The Effects of The Target's Learning on M&A Negotiations*

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Abstract

This paper studies the role of the target's learning about the bidder's private value in ongoing M&A negotiations. In our model, the target is imperfectly informed about the bidder's private value from the M&A deal. Since the stock price will partially aggregate traders' heterogeneous signals about such a value, the target will learn from the stock price and make the optimal choice in the negotiation. Traders take into account the target's learning when submitting trading orders to the market maker. Due the the target's learning, the target's stock price run-up has great informational effects on the M&A negotiation outcomes. In particular, the deal premium, the probability of a successful deal, and the target's expected payoff are all increasing in the run-up. From the view of outside econometricians without knowledge about the bidder's private value, the bidder's expected payoff is also increasing in the run-up. The target's learning increases the target's ex-ante payoff, but may jeopardize the success of a M&A deal with positive surplus.

KEYWORDS: M&A negotiation, run-up, managerial learning, market efficiency, real efficiency

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1 Introduction

This paper analyzes the effects of the target firm's managerial learning from the stock price in M&A negotiations. One important event that occurs during an ongoing private M&A negotiation is the huge increase in the target firm's stock price (run-up), as documented in many empirical researches. Schwert (1996) shows, based on a sample of exchange-listed target firm from 1975–1991, that the average run-up of successful deals is about 14.3% and the average run-up of unsuccessful deals is about 10%. Betton, Eckbo, Thompson, and Thorburn (2013), using a sample of 6, 100 initial takeover bids from the period 1980 through 2008, document that on average the targets of completed deals increase in value by 10%. While researchers all predict that the run-up may have significant effects on the M&A negotiation outcomes, such as trading premiums and deal completion probabilities, there is no agreement on the mechanism through which the run-up plays a role.

Run-ups are considered as one source of the target's bargaining power, which is a determinant of the M&A negotiation outcomes. The markup pricing hypothesis, raised by Schwert (1996), argues that run-ups increase bid premiums "one dollar to one dollar." Betton, Eckbo, Thompson, and Thorburn (2013) model the costly feedback loop, hypothesizing that the target can convince the bidder to transfer the run-ups entirely by forcing a higher bid premium.

In this paper, we analyze informational effects of run-ups in the M&A negotiation. We show that, even if the target does not use the run-up as a source of bargaining power, the run-up has significantly effects on the deal premium, the deal completion probability, and the payoffs to both the bidder and the target. Central to our analysis is the fact that the target is not perfectly informed about the M&A surplus, and traders in the stock market may possess noisy signals about the surplus. For example, the M&A surplus may include private values tied to the particular bidder, such as the bidder's gain by integrating the merged firms, or the bidder's future developments after acquiring the target. The target hardly knows exactly such values, while traders in the stock market may receive noisy signals about the values by individual researches. Therefore, the stock price, which aggregates traders' private signals, provides the target an informative signal about the bidder's private value from the M&A transaction and direct the target's behavior in the negotiation.

Turning to the details of our model, we analyze an M&A negotiation, in which the target makes a take-it-or-leave-it offer to the bidder.[1] Before making the offer, the information of such an ongoing negotiation is leaked to the stock market, and the target observes its stock price (run-up). The bidder knows his private value of acquiring the target from the M&A, but the target does not. There is a continuum of traders, who are trading the target's stock. Each of them receives a private signal about the bidder's private value, and then submit a price-dependent demand function to a competitive market maker. The market maker, who receives the aggregate demand from traders and observe the exogenous supply, sets a price to clear the market. Such a stock price aggregates traders' signals and provides the target a noisy signal about the bidder's private value. The target's learning connects the M&A negotiation to the stock market: the target learns from the run-up to make the offer, while traders take into account the target's learning when making the trading decisions.

After characterizing the unique monotone equilibrium, we first analyze the informational effects of the run-up on the M&A negotiation outcomes. In the equilibrium, given a run-up, traders hold positive positions if and only if their private signals land above a run-up-dependent threshold. Therefore, a higher run-up suggests more traders buying, which indicates a higher bidder's private value. When the run-up is higher, the target behaves more aggressively, asking for a higher premium. A higher required premium has two effects: first, conditional on a successful deal, the target's payoff is higher; second, the probability of the completion of the M&A negotiation is lower. By balancing these two effects, the target chooses the optimal asked premium, which is increasing in the run-up but with a lower speed than the belief updates of the bidder's private value based on the run-up. Therefore, in the equilibrium, the probability of the success of the M&A negotiation and the target's expected payoff are both increasing in the run-up.

Whether the bidder's payoff is increasing or decreasing in the run-up depends on the

[1] The take-it-or-leave-it bargaining protocol is purely for simplicity. Our results are robust under other bargaining protocols, where the target has some bargaining power to affect the bargaining outcomes.

information sets, conditional on which we analyze the bidder's payoff. Consider the bidder, who knows her own private value. Then a higher run-up leads to a higher asked premium. If her value is still higher than the asked premium, the deal will be successful, but the bidder's payoff decreases, since the takeover cost (i.e., the asked premium) becomes higher. Therefore, conditional on the bidder's information set that consists of her own private value and the run-up, the bidder's payoff is decreasing in the run-up. Now, consider outside econometricians, who do not know the bidder's private value. Their information set consists of only the run-up. Then while a higher run-up leads to a higher asked premium, a higher run-up suggests a higher bidder's private value. Since the asked premium increases in the run-up slower than the updated bidder's private value does, outside econometricians will conclude that the expected bidder's payoff is increasing in the run-up.

We then discuss the effects of the target's learning on the real economy. Because the target is risk-averse at the optimal asked premium, the more precise the information she has, the higher the target's expected payoff. Therefore, the more informative the stock price is, the stronger the incentive of the target to leak the information of the ongoing M&A negotiation to the stock market. Since the target is assumed to have no private information about the bidder's private value, the information leakage itself contains no information about the bidder's value.

However, the social welfare is different from the target's payoff. For any positive bidder's private value, it is socially optimal if the M&A deal is successful. We show that if people expect a negative bidder's private value ex-ante, and the stock price is sufficiently noisy, leaking the information of the ongoing M&A negotiation jeopardizes the success of an M&A deal with positive surplus. Therefore, the regulator should ban the information leakage to stock markets in a noisy markets.

Our paper is related to the literature of how financial market and its participants influence the negations outcomes of M&A. Edmans, Goldstein, and Jiang (2012) document that the firms whose stocks suffer from exogenous mutual fund redemption become more likely to be acquired during subsequent periods. Liu (2012) argues that bidder firms strategically overbid in order to signal high deal quality to the market and thus lower deal financing costs.

Moeller, Schlingemann, and Stulz (2007) and Chatterjee, John, and Yan (2012) empirically test the impact of divergence of opinion on acquirer abnormal returns and takeover premium, respectively. Our paper contribute to this strand of literature by showing how prices are formed from informed trading and how information impounded into prices affect negotiation outcomes through managerial learning.

Our paper is also related to the broad literature of managerial learning and feedback from financial markets (Subrahmanyam and Titman (1999, 2001), Chen, Goldstein, and Jiang (2007), Bond, Edmans, and Goldstein (2012)). Several papers have tested managerial learning during M&As. Luo (2005) shows that market reactions on takeover announcement predict the final deal consummation probability, supporting managerial learning. Kau, Linck, and Rubin (2008) find that agency problems affect such managerial learning behavior. Ouyang and Szewczyk (2012) document that acquirer firms learn from the market prices when they determine the size of the merger investment. The contribution of our paper to this literature is two-fold. First, we look at a different time window and one specific informational source, target run-up, that managers can learn from. Second, our theoretical results provide a new identification strategy to test the managerial learning hypothesis. Specifically, if the target's stock market characteristics have significant effects on the run-up but hardly affect the M&A deal premium, the managerial learning hypothesis is supported. In a recent complementary paper, Rajamani (2013) finds evidence that target run-up is positively related to the bidder's gain and deal completion probability, which supports the managerial learning hypothesis. Our paper not only provides theoretical foundations for Rajamani (2013)'s empirical evidences, but also derives other implications yet to be tested.

Our paper also contributes to the discussions whether real efficiency is increasing in market efficiency and whether disclosing the ongoing M&A negotiation is socially desirable. A conventional view is that the stock market, through managerial learning and feedback, guides corporate decisions and helps improve real efficiency. As a result, firms should disclose information on the potential investment projects in order to trigger the market to collect information and would be able to learn from it. However, this need not to be the case. Bond, Edmans, and Goldstein (2012) argues that price efficiency can be classified into two types:

forecasting price efficiency (FPE) and revelatory price efficiency (RPE). FPE is concerned with forecasting firm value, while RPE is about revealing useful information that guide real decisions and improve real efficiency. When price is only informative about the firm value, but not relevant for real decisions, market efficiency does not lead to real efficiency, as illustrated by Dow and Gorton (1997). Our model shows that, even when the price is revelatory, in the sense that it helps the target firm to make better decisions, an increase in the price efficiency can lead to a decrease in real efficiency, and the leakage of information of the ongoing negotiation should be banned in some market.

The rest of the paper is organized as follows. Section 2 lays out the model. We characterize a unique monotone equilibrium of the model in Section 3. We analyze the informational effects of the run-up in Section 4 and the real effects of the target's learning in Section 5. Section 6 concludes. The appendix contains all proofs not in the main text.

2 Model

In this section, we model an M&A negotiation, where the target firm learns from the stock market.

2.1 Timing

There are three periods, indexed by $t \in \{0, 1, 2\}$. In the first period $t = 0$, a bidder and a target begin a merger negotiation.[2] The information of this ongoing negotiation is leaked to the secondary market, where the target's stock is traded. There is a continuum of risk-neutral traders with measure 1, uniformly distributed over $[0, 1]$ and indexed by i. In period $t = 1$, knowing the ongoing M&A negotiation, each trader i submits a limit order book to a competitive market maker. The market maker, after aggregating demands from traders and observing an exogenous supply shock, sets a price P (run-up) to clear the market. In period

[2]We assume that there is no agency problem, so managers in the bidder firm and the target firm will maximize their own shareholders' benefits. Therefore, we refer to the bidder (target) firm and the manager of the bidder (target) firm as the bidder (target) for brevity.

$t = 2$, observing the stock price, the target makes a take-it-or-leave-it offer (premium) to the bidder, who then decides to accept the offer or not. In the former case, the M&A deal goes through, and the premium is publicly announced.

2.2 Payoffs

Denote by v the private value of the bidder. Let b be the offer premium requested by the target, and assume the stand-along values of both firms are 0. Then the take-it-or-leave-it property implies that the payoffs to the bidder and the target are respectively

$$\pi_b = (v - b) \cdot \mathbb{1}_{(v>b)} \quad \text{and} \quad \pi_T = b \cdot \mathbb{1}_{(v>b)},$$

where $\mathbb{1}_{(v>b)}$ is the indicator function that takes value of 1 if $v > b$. If trader i's ex-post demand is d_i, then his payoff π_i is

$$\pi_i = d_i(\pi_T - P).$$

2.3 Information and the Financial Market

All players share a common prior belief $v \sim \mathcal{N}(v_0, \eta^{-1})$. The realized value v is the bidder's private information and unknown to anyone else. Each trader i receives a private signal about $s_i = v + \epsilon_i$, where $\epsilon_i \sim \mathcal{N}(0, \gamma^{-1})$ is independent across traders. The target has no private information about v but can observe the stock price P.

The stock price P is set by the competitive market maker to clear the target's stock market. Each trader i, based on his private signal s_i and the public available price P,[3] submits a price-contingent demand schedule $d_i(\cdot) \in [-1, 1]$. The trading restriction is imposed due to risk neutrality of traders in our model, and in practice, can be justified by margin, capital and liquidity constraints. Individual trading strategies, as a result, are a mapping $d : \mathbb{R}^2 \to [-1, 1]$ from signal-price pairs (s_i, P) into feasible trading

[3]We assume that traders can condition on prices when deciding their trading decisions, as in Grossman and Stiglitz (1980).

positions. Aggregating traders' individual orders leads to the total demand by traders $D(v,P) = \int_0^1 d_i(s,P)\,\mathrm{d}\Phi(\sqrt{\gamma}(s-v))$, where $\Phi(\cdot)$ is the cdf of a standard normal distribution and $\Phi(\sqrt{\gamma}(s-v))$ represents the cross-sectional distribution of private signals s_i conditional on the realization of v.[4] There is an exogenous stochastic supply of the target's stock, denoted by $S(\xi,P)$. We assume that

$$S(\xi,P) = 1 - 2\Phi(\xi - P), \tag{1}$$

where $\xi \sim \mathcal{N}(0,\beta^{-1})$ represents liquidity shocks. Hence, P is set such that $D(v,P) = S(\xi,P)$.

2.4 Discussions of Assumptions

Before defining an equilibrium as the solution concept of the model, we discuss the model's key assumptions. If the M&A deal goes through, the bidder receives a private value v. This value consists of synergies, improved efficiencies from replacing the management team, and so on, and thus is tied to the particular bidder. As a result, it is natural to assume that the value v is the bidder's private knowledge. This assumption also introduces information asymmetry into the M&A negotiation, which may endogenously lead to the failure of the negotiation. On the other hand, the specification that the target is imperfectly informed is the root of the target's learning from the stock market, as in the literature of feedback effects between the financial market and the corporate decisions (e.g., Subrahmanyam and Titman (1999), Goldstein and Guembel (2008), and Bond, Goldstein, and Prescott (2010)).

In the M&A negotiation, the target makes a take-it-or-leave-it offer, and the bidder decides to accept it or not. This specific bargaining protocol is purely for simplicity; we only require the target has some bargaining power to affect the premium, so that it has incentives to learn from the market.[5] In particular, a take-it-or-leave-it offer is strategically similar

[4]We assume that the Law of Large Numbers applies to the continuum of traders, so that conditional on v the cross-sectional distribution of signal realizations ex post is the same as the ex ante distribution of traders' signals.

[5]To our knowledge, the M&A negotiations in practice can have thousands of protocols, which make the

to but much simpler than many other mechanisms of selling a company, such as sealed bid auctions with a reserved price and double auctions. It could also be viewed as the final round bidding in a finite horizon bargaining game.

The microstructure of the stock market follows Hellwig, Mukherji, and Tsyvinski (2006) and Albagli, Hellwig, and Tsyvinski (2013). Traders, after observing private signals, submit a price dependent demand function to the market maker; the market maker, after receiving the aggregate demand function and an exogenous supply shock, sets a price to clear the market. This market microstructure is a natural choice when individual traders are atomistic, possess heterogeneous signals, learn from the stock price, and maximize a nonlinear payoff function. The specific structure of the exogenous random supply $S(\xi, P) = 1 - 2\Phi(\xi - P)$ is upward-slopping and has a noise term to prevent the price from fully revealing the true fundamental. It follows Goldstein, Ozdenoren, and Yuan (2013) and Albagli, Hellwig, and Tsyvinski (2013) for tractability.

2.5 Equilibrium

We now formally define a perfect Bayesian equilibrium as the solution concept of this model.

Definition 1 (Equilibrium) *An asking premium of the target firm $b^*(P)$: $\mathbb{R} \to \mathbb{R}$, a symmetric trading strategy $d(s, P)$: $\mathbb{R}^2 \to [-1, 1]$, and a price function $P(v, \xi)$ constitute a perfect Bayesian equilibrium, if*

1. *for the target firm, $b^*(P) \in \operatorname{argmax}_b \mathbb{E}\left[b \cdot \mathbb{1}_{(v>b)} | P\right]$;*
2. *for any trader $i \in [0, 1]$, $d(s_i, P) \in \operatorname{argmax}_{d\in[-1,1]} \mathbb{E}\left[\left(b^* \cdot \mathbb{1}_{(v>b^*)} - P\right) \cdot d | s_i, P\right]$;*
3. *market clears: $D(v, P) = S(\xi, P)$; and*
4. *$\mathbb{E}[\cdot|P]$ and $\mathbb{E}[\cdot|s_i, P]$ are calculated w.r.t. posterior probability measures of v using Bayes' rule.*

M&A negotiation process a black box to outsiders.

3 Equilibrium Characterization

In this section, we solve the model and characterize the equilibrium. The most important feature of the model is the informational feedback effects between the M&A negotiation and the stock market. On one hand, before making an offer, the target makes inferences from the stock price, which imperfectly aggregates traders' dispersed beliefs about the bidder's private value of the target from the M&A deal. Because of the target's learning, the stock price has great impacts on outcomes of the M&A negotiation. On the other hand, traders take into account the target's equilibrium behavior in the M&A negotiation when submitting their orders to the market maker. Therefore, the negotiation outcomes and the trading in the market are interdependent and need to be solved simultaneously. In the following, we first propose a form of an equilibrium pricing function, based on which the target makes inferences for any given realized price. Then we solve the optimal offer made by the target as a function of the realized price. We finally go back the stock market to solve traders' equilibrium trading strategies and verify the proposed pricing function is the equilibrium pricing function.

3.1 Negotiation Outcome

Assume the equilibrium pricing function $P = \sqrt{\gamma}\,(v - g(P)) + \xi$, which is derived from a cutoff trading strategy characterized by $g(P)$ that we will verify later. Recall that ξ represents the supply shock and $\xi \sim \mathcal{N}(0, \beta^{-1})$. Define $z = 1/\sqrt{\gamma}P + g(P) = v + 1/\sqrt{\gamma}\xi$. We show in the appendix that z is strictly increasing in P in an equilibrium, so z is a sufficient statistics of P. Using z to form posterior beliefs, the target's optimization problem is

$$\max_b \mathbb{E}\left[b \cdot \mathbb{1}_{(v>b)} | z\right]. \tag{2}$$

In making an offer, the target faces a tradeoff between premiums and the probability of the success of the M&A deal: an increase in the asked price b will increase the expected premium but reduce the probability of the success of the M&A deal.

The first order condition of the target's optimization problem can be simplified as

$$b \cdot \frac{f_v(b|z)}{1 - F_v(b|z)} = 1, \tag{3}$$

where $f_v(\cdot|z)$ and $F_v(\cdot|z)$ are posterior probability distribution function (pdf) and cumulative distribution function (cdf) of v conditional on signal z. Equation (3) has a very intuitive interpretation: at the optimum, for a unit increase in b, the marginal increase in the expected premium due to an increase in the asked price, $1 - F_v(b|z)$, is equal to the marginal decrease in the expected premium due to the decrease of the probability of a successful M&A deal, $bf_v(b|z)$.

We conclude this subsection with a lemma characterizing the properties of the optimal b^* that solves (3) under normal distributions.

Lemma 1 (Optimal Asking Price) *Suppose the equilibrium price of the stock market is in the form* $P = \sqrt{\gamma}(v - g(P)) + \xi$. *For each realized* z, *the target's equilibrium asked premium,* b^*, *is characterized by equation* (3). *In particular,*

1. *for any* z, b^* *is unique, and it is global maximum to* (2);
2. b^* *is increasing and convex in* z *with the slope* $\frac{\partial b^*}{\partial z} \in (0, \frac{\gamma\beta}{\eta+\gamma\beta})$, *and* $\lim_{z\to\infty} \frac{\partial b^*}{\partial z} = \frac{\gamma\beta}{\eta+\gamma\beta}$;
3. $b^* > 0$ *and there exists* $\tilde{z}$ *such that* $b^* < \frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}$ *for all* $z > \tilde{z}$.

A large z is indicative of a high value of v, and incentives the target to increase the asking price. Moreover, the speed at which the target increases the asking price, $\partial b^*/\partial z$, is always smaller than the speed at which it updates the size of v, $\gamma\beta/(\eta + \gamma\beta)$. As z becomes large enough, the adverse impact of increasing the asking price on the probability of a successful deal diminishes, so the target can reap almost the entire incremental surplus implied by one unit increase in z, and $\partial b^*/\partial z$ approaches $\gamma\beta/(\eta + \gamma\beta)$ in the limit.

$b^* > 0$ is intuitive since the target firm's reservation value is 0. When expected synergy is high (z exceeds a threshold $\tilde{z}$), the target firm will always set its asking price to be smaller than its posterior estimate of v, just to insure that deal is more likely to go through. This is optimal to the target, because the target becomes "risk-averse" when the value is sufficiently large: a little more asked premium may lead to a huge amount of loss.

3.2 Trading in the Stock Market

We restrict our attention to a monotone equilibrium in the trading market, where each trader i follows a cutoff trading strategy characterized by $g(P)$ as below:

$$d(s_i, P) = \begin{cases} 1, & \text{if } s_i > g(P) \\ \in [-1, 1] & \text{if } s_i = g(P) \\ -1, & \text{if } s_i < g(P) \end{cases} \tag{4}$$

Given the demand function in (4), we can calculate the aggregate demand from informed traders:

$$D(v, P) = \int_{g(P)-v}^{\infty} \phi\left(\frac{\epsilon}{\gamma^{-1/2}}\right) d\epsilon - \int_{-\infty}^{g(P)-v} \phi\left(\frac{\epsilon}{\gamma^{-1/2}}\right) d\epsilon = 1 - 2\Phi\left(\sqrt{\gamma}(g(P) - v)\right), \tag{5}$$

where $\phi(\cdot)$ is the standard normal pdf. From market clearing condition that $D(v, P) = S(\xi, P)$, it follows that, as we proposed,

$$P = \sqrt{\gamma}\,(v - g(P)) + \xi. \tag{6}$$

However, this is still an implicit expression of P, since we have not yet solved $g(P)$.

With the bid premium function b^* given by (3) and the price P by (6), we can now write trader i's expected payoff from buying one unit of the target's shares given its information set:

$$\mathbb{E}\left[b^* \cdot \mathbb{1}_{(v>b^*)} - P | s_i, P\right] \tag{7}$$

A trader will choose to buy the asset if and only if (7) is positive. From the proposed cutoff trading strategy in (4), a trader with a private signal equal to $g(P)$ is indifferent between buying or selling the stock, which implies that (7) is equal to 0 if we plug in $s_i = g(P)$.

Once $g(P)$ is solved, we can use it in (6) to solve P. Thereby, every element required in equilibrium Definition 1 is solved.

The following proposition 1 shows that there exists a unique monotone equilibrium as we have described, and characterizes it.

Proposition 1 (The Monotone Equilibrium) *The model has a unique monotone equilibrium.*

1. *The optimal offer premium b^* that the target firm would set in the bargaining process is the unique solution to the equation* (3)*.*

2. *The market price P is uniquely given by* (6) *and clears the market.*

3. *The informed traders' threshold trading strategies are uniquely determined by* (7)*; that is, there is a unique function $g(p) : \mathbb{R} \to \mathbb{R}$ such that the equilibrium trading strategy is given by* (4)*.*

4 Informational Effects of Run-up

In the equilibrium characterized in Proposition 1, the target's learning plays a role as a bridge connecting the M&A negotiation and the stock market. In particular, because of the target's learning, the stock price not only aggregates the dispersed beliefs about the negotiation outcomes in the stock market, but also affects the asked premium in the M&A negotiation and the probability of a successful deal. In this section, we analyze the relationship between the stock price and the M&A negotiation outcomes in the equilibrium with the informational feedback effects of the target's learning.

In the equilibrium, given a price P, traders hold a positive position of the stock if their signals are above the threshold $g(P)$; they hold a negative position otherwise. Since the supply function is exogenously given, a higher stock price suggests that more traders receive high signals and thus buy the stock. This is more likely to happen if the private value v is higher. Therefore, a higher stock price P is a signal that the bidder has a higher private value v, which will make the target ask a higher premium. Hence, the run-up impacts the equilibrium asked premium, the probability of a successful deal, and the target's expected payoff. The following Proposition 2 shows such effects of the stock price run-up.

Proposition 2 (Run-up effects on negotiation outcomes) *In the equilibrium characterized in Proposition 1, the offer premium required by the target firm $b^*(P)$, the conditional expected deal probability $\mathbb{E}\left[\mathbb{1}_{(v>b^*)}|P\right]$, and the expected payoff $\mathrm{E}\left[b^* \cdot \mathbb{1}_{(v>b^*)}|P\right]$ to the target firm are all increasing in the stock price run-up P.*

Proposition 2 follows immediately from Lemma 1 and the fact that z is strictly increasing in P. Since P reveals the private value v, as P increases, the perceived surplus of the M&A increases. With the bargaining power, the target then requires a larger portion of the surplus. However, as the target increases the asked premium, the chance of the deal being completed is jeopardized, which may lead to a lower expected payoff. The target balances this tradeoff when maximizing its expected payoff. Moreover, the higher the perceived surplus (due to a higher run-up P), the higher the marginal adverse effect of an increase in the asked premium. Therefore, as the run-up increases, the optimal asked premium b^* increases but at a lower speed than that of the increase in the perceived surplus $\mathbb{E}[v|P]$. In the appendix, we show that

$$0 < \frac{\partial b^*}{\partial P} < \frac{\gamma\beta}{\eta + \gamma\beta} \cdot \left(\frac{1}{\sqrt{\gamma}} + g'(P)\right) = \frac{\partial \mathrm{E}\left[v|P\right]}{\partial P} \tag{8}$$

Consequently, the target's equilibrium asked premium $b^*(P)$, the probability of a successful deal, and thus the target's expected payoff $\mathbb{E}\left[\mathbb{1}_{(v>b^*)}|P\right]$ are all increasing in the run-up P.

While the expected payoff to the target is increasing in the run-up, the bidder's payoff is decreasing in it. Because the bidder knows the the private value v, a higher run-up leads to a higher asked premium, which increases the bidder's acquisition cost and thus decreases her payoff. The fact that $v - b^*(P)$ is decreasing in P follows directly that $b^*(P)$ is increasing P, and it is consistent with the traditional view that the bidder's acquisition cost is increasing in the run-up, e.g. Schwert (1996). However, Rajamani (2013) documents that the bidder's gain is increasing with the target price run-up, cross-sectionally. These seemingly conflicting empirical facts coincide in the equilibrium characterized in Proposition 2. The distinction stems from different information sets, conditional on which we analyze the bidder's payoff. In the appendix, we show that $\mathbb{E}[(v-b^*)|v > b^*, P]$ is increasing in P. Also, from Proposition 2, we know that the probability $\Pr(v > b^*|P)$ is increasing in P. Given the fact that both $\mathbb{E}[(v-b^*)|v > b^*, P]$ and $\Pr(v > b^*|P)$ are positive, we have

$$\frac{d}{dP}\left[\mathbb{E}[(v-b^*)\mathbb{1}_{(v>b^*)}|P]\right] = \frac{d}{dP}\left\{\mathbb{E}[(v-b^*)|v > b^*, P]\cdot\Pr(v > b^*|P)\right\} > 0. \tag{9}$$

Therefore, from the bidder's point of view, higher run-ups leads to higher acquisition cost and thus lower payoff; however, from the outside econometricians' view, higher run-ups means higher M&A surplus, which dominates the higher acquisition cost, so the bidder's gain is higher. The following Proposition 3 summarizes the discussion about the effect of the run-up on the bidder's payoff.

Proposition 3 (Run-up Effects on Bidder's Gain) *In the equilibrium characterized in Proposition 1,*

1. *the bidder's gain conditional on the run-up P and her knowledge about the private value v, $(v-b^*)\mathbb{1}_{(v-b^*)}$, decreases in the run-up P; however,*
2. *outside econometricians, conditional only on P, conclude that the expected bidder's gain, $\mathbb{E}\left[(v-b^*)\mathbb{1}_{(v>b^*)}|P\right]$, increases in P.*

The informational effects of the run-up due to the target's learning have important empirical implications. In particular, that $b^*(P)$ is increasing in P provides a good identification strategy for testing the hypothesis that managers learn from the stock market, when making important corporate decisions, such as asked premiums in M&A negotiations. Consider the scenario where the target is still uncertain of the private value v, but her learning is shut down. That is, the run-up does not have informational effects. Then the only information based on which the target offers asked premium is the prior belief about the private value v. Denote by b_N the optimal asked premium when the target does not learn, then b_N is uniquely determined by the target's prior belief about the private value.[6] Therefore, without the target's learning, the covariance between the asked premium and the run-up is from the prior belief of the private value only. Furthermore, under the no learning hypothesis, the financial market characteristics will have no effect on the target's optimal asked premium, but will significantly affect the run-up. The following Proposition 4 summarizes these two identification strategies for testing the hypothesis that the target learns from the stock price.

Proposition 4 *Suppose the target* ***does not*** *learn from the stock price. Then*

1. *controlling the prior belief about the private value, the asked premium and the run-up are uncorrelated; and*

2. *while the stock market characteristics have significant effects on the run-up, they have no effect on the asked premium.*

If the empirical results reject the two hypotheses in Proposition 4, the empirical results support the hypothesis that the target learns from the stock market in M&A negotiations.

5 Real Effects of the Target's Learning

In our model, the information of the ongoing M&A negotiation is publicized to the stock market in period 0. This is the start of the target's learning process. This public information makes the stock price incorporate more information about the target, so publicizing this information will improve the market efficiency (Diamond (1985), Diamond and Verrecchia (1991), Kanodia (1980), and Fishman and Hagerty (1989)). However, as a general rule, federal securities laws do not require involving parties to publicly disclose the ongoing M&A negotiation, nor to keep its confidentiality, even if the negotiations are material, until the

[6]More generally, if the run-up has no informational effects, the target's gain conditional on a successful M&A deal (b_N in our model) should not depend on the run-up in any bargaining protocol, in which the target can affect the transaction term of the M&A deal. Otherwise, there is a run-up, according to which the target's behavior is not optimal in the negotiation process.

parties reach agreement. If the regulator aims to maximize the social welfare, the no requirement of disclosing or keeping confidential ongoing M&A negotiations implies that there is no clear conclusion whether the market efficiency will increase or decrease the real efficiency (see Bond, Edmans, and Goldstein (2012) for a review). In this section, we first analyze that whether the information leakage itself has signaling effects. That is, in our framework, whether disclosing or not disclosing the ongoing M&A negotiation signals the surplus of the M&A transaction. Then we discuss whether disclosing the ongoing M&A negotiation to increase the market efficiency is socially desirable.

Whether there are signaling effects of disclosing the ongoing M&A negotiation depends on which party, the bidder or the target, discloses such information. Because the target is assumed to have no private information about the private value v, if the target discloses, the disclosure itself will not signal the value v. Consider the scenario that the ongoing M&A negotiation is not disclosed to the stock market, so any trader's private signal about the private value v has $\gamma = 0$ precision. As a result, without the disclosure of the ongoing M&A negotiation, the stock price is not informative about the private value v. Hence, the target firm cannot learn from the stock price. The following Proposition 5 shows that the target's ex-ante payoff is increasing in the informativeness of the stock price, so it is dominating for the target to disclose the ongoing M&A negotiation, because of the value of learning.

Proposition 5 (Information Leakage and the Target Payoff) *In the equilibrium characterized in Proposition 1, the ex-ante expected payoff to the target firm,* $\mathbb{E}_z\left[\mathrm{E}\left[b^* \cdot \mathbb{1}_{(v>b^*)}|z\right]\right]$, *increases with price informativeness, measured by* $\gamma\beta$.

The results in Proposition 5 follow directly from the target's risk-aversion at the optimal asked premium: the more precise the signal used to derive the maximum, the greater the ex-ante payoff. When there is no information leakage or the price run-up is extremely noisy, the target firm would be unable to profit from learning. Proposition 5 then implies that since the target has strict incentives to disclose the ongoing M&A negotiation, and the target does not have private information about the private value v, the information leakage itself does not have any signaling effect. In our model, therefore, the bidder is unable to manipulate the stock price by leaking the ongoing M&A negotiation.

Given that in our model, the information of the ongoing M&A negotiation will be leaked to the market, the market efficiency will increase. Proposition 5 also implies that the market efficiency is desirable to the target, because the higher the market efficiency, the more valuable the target's learning. However, the regulator is concerned more about the social welfare. In our model, if the surplus of the M&A v is positive, then it is socially optimal if the M&A deal goes through; if the private value v is negative, the M&A deal will not go through for sure, because the target's asked premium is always positive. Therefore, if disclosing the information about the ongoing M&A negotiation may decrease the ex-ante probability of a successful M&A deal conditional on the surplus $v > 0$, the regulator should ban such a disclosure. The following Proposition 6 states that when the prior mean of the private value v is negative and the stock price is sufficiently uninformative, disclosure of the information of the ongoing M&A negotiation will jeopardize the probability of the success of M&A deals with positive surplus.

Proposition 6 (Ex-ante Deal Probability and Value Creation) *In the equilibrium characterized in Proposition 1, for each* $v_0 < 0$*, there is* $\underline{\gamma\beta}(v_0) > 0$*, such that* $\frac{\partial \mathbb{E}[\mathbb{1}_{(v>b^*)}]}{\partial \gamma\beta} < 0$ *for* $\gamma\beta \in \left(0, \underline{\gamma\beta}(v_0)\right)$*. Moreover,* $\underline{\gamma\beta}(v_0)$ *decreases in* v_0*.*

The adverse effects of the disclosure is due to the very noisy stock market and the very pessimistic prior belief. If the disclosure is banned, the target will offer the asked premium based only on the prior belief. Since the prior belief of a positive private value is low, without learning, the target will make a low asked premium. On the other hand, when the market is very noisy, the stock price could be high with a fairly large probability. As a result, the target will offer a too high asked premium, which decreases the probability of a successful M&A deal with a positive surplus.

Our model, therefore, has an important policy implication. While the target always has incentives to disclose the ongoing M&A negotiation to the stock market, sometimes such a disclosure should be banned. In particular, when the market is very noisy and the prior of the M&A surplus is sufficiently pessimistic, the regulator should closely monitor the information leakage, so that the ongoing negotiation could be kept confidential and thus a socially desirable M&A deal can go through with higher probability.

6 Conclusion

This paper demonstrates the great effects of the target's managerial learning about the bidder's private value in ongoing M&A negotiations. The target's learning leads to informational effects of stock price run-ups on deal outcomes. In particular, the M&A deal premium, the probability of a successful deal, the target's expected payoff, and the bidder's expected payoff (in the view of outside econometricians) are all increasing in the run-up. Therefore, even if the target does not use the run-up as bargaining power in the negotiation, the run-up still significantly affect the M&A negotiation outcomes.

We also show that the target always has incentives to leak the information of ongoing M&A negotiations to the stock market, due to the value of learning. However, such an information leakage may not be socially desirable. Specifically, when the stock market is very noisy and the prior belief about the bidder's private information is low, the leakage of such information will jeopardize the success of the deal with positive surplus, though it increases the market efficiency. Therefore, the regulator should ban the information leakage in some markets.

The model suggests a number of avenues for future research. On the theory side, the paper has studies the effect of the target's learning in a "static" environment. A potential extension would be to consider the target's learning effect in a "repeated" environment. While this paper consider M&A negotiations, it is also interesting to consider the effects of the target's learning in an M&A auction. On the empirical side, it delivers a number of new predictions on the informational effects of run-ups. It also provides an identification strategy to test the managerial learning hypothesis.

Appendix

We first present useful properties of Inverse Mills Ratio.

Corollary 1 *Denote* $\lambda(z) = \frac{\phi(z)}{1-\Phi(z)}$ *as the Inverse Mills Ratio, then* $0 < \lambda'(z) < 1$ *for all* z.

Proof.

$$\lambda'(z) = \lambda(z) \cdot (\lambda(z) - z) \tag{A.1}$$

Using Mills' Ratio inequality derived from Birnbaum (1942) and Sampford (1953) that $\frac{\sqrt{z^2+8}+3z}{4} < \lambda(z) < \frac{\sqrt{z^2+4}+z}{2}$ for $z > 0$ and the fact that $\lambda(z)$ is convex in z, it is straight forward to show that $0 < \lambda(z) \cdot (\lambda(z) - z) < 1$ for all z. ■

Proof to Lemma 1.

The target firm's optimization problem is

$$\begin{aligned} &\max_b \mathbb{E}\left[b \cdot \mathbb{1}_{(v>b)}|z\right] \\ =&\max_b b \cdot \left[1 - \Phi\left(\frac{b - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right] \end{aligned} \tag{A.2}$$

Its first order condition is

$$\left[1 - \Phi\left(\frac{b - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right] \cdot \left[1 - b \cdot \sqrt{\eta+\gamma\beta} \cdot \lambda\left(\frac{b - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right] = 0. \tag{A.3}$$

Next we show that there is unique solution to the target's F.O.C (A.3) and it is also the global maximum to its objective function in (A.2).

Existence, Uniqueness, and Global Maximum

Since the first term in (A.3) is positive, the F.O.C can be simplified as

$$1 - b \cdot \sqrt{\eta+\gamma\beta} \cdot \lambda\left(\frac{b - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) = 0. \tag{A.4}$$

LHS of (A.4) is strictly positive when $b \leq 0$ and approaches $-\infty$ as $b \to \infty$. So it crosses 0 at least once – only when $b > 0$. Derivative of LHS of equation (A.4) is equal to

$$-\sqrt{\eta+\gamma\beta} \cdot \lambda\left(\frac{b - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) - b(\eta+\gamma\beta) \cdot \lambda'\left(\frac{b - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) \tag{A.5}$$

which is negative when $b > 0$. Since (A.4) is strictly decreasing when $b > 0$, it crosses 0 only once. Therefore, a unique solution to (A.4), denoted by $b^* > 0$, is guaranteed. It also follows that (A.4) is positive when $b < b^*$ and negative when $b > b^*$, which means that the objective function in (A.2) is a single peaked function at $b = b^*$. The single-peaking directly implies global maximum.

Monotonicity and Convexity

Applying implicit function theorem to (A.4), we have

$$\begin{aligned}\frac{\partial b^*}{\partial z} &= \frac{b^*\gamma\beta\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)}{b^*(\eta+\gamma\beta)\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)+\sqrt{\eta+\gamma\beta}\lambda\left(\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)} \\ &= \frac{b^{*2}\gamma\beta\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)}{b^{*2}(\eta+\gamma\beta)\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)+1}\end{aligned} \tag{A.6}$$

Using (A.1), it follows that $0 < \frac{\partial b^*}{\partial z} < \frac{\gamma\beta}{\eta+\gamma\beta} < \frac{\gamma+\gamma\beta}{\eta+\gamma+\gamma\beta}$. From (A.6), we know $\frac{\partial b^*}{\partial z}$ is increasing in $b^{*2}\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)$. Using F.O.C in (A.4) and (A.1),

$$b^{*2}\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) = (\eta+\gamma\beta)^{-1/2}\, b^*\left[\lambda\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) - \left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right] \tag{A.7}$$

Since

$$\frac{\partial\left[\lambda\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)-\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right]}{\partial z} = \left[\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)-1\right]\cdot\left[\frac{\frac{\partial b^*}{\partial z}-\frac{\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right] > 0$$

and

$$\frac{\partial b^*}{\partial z} > 0,$$

their product, $b^{*2}\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)$, is also increasing in z. As a result, $\frac{\partial b^*}{\partial z}$ is also increasing in z, and b^* is convex in z. Moreover, both $\left[\lambda\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)-\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right] \to +\infty$ and $b* \to +\infty$ as $z \to +\infty$. It then follows that, as $z \to +\infty$, $b^{*2}\lambda'\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) \to +\infty$ and, from (A.6), $\frac{\partial b^*}{\partial z} \to \frac{\gamma\beta}{\eta+\gamma\beta}$.

Last, as b^* increases with z, $\lambda\left(\frac{b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)=\frac{1}{b^*\cdot\sqrt{\eta+\gamma\beta}}$ is decreasing in z and approaches 0 as z goes to $+\infty$. Let $\tilde{z}$ be such that $b^*(\tilde{z})-\frac{v_0\eta+\tilde{z}\gamma\beta}{\eta+\gamma\beta}=0$, then $b^*<\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}$ for all $z>\tilde{z}$. ■

Proof to Proposition 1.

We have used a proposed pricing function to derive b^*. Next, we confirm that, with b^*, traders' follow cutoff strategies characterized by $g(P)$, which lead to the pricing function as we initially proposed. Trader i's expected payoff from buying one unit of the target's shares given its information set:

$$\begin{aligned}&\mathbb{E}\left[b^*\cdot\mathbb{1}_{(v>b^*)}-P|s_i,P\right]\\=&b^*\cdot\left(1-\Phi\left(\frac{b^*-\frac{v_0\eta+s_i\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\right)-P\end{aligned} \tag{A.8}$$

We first show that (A.8) is increasing in s_i. Take first order derivative with respect to s_i, we have

$$b^*\phi\left(\frac{b^*-\frac{v_0\eta+s_i\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\frac{\gamma}{\sqrt{\eta+\gamma+\gamma\beta}}>0 \tag{A.9}$$

So trader i's profit of holding one share of target stock is increasing with his signal s_i. It thus supports the cutoff strategies we proposed in (4). $g(P)$ is determined through indifference condition, that is when $s_i=g(P)$, (A.8) is equal to 0. However, the existence of $g(P)$ is yet to be proved. Before we do that, we first show that price P is bounded.

We now consider two limiting case. First, all informed traders buy. It means (A.8) is positive when $s_i\to-\infty$, and therefore $P>0$. Second, all informed traders sell. It means (A.8) is negative when $s_i\to+\infty$, and therefore $P<b^*$. In sum, the price run-up in our model is bounded: $P\in(0,b^*)$.

The indifference condition is

$$b^*\cdot\left(1-\Phi\left(\frac{b^*-\frac{v_0\eta+\gamma g+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\right)-P=0 \tag{A.10}$$

We first show that LHS of (A.10) is increasing in g. Take first order derivative with respect to g, we have

$$b^*\phi\left(\frac{b^*-\frac{v_0\eta+g\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\sqrt{\eta+\gamma+\gamma\beta}\left(\frac{\gamma+\gamma\beta}{\eta+\gamma+\gamma\beta}-\frac{\partial b^*}{\partial z}\frac{\partial z}{\partial g}\right)$$
$$+\frac{\partial b^*}{\partial z}\frac{\partial z}{\partial g}\left(1-\Phi\left(\frac{b^*-\frac{v_0\eta+g\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\right)>0 \tag{A.11}$$

As $\frac{\partial z}{\partial g}=1$, (A.11) is positive since $0<\frac{\partial b^*}{\partial z}<\frac{\gamma+\gamma\beta}{\eta+\gamma+\gamma\beta}$. So LHS of (A.10) is strictly increasing in g. Moreover, using the boundaries on P, LHS of (A.10) approaches $b^*-P>0$ when $g\to+\infty$ and $-P<0$ when $g\to-\infty$. Existence and uniqueness of $g(P)$ is therefore guaranteed.

The last step to complete the proof is to derive the pricing function as in (6), which is followed directly from (4), (5), and (1). ■

Proof to Proposition 2.

Take total differentiation of equation of (A.10) with respective to P, we have

$$b^*\phi\left(\frac{b^*-\frac{v_0\eta+g\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\sqrt{\eta+\gamma+\gamma\beta}\left(\frac{\gamma g'(P)+\gamma\beta\left(\frac{1}{\sqrt{\gamma}}+g'(P)\right)}{\eta+\gamma+\gamma\beta}-\frac{\partial b^*}{\partial z}\left(\frac{1}{\sqrt{\gamma}}+g'(P)\right)\right)$$
$$+\frac{\partial b^*}{\partial z}\left(\frac{1}{\sqrt{\gamma}}+g'(P)\right)\left(1-\Phi\left(\frac{b^*-\frac{v_0\eta+g\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}\right)\right)-1=0. \tag{A.12}$$

Rearrange and we have

$$g'(P)=\frac{1-\frac{1}{\sqrt{\gamma}}\left(b^*\phi(K)\sqrt{\eta+\gamma+\gamma\beta}\left(\frac{\gamma\beta}{\eta+\gamma+\gamma\beta}-\frac{\partial b^*}{\partial z}\right)+\frac{\partial b^*}{\partial z}(1-\Phi(K))\right)}{b^*\phi(K)\sqrt{\eta+\gamma+\gamma\beta}\left(\frac{\gamma+\gamma\beta}{\eta+\gamma+\gamma\beta}-\frac{\partial b^*}{\partial z}\right)+\frac{\partial b^*}{\partial z}(1-\Phi(K))} \tag{A.13}$$

where $K\equiv\frac{b^*-\frac{v_0\eta+g\gamma+(P/\sqrt{\gamma}+g)\gamma\beta}{\eta+\gamma+\gamma\beta}}{(\eta+\gamma+\gamma\beta)^{-1/2}}$. Then

$$\frac{\partial b^*}{\partial P}=\frac{\partial b^*}{\partial z}\left(\frac{1}{\sqrt{\gamma}}+g'(P)\right)$$
$$=\frac{\partial b^*}{\partial z}\cdot\frac{1+\frac{1}{\sqrt{\gamma}}b^*\phi(K)\sqrt{\eta+\gamma+\gamma\beta}\left(\frac{\gamma}{\eta+\gamma+\gamma\beta}\right)}{b^*\phi(K)\sqrt{\eta+\gamma+\gamma\beta}\left(\frac{\gamma+\gamma\beta}{\eta+\gamma+\gamma\beta}-\frac{\partial b^*}{\partial z}\right)+\frac{\partial b^*}{\partial z}(1-\Phi(K))}>0 \tag{A.14}$$

where the last inequality follows from $0 < \frac{\partial b^*}{\partial z} < \frac{\gamma\beta}{\eta+\gamma\beta} < \frac{\gamma+\gamma\beta}{\eta+\gamma+\gamma\beta}$.

Conditional on P (or equivalently z), the probability of successful deal is

$$\mathrm{E}\left[\mathbb{1}_{(v>b^*)}|P\right] = 1 - \Phi\left(\frac{b^* - \frac{v_0\eta+(P/\sqrt{\gamma}+g(P))\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right) \tag{A.15}$$

$$\frac{\partial \mathrm{E}\left[\mathbb{1}_{(v>b^*)}|P\right]}{\partial P} = \phi(K)\left(\frac{\gamma\beta}{\eta+\gamma\beta} - \frac{\partial b^*}{\partial z}\right)\left(\frac{1}{\sqrt{\gamma}} + g'(P)\right) > 0.$$

The expected payoff conditional on P is the product of b^* and $\mathrm{E}\left[\mathbb{1}_{(v>b^*)}|P\right]$. Since both b^* and $\mathrm{E}\left[\mathbb{1}_{(v>b^*)}|P\right]$ are positive and increasing in P, their product is also increasing in P. ■

Proof to Proposition 3.

The bidder's expected gain conditional on the price P and the deal going through is:

$$\begin{aligned}&\mathrm{E}\left[v - b^*|v > b^*, P\right]\\ =&\frac{v_0\eta + (P/\sqrt{\gamma}+g(P))\gamma\beta}{\eta+\gamma\beta} - b^* + (\eta+\gamma\beta)^{-1/2}\lambda\left(\frac{b^* - \frac{v_0\eta+(P/\sqrt{\gamma}+g(P))\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\end{aligned}$$

Its derivative w.r.t. P is

$$\begin{aligned}\frac{\partial \mathrm{E}\left[v - b^*|v > b^*, P\right]}{\partial P} =& \frac{\partial \mathrm{E}\left[v - b^*|v > b^*, P\right]}{\partial z} \cdot \frac{\partial z}{\partial P}\\ =& \left(\frac{\gamma\beta}{\eta+\gamma\beta} - \frac{\partial b^*}{\partial z}\right)\left(1 - \lambda'(K)\right)\left(\frac{1}{\sqrt{\gamma}} + g'(P)\right) > 0.\end{aligned}$$

The inequality follows since $\frac{\partial b^*}{\partial z} < \frac{\gamma\beta}{\eta+\gamma\beta}$ and $\lambda'(K) < 1$.

The bidder's expected gain conditional on P is

$$\mathbb{E}\left[(v-b^*)\cdot \mathbb{1}_{(v>b^*)}|P\right] = \mathbb{E}\left[v - b^*|v > b^*, P\right] \cdot \mathbb{E}\left[\mathbb{1}_{(v>b^*)}|P\right]$$

Since both $\mathbb{E}\left[v - b^*|v > b^*, P\right]$ and $\mathbb{E}\left[\mathbb{1}_{(v>b^*)}|P\right]$ are positive and increasing in P, their product is also increasing in P. ■

Proof to Proposition 5.

We compare two situations. In the first scenario, the sufficient statistics for price z has conditional (on v) precision of $\gamma\beta$. In the second, we increase its conditional precision by Δ and denote the sufficient statistics as z' to differentiate it from the first case. z' has conditional precious of $\gamma\beta+\Delta$, and observing z' is informationally equivalent to z and Δz, where Δz is conditionally independent with z' and z and has a conditional precision equal to Δ. As a result, we have

$$\begin{aligned}
\mathbb{E}_{\{v,z'\}}\left[b^*(z')\cdot\mathbb{1}_{(v>b^*(z'))}\right] =& \mathbb{E}_{\{v,z,\Delta z\}}\left[b^*(z,\Delta z)\cdot\mathbb{1}_{(v>b^*(z,\Delta z))}\right] \\
=& \mathbb{E}_{\{z,\Delta z\}}\left[\mathbb{E}\left[b^*(z,\Delta z)\cdot\mathbb{1}_{(v>b^*(z,\Delta z))}|z,\Delta z\right]\right] \\
>& \mathbb{E}_{\{z,\Delta z\}}\left[\mathbb{E}\left[b^*(z)\cdot\mathbb{1}_{(v>b^*(z))}|z,\Delta z\right]\right] \\
=& \mathbb{E}_{\{v,z,\Delta z\}}\left[b^*(z)\cdot\mathbb{1}_{(v>b^*(z))}\right] \\
=& \mathbb{E}_{\{v,z\}}\left[b^*(z)\cdot\mathbb{1}_{(v>b^*(z))}\right]
\end{aligned} \tag{A.16}$$

where the inequality in (A.16) follows from the fact that $b^*(z,\Delta z)\in\text{argmax}_b\,\mathbb{E}\left[b\cdot\mathbb{1}_{(v>b)}|z,\Delta z\right]$, which in turn implies that $\mathbb{E}\left[b^*(z,\Delta z)\cdot\mathbb{1}_{(v>b^*(z,\Delta z))}|z,\Delta z\right]\geq\mathbb{E}\left[b^*(z)\cdot\mathbb{1}_{(v>b^*(z))}|z,\Delta z\right]$, where the equal sign only holds for specific values of z and Δz such that $b^*(z,\Delta z)=b^*(z)$. Next we compare the case with information leakage to that without.

Without information leakage, target firm require a offer premium b_N^* that satisfy

$$b_N^*\in\underset{b}{\text{argmin}}\,\mathrm{E}\left[b\cdot\mathbb{1}_{(v>b)}\right] \tag{A.17}$$

Its first order condition is

$$1-b_N^*\sqrt{\eta}\lambda\left(\frac{b_N^*-v_0}{\eta^{-1/2}}\right)=0 \tag{A.18}$$

The ex-ante expected payoff to target without information leakage is

$$\mathrm{E}\left[b_N^*\cdot\mathbb{1}_{(v>b_N^*)}\right]=\mathrm{E_z}\left[\mathrm{E}\left[b_N^*\cdot\mathbb{1}_{(v>b_N^*)}|z\right]\right]<\mathrm{E_z}\left[\mathrm{E}\left[b^*\cdot\mathbb{1}_{(v>b^*)}|z\right]\right]$$

The last inequality follows from the fact that b^* maximizes $\mathrm{E}\left[b\cdot\mathbb{1}_{(v>b)}|z\right]$, so $\mathrm{E}\left[b_N^*\cdot\mathbb{1}_{(v>b_N^*)}|z\right]\leq\mathrm{E}\left[b^*\cdot\mathbb{1}_{(v>b^*)}|z\right]$ where the equal sign only holds for one specific value of z. ■

Proof to Proposition 6.

The ex-ante deal probability is

$$\begin{aligned}\mathbb{E}[\mathbb{1}_{(v>b^*)}] &= \mathbb{E}\left[\mathbb{E}[\mathbb{1}_{(v>b^*)}|z]\right] \\ &= \int_{-\infty}^{+\infty}\left[1-\Phi\left(\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right] f_z(z)\,\mathrm{d}z\end{aligned}$$

where $f_z(z)$ is the pdf of z and $f_z(z)=\frac{1}{\sqrt{\eta^{-1}+(\gamma\beta)^{-1}}}\phi\Big(\frac{z-v_0}{\sqrt{\eta^{-1}+(\gamma\beta)^{-1}}}\Big)$. The derivative of the ex-ante deal probability is

$$\begin{aligned}\frac{\partial\,\mathbb{E}[\mathbb{1}_{(v>b^*)}]}{\partial\gamma\beta} &= \int_{-\infty}^{+\infty}\left[1-\Phi\left(\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right]\frac{\partial f_z(z)}{\partial\gamma\beta}\,\mathrm{d}z \\ &+\int_{-\infty}^{+\infty}\frac{\partial\left[1-\Phi\left(\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right]}{\partial\gamma\beta} f_z(z)\,\mathrm{d}z \end{aligned} \tag{A.19}$$

We now evaluate above derivative at $\gamma\beta=0$, then the first term is

$$\left[1-\Phi\big(\sqrt{\eta}(b_N-v_0)\big)\right]\int_{-\infty}^{+\infty}\frac{\partial f_z(z)}{\partial\gamma\beta}\,\mathrm{d}z = C\cdot\int_{-\infty}^{+\infty}\left[\frac{(z-v_0)^2}{\sigma_z^2}-1\right]f_z(z)\,\mathrm{d}z=0 \tag{A.20}$$

where b_N is the solution to (A.18) and C is a quantity that is independent of z.

Next we calculate the second term.

$$\begin{aligned}\frac{\partial\left[1-\Phi\left(\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\right]}{\partial\gamma\beta} &= -\,\phi\left(\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}\right)\left\{\sqrt{\eta+\gamma\beta}\left(\frac{\partial b^*}{\partial\gamma\beta}-\frac{\eta(z-v_0)}{(\eta+\gamma\beta)^2}\right)\right. \\ &\left.+\frac{1}{2\sqrt{\eta+\gamma\beta}}\left(b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}\right)\right\}\end{aligned} \tag{A.21}$$

To simplify the representation, we now define $G=\frac{b-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}}{(\eta+\gamma\beta)^{-1/2}}$ and $H=\sqrt{\eta+\gamma\beta}\left(\frac{\partial b^*}{\partial\gamma\beta}-\frac{\eta(z-v_0)}{(\eta+\gamma\beta)^2}\right)+\frac{1}{2\sqrt{\eta+\gamma\beta}}\left(b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}\right)$. Differentiate (A.4) w.r.t. $\gamma\beta$, we have

$$\frac{\partial b^*}{\partial\gamma\beta}\lambda(G)+b^*\lambda'(G)\left[\sqrt{\eta+\gamma\beta}\left(\frac{\partial b^*}{\partial\gamma\beta}-\frac{\eta(z-v_0)}{(\eta+\gamma\beta)^2}\right)+\frac{1}{2\sqrt{\eta+\gamma\beta}}\left(b^*-\frac{v_0\eta+z\gamma\beta}{\eta+\gamma\beta}\right)\right]=-\frac{1}{2}(\eta+\gamma\beta)^{-3/2}$$

Rearrange and we have

$$\frac{\partial b^*}{\partial \gamma\beta} = \frac{b^*\lambda'(G)\left[\sqrt{\eta+\gamma\beta}\frac{\partial b^*}{\partial \gamma\beta} - H\right] - \frac{1}{2}(\eta+\gamma\beta)^{-3/2}}{\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)}$$

Plug it into (A.21) and through simplification, we have

$$\begin{aligned}
\frac{\partial\left[1-\Phi(G)\right]}{\partial\gamma\beta} =& \frac{-\phi(G)}{\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)} \cdot \left\{ \sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) \left(\sqrt{\eta+\gamma\beta}\frac{\partial b^*}{\partial\gamma\beta} - H\right)\right. \\
&\left. - \frac{1}{2}(\eta+\gamma\beta)^{-1} - \left(\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)\right)\left(\sqrt{\eta+\gamma\beta}\frac{\partial b^*}{\partial\gamma\beta} - H\right)\right\} \\
=& \frac{-\phi(G)}{\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)} \cdot \left\{ -\frac{1}{2}(\eta+\gamma\beta)^{-1} - \lambda(G)\left(\sqrt{\eta+\gamma\beta}\frac{\partial b^*}{\partial\gamma\beta} - H\right)\right\} \\
=& \frac{\phi(G)}{\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)} \cdot \left\{ \frac{1}{2}(\eta+\gamma\beta)^{-1} + \lambda(G)\left[\frac{\eta(z-v_0)}{(\eta+\gamma\beta)^{3/2}} - \frac{1}{2}\frac{1}{\sqrt{\eta+\gamma\beta}}\left(b^* - \frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}\right)\right]\right\} \\
=& \frac{\phi(G)}{\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)} \cdot \frac{1}{\sqrt{\eta+\gamma\beta}}\lambda(G)\left[\frac{\eta(z-v_0)}{\eta+\gamma\beta} + \frac{1}{2}\frac{v_0\eta + z\gamma\beta}{\eta+\gamma\beta}\right] \\
& \hspace{20em} \text{(using (A.4))} \\
=& \frac{\phi(G)}{\sqrt{\eta+\gamma\beta}\, b^*\lambda'(G) + \lambda(G)} \cdot \frac{1}{2\sqrt{\eta+\gamma\beta}}\lambda(G)\left[\frac{\eta(z-v_0)}{\eta+\gamma\beta} + z\right]
\end{aligned}$$

which evaluated at $\gamma\beta = 0$ is

$$\left.\frac{\partial\left[1-\Phi(G)\right]}{\partial\gamma\beta}\right|_{\gamma\beta=0} = \frac{\phi(G_N)}{\sqrt{\eta}\, b^*\lambda'(G_N) + \lambda(G_N)} \cdot \frac{1}{2\sqrt{\eta}}\lambda(G_N)\left[(z-v_0)+z\right],$$

where $G_N = \sqrt{\eta}(b_N - v_0)$ and is independent of z. Then

$$\int_{-\infty}^{+\infty} \left.\frac{\partial\left[1-\Phi(G)\right]}{\partial\gamma\beta}\right|_{\gamma\beta=0} f_z(z)\,\mathrm{d}z = \frac{\phi(G_N)}{\sqrt{\eta}\, b^*\lambda'(G_N) + \lambda(G_N)} \cdot \frac{1}{2\sqrt{\eta}}\lambda(G_N)\cdot v_0$$

Combined with (A.19) and (A.20), it follows that $\frac{\mathbb{E}\left[\mathbb{1}_{(v>b^*)}\right]}{\partial\gamma\beta}\Big|_{\gamma\beta=0} > 0$ if $v_0 > 0$ and $\frac{\mathbb{E}\left[\mathbb{1}_{(v>b^*)}\right]}{\partial\gamma\beta}\Big|_{\gamma\beta=0} < 0$ if $v_0 < 0$. Last, by continuity of $\frac{\mathbb{E}\left[\mathbb{1}_{(v>b^*)}\right]}{\partial\gamma\beta}$ in $\gamma\beta$, each of above results must hold for a nearby region to the right $\gamma\beta = 0$, respectively. ■

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