$.

$$V_i = E(V_i)\exp\left(-\tfrac{1}{2}\sigma_i^2 + \sigma_i Z_i\right) \qquad \text{for } i = \text{A or B} \tag{A.1}$$

We assume that the drift is absent, or the discount rate is equal to zero. The normally distributed variables Z_A and Z_B are correlated by a factor ρ.

After due diligence, Player A offers a bid b_A and truncates the distribution on its target value by the value V'_A (with $V'_A > b_A$), which is implied by this bid as we will show later. Z_A cannot take values below $k = \left(\ln(V'_A) - \ln(E(V_A)) + \tfrac{1}{2}\sigma_A^2\right)/\sigma_A$. The expected value is now given by

$$E(V_A \mid V'_A) = \int_k^\infty E(V_i)\exp\left(-\tfrac{1}{2}\sigma_A^2 + \sigma_A x\right) f(x)/N(-k)dx = \frac{E(V_A)N(\sigma_A - k)}{N(-k)} \tag{A.2}$$

where f(x) is the probability density function of the normal distribution and $f(x)/N(-k)$ gives the pdf. of the truncated distribution. The updated expected value of Player B's target value also depends on the truncation of Z_A by k:

$$E(V_B \mid V'_A) = \int_{-\infty}^\infty \int_k^\infty E(V_B)\exp\left(-\tfrac{1}{2}\sigma_B^2 + \sigma_B y\right) g(x,y)/N(-k)dxdy = \frac{E(V_B)N(\rho\sigma_B - k)}{N(-k)} \tag{A.3}$$

where $g(x,y)$ is the pdf. of the bivariate normal distribution.

The value of the option under the risk neutral measure Q conditional on the implied bid V_A' is given by

$$C(1) = E_Q\left(\max(V_B(2) - V_A(1), 0) \mid V_A'\right) \tag{A.4}$$

We can rewrite this to

$$C(1) = E_Q\left(V_B(2) 1_{\{V_B(2) > V_A(2) | V_A(2) > V_A'\}} - V_A(2) 1_{\{V_B(2) > V_A(2) | V_A(2) > V_A'\}} \mid V'\right) \tag{A.5}$$

which in turn can be rewritten by changing the numeraire:[4]

$$C(1) = V_B(1) \times Q_{V_B}\left(V_B(2) > V_A(2) \mid V_A(2) > V_A'\right) - V_A(1) \times Q_{V_A}\left(V_B(2) > V_A(2) \mid V_A(2) > V_A'\right) \tag{A.6}$$

The conditional probabilities can be calculated by adjusting the drift of the geometric Brownian motions describing $V_A(t)$ and $V_B(t)$ in accordance to the right probability measure Q_{V_A} or Q_{V_B}. The solution is given by Eq. (5) or

$$E_1(V_B(1) \mid V_A') M(d_1, d_2, \rho_1) / N(d_2) - E_1(V_A(1) \mid V_A') M(e_1, e_2, \rho_1) / N(e_2) \tag{A.7}$$

where the parameters of the standard bivariate and univariate normal distribution function M and N are given by

---

[4] See Geman, El Karoui, and Rochet (1995).

$$d_1 = \frac{\ln(E(V_B)) - \ln(E(V_A)) + \frac{1}{2}\sigma_{B/A}^2}{\sigma_{B/A}} \qquad d_2 = \frac{\ln(E(V_A)) - \ln(V_A') + \rho\sigma_A\sigma_B - \frac{1}{2}\sigma_A^2}{\sigma_A}$$

$$e_1 = \frac{\ln(E(V_B)) - \ln(E(V_A)) - \frac{1}{2}\sigma_{B/A}^2}{\sigma_{B/A}} \qquad e_2 = \frac{\ln(E(V_A)) - \ln(V_A') + \frac{1}{2}\sigma_A^2}{\sigma_A}$$

The variance of the ratio $V_B(1)/V_A(1)$ is given by $\sigma_{B/A}^2 = \sigma_A^2 + \sigma_B^2 - 2\rho\sigma_A\sigma_B$, while the correlation between the ratio $V_B(1)/V_A(1)$ and the variable $V_A(1)$ is given by $\rho_1 = \dfrac{\rho\sigma_B - \sigma_A}{\sigma_{B/A}}$.

B. Derivation of Player A's option under an accommodating strategy

After due diligence, Player A knows the realization of $Z_A^*(2) = l = \left(\ln(V_A^*) - \ln(E(V_A)) + \frac{1}{2}\sigma_A^2\right)/\sigma_A$ and can therefore infer a more precise expected value of Player B's target value, which is given by the conditional expectation

$$E_1(V_B(2)\,|\,V_A^*) = \int_{-\infty}^{\infty} E(V_B(0))\exp\left(-\tfrac{1}{2}\sigma_A^2 + \sigma_A y\right)g(l,y)dy = V_B(0)\varphi(l - \sigma_B\rho)/\varphi(l) \qquad \text{(A.8)}$$

Also, the conditional uncertainty on the value $V_B(2)$ is smaller and the standard deviation is given by $\sqrt{(1-\rho^2)}\sigma_B$. The value of the option is now

$$D(1) = E_Q(\max(V_A^* - \max(V_B(2), b_A), 0)) \qquad \text{(A.9)}$$

This can be rewritten by changing the numeraire as

$$D(1) = V_A^* Q(V_B(2) < V_A(2)) - V_B(1) Q_{V_B}(V_B(2) < V_A(2), V_B(2) > b_A) - b_A Q(V_B(2) < b_A) \quad \text{(A.10)}$$

By changing the drift under the right probability measure we arrive at

$$D(1) = V_A^* N(d_1) - E_1(V_B(2) \mid V_A^*)\big(N(e_1) - N(e_2)\big) - b_A N(f_1) \quad \text{(A.11)}$$

where the parameters are given by

$$d_1 = \frac{\ln(V_A^*) - \ln(E_1(V_B(1) \mid V_A^*)) + \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B}$$

$$e_1 = \frac{\ln(V_A^*) - \ln(E_1(V_B(1) \mid V_A^*)) - \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B} \qquad e_2 = \frac{\ln(b_A) - \ln(E_1(V_B(1) \mid V_A^*)) - \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B}$$

$$f_1 = \frac{\ln(b_A) - \ln(E_1(V_B(1) \mid V_A^*)) + \frac{1}{2}(1-\rho^2)\sigma_B^2}{\sqrt{(1-\rho^2)}\sigma_B}$$

The option value decreases in the level of the opening bid b_A. For a higher opening bid, the expected acquisition price increases, while the probability of a successful acquisition is not altered. To maximize the value of the bidding contest, Player A will therefore offer a bid as low as possible, i.e. equal to the *RES*.

C. Derivation of Player B's option to bid when Player A accommodates

When Player A does not offer a pre-emptive bid, it signals to Player B that its value is lower than the threshold, b_A^{imp}, above which pre-emption is preferred. In addition to the minimal price (value for Player A) truncating the value distribution from below, the distribution is now also truncated from above, enabling a more accurate valuation of the option to bid on the target. The normally distributed variable, Z_A, cannot take values below $k_1 = \left(\ln(RES) - \ln(E(V_A)) + \frac{1}{2}\sigma_A^2\right)/\sigma_A$ or above $k_2 = \left(\ln(b_A^{imp}) - \ln(E(V_A)) + \frac{1}{2}\sigma_A^2\right)/\sigma_A$. In this case, the conditional expected value is given by:

$$
\begin{aligned}
&E(V_A \mid b_A = RES) = \int_{k_1}^{k_2} E(V_i)\exp\left(-\tfrac{1}{2}\sigma_A^2 + \sigma_A x\right) f(x) / \left(N(k_2) - N(k_1)\right) dx = \\
&= E(V_A)\left(N\left(k_2 - \sigma_A\right) - N\left(k_1 - \sigma_A\right)\right) / \left(N(k_2) - N(k_1)\right)
\end{aligned}
\tag{A.12}
$$

The conditional expected value for player B is given by

$$
\begin{aligned}
&E(V_B \mid b_A = RES) = \int_{-\infty}^{\infty}\int_{k_1}^{k_2} E(V_B)\exp\left(-\tfrac{1}{2}\sigma_B^2 + \sigma_B y\right) g(x,y) / \left(N(k_2) - N(k_1)\right) dxdy = \\
&E(V_B)\left(N\left(k_2 - \rho\sigma_B\right) - N\left(k_1 - \rho\sigma_B\right)\right) / \left(N(k_2) - N(k_1)\right)
\end{aligned}
\tag{A.13}
$$

The value of the option for Player B conditional on the bid RES and the pre-emption threshold b_A^{imp} is given by

$$
E(1) = E_Q\left(\max(V_B(2) - V_A(2), 0) \mid RES < V_A(2) < b_A^{imp}\right) \tag{A.14}
$$

We can rewrite this to:

$$
\begin{aligned}
&E(1) = E_Q\left(V_B(2) 1_{\{V_B(2) > V_A(2) \mid RES < V_A(2) < b_A^{imp}\}} \mid RES < V_A(2) < b_A^{imp}\right) - \\
&E_Q\left(V_A(2) 1_{\{V_B(2) > V_A(2) \mid RES < V_A(2) < b_A^{imp}\}} \mid RES < V_A(2) < b_A^{imp}\right)
\end{aligned}
\tag{A.15}
$$

which in turn can be rewritten by changing the numeraire:

$$E(1) = V_B(1) \times Q_{V_B}\left(V_B(2) > V_A(2) \mid RES < V_A(2) < b_A^{imp}\right) - V_A(1) \times Q_{V_A}\left(V_B(2) > V_A(2) \mid RES < V_A(2) < b_A^{imp}\right) \tag{A.16}$$

The conditional probabilities can be calculated by adjusting the drift of the geometric Brownian motions describing $V_A(t)$ and $V_B(t)$ in accordance to the right probability measure Q_{V_A} or Q_{V_B}. The solution is given by

$$E(1) = E_1(V_B(1) \mid b_A)\left(M(d_1, d_3, -\rho_1) - M(d_1, d_2, -\rho_1)\right) / \left(N(d_3) - N(d_2)\right) - E_1(V_A(1) \mid b_A)\left(M(e_1, e_3, -\rho_1) - M(e_1, e_2, -\rho_1)\right) / \left(N(e_3) - N(e_2)\right) \tag{A.17}$$

where the parameters of the standard, bivariate and univariate normal distribution function *M* and *N* are given by

$$d_1 = \frac{\ln(E(V_B)) - \ln(E(V_A)) + \frac{1}{2}\sigma_{B/A}^2}{\sigma_{B/A}} \qquad d_2 = \frac{\ln(RES) - \ln(E(V_A)) - \rho\sigma_A\sigma_B + \frac{1}{2}\sigma_A^2}{\sigma_A}$$

$$d_3 = \frac{\ln(E(b_A^{imp})) - \ln(E(V_A)) - \rho\sigma_A\sigma_B + \frac{1}{2}\sigma_A^2}{\sigma_A}$$

$$e_1 = \frac{\ln(E(V_B)) - \ln(E(V_A)) - \frac{1}{2}\sigma_{B/A}^2}{\sigma_{B/A}} \qquad e_2 = \frac{\ln(RES) - \ln(E(V_A)) - \frac{1}{2}\sigma_A^2}{\sigma_A}$$

$$e_3 = \frac{\ln(E(b_A^{imp})) - \ln(E(V_A)) - \frac{1}{2}\sigma_A^2}{\sigma_A}$$

D. *Proof that Player B's option value increases in value when acknowledging that Player A accommodates*

The option value $E(1)$ can be written as a function of $C(1|b_A)$ with an offer b_A equal to the reservation price, *RES*, or the threshold, b_A^{imp}:

$$E(1) = \frac{(1 - N(k_1))C(1 \mid RES) - ((1 - N(k_2))C(1 \mid b_A^{imp})}{N(k_2) - N(k_1)} \tag{A.18}$$

The value of the option $E(1)$ can only become lower than $C(1|RES)$ when $C(1|b_A^{imp})$ is higher than $C(1|RES)$. This cannot happen, as the value of the option $C(1|RES)$ is always larger than *I,* otherwise the *RES* acts as the pre-emptive bid and $C(1|RES)=C(1|b_A^{imp})<I$. Hence $E(1) > C(1|RES)$. When $\rho\sigma_B > \sigma_A$ Player B's option value strictly increases in Player A's bid, but then a pre-emptive bid cannot be made and b_A^{imp} does not exist. When the reservation price is already deterrent, $E(1)$ equals zero.

E. *Proof of the existence of a Bayesian-Nash equilibrium*

We assume that Player A has invested in due diligence and is informed about its actual target value, $V_A^* > RES$. This player can offer any bid b_A higher than or equal to the reservation price, *RES*. In a possible bid contest it will raise its bid until its target value has been reached. Player B can decide to invest an amount *I* in due diligence, observes then its actual target value V_B^* and joins the bidding contest if V_B^* is higher than the opening bid of Player A. If Player B decides not to invest, it will not be informed and cannot enter the bidding contest.

There are multiple equilibria. They are of the form that Player A offers a high bid, b'_A, when its valuation exceeds a certain threshold, V'_A, and offers the reservation price in the other case. The high pre-emptive bid is given by $b'_A = V'_A - D(1, V'_A)$. Player B will invest in due diligence when Player A's opening bid equals the reservation price and will enter the bidding contest if its actual target value exceeds the reservation price. Player B does not invest in due diligence when it observes the high pre-emptive bid.

Player B is deterred by the bid b'_A since Player A will only offer this bid when its valuation exceeds the threshold V'_A. At any actual target value higher than this threshold, Player B's option value is lower than its cost. The minimal value of this threshold V'_A to be deterrent is given by b_A^{imp}, which is defined by the following condition:

$$b_A^{imp} = \inf\left\{ b_A \mid C(1, b_A) \leq I, \frac{\partial C(1, b_A)}{\partial b_A}(b_A^{imp}) < 0 \right\} \tag{A.19}$$

The accompanying pre-emptive bid is given by $\tilde{b}_A = \tilde{V}_A - D(1, \tilde{V}_A)$. For any value $V_A^* > b_A^{imp}$, Player B is deterred by the pre-emptive bid, as $\frac{\partial C(1, b_A)}{\partial b_A}(V_A^*) < 0$ holds for all $V_A^* > b_A^{imp}$.

When, on the other hand, the second part of the condition in (A.19) does not hold, the knowledge that $V_A^* > V'_A$ could invite Player B to enter the bidding contest rather than deter him. In this case a maximum level of the threshold exists and is given by the conditions:

$$b_A^{\max} = \max\left\{ b_A \mid C(1, b_A) \leq I, \frac{\partial C(1, b_A)}{\partial b_A}(b_A^{\max}) > 0 \right\} \tag{A.20}$$

The optimal Bayesian-Nash equilibrium is given by the following set of strategies.

Player A's strategy: offer an accommodating bid, *RES*, when the actual target value, V_A^*, is less than the threshold b_A^{imp} and offer a pre-emptive bid, $\tilde{b}_A$, when the actual target value, V_A^*, exceeds the threshold, b_A^{imp}.

Player B's strategy: when observing an accommodating bid, *RES*, invest in due diligence and join a bidding contest and when observing a pre-emptive bid, $\tilde{b}_A$, do not invest in due diligence and do not join a bidding contest.

Proof

Suppose that $V_A^* > b_A^{imp}$ and Player A still offers an accommodating bid. Player B will then enter the bidding contest and Player A's payoff is the lower option value *D*(1), instead of the higher pre-emption value, $V_A^* - \tilde{b}_A$. Pre-emption would be preferred. Suppose that $V_A^* < b_A^{imp}$ and Player A offers the pre-emptive bid. Player B will not enter the bidding contest and Player A's payoff will be $V_A^* - \tilde{b}_A$, while the value of accommodating *D*(1) is higher. As a consequence, Player A's strategy is optimal.

Suppose that Player B does not invest in due diligence and observes an accommodating bid. Its payoff will be zero, while if it would have entered, it would receive the positive amount of $E(1) - I$. Investing in due diligence is preferred. Suppose that Player B does invest in due diligence and observes a pre-emptive bid. Its payoff will be the negative amount of $C(1 \mid \tilde{b}_A) - I$, while not investing would have yielded a payoff of zero. As a consequence, Player B's strategy is optimal. Note that in case of positive correlation $V_A^* - \tilde{b}_A > D(1)$ for all $V_A^* > b_A^{imp}$ and that $V_A^* - \tilde{b}_A < D(1)$ for all $V_A^* < b_A^{imp}$.

This forms the optimal set of strategies, as the payoff to the first player is maximized by choosing the pre-emptive bid $\tilde{b}_A$ and threshold b_A^{imp}. By choosing a higher threshold V_A' the value of either entering a bid contest or pre-emption is reduced for any actual target value

$V_A^* > b_A^{imp}$. If Player A would still choose to pre-empt, its payoff is reduced, as the pre-emptive bid has increased. If Player A does not pre-empt anymore, but accommodates, its payoff is reduced as well. The value of accommodation is less than the value of pre-emption with the lowest pre-emptive bid $\widetilde{b}_A$, as $\frac{\partial D(1)}{\partial V_A^*}(b_A^{imp}) < 1$. This condition might not hold in case of negative correlation and high implied pre-emptive bids. We will address this issue in the next subsection of this appendix.

Summarizing, Player A will not offer a bid other than *RES* or the pre-emptive bid $\widetilde{b}_A$. A bid higher than $\widetilde{b}_A$ would yield a lower payoff for Player A. Player B will still not join the bidding contest, and Player A has only raised its acquisition price. A bid between *RES* and $\widetilde{b}_A$ would also yield a lower payoff. Player B will enter the bidding contest and only the expected price is raised, but the probability of a successful takeover is not altered. Finally, a bid lower than *RES* is not feasible, as the present owners will only sell at a bid of at least size *RES*. We refer to Fishman (1988) for an in-depth analysis of the equilibrium concept.

F. Additional remarks for the case with negative correlation

In the case of negative correlation, Player A's value of the option to accommodate can become so large at high actual target values that it exceeds the payoff of the pre-emptive bid. The likely outcome of Player B's due diligence is a target value smaller than the reservation price, as the players are negatively correlated. Hence, for low and high actual target values an accommodating bid is offered, while for intermediate actual target values the pre-emptive bid is offered. The pre-emptive bid, $\widetilde{b}_A$, and the high threshold above which accomodation is preferred again, $\widetilde{V}_A$, are given by

$$\widetilde{b}_A = \inf\{b_A : E(0, b_A) < I\},\ \widetilde{V}_A = \inf\{V_A : D(1) > V_A - \widetilde{b}_A\} \tag{A.21}$$

When Player A has offered the accommodating bid, Player B knows that Player A's actual target value is between the reservation price *RES* and the threshold b_A^{imp} or above the higher threshold $\widetilde{V}_A$. Player B's option value can now be written as

$$E(1) = \frac{(1 - N(k_1))C(1 \mid RES) - ((1 - N(k_2))C(1 \mid b_A^{imp}) + ((1 - N(k_3))C(1 \mid \widetilde{V}_A)}{N(k_2) - N(k_1) + 1 - N(k_3)} \tag{A.22}$$

The probability that Player A's value is above the threshold $\widetilde{V}_A$ and offers the accommodating bid is given by $N(k_3)$, where $k_3 = \left(\ln(\widetilde{V}_A) - \ln(E(V_A)) + \frac{1}{2}\sigma_A^2\right)/\sigma_A$. As the option value of Player B $C(1|b_A)$ is strictly decreasing in the bid b_A when correlation is negative, it is clear that $C(1|RES) > C(1|b_A^{imp}) > C(1|\widetilde{V}_A)$ and therefore $E(1)$ is always larger than $C(1|RES)$. Player B will therefore always invest in due diligence when Player A offers an accommodating bid. The following set of strategies forms a Bayesian-Nash equilibrium in case of negative correlation.

Player A's strategy: offer an accommodating bid, *RES*, when the actual target value, V_A^*, is less than the threshold $\widetilde{b}_A$ or above the threshold $\widetilde{V}_A$ and offer a pre-emptive bid, $\widetilde{b}_A$, when the actual target value, V_A^*, lies between the thresholds b_A^{imp} and $\widetilde{V}_A$.

Player B's strategy: when observing an accommodating bid, *RES*, invest in due diligence and join a bidding contest and when observing a pre-emptive bid, $\widetilde{b}_A$, do not invest in due diligence and do not join a bidding contest. The proof is analogous to the case of positive correlation.

It could occur that $b_A^{imp} \geq \widetilde{V}_A$ and the pre-emptive bid will never be offered. This is the case when $\frac{\partial D(1)}{\partial V_A^*}(b_A^{imp}) > 1$.

References

Bagnoli, M., Lipman, B., 1988. Successful takeovers without exclusion. Review of Financial Studies 1, 89-110.

Barney, J., 1986. Strategic factor markets: expectations, luck, and business strategy. Management Science 32 (10), 1231-1241.

Barney, J., 1988. Returns to bidding firms in mergers and acquisitions: reconsidering the relatedness hypothesis. Strategic Management Journal 9 (Summer Special Issue), 71-78.

Bernardo, A., Chowdhry, B., 2002. Resources, real options, and corporate strategy.Journal of Financial Economics 63 (2), 211-234.

Bradley, M., Desai, A., Kim, E., 1983. The rationale behind interfirm tender offers: information or synergy? Journal of Financial Economics 11, 183-206.

Bruner, R., 2002. Does m&a pay? A survey of evidence for the decision-maker. Journal of Applied Finance 12 (1), 48-68.

Burkart, M., 1995. Initial shareholdings and overbidding in takeover contests. Journal of Finance 50, 1491-1515.

Campbell, A., Goold, M., Alexander, M., 1995. Corporate strategy: the quest for parenting advantage. Harvard Business Review 73, 120-132.

Capron, L., Mitchell, W., Swaminathan, A., 2001. Asset divestiture following horizontal acquisitions: a dynamic view. Strategic Management Journal 22 (9), 817-844.

Capron, L., Pistre, N., 2002. When do acquirers earn abnormal returns? Strategic Management Journal 23, 781-794.

Chatterjee, S., 1986. Types of synergy and economic value: the impact of acquisitions on merging and rival firms. Strategic Management Journal 7 (2), 119-139.

Chatterjee, S., 1992. Source of value in takeovers: synergy or restructuring - implications for target and bidder firms. Strategic Management Journal 13 (4), 267-286.

Chowdry, B., Jegadeesh, N., 1994. Pre-tender offer share acquisition strategy in takeovers. Journal of Financial and Quantitative Analysis 29 (1), 117-129.

Fishman, M., 1988. A theory of preemptive takeover bidding. The Rand Journal of Economics 19, 88-101.

Franks, J., Harris, R., 1989. Shareholder wealth effects of corporate takeovers. The UK experience 1955-1985. Journal of Financial Economics 23, 225-249.

Fuller, K., Netter, J., Stegemoller, M., 2002. What do returns to acquiring firms tell us? Evidence from firms that make many acquisitions. Journal of Finance 57 (4), 1763-1793.

Geman, H., El Karoui, N., Rochet, J.-C., 1995. Changes of numeraire, changes of probability measure and option pricing. Journal of Applied Probability 32, 443-458.

Grossman, S., Hart, O., 1980. Takeover bids, the free-rider problem and the theory of the corporation. Bell Journal of Economics 11, 42-64.

Grossman, S., Hart, O. 1981. The allocational role of takeover bids in situations of asymmetric information. Journal of Finance 36, 253-270.

Harrison, J., Hitt, M., Hoskisson, R., Ireland, R., 2001. Resource complementarity in business combinations: extending the logic to organizational alliances. Journal of Management 27, 679-690.

Hartzell, J., Ofek, E., Yermack, D., 2004. What's in it for me? CEO's whose firms are acquired. The Review of Financial Studies 17 (1), 37-61.

Hirshleifer, D., Png, I., 1989. Facilitation of competing bids and the price of a takeover bid. The Review of Financial Studies 2, 587-606.

Huang, Y., Walkling, R., 1987. Target abnormal returns associated with acquisition announcements: payment, acquisition form, and managerial resistance. Journal of Financial Economics 19, 329-349.

Jarrell, G., Poulsen, A., 1989. The returns to acquiring firms in tender offers: evidence from three decades. Financial Management 18 (3), 12-19.

Jennings, R., Mazzeo, M., 1993. Competing bids, target management resistance, and the structure of takeover bids. The Review of Financial Studies 6 (4), 883-909.

Kaplan, S., 1989. Management buy-outs: evidence of taxes as a source of value. Journal of Finance 44 (3), 611-632.

King, D., Dalton, D., Daily, C., Covin, J., 2004. Meta-analyses of post-acquisition performance: indications of unidentified moderators. Strategic Management Journal 25, 187-200.

Krishna, V. (2002). Auction Theory. Academic Press.

Lambrecht, B., 2004. The timing and terms of mergers motivated by economies of scale. Journal of Financial Economics 72, 41-62.

Lang, L., Stulz, R., Walkling, R., 1991. A test of the free cash flow hypothesis: the case of bidder returns. Journal of Financial Economics 29, 315-335.

Margrabe, W., 1978. The value of an option to exchange one asset for another. Journal of Finance 33 (1), 177-186.

Morellec, E., Zhdanov, A., 2004. The dynamics of mergers and acquisitions. Simon School of Business Working Paper No. FR 01-11

Nathan, K., O'Keefe, T., 1989. The rise in takeover premiums: an exploratory study. Journal of Financial Economics 23, 101-119.

Seth, A., 1990. Value creation in acquisitions: a re-examination of performance issues. Strategic Management Journal 11 (2), 99-115.

Seth, A., Song, K., Pettit, R., 2000. Synergy, managerialism or hubris ? An empirical examination of motives for foreign acquisitions of US firms. Journal of International Business Studies 31 (3), 387-406.

Shleifer, A., Vishny, R., 1986. Large shareholders and corporate control. Journal of Political Economy 94, 461-488.

Singh, H., Montgomery, C., 1987. Corporate acquisition strategies and economic performance. Strategic Management Journal 8 (4), 377-386.

Slusky, A., Caves, R., 1991. Synergy, agency, and the determinants of premia paid in mergers. Journal of Industrial Economics 39 (3), 277-296.

Smit, J., 2001. Acquisition strategies as option games. Journal of Applied Corporate Finance 14 (2), 79-89.

Smith, K., Triantis, A., 1994. The value of options in strategic acquisitions. In: Trigeorgis, L. (Ed.), Real Options in Capital Investment: Models, Strategies, and Applications. Praeger, New York.

Song, M., Walkling, R., 1993. The impact of managerial ownership on acquisition attempts and target shareholder wealth. Journal of Financial and Quantitative Analysis 28 (4), 439-457.

Stulz, R., 1988. Managerial control of voting rights. Journal of Financial Economics 20, 25-54.

Stulz, R., Walkling, R., Song, M., 1990. The distribution of target ownership and the division of gains in successful takeovers. Journal of Finance 45, 817-833.

Zahra, S., George, G., 2002. Absorptive capacity: a review, reconceptualization, and extension. Academy of Management Review 27, 185-203.

Footnotes

[i] Bernardo and Chowdry (2002) also link a firm's resources to its real options. A firm will make specialized or general investments, depending on what it expects to learn about its resources.

[ii] The target is then acquired at the second highest player's value. For an excellent overview of auction theory see Krishna (2002).

[iii] There are several alternative explanations with respect to how value creation is distributed between target and acquirer. Market power, hubris, overpayment, and other factors play a role (Chatterjee (1992); Seth, Song, and Pettit (2000); Capron, Mitchell, and Swaminathan (2001)). Moreover, agency-related and free-rider problems are important variables as well (e.g., Grossman and Hart (1980); Bagnoli and Lipman (1988); Stulz (1988); Lang, Stulz, and Walkling (1991); Slusky and Caves (1991); Jennings and Mazzeo (1993); Song and Walkling (1993); Burkart (1995); Hartzell, Ofek, and Yermack (2004)) but our model does not consider these problems. For a more comprehensive discussion on value appropriation in acquisitions, we refer to Bruner (2002), Capron and Pistre (2002) and King, Dalton, Daily, and Covin (2004).

[iv] Distinctive competences provide an isolating mechanism and allow acquirers to capture the value creation brought about by these unique resources (e.g., Chatterjee (1986), Singh and Montgomery (1987); Barney (1988); Bradley, Desai, and Kim (1988); Jarrell and Poulsen (1989); Nathan and O'Keefe (1989); Slusky and Caves (1991)).

[v] For instance, in the study of Bradley, Desai, and Kim (1988) 65 out of 73 multiple bidder contests involved only two bidders.

[vi] In a takeover, a potential acquirer has to invest resources in searching for an appropriate target, evaluating potential sources of value and preparing the actual bid. These costs include fees to counsel and to investment banks, management time and the cost of obtaining the required amount of financing. Initial investigation of and identification of valuable targets may be a very costly activity (e.g., Chowdry and Nanda (1993); Burkart (1995)).

[vii] In a risk neutral world, the present value equals the expected value, if the discount rate is zero. For simplicity, we do not apply a risk-free time discount, as the entire acquisition game takes place within a short time horizon. Introducing a discount rate would not alter the model's results.

viii Takeover contests can last weeks or even months. Bradley, Desai, and Kim (1988) report that for their sample of multiple-bidder contests the ultimately successful offer was made on average more than six weeks after the initial offer.

ix Alternatively, we could have assumed that the actual target values are lognormally distributed at $t = 2$, but the Brownian motion describes precisely the due diligence process.

x The notion of time in the Brownian motions $Z_A(t)$ and $Z_B(t)$ relates to the information that is released at a certain stage in the due diligence process (between begin $t = 0$ and end $t = 1$) and should not be confused with the decision at discrete time in the overall model, where Player A first investigates between time 0 and 1 and Player B investigates between time 1 and 2. If viewed in this way, the Brownian motions should be defined as $Z_A(t)$ and $Z_B(t\text{-}1)$.

xi Barney (1986) and Fishman (1988) make this assumption as well: without being informed, acquirers can create value only when they are lucky.

xii As we will discuss later, Player A's bid signals that its actual target value is strictly higher than the bid and at least equal to the implied bid, V_A'.

xiii In Eq. (2) the option value is updated for the information on the minimal acquisition price revealed by b_A. In the Appendix Eq. (A.17) we present the option value for Player B when there is also information in the type of bid (pre-emptive or accommodating).

xiv The derivation of Eq. (5) and Eq. (9) can be found in the Appendix.

xv In Section III.C and in Eq. (A.17) of the Appendix we present a solution that updates this option value for both the minimal value for Player A and the signal given by whether it follows an accommodating or pre-emptive strategy.

xvi Note that $d_2 = \rho\sigma_B - k$ and $e_2 = \sigma_A - k$, which enables us to further simplify Eq. (5).

xvii The maximum is, however, often located close to a bid of zero and the curve seems to be strictly decreasing.

xviii Only in the special case of negative correlation a decline in Player B's value might offset the increase in volatility.

xix For negative correlation option value might decrease as compared to the base case, since the bid's adverse effect on Player B's expected value is smaller.

xx In the case of negative correlation, the option value converges for higher target values to the maximum value appropriation, $V_A^* - RES$ (or a 45 degree line), as it is becoming less and less likely that Player B's value would exceed the reservation price. For positive correlation the value of the option is always less than this 45 degree line, as the acquisition price is likely higher than the reservation price.

[xxi] In the simple case (not depicted) when no correlation is present, $\rho = 0$, the higher uncertainty has no influence on the price and the same option value would result.

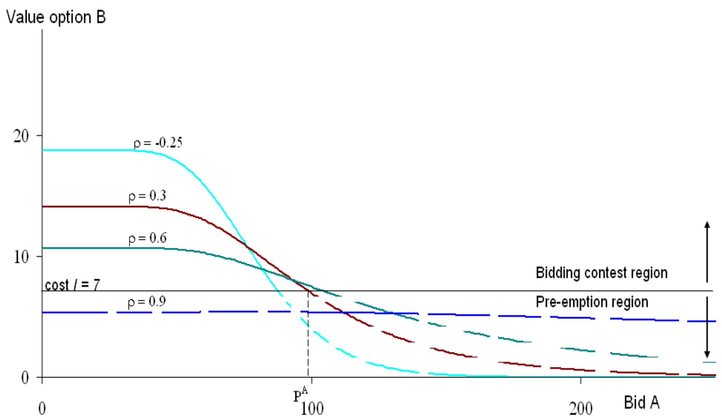
[xxii] The value appropriation for actual target values where a pre-emptive bid is chosen is minimal for this correlation level. In Panel A a correlation of 0.63 would minimize value appropriation for large actual target values.

[xxiii] The minimal value appropriation under pre-emption is now attained at a correlation of 0.41 instead of 0.63 in the base case. Panel B shows that the pre-emptive bid for a correlation level of $\rho = 0.6$ is lower than for $\rho = 0.3$ and value appropriation is accordingly higher.

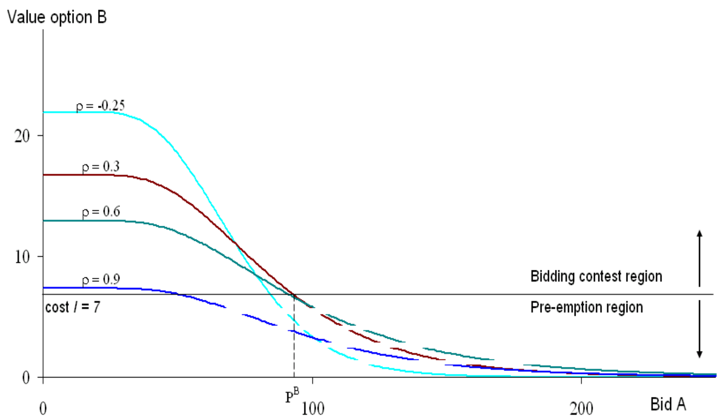
[xxiv] Bernardo and Chowdhry (2002) suggest, for example, that younger and smaller firms still have a lot to learn about (the value of) their resources and therefore face higher uncertainty than more mature and larger firms.

Figure 1. Second bidder's (Player B) option value to enter a bidding contest after observing the first bidder's offer (Player A) at time 1.

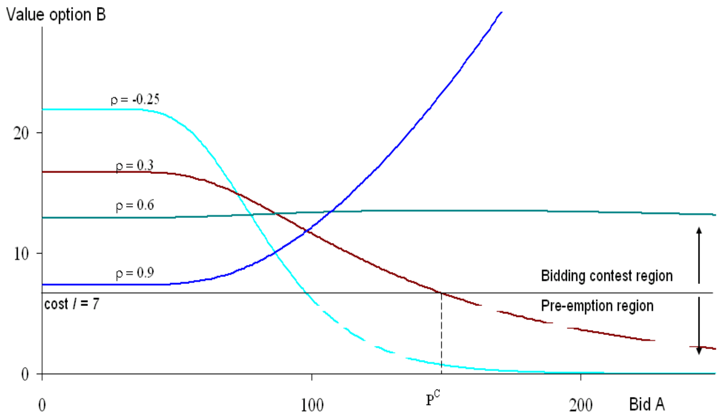
Panel A. Base Case



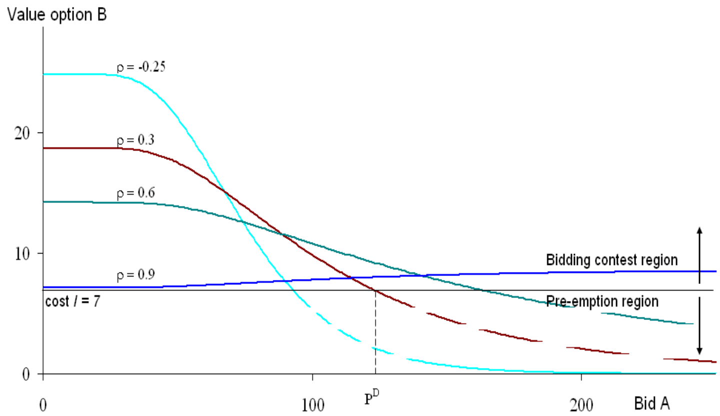
Panel B. Larger Uncertainty to Player A:
Option value increases and decreases compared to base case



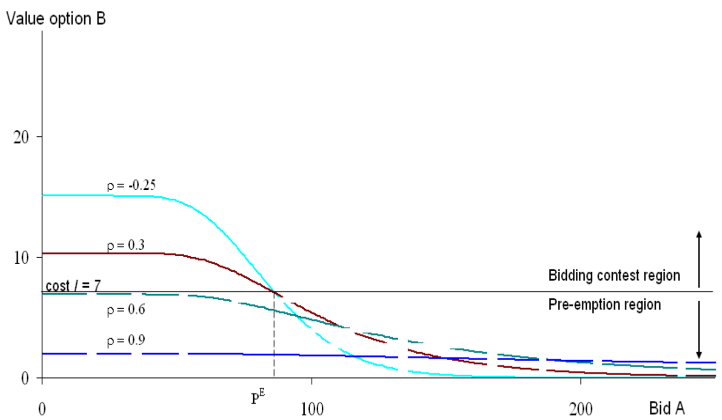
Panel C. Larger Uncertainty to Player B:
Option value increases compared to base case



Panel D. Larger Uncertainty to Both Players:
Option value increases compared to base case



Panel E. Larger Expected Value for Player A:
Option value decreases compared to base case



Panel F. Larger Expected Value for Player B:
Option value increases compared to base case

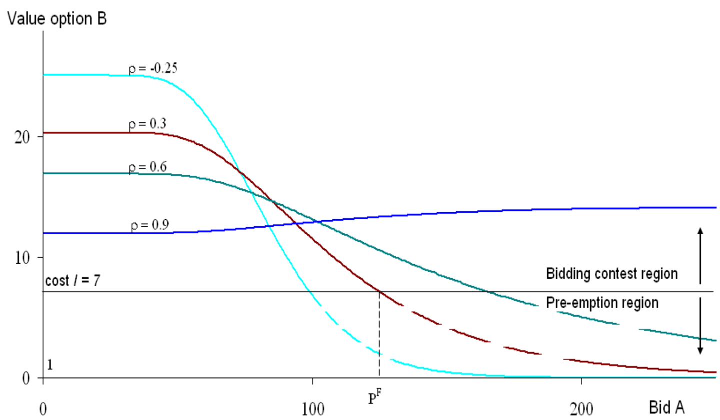
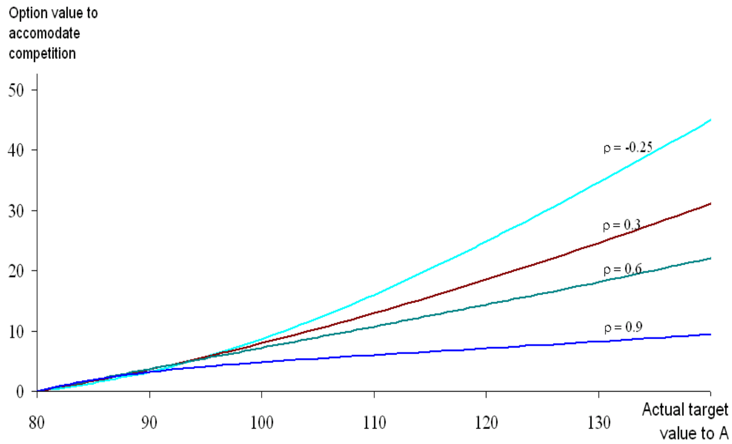
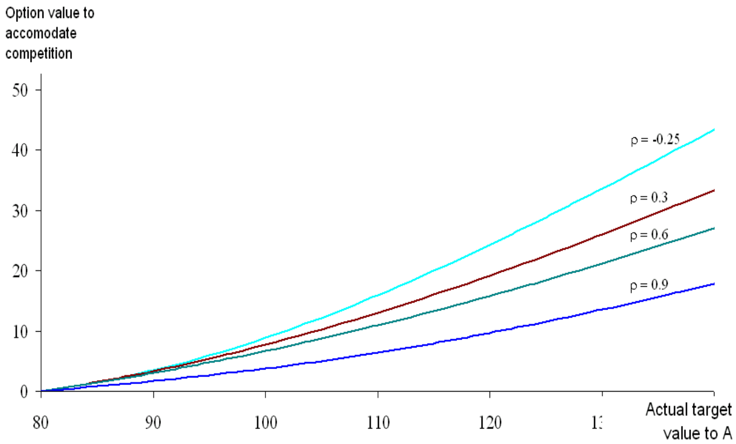


Figure 2. First bidder's (Player A) option value to accommodate competition at time 1.

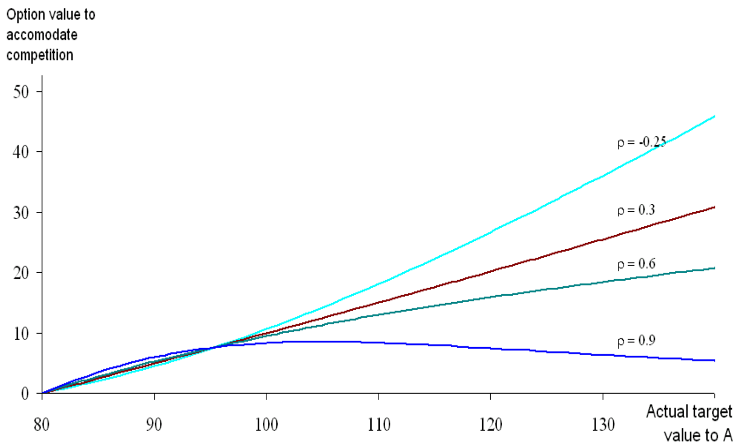
Panel A. Base Case



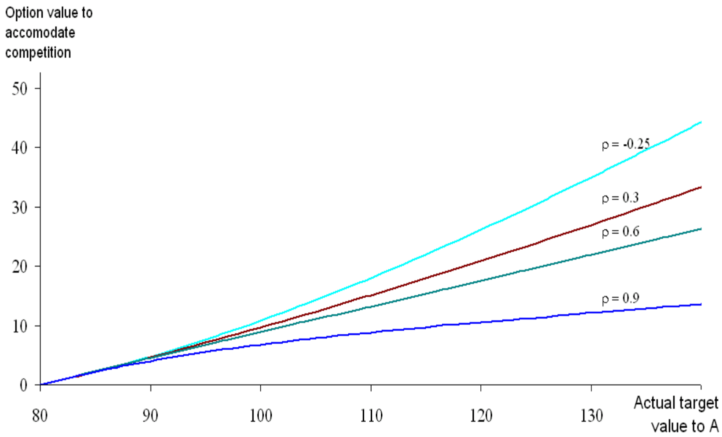
Panel B. Larger Uncertainty to Player A:
Option value increases and decreases compared to base case



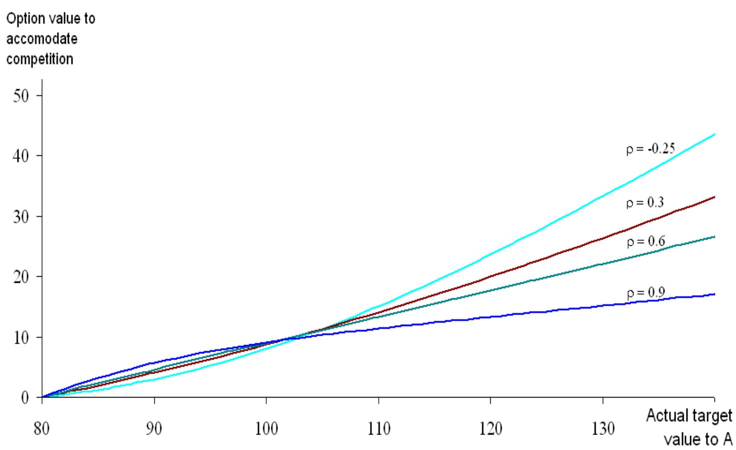
Panel C. Larger Uncertainty to Player B:
Option values increases and decreases compared to base case



Panel D. Larger Uncertainty to Both Players:
Option value increases or decreases compared to base case



Panel E. Larger Expected Value to Player A:
Option value increases and decreases compared to base case



Panel F. Larger Expected Value to Player B:
Option value decreases compared to base case

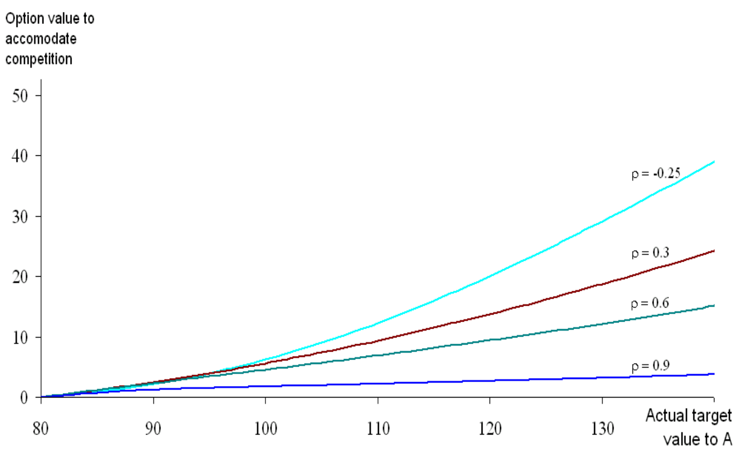
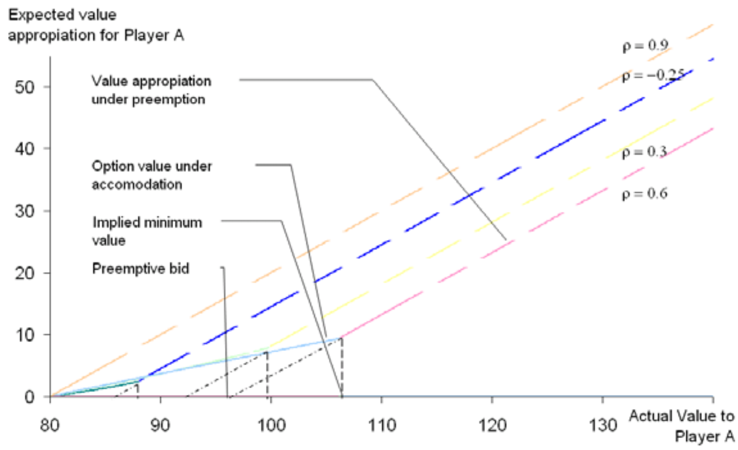
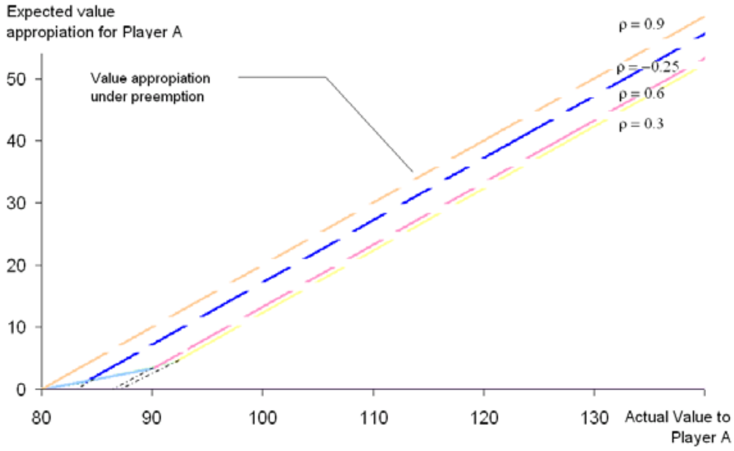


Figure 3. First bidder's (Player A) expected value appropriation of a bidding contest with opportunity to pre-empt or accommodate rival bidder (Player B) at time 1.

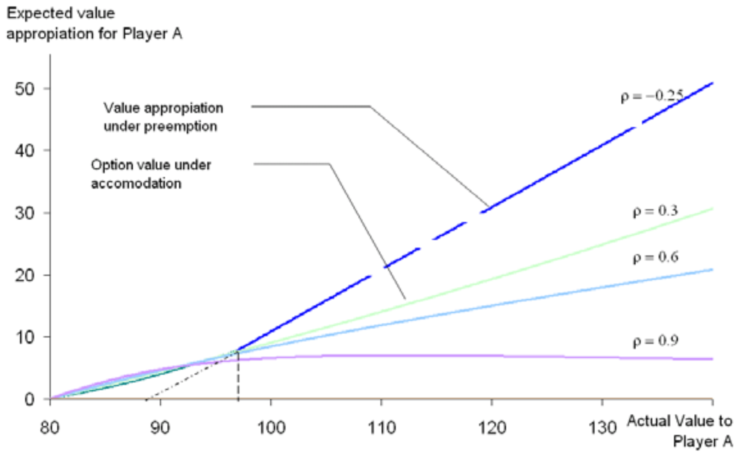
Panel A. Base Case



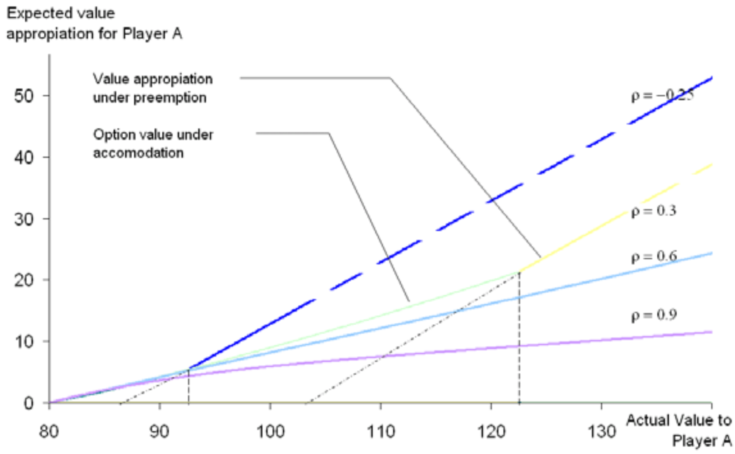
Panel B. Larger Uncertainty to Player A:
Value appropriation increases compared to base case



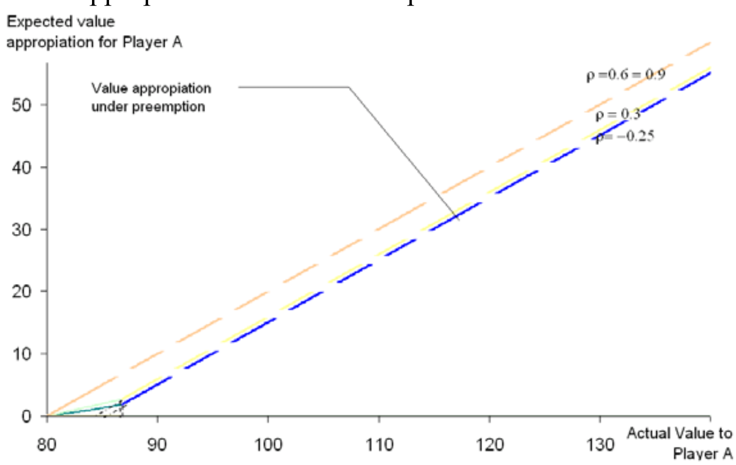
Panel C. Larger Uncertainty to Player B:
Value appropriation increases and decreases compared to base case



Panel D. Larger Uncertainty to Both Players:
Value appropriation increases and decreases compared to base case



Panel E. Larger Expected Value to Player A:
Value appropriation increases compared to base case



Panel F. Larger Expected Value to Player B:
Value appropriation decreases compared to base case

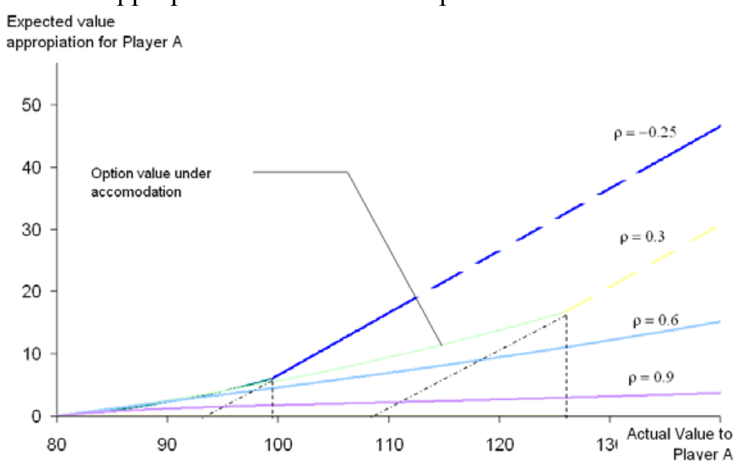


Figure 4. Timing of the due diligence investment game

		Player B	
		invest	wait
Player A	invest	(N_A, N_B)	(F_A, S_B)
	wait	(S_A, F_B)	(D_A, D_B)

Figure 1. Second bidder's (Player B) option value to enter a bidding contest after observing the first bidder's offer (Player A) at time 1.

Fig. 1 shows the value of the second bidder's option to enter a bidding contest as a function of the first bidder's implied opening bid. In each panel the curves represent different correlation levels between Player A's and Player B's target value. Panel A shows the standard case where both players' expected value equals 100 and uncertainty is 30%. In Panel B, only uncertainty for Player A has risen to 40%, while in Panel C only uncertainty for Player B has increased to 40%. In Panel D both players' uncertainty has increased to 40%. In Panel E Player A's expected target value rises to 110, while in Panel F Player B's expected target value is 110. In all panels, we assume a due diligence cost of 7. The level of the implied pre-emptive bid is given by that implied bid at which the option value equals the costs. A dotted line represents option value if the second bidder does not purchase the option to enter the bidding contest. A continuous line represents the option value when the second bidder will purchase the option and enters the bidding contest.

Figure 2. First bidder's (Player A) option value to accommodate competition at time 1.

Fig. 2 shows the value of the first bidder (Player A)'s option value to allow competition (Player B) to enter the takeover contest at time 1 (accommodation) as a function of its actual target value. If the second bidder enters a bidding contest, the first bidder's payoff of the potential acquisition is affected as the rival raises the takeover price. Panel A shows the standard case where both players' expected value equals 100 and uncertainty is 30%. In Panel B only uncertainty for Player A has risen to 40%, while in Panel C only uncertainty for Player B has increased to 40%. In Panel D both players' uncertainty has increased to 40%. In Panel E Player A's expected target value rises to 110, while in Panel F Player B's expected target value is 110. In all panels, the reservation price equals 80.

Figure 3. First bidder's (Player A) expected value appropriation of a bidding contest with opportunity to pre-empt or accommodate rival bidder (Player B) at time 1.

Fig. 3 shows the first bidder's (Player A) expected value appropriation in the bidding contest with the opportunity to pre-empt or accommodate the rival bidder (Player B) at time 1. Expected acquirer return is certain if the pre-emptive bid is quoted (represented by the dotted line), and uncertain when competition is accommodated. In the latter case, it is equal to the expected value of the real option to accomodate competition (represented by the continuous line). The pre-emptive bid is given by the intersection of the dotted line with the X-axis. Panel A shows the standard case where both players' expected value equals 100 and uncertainty is 30%. In Panel B, only uncertainty for Player A has risen to 40%, while in Panel C only uncertainty for Player B has increased to 40%. In Panel D both players' uncertainty has increased to 40%. In Panel E Player A's expected target value rises to 110, while in Panel F Player B's expected target value is 110. In all panels, the reservation price equals 80.

Figure 4. Timing of the due diligence investment game

A player can either wait or invest in due diligence. When both players invest they receive the option value of a bidding contest reduced by the due diligence costs. The value of entering first is given by the expected value of either a deterrence or an accommodating strategy reduced by the due diligence costs. The value of entering second is given by the value of entering the bidding contest when it is optimal to invest in due diligence. The deferral value is the present value of the next period's game.

04/219 **G. POELS, A. MAES, F. GAILLY, R. PAEMELEIRE**, The Pragmatic Quality of Resources-Events-Agents Diagrams: an Experimental Evaluation, January 2004, 23 p.

04/220 **J. CHRISTIAENS,** Gemeentelijke financiering van het deeltijds kunstonderwijs in Vlaanderen, Februari 2004, 27 p.

04/221 **C.BEUSELINCK, M. DELOOF, S. MANIGART**, Venture Capital, Private Equity and Earnings Quality, February 2004, 42 p.

04/222 **D. DE CLERCQ, H.J. SAPIENZA**, When do venture capital firms learn from their portfolio companies?, February 2004, 26 p.

04/223 **B. LARIVIERE, D. VAN DEN POEL**, Investigating the role of product features in preventing customer churn, by using survival analysis and choice modeling: The case of financial services, February 2004, 24p.

04/224 **D. VANTOMME, M. GEUENS, J. DE HOUWER, P. DE PELSMACKER**, Implicit Attitudes Toward Green Consumer Behavior, February 2004, 33 p.

04/225 **R. I. LUTTENS, D. VAN DE GAER**, Lorenz dominance and non-welfaristic redistribution, February 2004, 23 p.

04/226 **S. MANIGART, A. LOCKETT, M. MEULEMAN et al.**, Why Do Venture Capital Companies Syndicate?, February 2004, 33 p.

04/227 **A. DE VOS, D. BUYENS**, Information seeking about the psychological contract: The impact on newcomers' evaluations of their employment relationship, February 2004, 28 p.

04/228 **B. CLARYSSE, M. WRIGHT, A. LOCKETT, E. VAN DE VELDE, A. VOHORA**, Spinning Out New Ventures: A Typology Of Incubation Strategies From European Research Institutions, February 2004, 54 p.

04/229 **S. DE MAN, D. VANDAELE, P. GEMMEL**, The waiting experience and consumer perception of service quality in outpatient clinics, February 2004, 32 p.

04/230 **N. GOBBIN, G. RAYP,** Inequality and Growth: Does Time Change Anything?, February 2004, 32 p.

04/231 **G. PEERSMAN, L. POZZI,** Determinants of consumption smoothing, February 2004, 24 p.

04/232 **G. VERSTRAETEN, D. VAN DEN POEL,** The Impact of Sample Bias on Consumer Credit Scoring Performance and Profitability, March 2004, 24 p. (forthcoming in *Journal of the Operational Research Society*, 2004).

04/233 **S. ABRAHAO, G. POELS, O. PASTOR,** Functional Size Measurement Method for Object-Oriented Conceptual Schemas: Design and Evaluation Issues, March 2004, 43 p.

04/234 **S. ABRAHAO, G. POELS, O. PASTOR,** Comparative Evaluation of Functional Size Measurement Methods: An Experimental Analysis, March 2004, 45 p.

04/235 **G. PEERSMAN,** What caused the early millennium slowdown? Evidence based on vector autoregressions, March 2004, 46 p. (forthcoming in *Journal of Applied Econometrics*, 2005)

04/236 **M. NEYT, J. ALBRECHT, Ph. BLONDEEL, C. MORRISON,** Comparing the Cost of Delayed and Immediate Autologous Breast Reconstruction in Belgium, March 2004, 18 p.

04/237 **D. DEBELS, B. DE REYCK, R. LEUS, M. VANHOUCKE,** A Hybrid Scatter Search / Electromagnetism Meta-Heuristic for Project Scheduling, March 2004, 22 p.

04/238 **A. HEIRMAN, B. CLARYSSE,** Do Intangible Assets and Pre-founding R&D Efforts Matter for Innovation Speed in Start-Ups?, March 2004, 36 p.

UNIVERSITEIT GENT

FACULTEIT ECONOMIE EN BEDRIJFSKUNDE
HOVENIERSBERG 24
9000 GENT

Tel. : 32 - (0)9 – 264.34.61
Fax. : 32 - (0)9 – 264.35.92

04/239 **H. OOGHE, V. COLLEWAERT,** Het financieel profiel van Waalse groeiondernemingen op basis van de positioneringsroos, April 2004, 15 p.

04/240 **E. OOGHE, E. SCHOKKAERT, D. VAN DE GAER,** Equality of opportunity versus equality of opportunity sets, April 2004, 22 p.

04/241 **N. MORAY, B. CLARYSSE,** Institutional Change and the Resource Flows going to Spin off Projects: The case of IMEC, April 2004, 38 p.

04/242 **T. VERBEKE, M. DE CLERCQ,** The Environmental Kuznets Curve: some really disturbing Monte Carlo evidence, April 2004, 40 p.

04/243 **B. MERLEVEDE, K. SCHOORS,** Gradualism versus Big Bang: Evidence from Transition Countries, April 2004, 6 p.

04/244 **T. MARCHANT,** Rationing : dynamic considerations, equivalent sacrifice and links between the two approaches, May 2004, 19 p.

04/245 **N. A. DENTCHEV,** To What Extent Is Business And Society Literature Idealistic?, May 2004, 30 p.

04/246 **V. DE SCHAMPHELAERE, A. DE VOS, D. BUYENS,** The Role of Career-Self-Management in Determining Employees' Perceptions and Evaluations of their Psychological Contract and their Esteemed Value of Career Activities Offered by the Organization, May 2004, 24 p.

04/247 **T. VAN GESTEL, B. BAESENS, J.A.K. SUYKENS, D. VAN DEN POEL, et al.,** Bayesian Kernel-Based Classification for Financial Distress Detection, May 2004, 34 p. (forthcoming in *European Journal of Operational Research*, 2004)

04/248 **S. BALCAEN, H. OOGHE,** 35 years of studies on business failure: an overview of the classical statistical methodologies and their related problems, June 2004, 56 p.

04/249 **S. BALCAEN, H. OOGHE,** Alternative methodologies in studies on business failure: do they produce better results than the classical statistical methods?, June 2004, 33 p.

04/250 **J. ALBRECHT, T. VERBEKE, M. DE CLERCQ,** Informational efficiency of the US SO_2 permit market, July 2004, 25 p.

04/251 **D. DEBELS, M. VANHOUCKE,** An Electromagnetism Meta-Heuristic for the Resource-Constrained Project Scheduling Problem, July 2004, 20 p.

04/252 **N. GOBBIN, G. RAYP**, Income inequality data in growth empirics : from cross-sections to time series, July 2004, 31p.

04/253 **A. HEENE, N.A. DENTCHEV,** A strategic perspective on stakeholder management, July 2004, 25 p.

04/254 **G. POELS, A. MAES, F. GAILLY, R. PAEMELEIRE,** User comprehension of accounting information structures: An empirical test of the REA model, July 2004, 31 p.

04/255 **M. NEYT, J. ALBRECHT,** The Long-Term Evolution of Quality of Life for Breast Cancer Treated Patients, August 2004, 31 p.

04/256 **J. CHRISTIAENS, V. VAN PETEGHEM,** Governmental accounting reform: Evolution of the implementation in Flemish municipalities, August 2004, 34 p.

04/257 **G. POELS, A. MAES, F. GAILLY, R. PAEMELEIRE,** Construction and Pre-Test of a Semantic Expressiveness Measure for Conceptual Models, August 2004, 23 p.

04/258 **N. GOBBIN, G. RAYP, D. VAN DE GAER,** Inequality and Growth: From Micro Theory to Macro Empirics, September 2004, 26 p.

UNIVERSITEIT GENT

FACULTEIT ECONOMIE EN BEDRIJFSKUNDE
HOVENIERSBERG 24
9000 GENT

Tel. : 32 - (0)9 – 264.34.61
Fax. : 32 - (0)9 – 264.35.92

WORKING PAPER SERIES

04/259 **D. VANDAELE, P. GEMMEL,** Development of a measurement scale for business-to-business service quality: assessment in the facility services sector, September 2004, 30 p.

04/260 **F. HEYLEN, L. POZZI, J. VANDEWEGE,** Inflation crises, human capital formation and growth, September 2004, 23 p.

04/261 **F. DE GRAEVE, O. DE JONGHE, R. VANDER VENNET,** Competition, transmission and bank pricing policies: Evidence from Belgian loan and deposit markets, September 2004, 59 p.

04/262 **B. VINDEVOGEL, D. VAN DEN POEL, G. WETS,** Why promotion strategies based on market basket analysis do not work, October 2004, 19 p. (forthcoming in *Expert Systems with Applications*, 2005)

04/263 **G. EVERAERT, L. POZZI,** Bootstrap based bias correction for homogeneous dynamic panels, October 2004, 35 p.

04/264 **R. VANDER VENNET, O. DE JONGHE, L. BAELE,** Bank risks and the business cycle, October 2004, 29 p.

04/265 **M. VANHOUCKE,** Work continuity constraints in project scheduling, October 2004, 26 p.

04/266 **N. VAN DE SIJPE, G. RAYP,** Measuring and Explaining Government Inefficiency in Developing Countries, October 2004, 33 p.

04/267 **I. VERMEIR, P. VAN KENHOVE,** The Influence of the Need for Closure and Perceived Time Pressure on Search Effort for Price and Promotional Information in a Grocery Shopping Context, October 2004, 36 p.

04/268 **I. VERMEIR, W. VERBEKE**, Sustainable food consumption: Exploring the consumer attitude – behaviour gap, October 2004, 24 p.

04/269 **I. VERMEIR, M. GEUENS**, Need for Closure and Leisure of Youngsters, October 2004, 17 p.

04/270 **I. VERMEIR, M. GEUENS**, Need for Closure, Gender and Social Self-Esteem of youngsters, October 2004, 16 p.

04/271 **M. VANHOUCKE, K. VAN OSSELAER**, Work Continuity in a Real-life Schedule: The Westerschelde Tunnel, October 2004, 12 p.

04/272 **M. VANHOUCKE, J. COELHO, L. V. TAVARES, D. DEBELS**, On the morphological structure of a network, October 2004, 30 p.

04/273 **G. SARENS, I. DE BEELDE**, Contemporary internal auditing practices: (new) roles and influencing variables. Evidence from extended case studies, October 2004, 33 p.

04/274 **G. MALENGIER, L. POZZI**, Examining Ricardian Equivalence by estimating and bootstrapping a nonlinear dynamic panel model, November 2004, 30 p.

04/275 **T. DHONT, F. HEYLEN**, Fiscal policy, employment and growth: Why is continental Europe lagging behind?, November 2004, 24 p.

04/276 **B. VINDEVOGEL, D. VAN DEN POEL, G. WETS**, Dynamic cross-sales effects of price promotions: Empirical generalizations, November 2004, 21 p.

04/277 **J. CHRISTIAENS, P. WINDELS, S. VANSLEMBROUCK,** Accounting and Management Reform in Local Authorities: A Tool for Evaluating Empirically the Outcomes, November 2004, 22 p.

04/278 **H.J. SAPIENZA, D. DE CLERCQ, W.R. SANDBERG**, Antecedents of international and domestic learning effort, November 2004, 39 p.

04/279 **D. DE CLERCQ, D.P. DIMO**, Explaining venture capital firms' syndication behavior: A longitudinal study, November 2004, 24 p.

FACULTEIT ECONOMIE EN BEDRIJFSKUNDE
HOVENIERSBERG 24
9000 GENT

Tel. : 32 - (0)9 – 264.34.61
Fax. : 32 - (0)9 – 264.35.92

WORKING PAPER SERIES

04/280 **T. FASEUR, M. GEUENS**, Different Positive Feelings Leading to Different Ad Evaluations: The Case of Cosiness, Excitement and Romance, November 2004, 17 p.

04/281 **B. BAESENS, T. VAN GESTEL, M. STEPANOVA, D. VAN DEN POEL**, Neural Network Survival Analysis for Personal Loan Data, November 2004, 23 p.

04/282 **B. LARIVIÈRE, D. VAN DEN POEL**, Predicting Customer Retention and Profitability by Using Random Forests and Regression Forests Techniques, December 2004, 30 p.

05/283 **R. I. LUTTENS, E. OOGHE,** Is it fair to “make work pay”?, January 2005, 28 p.

05/284 **N. A. DENTCHEV,** Integrating Corporate Social Responsibility In Business Models, January 2005, 29 p.

04/285 **K. FARRANT, G. PEERSMAN**, Is the exchange rate a shock absorber or a source of shocks? New empirical evidence, January 2005, 26 p. (forthcoming *Journal of Money Credit and Banking*, 2005)

04/286 **G. PEERSMAN**, The relative importance of symmetric and asymmetric shocks and the determination of the exchange rate, January 2005, 24 p.

04/287 **C. BEUSELINCK, M. DELOOF, S. MANIGART**, Private Equity Investments and Disclosure Policy, January 2005, 44 p.