Learning, hubris and corporate serial acquisitions

by

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(second draft)

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Abstract

Recent empirical research has shown that, from deal to deal, serial acquirers' cumulative abnormal returns (CAR) are declining. This has been most often attributed to CEOs hubris. We question this interpretation. Our theoretical analysis shows that (i) a declining CAR from deal to deal is <u>not sufficient</u> to reveal the presence of hubris, (ii) if CEOs are learning, economically motivated and rational (in the sense of maximizing their own utility function based on unbiased beliefs), a declining CAR from deal to deal <u>should</u> be observed, (iii) predictions can be derived about the impact of learning and hubris on the time between successive deals and, finally, (iv) predictions about the CAR and about the time between successive deal trends lead to testable empirical hypotheses.

For more than twenty years, an intensive debate has ensued about acquirers' motivations in mergers and acquisitions (M&A). This is most likely due to early empirical results showing that acquirers' cumulative abnormal returns (CAR) around the announcement date are at best equal to zero or, worse, even negative (Jensen and Ruback, 1983). Why would firms undertake acquisitions if not to create value? Several arguments have been proposed in the literature to explain this puzzling result including the hubris hypothesis (Roll, 1986).[1] Recent contributions help to resolve this puzzle to some extent. In particular, Moeller *et al.* (2004) by extending the analysis to a much larger sample of deals (more than 10,000), find clear evidence of a size effect: on average, acquirers' CAR are positive and significant (around 1.5%) but, the larger the deal, the smaller (or more negative) the CAR becomes. Early studies, focusing only on large deals between listed companies, were affected from a sample selection bias.

However recent empirical studies raise a new, and perhaps even more challenging, puzzle: the CARs of serial acquirers are declining from deal to deal (e.g., Fuller *et al.*, 2002; Billett and Qian, 2005; Conn *et al.*, 2005; Croci, 2005; Ismail, 2005; Ahern, 2006). Table 1 summarizes the main findings of these papers. In most of the quoted references, the downward trend in CAR is interpreted as a clear evidence of hubris or of its development across the deal sequence (an exception is Ahern (2006)). Even if at first sight, the hubris argument appears appealing, this explanation is questionable within the framework of Roll (1986). Hubris, as defined originally, should be empirically associated with ex-post observable overbidding and a significant probability of negative CAR. However, the above quoted papers report either significant positive or insignificant CAR across the deal sequence.[2]

Moreover, the hubris explanation is in sharp contrast with the claims of both the management literature and consulting firms. The management literature suggests that acquirers have a great potential to learn from experience (Hayward, 2002; Harding and Rovit, 2004). The professional press and consulting firms also emphasize that successful frequent acquirers are on a learning curve: "They often start with small, lower-risk deals and build capabilities in deal making. They

[1] Without being exhaustive, other arguments put forward are the acquisition program effect (Schipper and Thompson, 1983; Malatesta and Thompson, 1985), the free cash-flow theory and the empire building motivation (Jensen, 1986).
[2] A notable exception is Billet and Qian (2005), where the authors, focusing only on large (over than 100 millions USD) M&As between listed companies, report significant negative abnormal returns for the acquirers across the deal sequence.

institutionalize the processes and create a feedback loop to learn from mistakes" (Rovit *et al.*, 2003). But how could declining acquirer CAR be consistent with any form of learning?

The above question is quite important. Indeed, if hubris really does explain the declining trend of CARs, concerns must be raised about both the selection process of CEOs and about corporate governance mechanisms. We propose an alternative and perhaps more palatable explanation. Our intuition is the following: if acquirers are learning, they improve their target selection and integration processing abilities from deal to deal. The risk associated with acquisitions decreases. In equilibrium, less risk is associated with less return; i.e., a declining trend in successive CARs.

The learning and hubris based interpretation of the declining CAR trend rests on the central role of CEOs in the acquisition decision process. Personal characteristics of CEOs are indeed known to influence the managing style of firms (Bertrand and Schoar, 2003) and this is particularly true for large investment decisions such as M&As (Park, 2003; Sitkin, 2004). Moreover, according to Palter and Srinivisan (2006), the tenure of an executive is the most important differentiator between successful and unsuccessful acquirers. Even if smaller deals are supervised by low-level executives, hubris and/or learning could still affect behavior. So, to develop a theory of the CAR's pattern from deal to deal, we focus on decision maker's behavior. For convenience we refer to the decision maker as the CEO and it could actually be the CEO himself (for large deals), or the CFO (for intermediate deals) or some lower ranking executive (for small deals).

To better understand the CAR pattern from deal to deal, we develop a formal model of the CEO decision process and explore its consequences on observable bids, prices, the time between successive deals (TBD), and the CAR. Our main results are such as follow:

(i) a CAR declining trend <u>should</u> be observed for rational[3] and economically motivated CEOs that learn from deal to deal. Learning enables the CEO to develop more precise valuations of successive targets; i.e., they become sequentially less risky, *ceteris paribus*. Taking into account CEO risk aversion, for a given level of expected value, this uncertainty reduction increases target valuation. This translates into higher bids, prices and, therefore (assuming semi-strong efficiency), a declining CAR. In short, the lower the valuation risk, the higher the price the CEO is ready to pay.

[3] By a rational CEO, we mean a utility maximizing agent making decision on the basis of unbiased beliefs (see Section 2).

(ii) learning also has implications for the TBD. Taking into consideration that the CEO valuation increases with learning (for a given level of expected value) and that the CEO bidding function (under quite general assumptions) is strictly increasing in his valuation, the probability that the CEO will win the auction also increases from deal attempt to deal attempt. Learning should lead therefore to a decreasing TBD.

(iii) these results indicate that a declining CAR trend is NOT necessarily due to hubris; it is also compatible with learning. As it is also pointed out in Conn *et al.* (2005) or Ahern (2006), a declining CAR trend is not specific to any given assumption in fact: it could be due to hubris, to learning but also to a time-varying investment opportunity set (Klasa and Stegemoller (forthcoming Financial Management)), some form of mean reversion or simply to chance. However, our model delivers predictions simultaneously about the CAR trend and the TBD. This allows us to derive implications that are specific to learning and, therefore, open the door to empirical tests of the presence of learning in acquisition programs.

This paper is organized in 4 sections. The first section is dedicated to the study of the CEO's reservation value of the target (the maximum price he will be willing to pay). This valuation step is strictly ex-ante in the sense that it takes place before the beginning of the bidding or bargaining process. Competition, at this stage, is therefore considered to be exogenous. We model the CEO as a risk averse rational economically motivated agent. Risk aversion is justified because CEOs' personal portfolios are inherently under-diversified. Their physical and human capital is invested disproportionately in their company (e.g., Hall and Murphy, 2002; Malmendier and Tate, 2006; Becker, 2006). By a rational agent, we mean an individual making decisions that maximize his expected utility, using unbiased beliefs and learning reflected in Bayesian updating. By economically motivated, we mean a CEO whose wage contract is a function of deal completion, as it is most often in practice (e.g., Datta *et al.*, 2001; Rosen, 2004). The trade-off faced by the CEO is as follows: the higher the target's valuation, the higher the probability of doing the deal (assuming that the bidding function is increasing in the valuation). But the higher the valuation, the higher the price paid in case of deal completion (assuming that the price function is increasing in the bids). So, a high valuation means a high probability of deal completion but also a high risk of over-payment relative to the ex-post realized value creation. In this framework, we derive the CEO's reservation valuation (the valuation that maximizes his expected utility). We then analyze how his expected bonus and its variance affect this reservation valuation.

In Section 2 we explore the CEO's bidding behavior and its implications on the price determination process. We study three cases, each one corresponding to a specific situation: ascending auctions (capturing large takeovers among publicly traded firms), first price auctions (closer to the case of private auctions organized by financial intermediaries) and direct bargaining (representing direct agreements between merging firms). We show, using classical arguments of game and auction theory, that in each case, the equilibrium bidding function is strictly increasing in the target valuation. We then highlight the conditions under which the price function is itself increasing in the bids. Connecting valuation, bids and prices is an important ingredient to allow empirical predications to be formulated about market reactions. Acquirers' valuations are not observable *per se*. Only investors' reactions (the CAR, and to a more limited extend, bids and prices) are available to the researcher.

Section 3 is devoted to the formulation of empirical predictions. We first focus on market reactions to the deal announcement (CAR), assuming semi-strong form efficiency. We then examine the TBD. In both cases, we are interested in the ex-post observable empirical consequences of learning. Finally, we ask how hubris affects the model predictions. Hubris is defined as an initial cognitive bias, leading either to over-optimism (an over-evaluation of the expected value creation) or over-confidence (an under-estimation of the level of risk), as in Malmendier and Tate (2006). In both cases, this leads to overbidding, increasing the likelihood of overpayment and of value destruction for the bidding firm's shareholders. If the CEO survives (Mitchell and Lehn, 1990) and if he learns from past difficult experiences, overbidding should decline from deal to deal (either because of downward revision of expected value creation or an upward revision of the risk associated with the deal attempt). Using the same arguments as for rational CEOs, the CAR should increase from deal to deal; also, the TBD should increase.

To sum-up, for rational CEOs, both the CAR and the TBD should decline from deal to deal. For hubris infected CEOs (who nonetheless learn something from past mistakes), the reverse pattern should be observed; viz., an increasing CAR and increasing TBD. It is these clear and specific predictions about <u>both</u> the CAR and the TBD, and their contrast between rational and hubris infected CEOs, that are specific to our framework. We conclude our section about empirical implications by stressing potential endogenous sample selection issues. Indeed, to complement the winner's curse sample selection bias identified in Roll (1986), we discuss the potential presence of a second sample selection bias: a CEO survival bias. If corporate governance mechanisms (either internal or external) play their role, hubris infected CEOs should survive in lower numbers than rational CEOs.

The final section summarizes and concludes.

1. The Acquiring CEO's reservation value

The acquiring CEO's reservation value of the target is the value that maximizes the CEO's expected utility.[4] For simplicity, potential competition is held exogenous in the CEO's calculation at this stage. An endogenous treatment will be provided in Section 2, when the analysis turns to bidding and offering prices.

1.1. Target value and expected synergies

In contrast to Shleifer and Vishny (2003), we assume that the capital markets are efficient in the sense that the market price is an unbiased estimate of the target firms' true economic value as a stand alone venture. Hence, acquisitions are not motivated by under-evaluation. Denote the target's market value MV_T. The synergy potentially created by the merger is not perfectly known to the acquirer. It is a random variable (denoted $\tilde{s}_t$) and is defined as a proportion of MV_T. So, the target's market value in a completed acquisition becomes:

$$MV_T \,|\, \text{acquisition} = MV_T(1 + \tilde{s}_t)\,. \tag{1.1}$$

Following the auction literature, $\tilde{s}_t$ must be understood as a private value to the acquirer and does not depend on the valuations of other potential acquirers. This implies that our setup applies more to strategic than financial acquisitions. Indeed, as stressed by Bullow *et al.* (1999), value creation in strategic acquisitions is (more) driven by synergies specific to the bidder. In financial acquisitions, value creation is mainly driven by under-evaluation or diversification. The sources of value creation are therefore more common to all potential bidders. We assume that $\tilde{s}_t$ follows a Gaussian distribution $N(\mu_s, \sigma_s^2)$ where μ_s and σ_s^2 are respectively the expected synergy and

[4] The CEO reservation value can also be understood as the maximum price he is ready to pay to acquire the target or the price above which acquiring the target would negatively affect his current utility: if the price to be paid exceeds this level of valuation, the CEO will not attempt the deal. This is in fact a participation constraint.

the variance of the synergy.[5] However, the CEO has limited information and perceives $N(\mu_s, \hat{\sigma}^2_{s,t})$ at deal *t*, where $\hat{\sigma}^2_{s,t}$ represents the CEO perception of the uncertainty associated with synergy at that time.[6] We use ~ to indicate a random variable and ^ to indicate that a perception as opposed to a true parameter. Imperfect knowledge means that $\hat{\sigma}^2_{s,t} \geq \sigma_s$.

Two comments are worthwhile at this stage:

- the CEO is assumed to have unbiased anticipations (he knows μ_s). This might appear unrealistic but it allows us to draw a clear distinction between rational CEOs and hubris infected CEOs, (which will be analyzed in Section 3.3.) Hubris infected CEOs can indeed be characterized by biased priors.
- μ_s is constant from deal to deal. This enables us to keep the investment opportunity set constant. Our objective is to isolate the effects of simple learning on CEO behavior and an evolving investment opportunity set would bring irrelevant complications.

1.2. Learning

Learning has long been recognized as an important determinant of decisions. Firms learn about the environment in which they operate (e.g., Prescott, 1972; Grossman *et al.*, 1977, Zeira, 1987; Rob, 1991; Berk *et al.*, 2004) or about themselves (e.g., Jovanovic and MacDonald, 1994; Bernardo and Chowdhry, 2002). Since firms (and their CEOs) often undertake acquisition programs (Schipper and Thompson, 1983; Asquith, Bruner and Mullins, 1983; Malatesta and Thompson, 1985; Fuller *et al.*, 2002) it seem reasonable that they should learn from each completed deal. We therefore introduce learning explicitly in the form of a Bayesian updating process from deal to deal. Market reactions to each deal's announcement represent signals sent to the CEO about potential synergies, denoted $\tilde{\eta}_t$. They are assumed to be unbiased and follow a Gaussian distribution $N(\mu_s, \sigma^2_\eta)$, where σ^2_η, known to the CEO, captures the precision of signals sent by the market (or the market's informativeness).[7]

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[5]Since the distribution of $\tilde{s}_t$ is unbounded, this specification conceivably allows a negative market value. In Appendix 1, we present an alternative specification, in which the market value of the target, conditional on a successful acquisition, is $MV_T \times e^{\tilde{s}_t}$ with $\tilde{s}_t$ normally distributed. Using the properties of the log-normal distribution, explicit solutions can be obtained but they are algebraically more messy and offer no additional insights.

[6] Note that in a classical ex-ante rational setup, $\hat{\sigma}^2_{s,t} = \sigma^2_s$; i.e., the CEO knows the true uncertainty of the synergies.

[7] The unbiased signal distribution is consistent with efficient markets.

Concerns could be raised about how reactions around past deal provide any information at all about a current deal attempt. This interesting question is studied by Hayward (2002). The author focuses on conditions that permit organizational learning to take place during serial acquisitions. We assume that these conditions are fulfilled and that learning is possible. Using the Bayesian conjugate prior, the CEO posterior estimates of $\hat{\mu}_{s,t}$ and $\hat{\sigma}^2_{s,t}$ are:

$$\hat{\mu}_{s,t} = \frac{\left(\frac{1}{\hat{\sigma}^2_{s,0}}\mu_s + \frac{1}{\sigma^2_\eta}\sum_{i=1}^{t-1}\eta_i\right)}{\frac{1}{\hat{\sigma}^2_{s,0}} + (t-1)\frac{1}{\sigma^2_\eta}} = \frac{\left(\frac{1}{\hat{\sigma}^2_{s,0}}\mu_s + \frac{1}{\sigma^2_\eta}(t-1)\mu_s\right)}{\frac{1}{\hat{\sigma}^2_{s,0}} + (t-1)\frac{1}{\sigma^2_\eta}} = \mu_s, \tag{1.2}$$

$$\frac{1}{\hat{\sigma}^2_{s,t}} = \frac{1}{\hat{\sigma}^2_{s,0}} + (t-1)\frac{1}{\sigma^2_\eta}, \tag{1.3}$$

where $N(\mu_s, \hat{\sigma}^2_{s,0})$ is the CEO prior and *(t-1)* is the number of prior deals completed by the CEO. This setup could be extended to accommodate signals sent by rival acquirers without changing the nature of the argument.

For a CEO with unbiased anticipations, when the market is efficient and delivers signals centered on the population parameter, Equation (1.2) shows that the perception of the expected synergy is simply the population value. The variance of the posterior distribution in Equation (1.3) depends on the precision of the information sent to the CEO (the inverse of the signal variance σ^2_η). Note that as σ^2_η grows, the signal precision falls and there is a smaller revision in the posterior precision; indeed, if the signal is totally non-informative, the posterior precision is unaltered from the prior. Also, for positive and finite values of σ^2_η, the posterior precision becomes monotonically smaller with the number of deals; asymptotically, the CEO learns perfectly about the synergy in prospective acquisitions.

1.3. The CEO's decision problem

Assumptions. To estimate the target valuation that maximizes his own expected utility, the CEO will take into account both the probability of the takeover being successful (defeating the best competitor's offer) and the probability of being penalized ex-post, due to disappointing realized synergies with respect to the acquisition price. As shown in Mitchell and Lehn (1990), Kini *et al.*

(2004), and Lehn and Zhao (2006), potential dismissal is a real risk in practice. We model the CEO's decision process while assuming:

- Bids and prices are strictly increasing in the CEO's valuation (The conditions supporting this assumption will be explored in Section 2.)
- The CEO wage contract is given and exogenous. The interaction between CEO wages and M&A decisions would certainly be of great interest (empirical evidence points toward a connection between the two (see, e.g., Datta *et al.*, 2001; Rosen, 2004) and some interesting considerations can be found in Paredes (2005)) but this is beyond the scope of the present analysis;
- The form of ex-post penalty in case of disappointing synergies is also given and exogenous. In practice, it ranges from a one-shot financial penalty, through wage contract re-negotiation up to being fired, depending on the corporate governance mechanisms in place and the degree of CEO entrenchment. As with the CEO wage contract, a formal analysis of the interaction between M&A decisions, corporate governance mechanisms and entrenchment would be of interest (there is some interesting empirical evidence, see Mitchell and Lehn (1990)) but it is not the main focus of this paper. For ease of exposition, we assume the penalty is dismissal; but any other form of sanction would leave our analysis unchanged.

Outcomes. Three outcomes are possible (see Figure 1):

- **No Deal:** a competitor's acquisition price is higher or the target successfully rebuffs the bid;
- **Deal and CEO Retention:** the bid price is sufficient for the acquisition and realized synergies are sufficient for the CEO to avoid being fired;
- **Deal and CEO Dismissal**: the acquisition is successful but the CEO is fired due to disappointing ex-post synergies.

To determine his expected utility, the CEO takes into account the probability of the above potential outcomes as well as the expected compensation in each case. We denote φ_S the probability of a successful deal and φ_F the probability of being fired. Note that both probabilities increase with the acquisition price, which depends on the bid, a function of the CEO's valuation; formally:

$$\varphi_i = \varphi_i(p(\beta(v)) \text{ for } i \in \{S, F\}, \tag{1.4}$$

where *p(.)*, *β(.)* and *v* are, respectively, the price function, the bidding function and the CEO's valuation of the target. We mention this functional dependence explicitly only when necessary to avoid confusion and postpone to Section 2 the explicit analysis of *p(.)* and *β(.)*.

The two opposing forces at play in the CEO's decision problem give rise to the following conditions on the relations between the probabilities (φ_S and φ_F) and the target valuation:

- $\varphi_S' \equiv \dfrac{\partial \varphi_S}{\partial v} > 0$: the probability of a successful deal increases with target valuation;
- $\varphi_F' \equiv \dfrac{\partial \varphi_S}{\partial v} > 0$: the probability of dismissal increases also with target valuation

(remember that a higher valuation means a higher bid and, therefore, a higher paid price under our assumptions).

CEO wage contract. We use *L*, $B + bMV_T\widetilde{s}_t$ and *W* to denote various components of the CEO's compensation contract; viz.,

- *W* is the present value of the future compensation from existing activities;
- $B + bMV_T\widetilde{s}_t$ is the bonus in case of deal completion, composed of a fixed cash bonus *B* and a variable component *b*, linked to the synergies;
- *L* denotes the loss in the event of dismissal.

W, *B*, *b* and *L* are known positive constants.

This specification of the CEO compensation contract is in line with existing literature and with reality. For example, Hall and Liebman (1998) argue that CEOs are not paid like bureaucrats, since there is a strong relationship between firm performance and CEO compensation. During the 90s, equity-based compensation, which relates CEO remuneration to expected profits, has become the single largest source of income for US executives (see, e.g., Datta *et al.*, 2001, Hall and Murphy, 2002; Malmendier and Tate, 2006). Moreover, bonuses received by CEOs are significant after successful deal completions (see Grinstein and Hribar, 2004).

1.4. Expected Utility Maximization

We consider the case of a risk averse CEO (CEOs are known to be under-diversified - see Hall and Murphy (2002), Malmendier and Tate (2006), Becker (2006), Cai and Vijh (2006)). The expected utility of the CEO is given by:

$$E(U) = (1-\varphi_S)U(W) + \varphi_S(1-\varphi_F)E\left(U(W+B+bMV_T\widetilde{s}_t)\right) + \varphi_S\varphi_F U(W-L), \tag{1.5}$$

where $U(.)$ denotes the CEO utility function. We approximate it by an second-order Taylor series expansion around W. This leads to the following expressions:

$$U(W-L) = U(W) - LU'(W) + \frac{1}{2}L^2U''(W). \tag{1.6}$$

$$U(W+B+bMV_T\widetilde{s}_t) = U(W) + (B+bMV_T\widetilde{s}_t)U'(W) + \frac{1}{2}(B+bMV_T\widetilde{s}_t)^2U''(W). \tag{1.7}$$

Substituting Equations (1.6) and (1.7) into Equation (1.5) yields:

$$E(U) = U(W) + \varphi_S\begin{bmatrix}\left[(1-\varphi_F)(B+bMV_T\mu_s) - \varphi_F L\right]U'(W) \\ +\left[\varphi_F\dfrac{L^2}{2} + (1-\varphi_F)\dfrac{\left(b^2MV_T^2\hat{\sigma}_{s,t}^2 + (B+bMV_T\mu_s)^2\right)}{2}\right]U''(W)\end{bmatrix}. \tag{1.8}$$

The CEO chooses v, the target valuation, in order to maximize his expected utility. This leads to the following first order condition:

$$\begin{aligned}&\left[\varphi_S' - (\varphi_S\varphi_F)'\right](B+bMV_T\mu_s) - (\varphi_S\varphi_F)'L \\ &-\gamma\left[(\varphi_S' - (\varphi_S\varphi_F)')\frac{\left(b^2MV_T^2\hat{\sigma}_{s,t}^2 + (B+bMV_T\mu_s)^2\right)}{2} + (\varphi_S\varphi_F)'\frac{L^2}{2}\right] = 0\end{aligned}, \tag{1.9}$$

where γ is the absolute risk aversion coefficient $-U''(W)/U'(W)$.

1.5. Uncertainty specification

In order to solve the model (to obtain a closed form formula for the expected utility maximizing valuation of the target), we need to specify the probabilities φ_S and φ_F. Moreover, since these probability functions must be invertible for convenience we use uniform probability distributions. Although we specify φ_S and φ_F with respect to valuation, since it is the decision variable of the CEO, this is equivalent to specifying φ_S and φ_F with respect to prices, since prices are (assumed to be) an increasing function of bids, and bids are (assumed to be) an increasing function of valuations (see Equation 1.4).[8]

The probability of success φ_S. Financial markets determine the initial value of the target MV_T, which essentially fixes the minimum bid price. This minimum price also provides us with a natural lower bound for φ_S. Define V^- as $V^- = \beta^{-1}(p^{-1}(MV_T))$, this is to say the minimum target valuation such that the acquisition price would be MV_T. At V^-, the proposed acquisition price would be the target's current market value (MV_T) and there would be no incentive for target shareholders to sell their shares, so any deal attempt would fail with probability one (φ_S=0). The upper bound of φ_S should be determined by a valuation such that the deal attempt will succeed with certainty. We denote the corresponding valuation level as V_S^+, equal to some multiple of MV_T. φ_S is uniformly distributed between V^- and V_S^+. For a given valuation *v*, the probability of success is therefore $\varphi_S = (v - V^-)/(V_S^+ - V^-)$. Note that, as required, $\partial\varphi_S/\partial v$ is positive: the higher the valuation, the higher the probability of a successful deal.

The (conditional) probability of being dismissed φ_F. If CEO acquires the target, he risks being dismissed with probability φ_F. The target market value, MV_T, again provides a natural lower bound. Indeed, if *v* is equal to V^- (which means that the valuation is such that the proposed acquisition price is the current target market value), there is no reason for the CEO to be fired and φ_F should be zero.[9] Following the same logic as for φ_S, the upper bound of φ_F is defined as a target valuation level so high that the price paid would lead, with probability one, to highly disappointing ex-post realized synergies relative to the acquisition price. The CEO would then be

[8] Since φ_S and φ_F are cumulative density functions, they are strictly increasing in their arguments. As p(.) and β(.) are also increasing in their arguments, $\partial\varphi(p(\beta(v))/\partial v$ has the same sign as $\partial\varphi(v)/\partial v$.

[9] It could be argued that if the CEO has wasted a lot of his time and the time of others on valuing the deal, only to come up with the market value, maybe he should be fired for being wasteful. We abstract here from this complication for ease of exposition.

penalized (fired) with probability one. We denote this valuation level V_F^+. The probability of being fired is therefore uniformly distributed between V^- and V_F^+ and equal to $\varphi_F = (v - V^-)/(V_F^+ - V^-)$. We note that, as expected, $\partial\varphi_F/\partial v$ is positive: the higher the valuation, the higher the probability of being fired.

Common upper bounds. It is easy to see that, ex-ante, φ_S and φ_F must have common range. As explained above, they have the same lower bound V^-. Suppose that $V_F^+ > V_S^+$, for any valuation between V_F^+ and V_S^+, the deal would succeed with probability one and the probability of being fired would continue to increase. Hence, there would be no reason for the CEO to value the target above V_S^+. The same kind of argument applies for the case $V_F^+ < V_S^+$. So, we assume, without loss of generality, that $V_F^+ = V_S^+$: φ_S and φ_F have common range. We can now explicitly relate V_F^+ and V_S^+ to some multiple of the target market value MV_T. We denote it θ: $V_F^+ = V_S^+ = V^+ = \beta^{-1}(p^{-1}(\theta MV_T))$.

The unconditional probabilities. The probabilities of missing out on the deal, doing the deal and not being fired and doing the deal and being fired are respectively (see Figure 2) $(1-\varphi_S)$, $\varphi_S(1-\varphi_F)$ and $\varphi_S\varphi_F$.

- $(1-\varphi_S) = \dfrac{V^+ - v}{V^+ - V^-}$, the probability of missing out on the deal decreases linearly as v increases (see Figure 2, Panel A);
- $(\varphi_S(1-\varphi_F)) = \left(\dfrac{v - V^-}{V^+ - V^-}\right)\left(\dfrac{V^+ - v}{V^+ - V^-}\right)$, the probability doing the deal and not being fired is a concave function (see Figure 2, Panel B). When v is close to V^- (no premium over the prevailing market price), increasing v has a strong impact on the probability of doing the deal and not being fired. When v is still low, its impact on the probability of being fired is marginally low. When v is high, the probability of doing the deal (the sum of $(\varphi_S\varphi_F)$ and $\varphi_S(1-\varphi_F)$) increases but the probability of being fired eventually dominates;

- $(\varphi_S \varphi_F) = \left(\frac{v - V^-}{V^+ - V^-} \right)^2$, the probability of being fired (given that the deal attempt has succeeded) is convex (see Figure 2, Panel C). For high v the increase in the probability of being fired becomes significant. This captures the intuition that the corporate governance system (either internal or external) comes into play as a last resort mechanism. The CEO risks dismissal when the deal brings wealth destruction for bidder shareholders; but even below that extreme, dismissal is possible simply because the acquisition price is excessive relative to the realized synergies ex post. This property of our specification is consistent with the empirical results provided by Mitchell and Lehn (1990), Kini *et al.* (2004), and Lehn and Zhao (2006).

1.6. Reservation Value

Using the definition of φ_S and φ_F, we can now compute the derivative of φ_S and $(\varphi_S \varphi_F)$ with respect to v, the CEO valuation of the target:

$$\frac{\partial \varphi_S}{\partial v} = \frac{1}{V^+ - V^-} = \frac{1}{\beta^{-1}(p^{-1}(\theta MV_T)) - \beta^{-1}(p^{-1}(MV_T))}. \tag{1.10}$$

$$\frac{\partial(\varphi_S \varphi_F)}{\partial v} = \frac{2(v - V^-)}{(V^+ - V^-)^2} = \frac{2(v - \beta^{-1}(p^{-1}(MV_T)))}{\beta^{-1}(p^{-1}(\theta MV_T)) - \beta^{-1}(p^{-1}(MV_T))}. \tag{1.11}$$

Using equations (1.10) and (1.11), it is possible to solve the CEO's first order condition (Equation (1.9)). This results in Proposition 1.

Proposition 1. CEO's reservation value of the target

Under the assumptions of Sections 1.1 to 1.5, which can be summarized as CEO risk aversion, uniformly distributed probability of being penalized in case of disappointing ex-post realized synergies relative to the acquisition price and exogenous competition, a linear wage contract, Bayesian learning based on previous deal experience and efficient financial markets, the CEO's reservation valuation is:

$$\frac{v^* - V^-}{V^+ - V^-} = \frac{1}{2} \frac{(B + bMV_T\mu_s - \gamma/2\,(B + bMV_T\mu_s)^2) - \gamma/2\, b^2 MV_T^2 \hat{\sigma}_{s,t}^2}{((B + bMV_T\mu_s - \gamma/2\,(B + bMV_T\mu_s)^2) - \gamma/2\, b^2 MV_T^2 \hat{\sigma}_{s,t}^2) + (L + \gamma/2\, L^2)}. \tag{1.12}$$

Proposition 1 is a key to understanding the effect of learning on the CEO's decision process: it connects the CEO's reservation value (the maximum price he is willing to pay) to his risk aversion (γ), expected synergies (μ_s) and his perception of the risk associated with synergies ($\hat{\sigma}^2_{s,t}$). Equations (1.2) and (1.3) display the Bayesian updating process used by the CEO to incorporate signals sent by the market. So, the combination of Proposition 1 and equations (1.2) and (1.3) represent tools for exploring the learning mechanism. To use them fully, we must now establish the links between the CEO reservation value, his bidding function and his offering price function (up to now, we have simply assumed that these functions are strictly increasing in his valuation).

To interpret Proposition 1, we point out two features:

- $(B + bMV_T\mu_s - \gamma/2\,(B + bMV_T\mu_s)^2 - \gamma/2\,b^2MV_T^2\hat{\sigma}^2_{s,t})$ is the risk adjusted bonus and $(L + \gamma/2\,L^2)$ is the risk adjusted loss.
- the risk adjusted bonus must be positive. Proof: Note that the probabilities φ_S and φ_F, estimated at v^*, must (by definition) be positive. Also note that when L is zero (implying no loss in case of dismissal), Equation (1.12) implies v^* equals to $(V^+ + V^-)/2$. This is intuitive since the reservation value should maximize the probability of a successful takeover and not being fired (see Figure 2 – Panel B). However, if L is positive (which we assume), the optimal valuation is below $(V^+ + V^-)/2$ (see Figure 2, Panel B)[10]. In this region, the derivative of $\varphi_S(1-\varphi_F)$ with respect to v^* is positive. Computing this derivative and taking into account its positive sign leads to a positive risk adjusted bonus $(B + bMV_T\mu_s - \gamma/2\,(B + bMV_T\mu_s)^2 - \gamma/2\,b^2MV_T^2\hat{\sigma}^2_{s,t})$.

1.7. Determinants of the CEO's reservation value

The CEO's reservation value and the perceived synergies are connected through the CEO's wage contract. We study here how the CEO's reservation value will be affected by the expected bonus and its variance.

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[10] It can be shown that the derivative of v^* with respect to L is negative.

Expected bonus. We are interested in the sign of $\partial v^* / \partial(B + bMV_T\mu_s)$. A mechanical application of calculus rules to Equation (1.12) shows that, as $(B + bMV_T\mu_s)$ must be positive (see Section 1.6), the sign of the derivative is determined by the sign of $(1-\gamma(B + bMV_T\mu_s))$, which is positive if $(B + bMV_T\mu_s) < 1/\gamma$. We also know from Section 1.6 that $(B + bMV_T\mu_s) - (\gamma/2)(B + bMV_T\mu_s)^2$ must be greater than $(\gamma/2)b^2MV_T^2\hat{\sigma}_{s,t}^2$. This second condition translates into $(B + bMV_T\mu_s)$ smaller than $(2/\gamma) - (b^2MV_T^2\hat{\sigma}_{s,t}^2 / (B + bMV_T\mu_s))$. These two conditions lead to the situation presented in Figure 3:

- for $(B + bMV_T\mu_s)$ between 0 and $1/\gamma$: $\partial v^* / \partial(B + bMV_T\mu_s)$ is positive. An increase in the expected bonus leads to an increase in the CEO's reservation value.
- for $(B + bMV_T\mu_s)$ between $1/\gamma$ and $(2/\gamma) - (b^2MV_T^2\hat{\sigma}_{s,t}^2 / (B + bMV_T\mu_s))$, the derivative is negative. This second situation might seem strange as an increase in the expected bonus could lead to a decrease in the CEO's reservation value. Such a possibility is a consequence of the convexity of $\varphi_S\varphi_F$, depicted in Figure 2 – Panel C. A high expected bonus combined with a low bonus variance dramatically increases the CEO's loss in the event of dismissal. Rather than vigorously pursuing the deal, the CEO responds by reducing the risk of being fired. In short, he has more to loose than to win[11]. Such behavior is consistent with (internal or external) corporate control mechanisms that become more vigorous after value destruction (the unconditional probability of dismissal is convex with respect to the premium).
- if $\hat{\sigma}_{B,t} / (B + bMV_T\mu_s)$ is greater than $1/\gamma$ (the risk of the expected bonus is high and/or its expectation is low), $\partial v^* / \partial(B + bMV_T\mu_s)$ is unambiguously positive.

Expected bonus variance. The sign of $\partial v^* / \partial b^2MV_T^2\hat{\sigma}_{s,t}^2$ depends on the sign of the derivatives of $(b + bMV_T\mu_s) - (\gamma/2)(b + bMV_T\mu_s)^2 - (\gamma/2)b^2MV_T^2\hat{\sigma}_{s,t}^2$ with respect to $b^2MV_T^2\hat{\sigma}_{s,t}^2$. The risk aversion coefficient γ being positive by definition, the sign of $\partial v^* / \partial b^2MV_T^2\hat{\sigma}_{s,t}^2$ is negative. An increase in the (perceived) variance of the expected bonus leads to a decrease in the CEO's reservation value.

To sum-up, we obtain the following results:

[11] A similar argument is used by Barro (2006) to explain the equity premium puzzle.

- for $0 \leq (B + bMV_T\mu_s) < \frac{1}{\gamma}$:

$$\frac{\partial v^*}{\partial(B + bMV_T\mu_s)} > 0 \tag{1.13}$$

- for $\frac{1}{\gamma} < (B + bMV_T\mu_s) < (\frac{2}{\gamma}) - \left(\frac{b^2 MV_T^2 \hat{\sigma}_{s,}^2}{(B + bMV_T\mu_s)}\right)$:

$$\frac{\partial v^*}{\partial(B + bMV_T\mu_s)} < 0 \tag{1.13'}$$

- and

$$\frac{\partial v^*}{\partial b^2 MV_T^2 \hat{\sigma}_{s,t}^2} < 0 \tag{1.14}$$

Having established results (1.13) and (1.14), we can focus on their implications for CEO learning.

2. Bidding and buying the target

The previous section derived the CEO's reservation value for the target. Valuations are however not observable *as such*. They are one of the main drivers of decisions but only the decisions themselves are observable. Within the M&A context, the CEO's decision is the bid chosen in the attempt to acquire the target. Hence, we have to associate bids with valuations. This is however only an intermediate step. The ex post observable acquisition price will only emerge after bids have been confronted with rival bids and target shareholders reactions. The acquisition price essentially determines whatever wealth is created or destroyed for the bidding firm's shareholders. This section is dedicated to filling in the details between valuations, bids and ex-post observable prices.

In Section 1, we assumed that the CEO bidding function and the resulting price function were strictly increasing in his valuation. This assumption played an important role, as it allowed us to go back and forth from the valuation space to the price space. What are the sufficient conditions for such an assumption to hold? To provide an answer to this question, in such a way that empirical predictions can be provided, we have to consider the wide diversity of contexts in which M&A operations can take place.

When talking about the M&A market, most often, large and highly publicized takeover contests come into mind. Already in the beginning of the eighties, the Conoco takeover (Ruback, 1982) attracted a great deal of attention. Since then, numerous M&A announcements have been tracked by the financial press (a recent example being Mittal – Arcelor). It is by reference to these cases that target acquisitions have most often been modeled as ascending auctions (see Bullow *et al.* (1999) or Betton *et al.* (2005)), in which a set of bidders compete to acquire a target, putting increasing bids on the table until all but one bidders quit. Under some restrictive assumptions (independent private valuations, quasi-linear payoffs, risk-neutral bidders), the Myerson's lemma holds (see Theorem 3.3 in Milgrom (2004)) and the ascending auction is revenue and pay-off equivalent to the second best price auction, which simplifies greatly the analysis. But public tender offers represent only one form taken by M&A operations and, even if they are frequently very large deals, they represent a minority of cases. Schwert (2000) reports 763 tender offers out of 2,346 deals (33%) during the period 1975-1996. Hostile bids are even less frequent. Andrade *et al* (2001), studying the period 1973-1998, report the percentage of hostile bids varying from 4% (1990-1998) to 14.3% (1980-1989).

How then are firms sold in the remaining cases? Boone and Mulherin (forthcoming *Journal of Finance*) report new and interesting results. The authors study a sample of 400 acquisitions from the nineties. Using data from SEC merger documents, they show that half of the targets were auctioned among multiple bidders and that the remaining half were sold through a direct negotiation between the parties. Hansen (2001) studies in detail the process with which firms are auctioned by financial intermediaries; a key difference from tender offers is frequent use of a sealed-bid first price auction. In contrast, for direct negotiation acquisitions, there is no direct competition. To sum-up, there are at least three distinct forms of M&A deals: public tender offers, private auctions organized by financial intermediaries and direct negotiation between the parties. This section is devoted to the bidding and pricing implications of each type.

The three most important issues are:

- CEO risk-aversion;
- Acquirers' asymmetry: Section 1 models how learning affect private valuations of the target. But learning comes from experience accumulated with previous deals and previous deals are publicly known. Therefore, when potential acquirers compete to buy a target, they know something about the historical records of each other. This implies an asymmetry in the information about previous valuations. In ascending auctions or first

price sealed-bid auctions, this asymmetry is presumably taken into account by rational bidders. Asymmetry among potential acquirers' is explicitly modeled in Povel and Singh (2006), where the authors establish how targets should optimally sell themselves;

- positive correlation of acquirers' valuations: a major empirical phenomenon about M&As is their appearance in waves (see, e.g., Mitchell and Mulherin, 1996). It has been argued that it could be due to systematic mis-valuations in financial markets (Shleifer and Vishny, 2003) or to common market or industry wide shocks (Harford, 2004). Common shocks are a clear source of positive correlation between synergies potentially implemented by acquirers.

Having identified the key features to take into account, we are led to Proposition 2 below. Proofs are provided in Appendix 2, so the text is limited to a summary of the intuition. Note that the analysis is based on the Bayesian Nash equilibrium concept and the Harsanyi coherence doctrine.

Proposition 2. Bidding and price functions

Auctions. *Under the assumptions of risk averse CEOs (with a monotonic and log supermodular utility function), asymmetric but positively correlated reservation valuations and competition limited to two acquirers, the equilibrium bidding and price functions in tender offers and private auctions are strictly increasing in the reservation value of the winning CEO.*

Bargaining. *Under the assumptions of a risk averse acquirer CEO (with a monotonic and log supermodular utility function) and a target with random positively correlated reserve price, the equilibrium bidding and price functions are strictly increasing in the CEO's reservation value.*

Proofs: see Appendix 2.

The bidding and price determination mechanisms of tender offers and private auctions are respectively the open ascending auction and the sealed-bid first-price auction. In the case of an ascending auction, the auctioneer starts the process at some low price and increases it progressively. Bidders quit the auction as the price rises until only one bidder remains. The last bidder wins the auction and pays the price that prompted the second-to-last bidder to exit. In an ascending auction, the dominant strategy is therefore to bid one's own risk-adjusted valuation[12]: by quitting at an inferior price level, the bidder looses the opportunity to make a profitable

[12] It is important to stress that a CEO is not going to bid his expected valuation because he is risk averse and the valuation is risky (see Section 1.) Hence, the dominant strategy is to bid a risk-adjusted valuation v^* . In this sense, the combination of uncertain valuation and risk aversion produces an effect analogous to the winner's curse anticipation, which translates also into an ex-ante bid reduction.

acquisition but by bidding more, he risks paying more than the target is really worth. This result holds even in the case of risk aversion, asymmetry and correlation. So, in an ascending auction, the bidding function is increasing in the reservation valuation. The acquisition price, conditionally on winning the auction, is the risk-adjusted valuation of the next-to-last bidder. If the bidders' valuations are independent, there is no connection between a given bidder's risk-adjusted valuation and the winning price. If, however, bidders' valuations are positively correlated, then an increase in a given bidder's risk-adjusted valuation will be statistically associated with an increase in other bidders' risk-adjusted valuations. In such a case, the price function is increasing with the next-to-last bidder risk-adjusted valuation.

Let us now turn to the case of a sealed-bid first price auction. The winning bidder is the one who proposes the highest price and he will pay his bid. The determination of the equilibrium bidding function is based, in this case, on the maximization of the bidder's expected payoff. As shown in Appendix 2, in the case of risk aversion, asymmetry and positively correlated valuation, we obtain (using the framework of Maskin and Riley (2000b)) a set of differential equations that characterizes equilibrium behaviors of bidders. Technical arguments (using the single crossing difference condition and the monotonic selection theorem – see Milgrom (2004)) show that the induced equilibrium bidding function is increasing in the bidders' valuation. As the price paid by the winning bidder is his own bid, the price function (by definition) is also increasing in the (winning) bidder's valuation.

In direct negotiations, the bidding behavior of the acquirer is influenced by some form of information asymmetry (see Hansen (1987) for an application involving the choice of payment medium). We capture this asymmetry by assuming that the seller's reserve price is unknown to the acquirer. Assuming moreover that the dominant strategy of the acquirer is a first and final offer (see Samuelson (1984) for an analysis of the context in which such a result holds), the equilibrium bidding function of the acquirer can easily be derived. The same technical arguments as used for first-price sealed-bid auctions imply that the bidding function is increasing in the bidder valuation. Since the bidder pays his own bid if accepted by the seller, the price function is (again by definition) increasing in the bidder's valuation.

3. Ex-post observable implications

This section is devoted to the observable consequences of Propositions 1 and 2. Since deals are publicly announced for listed acquirers, market reactions are typically available. However, bids and premiums over the target's value are more problematic. Among other difficulties is the complexity of payments (e.g., a package containing stock, cash and other contingent claims) and the paucity of information about private targets. Perhaps these empirical constraints explain why most recent large sample studies focus on acquirers' CARs (see Table 1).[13] We begin this section by establishing the relation between bids, prices and market reactions to deal announcements (CARs). We then study how Propositions 1 and 2 help to deliver empirical predictions about CARs and the time between successive deals (TBD.) Finally, we look at how hubris affects these predictions.

3.1. Investor information and the CAR

Strong-form market efficiency would imply that investors could, using bids, invert the CEOs' utility function to deduce his private valuation. But strong-form efficiency is an unsustainable assumption (see Grossman and Stiglitz (1980)). More important, it seems implausible that investors actually know any CEOs utility function.[14] Consequently, we rely on the more compelling semi-strong version of market efficiency, wherein investors process all pertinent public information.[15]

Schipper and Thompson (1983) and Malatesta and Thompson (1985) emphasize that the market reaction at the start of an acquisition program capitalize the anticipated wealth effects of the whole program, not just that of the current single acquisition. Hence market reactions to subsequent deal announcements are merely revisions of the initial anticipation and are affected only by the incremental information content. This acquisition program anticipation effect does not suggest any particular trend in the observed CAR from deal to deal (except that the CAR for the

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[13] One exception is Officer (forthcoming *Journal of Financial Economics*), where the author produces evidence on acquisition discounts obtained for unlisted targets using the comparable industry transaction method.

[14] Note that strong-form efficiency also implies that investors would, at the very first deal announcement of an acquisition program, form an unbiased anticipation of the whole acquisition program's wealth creation, taking into account the CEO's private information and his anticipated future learning. Reactions to successive deal announcements would then be driven entirely by new information so the CAR pattern from deal to deal would be purely random.

[15] We are aware that the long-term (abnormal) performance literature is still debating semi-strong formefficiency (see Fama (1998)). However, many short-term event studies still rely on it implicitly.

first deal should be larger – at least in absolute value – since its contains more information.) So, if we adhere to the acquisition program anticipation effect, predictions about the CAR from deal to deal must be understood as predictions about the trend of anticipations revisions rather than about the trend of wealth effects *per se*.

We can now formally establish the link between the CEO's reservation valuation, his bidding behavior, the acquisition price and market reactions as measured by the CAR. The acquirer CAR around the announcement date is:

$$CAR_A = \frac{\left(\dfrac{\mu_s MV_T}{R}\right) - \left(p(\beta(v^*)) - MV_T\right)}{MV_A} \tag{3.1}$$

where MV_A is the acquirer market value and $1/R$ is the discount factor. Abnormal returns are the difference between the risk adjusted expected synergy and the premium paid to acquire the target, divided by the acquirer's market value. Under our semi-strong efficiency assumption, investors' synergy anticipation is μ_s. This explains why, in Section 1, market reactions to deal announcements were modeled as signals $\tilde{\eta}_t$ drawn from $N(\mu_s, \sigma_\eta^2)$; i.e., market reactions are unbiased. From Proposition 2, bids and ex-post prices are strictly increasing in the CEO's reservation value v^*; consequently, Equation (3.1) highlights the negative relation between ex-post observed abnormal returns and the CEO's valuation:

$$\frac{\partial CAR_A}{\partial v^*} = -\frac{1}{MV_A}\frac{\partial p(\beta(v^*))}{\partial v^*} < 0\,. \tag{3.2}$$

Equation (3.2) connects the CEO's reservation value to investors' reactions. We are now in position to better understand the observable implications of learning and hubris.

3.2. Empirical implications of learning

As explained in Section (1.2), learning is the process by which the CEO incorporates signals sent by the market at each deal announcement. The Bayesian updating rule progressively forms more precise beliefs about the potential synergies (Equation (1.3)). Learning has implications for both the pattern of CARs from deal to deal and the probability that the CEO succeeds in making a deal.

The CAR from deal to deal. Using equations (3.2) and (1.14), it is now possible to explore the implications of learning on the observed CAR around deal announcements. The logical consequences of rational CEO's learning are presented in Figure 4 – Panel A - left chart: the more the CEO learns (receives signals from the market), the more accurate his forecasting ability, and the lower $\hat{\sigma}^2_{s,t}$ (see Equation (1.3)). A decrease in $\hat{\sigma}^2_{s,t}$ leads to an increase in the CEO's reservation value (see Equation (1.14)), which translates (by Proposition 2) into more aggressive bidding behavior and higher acquisition prices. Consequently, the acquirer's CAR (see Equation (3.2)) declines from deal to deal. This conclusion seems counterintuitive but it is simply a consequence of the risk reduction that learning allows. According to our model, the results cited in Table 1 are compatible with learning (with the exception of Billet and Qian (2005), who report systematically negative CAR). Therefore, a declining CAR trend from deal to deal does NOT necessarily imply the existence of hubris. Our conclusion is obtained with a constant investment opportunity set (constant μ_s from deal to deal) and thus is not caused by decreasing investment opportunities. It is not a consequence of hubris (or any other form of cognitive bias), since the CEO know the true expected synergy μ_s and is a Bayesian updater. Instead, it is a direct consequence of learning.

The probability of doing deals and the TBD. More aggressive bidding affects the probability of a deal. This can be seen for tender offers[16], as analyzed in Section 2 (and Appendix 2). Recall that the derivation is limited to two rival potential acquirers competing for a given target. Denote by $F_{v_j^*}(.|v_i^*)$ the cumulative probability distribution of CEO *j's* (the opponent) reservation value conditional on CEO *i's* reservation value (the reservation value are positively correlated). Then, the probability that CEO *i* wins the competition is simply:

$$\Pr(\text{CEO}_i \text{ valuation} > \text{CEO}_j \text{ valuation}) = F_{v_j^*}(v_i^*|v_i^*). \tag{3.3}$$

So, the effect of learning on the probability of winning the competition is:

$$\frac{dF_{v_j^*}(v_i^*|v_i^*)}{d\hat{\sigma}^2_{i,t}} = f_{v_j}(v_i^*|v_i^*)\frac{dv_i^*}{d\hat{\sigma}^2_{i,t}} \leq 0 \ . \tag{3.4}$$

[16] A similar argument is valid for the cases of private auction and direct negotiation.

On the right of the equality in (3.4), the first term is a density function and is therefore non-negative and the second term is negative by Equation 1.14. Since learning, by Equation (1.3) reduces $\hat{\sigma}^2_{i,t}$, learning leads to an increase in the probability of acquiring the target. This is intuitive: the higher the valuation, the more aggressive the bidding behavior, the higher the probability of outbidding competitors, *ceteris paribus*. Since the investment opportunity set is constant (the number of acquisition opportunities per time period is constant), learning brings a reduction in the average elapsed TBD (see Figure 4 – Panel A – right chart).

3.3. On the implications of hubris and ex-post sample selection bias

Hubris. How does hubris affect the empirical implications of learning? To explore such an issue, we must first define precisely what hubris means. Following Malmendier and Tate (2006), hubris is a cognitive bias in the CEO's decision making process. Hubris can affect either the CEO's initial perception (the anticipated synergy at the first deal attempt), or his learning process (the interpretation of market reactions to past deals), or both. For simplicity, we now assume that hubris affects the CEO's initial perception.[17] If he is not fired after completing his first acquisition, we assume he will learn something, despite the initial hubris. From deal to deal, this learning process should bring a progressive correction of the initial bias. Perhaps this assumption does not describe the behavior of every CEOs seemingly infected by hubris (well-known instances reported in the financial press do allow for much optimism… (Bernard Ebbers of WorldCom, Dennis Kozlowski of Tyco, and Jean-Marie Messier of Vivendi Universal, among others.) But it seems reasonable to presume that CEOs unable to overcome hubris will be fired at a higher rate than others who correct erroneous initial assessments. Learning CEOs should therefore have a higher survival rate.[18]

A CEO's initial perception may be biased in two dimensions: with respect to expected synergies or with respect to the perceived volatility of synergies. Hubris can be characterized as over-optimism ($\hat{\mu}_{0,s} > \mu_s$) or as over-confidence ($\hat{\sigma}^2_{0,t} < \sigma^2_{0,t}$). Since either cognitive biases leads to the same empirical predications, we analyze only the first case and define a hubris-infected CEOs as having the prior $N(\hat{\mu}_{0,s}, \hat{\sigma}^2_{s,0})$, with $\hat{\mu}_{0,s} > \mu_s$. The immediate consequence is that Equation (1.2) no longer holds:

[17] Analyzing the empirical consequences of growing hubris from deal to deal could be a promising future research avenue, perhaps pertinent to large and active serial acquirers headed by notoriously overconfident CEOs.

[18] This raises a question of why, in the long run, any CEOs at all remain hubris infected. Perhaps an endogenous treatment of corporate governance mechanisms would provide the key to an answer, an interesting issue for future research.

$$\hat{\mu}_{s,t} = \frac{\left(\frac{1}{\hat{\sigma}_{s,0}^2} \hat{\mu}_{0,s} + \frac{1}{\sigma_\eta^2} \sum_{i=1}^{t-1} \eta_i \right)}{\frac{1}{\hat{\sigma}_{s,0}^2} + (t-1) \frac{1}{\sigma_\eta^2}} > \mu_s \tag{3.5}$$

But, if signals send by the market are informative:

$$\lim_{t \to \infty} \hat{\mu}_{s,t} = \frac{\left(\frac{1}{\hat{\sigma}_{s,0}^2} \hat{\mu}_{0,s} + \frac{1}{\sigma_\eta^2} \sum_{i=1}^{t-1} \eta_i \right)}{\frac{1}{\hat{\sigma}_{s,0}^2} + (t-1) \frac{1}{\sigma_\eta^2}} = \mu_s \tag{3.6}$$

The CEO's perception of expected synergies converges towards the true population value: learning progressively corrects the initial distorted perception.

Before exploring the empirical predictions of hubris, we should mention that the cognitive bias does not by itself violate the Harsanyi coherence doctrine. So long as the CEO's beliefs remain internally consistent, the Bayesian Nash equilibrium solution concept used in Section 2 remains well defined.

As hubris infected CEOs (or equivalently over-optimistic CEOs in our setup) over-value the target; using the implications of Proposition 2, they overbid. Following the same reasoning as in Section 3.2, they over-pay for the target. One should therefore observe either an initial negative CAR or a surprisingly low initial CAR (with respect to the true potential synergies).[19] With subsequent learning, the same CEOs should progressively correct their initial perceptions, improve their valuation abilities, bid more cautiously, and reduce any value destruction. But, as they bid less aggressively, they should win less frequently in competition with other acquirers. These predictions are summarized in Figure 4 – Panel B and C.[20] In the case of a negative initial CAR (Panel B), the source of learning is the negative investor reaction at the first deal's announcement. In the case of a low initial CAR (relative to the true synergies), the source of the

[19]Overbidding will not necessarily result in a negative CAR if synergies are high enough. The hubris-infected CEO bid could concede too high a fraction of the wealth created to target shareholders but still retain some wealth for acquiring shareholders.

[20]As explained in Section 1.7 (see equations (1.13) and (1.13')), we must remain careful at this point of the analysis. For already highly remunerated CEOs, risk-aversion could lead to the opposite behavior.

learning could be the action of a well-informed shareholder (who is aware of the CEO's overbidding behavior) or the CEO's reaction to a disappointingly low CAR.

These implications contrast sharply with the literature's previous contention that hubris-infected CEO's should experience a declining CAR from deal to deal. If hubris-infected CEOs also learn (an assumption difficult to dismiss out of hand, particularly given internal and external corporate governance mechanisms), the observed CAR trend should actually be growing (in the case of Panel C, at least relative to the CAR that would have been observed with rational CEOs.) The decreasing rhythm (i.e., growing TBD) for hubris-infected CEOs is indirectly pointed out in Conn *et al.* (2004).

Sections 3.2 and 3.3 imply our third and final proposition.

Proposition 3. Empirical implications of learning and hubris

Under the assumptions of Proposition 1 and Proposition 2, assuming semi-strong form market efficiency, the CAR and TBD trends of acquisition programs undertaken by rational CEOs should be decreasing (see Figure 4 – Panel A). For hubris infected CEOs, (whose cognitive biases are assumed to affect their prior perceptions of expected synergies), the CAR and TBD trends of acquisition programs should be increasing (see Figure 4 – Panels B and C).

Proposition 3 contains a strong claim: hubris infected CEOs (if hubris is characterized by a biased prior perception of expected synergies) should generate increasing CARs from deal to deal because of learning. Moreover, the predictions of Proposition 3 on both the CAR and the TBD, for rational and hubris infected CEOs, are specific to our learning framework. In particular, decreasing investment opportunities could explain a declining CAR, but it would be common to both types of CEOs.

Ex-post sample selection biases and errors-in-variable issues. Although we have derived clear empirical implications of learning and hubris, empirical tests of the above predictions are subject to important difficulties. Two of the most important are likely to be sample selection biases and errors-in-variables.

Roll (1986) describes the potential impact of the winner's curse and hubris on the ex-post observed abnormal returns. Our analysis suggests a second sample selection phenomenon; viz., we do not observe deals that would have been undertaken by dismissed CEOs. These two biases work in opposite directions:

- as explained in Roll (1986), hubris-infected CEOs overbid and are subject to the winner's curse. Since we observe mainly those who consummate deals, we most probably observe a disproportionate number of over-optimistic CEOs.
- conversely, CEOs who pay too much for targets are more likely to be fired. Hence, a disproportionate number of surviving CEO's are less likely to be hubris infected.

Which of these two biases dominates? The answer to this empirical question depends, *inter alia*, on the pressure of corporate control mechanisms (the convexity of $\varphi_S \varphi_F$ in Section 1) and on the strength of hubris (the amplitude of the difference $\hat{\mu}_{0,s} - \mu_s$).

Figure 4 – Panels A and C reveal an errors-in-variable problem. The sub-sample of acquisition programs characterized by an initial positive CAR should include both rational CEOs (Panel A) and hubris-infected CEOs (Panel C). This mixture will weaken the ex-post empirically observable consequences of learning, as the ex-post observable trend of CAR and BTD will depend on the relative proportion of rational and hubris-infected CEOs. Only the use of some exogenous instrument to identify hubris-infected CEOs could completely resolve this problem.

A final comment: As highlighted in Panel C of Figure 4, the CAR for hubris-infected CEOs may be positive at the beginning of the M&A program. Then, if instead of learning, CEOs become subject to even more hubris, one might observe the same patterns as in Panel A (for learning rational CEOs), but most probably with a smaller or even negative CAR. Therefore, what is really unique to our learning setup are predictions of Panel B and C. They can not be generated by growing hubris or a shrinking investment opportunity set. The key to an empirical test is therefore to identify a subsample of CEOs that (i) destroy wealth at the first deal and (ii) are most likely hubris infected.

4. Conclusion

The declining trend of CARs in acquisition programs is an empirical fact. The theory presented here suggests that the pattern is not necessarily due to CEOs infected by hubris. Economically motivated risk averse rational CEOs who learn from investor reactions to past deal announcements, should adopt a behavior that leads to the observed empirical pattern. However, the declining CAR trend could be due to other causes, such as a declining investment opportunity set or increasing competition during merger waves.

But our learning hypothesis delivers specific and unique predictions that can serve as the bases for distinguishing empirical tests. These predictions are about both the announcement period cumulative abnormal return of acquiring firms (the CAR) and about the time between successive acquisitions, (TBD), for both rational and hubris infected CEOs. In short, rational CEOs, learning form deal to deal, should bid more aggressively over time. The fraction of synergies they concede to target shareholders should increase over time, leading to a declining CAR, and more frequent success in beating competitors, hence reducing also the TBD). The reverse should hold for hubris-infected CEOs.

Sample selection biases and errors-in-variables issues loom as important conundrums in empirical tests. In particular, hubris-infected CEOs exposed to both the winner curse and survival bias. Further, a potential mixture of rational and hubris-infected CEOs in the wealth-creating sub-sample of CEOs call for the use of exogenous instruments allowing the identification of hubris-infected CEOs.

Our conclusions are obtained within a private valuation framework where synergies are assessed without considering potential competing bidders. Extending the analysis to a common value framework might bring additional insights. In common-value auctions, bidders' valuations depend on the valuations of competitors, which are revealed by their bidding behavior. Modeling such a situation is complex but perhaps worthwhile.

Notations and conventions

~	Indicates a random variable
^	Indicates a perceived value of a population parameter
μ_s	Population (or real) value of expected synergies
$\hat{\mu}_{s,t}$	Expected synergies at deal *t* as perceived by the CEO
MV_T	Target market value
$\tilde{s}_t$	Synergies created by the merger
σ_s^2	Population (or real) value of the variance of synergies
$\hat{\sigma}_{s,t}^2$	Variance of the synergies at deal *t* as perceived by the CEO
$\tilde{v}_t$	Signal sent by the market at deal *t* announcement about potential synergies
σ_v^2	Variance of the signals sent by the market (market informativeness)
φ_S	Probability of successful deal
φ_F	Probability of CEO being firing due to disappointing synergies ex post
v	CEO valuation of the target
$p(.)$	Price function
$\beta(.)$	Bidding function
W	Present value of the CEO's current wage contract
L	Penalty incurred by the CEO from being dismissed
$B + b\tilde{s}_t$	CEO bonus associated with a successful deal (*B* is the fixed part and *b* is the variable part)
$U(.)$	CEO Utility function
γ	CEO risk aversion
V^-	Minimum valuation of the target to have any chance of a successful deal
$V_S^+ = \beta^{-1}(p^{-1}(\theta MV_T))$	Target valuation, defined as some multiple θ of the current market value, such that the induced bid guarantees that the deal attempt will succeed with probability one
$V_F^+ = \beta^{-1}(p^{-1}(\theta MV_T))$	Target valuation, defined as some multiple θ of the current market value, such that the induced price would be so high that ex-post synergies would be highly disappointing and would lead, with probability one, to the CEO being fired.
$F_{v_j^*}(.\vert v_i^*)$	The distribution of CEO *j* reservation values conditional on CEO *i* reservation values
$\pi_i(b, v_i^*)$	CEO *i* expected surplus when he has valuation v_i^* and bids *b*.

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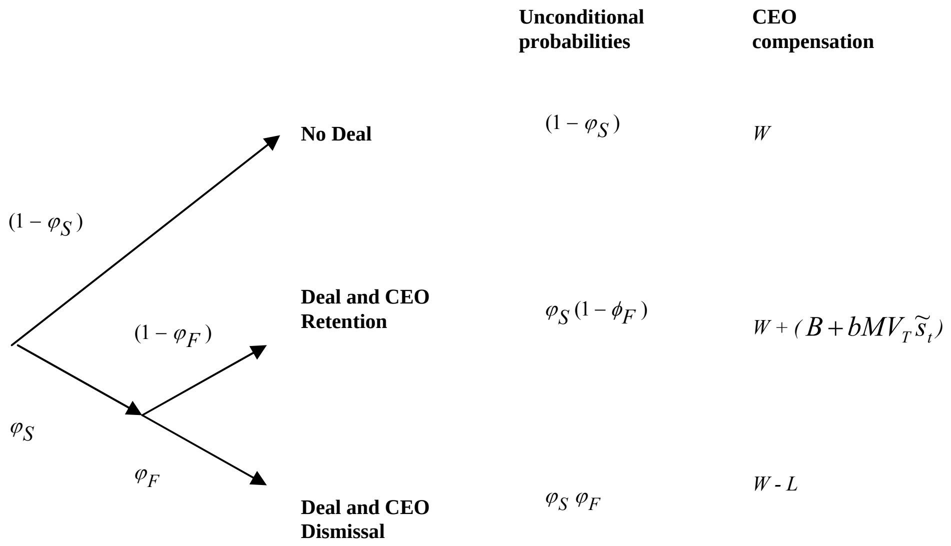
Table I

Evidence From the Literature on Bidders' CAR Patterns Across Deals

This table displays average bidders' cumulative abnormal returns (CAR) during acquisition programs. *N* is the total number of acquisitions in the sample.

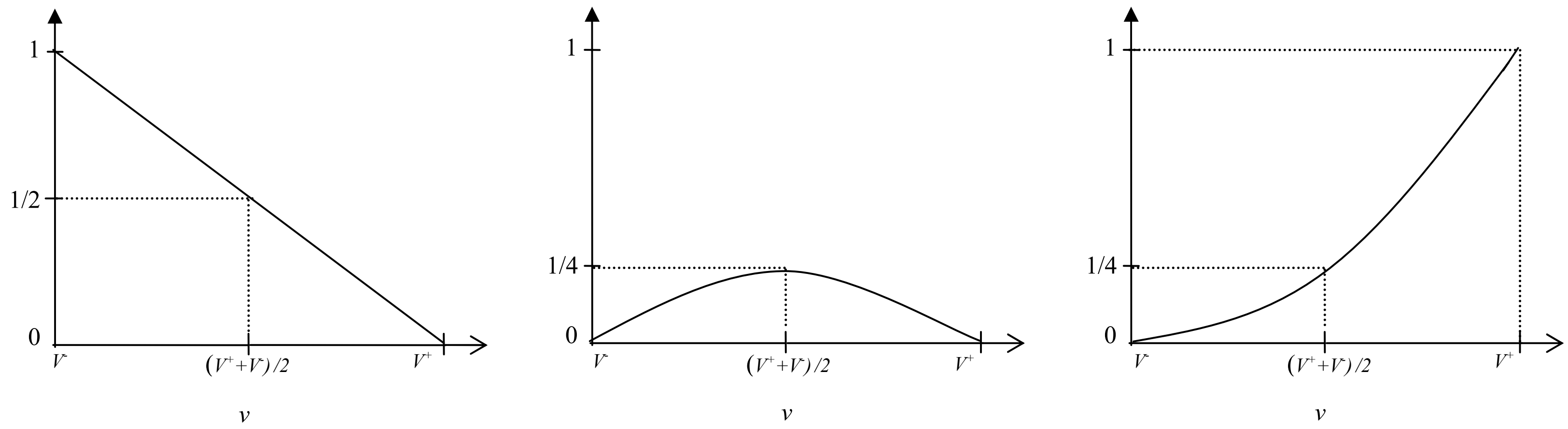
	Sample features	**Deal sequence**					
Fuller *et al.* (2002)	Period: 1990-2000		**1st**			**5th and >5**	
5-day Market-Adjusted	*N*=3,135		2.74%			0.52%	
CAR	U.S. bidders						
Croci (2005)	Period: 1990-2002	**1st**	**2nd**	**3rd**	**4th**	**5th**	**>5**
5-day Market Model	*N*=4,285	1.60%	1.62%	1.13%	1.00%	1.12%	-0.41%
CAR	U.S. bidders						
Billett and Qian (2005)	Period: 1985-2002	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
5-day Market Model	*N*=3,702	-0.10%	-1.54%	-1.37%	-1.66%	-1.21%	-1.74%
CAR	U.S. bidders and listed U.S. targets						
Ismail (2006)	Period: 1985-2004	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
5-day Market Model	*N*=16,221	1.41%	1.52%	1.44%	0.81%	0.22%	0.32%
CAR	U.S. bidders						
Conn *et al.* (2005)	Period: 1984-1998;	**1st**	**2nd – 3rd**			**>3**	
3-day Market-Adjusted	*N*=3,842	0.88%	0.46%			-0.16%	
CAR	U.K. bidders						
Ahern (2006)	Period: 1981-2004	**1st**	**2nd**	**3rd**	**4th**	**5th**	**>5**
5-day Market –Adjusted	*N*=12,942	3.19%	2.10%	1.53%	1.52%	0.84%	-0.11%
CAR	U.S. bidders						

Figure 1



The CEO's decision problem. φ_S denotes the probability of a successful deal and φ_F the probability of being dismissed after disappointing ex-post realized synergies with respect to the acquisition price, conditionally on having done the deal. W, $B + bMV_T\widetilde{s}_t$, and L denote, respectively, the present value of the CEO's current compensation, his bonus after deal completion and his loss from being dismissed.

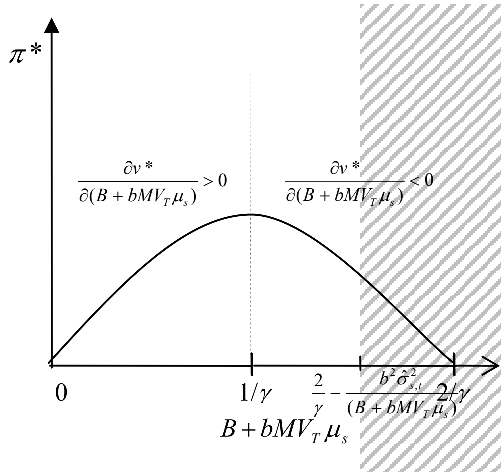
Figure 2



Panel A. No Deal | Panel B. Deal and CEO Retention | Panel C. Deal and CEO Dismissal

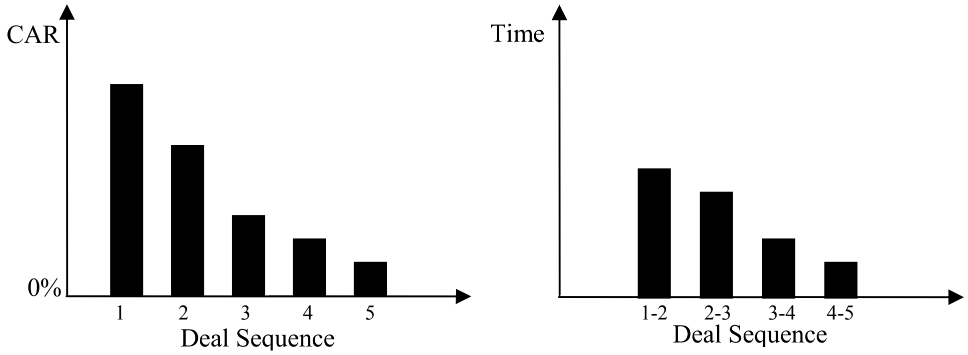
Unconditional probabilities as functions of target valuation *v*. Panel A plots the probability of missing out on the deal, which decreases linearly as *v* increases. Panel B shows the probability doing the deal and not being fired. Panel C plots the probability of being fired, given that the CEO has completed the acquisition. The y-axis gives the probability, and the x-axis gives the level of *v*.

Figure 3

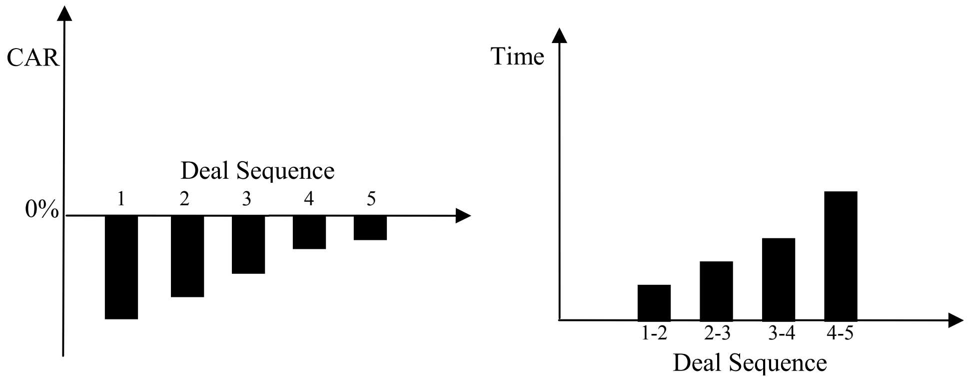


The CEO's reservation value as a function of the expected bonus. The curve depicted plots the CEO's reservation value with respect to $(B + bMV_T \mu_s)$, which is the expected bonus in case of deal completion. The dashed area denotes the zone of inadmissible parameter values. If $(B + bMV_T \mu_s) > (2/\gamma) - (\hat{\sigma}_{s,t}^2 / (B + bMV_T \mu_s))$ than some unconditional probability outcomes are negative.

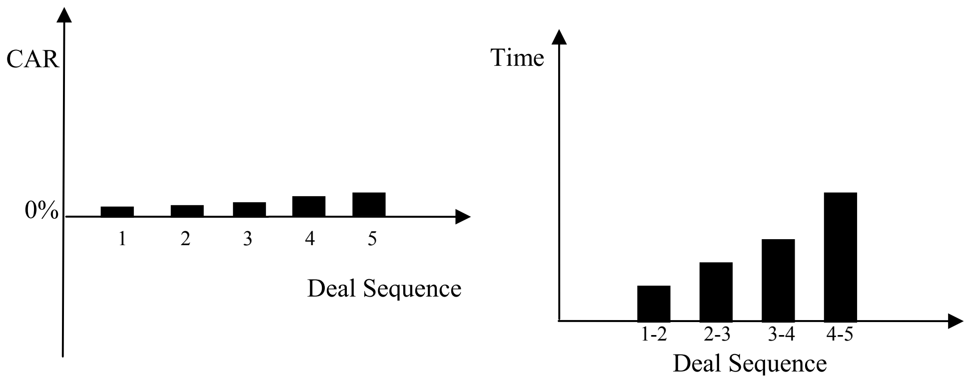
Figure 4



Panel A. Rational CEOs



Panel B. Hubris infected CEOs – initial negative CAR



Panel C. Hubris infected CEOs – initial disappointing CAR

Bidder cumulative abnormal returns (CAR) and time between successive deals (TBD). The X-axis represents the deal sequence order number in an acquisition program undertaken by the same CEO. The Y-axis is either the ex-post observable CAR or the TBD. Panel A – left chart, considering rational CEOs, shows the declining pattern of ex-post observable CARs from deal to deal, as a consequence of the learning process. The associated right chart highlights the shortening TBD. Panel B, focusing on hubris infected CEOs, illustrates the opposite pattern. Panel C summarizes predictions for hubris-infected CEOs when investors' reactions are positive but disappointing.

Appendix 1

Market value of the target in case of acquisition: an alternative specification

As in Section 1, the synergy potentially created by the merger is not perfectly known to the acquirer. We denote it $\tilde{s}_t$. We however specify this time the target market value (MV_T) in case of deal completion as:

$$MV_T \big| \text{acquisition} = MV_T \times e^{\tilde{s}_t} \tag{A1.1}$$

instead of Equation (1.1). This modification sets the lower bound on the target market value to zero in case of acquisition. We still assume that $\tilde{s}_t$ follows a Gaussian distribution $N(\mu_s, \sigma_s^2)$.

In this modified setup, the CEO's bonus follows a log-normal distribution with first and second moments given by:

$$E\left(B + bMV_T(e^{\tilde{s}_t} - 1)\right) = B + bMV_T\left[e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} - 1\right] \tag{A1.2}$$

(instead of $B + b\mu_s$ in the Section 1 setup).

$$\begin{aligned} E\left(\left(B + bMV_T(e^{\tilde{s}_t} - 1)\right)^2\right) &= B^2 + b^2 MV_T^2\left[e^{2\mu_s + 2\hat{\sigma}_{s,t}^2} - 2e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} + 1\right] \\ &+ 2bMV_T\left[e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} - 1\right] \end{aligned} \tag{A1.3}$$

(instead of $b^2 MV_T^2 \hat{\sigma}_{s,t}^2 + (B + bMV_T\mu_s)$ in the Section 1 setup).

By doing the necessary adjustments to Section 1.6, the CEO's reservation value of the target becomes:

$$\frac{v^* - V^-}{V^+ - V^-} = \frac{1}{2}\frac{B + bMV_T\left[e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} - 1\right] - \gamma/2\left[B^2 + b^2MV_T^2\left[e^{2\mu_s + 2\hat{\sigma}_{s,t}^2} - 2e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} + 1\right] + 2bMV_T\left[e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} - 1\right]\right]}{\left(B + bMV_T\left[e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} - 1\right] - \gamma/2\left[B^2 + b^2MV_T^2\left[e^{2\mu_s + 2\hat{\sigma}_{s,t}^2} - 2e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} + 1\right] + 2bMV_T\left[e^{\mu_s + \frac{1}{2}\hat{\sigma}_{s,t}^2} - 1\right]\right]\right) + \left(L + \gamma/2\, L^2\right)} \tag{A1.4}$$

So, using the Equation (A1.1) specification and properties of the log-normal distribution, we can still derive the CEO's reservation value. Equation (A1.4) can be used to explore, as in Section 1.7, the determinants of the CEO's reservation value. For example, it can be shown that a sufficient condition for the CEO's reservation value to decline with perceived synergies is that the risk aversion coefficient γ be bigger than 2.

To sum-up, it is technically possible to adopt a specification such that the lower bound of the target market value in case of acquisition is zero. But this complicates the exposition without providing more insights.

Appendix 2

Proofs of proposition 2

A2.1 Tender offers

Tender offers are a form of ascending open (or English) auction.[21] We assume private valuations (the CEO's reservation values obtained at Proposition 1), risk-averse and asymmetric bidders (the CEOs in competition). Valuations are positively correlated.[22] We limit our analysis to the case of two bidders (denoted *i* and *j*) and analyze the situation from the point of view of bidder *i*. This restriction simplifies greatly the analysis but the results here could be extended to the case of *N* bidders, in the more general framework of Milgrom and Weber (1982). We denote by $F_{v_j^*}(.|v_i^*)$ the distribution of CEO *j's* reservation value conditional on CEO *i's* reservation value (and by $f_{v_j^*}(.|v_i^*)$ the corresponding density function). The positive statistical association between CEO valuations is captured by assuming that $F_{v_j^*}(.|v_i^*)$ has increasing differences:

$$\forall v_j^{*+} > v_j^*, v_i^{*+} > v_i^* : F_{v_j^*}(v_j^{*+}|v_i^{*+}) - F_{v_j^*}(v_j^*|v_i^{*+}) \geq F_{v_j^*}(v_j^{*+}|v_i^*) - F_{v_j^*}(v_j^*|v_i^*) \qquad \text{(A2.1)}$$

These increasing difference conditions are equivalent to imposing that $\partial F(v_j^*|v_i^*)/\partial v_j^*$ is increasing in v_i^*. In other words, the higher CEO *i's* reservation value, the higher the rate at which the CEO *j's* valuation is increasing.

Equilibrium bidding function

By using classical game theory arguments, it is straightforward to show that the dominant strategy for each CEO is to bid up to his own risk-adjusted reservation value. The arguments are as follows:

- assume the CEO *i* chooses a bid *b* above his own risk-adjusted reservation value v_i^*. If he looses the tender offer, his payoff is zero. If he wins, he has to pay *b* > v_i^*. But by the definition of the risk-adjusted reservation value, he get a negative payoff;
- assume the CEO *i* chooses a bid *b* below his own risk-adjusted reservation value v_i^*. If CEO *j's* bid is such that CEO *i* wins the tender offer, since the price paid by CEO *i* is the price level at which CEO *j* quits, CEO *i* would have had the same payoff by bidding v_i^* instead of *b*. But, if the

[21] English auction are auctions in which the auctioneer, starting from an initial low price, progressively increases the price, until when only one bidder remains. The bidder left then pays this final price.

[22] Since Milgrom and Weber (1982), the more general concept of affiliation has been introduced in auction theory to deal with statistically interdependent valuations. Positive correlation is a special case of affiliation (see Milgrom (2004), p. 137).

CEO *j's* bid is between *b* and v_i^*, the CEO *i* will loose the tender offer while he would have won by bidding v_i^* with a positive payoff. The CEO *i* is therefore worse off bidding *b* instead of v_i^*. Irrespective of asymmetry, risk-aversion and correlated valuations, the equilibrium bidding strategy for bidder *i* is therefore simply to bid his risk-adjusted reservation value:

$$\beta(v_i^*) = v_i^* \tag{A2.2}$$

The equilibrium bidding function is clearly increasing in the CEO's risk-adjusted reservation value. Note that, even if the arguments developed here are the same as those used to prove the equivalence between the ascending open auction and the second-best price auction in an independent private value setup, this equivalence does not extend to the case of *N* bidders with correlated valuations. Milgrom and Weber (1982) show how to model the dominant strategy in an ascending auction in such a framework.

Expected payment conditional on winning

The ex-post observable price is the price paid by the winner of the tender offer. In the open ascending auction setup with two acquirers, it is the expected bid (or risk-adjusted reservation value) of the loosing acquirer:

$$p(v_i^* \big| v_j^* < v_i^*) = \int_{V^-}^{v_i^*} v_j^* f_{v_j^*}(v_j^* \big| v_i^*) dv_j^* \tag{A2.3}$$

Note that, using Equation (A2.2), this is equivalent to:

$$p(\beta(v_i^*) \big| \beta(v_j^*) < \beta(v_i^*)) = \int_{\beta(V^-)}^{\beta(v_i^*)} \beta(v_j^*) f_{\beta(v_j^*)}(\beta(v_j^*) \big| \beta(v_i^*)) d\beta(v_j^*) \tag{A2.3'}$$

The derivative of the price function with respect to the CEO *i* reservation value v_i^* is:

$$\frac{\partial p(v_i^* \big| v_j^* < v_i^*)}{\partial v_i^*} = v_j^* f_{v_j^*}(v_j^* \big| v_i^*) + \int_{V^-}^{v_i^*} \frac{dv_j^* f_{v_j^*}(v_j^* \big| v_i^*)}{dv_i^*} dv_j^* \tag{A2.4}$$

By the increasing differences property of $F(v_j^* \big| v_i^*)$ (see Equation (A2.1)), the derivative of the price function with respect to CEO *i's* risk-adjusted reservation value v_i^* is therefore positive. The ex-post observable price is an increasing function of the CEO's risk-adjusted reservation value. It is interesting to note this result is obtained thanks the increasing differences property of $F_{v_j^*}(.|v_i^*)$. If valuations were independent, Equation (A2.4) would be equal to zero. The increase in the CEO *i* risk-adjusted valuation would have a positive impact on his own equilibrium bid but would have no effect on the equilibrium bid of the rival and, therefore, no effect on the price paid when winning the tender offer contest. In the setup of open ascending auctions, it is actually the positive statistical association between the valuations that induces price increases with valuations.

A.2. Private auctions

We now turn to the case of private auctions organized by financial intermediaries. Hansen (2001) provides an in-depth presentation of the institutional setting of such auctions. The key feature for our analysis is that these are usually sealed bid first-price auctions. They are very different from open ascending auctions and a question is whether bids and price are still strictly increasing in valuation. The analysis has to take into account CEO risk aversion, asymmetry and interdependent valuations.

Equilibrium bidding function

Asymmetric first price auctions are analyzed in Maskin and Riley (2001b). The authors study a setup where there is a strong bidder and a weak bidder. We assume the strong bidder is a CEO that has made acquisitions in the past (and has learned) – denote him CEO *i* - and the weak bidder as less experienced – denote him CEO *j*. Maskin and Riley (2001b) do not explicitly deal with risk aversion and interdependence. However, assuming that the CEOs utility functions are log supermodular[23] and considering the interdependence between valuations and the private nature of valuations, Proposition 5 of Maskin and Riley (2001a) establishes the existence of a pure strategy equilibrium in a first-price auction. As pointed out by the authors, sufficient conditions for the log supermodularity of the utility function are that preferences are monotonic and exhibit either risk aversion or risk neutrality. Risk aversion is assumed here and monotonic preferences are by construction since the CEO's reservation value is obtained by maximizing his expected utility (Section 1.4).

Following Maskin and Riley (2001b), denote by $\pi_i(b, v_i^*)$ CEO i*'s* expected surplus when he bids *b* and has valuation v_i^*. The CEO *i* decision problem is then:

[23] In a private-value setup, log supermodularity imposes the following restriction: $\dfrac{\partial^2 \log \pi_i(b, v_i^*)}{\partial b \partial v_i^*} \geq 0$, where $\pi_i(b, v_i^*)$ is the CEO *i* expected surplus.

$$
\begin{aligned}
&\underset{b}{\text{Max}}\,\pi(b,v_i^*)\\
&=\underset{b}{\text{Max}}\,U_i\left(v_i^*-b\right)\Pr(v_j^*<\beta_j^{-1}(b)\big|v_i^*)\\
&=\underset{b}{\text{Max}}\,U_i\left(v_i^*-b\right)F_{v_j^*}(\beta_j^{-1}(b)\big|v_i^*)
\end{aligned}
\tag{A2.5}
$$

We first take the log to obtain:

$$
\underset{b}{\text{Max}}\log\pi(b,v_i^*)=\underset{b}{\text{Max}}\left[\log(U_i\left(v_i^*-b\right))+\log(F_{v_j^*}(\beta_j^{-1}(b)\big|v_i^*))\right] \tag{A2.6}
$$

and then differentiate with respect to *b* to obtain the following first order condition:

$$
\frac{-U_i\,'(v_i^*-b)}{U_i(v_i^*-b)}+\frac{f_{v_j^*}(\beta_j^{-1}(b)\big|v_i^*)}{F_{v_j^*}(\beta_j^{-1}(b)\big|v_i^*)\beta_j(v_j^*)}=0 \tag{A2.7}
$$

Applying the same development to CEO *j*, we obtain the characterization of the equilibrium bidding functions in our setup (the equivalent of Equation (3.12) in Maskin and Riley (2001b)[24]):

for CEO *i*:

$$
\frac{f_{v_j^*}(\beta_j^{-1}(b)\big|v_i^*)}{F_{v_j^*}(\beta_j^{-1}(b)\big|v_i^*)\beta_j(v_j^*)}=\frac{U_i\,'(v_i^*-b)}{U_i(v_i^*-b)};
$$

(A2.8)

for CEO *j*:

$$
\frac{f_{v_i^*}(\beta_i^{-1}(b)\big|v_j^*)}{F_{v_i^*}(\beta_i^{-1}(b)\big|v_j^*)\beta_i(v_i^*)}=\frac{U_j\,'(v_j^*-b)}{U_j(v_j^*-b)}.
$$

Equation (A2.8) characterizes the equilibrium bidding functions of CEO *i* and CEO *j*. To ascertain whether they are increasing in their respective reservation values, one can appeal to the monotonic selection theorem (Milgrom (2004), Theorem (4.1)). Assuming log supermodular utility, the expected surplus

[24] The boundary conditions emanating from the common range argument (equation (3.13) in Maskin and Riley (2001b)) apply also in our setup.

function $\pi_i(b, v_i^*)$, satisfies the strict single crossing difference conditions.[25] Therefore, by monotonic selection, the CEOs' equilibrium bidding functions $\beta_i(v_i^*)$ and $\beta_j(v_j^*)$ must be non-decreasing in their respective reservation values. It remains to be proved that they are strictly increasing.

Assume the contrary. Then, there would exist a range of reservation values v_i^* for which CEOs would offer a constant bid *b*;

- with some probability, ties would occur.[26] In case of ties, each of the two CEOs could win with probability one instead of probability ½ by increasing their bid by a small amount ε. Since ε (the cost of increasing the bid) can be arbitrarily small, it would always be profitable to increase the bid.
- ties are therefore incompatible with the equilibrium and the equilibrium bidding functions must be strictly increasing in the CEOs reservation values.

Expected payment conditional on winning

The ex-post observable price in the sealed-bid first price auction is the bid of the winning bidder. We have just established that the CEOs bidding functions are strictly increasing in their reservation values, so we know that this holds also for prices.

A.3. Direct negotiation

Direct negotiations involve bargaining between a single acquirer and a single target. As pointed out in the introduction of Section 2, direct negotiations between parties are frequent in merger deals. Samuelson (1984) studies optimal bargaining with information asymmetry. He shows that a bidder facing informational asymmetry about the value of the good, will find it optimal to make a first and final offer. Hansen (1987) uses this insight to investigate the role of the payment medium in the context of M&As. We use here the same setup to explore bidding behavior (and the ex-post observable price consequences) of the CEO.

Assuming that it's optimal for the acquiring CEO to make a first and final offer, we still need to worry about the source of information asymmetry. It seems natural way to presume that the acquiring CEO is uncertain about the target shareholders' reserve price. We denote the distribution of the target

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[25] To see this, note that $(\partial^2 \log \pi_i(b, v_i^*) / \partial b \partial v_i^*) \geq 0$, which is the constraint imposed by the log supermodularity assumption in a private value setup, is one of the sufficient conditions to insure that the single crossing difference condition is fulfilled (see Milgrom (2004), p. 100, condition (ii)).

[26] With continuous support of the reservation valuations, the probability of ties ($v_i^* = v_j^*$) is zero but the probability that the reservation valuations fall in the same range is strictly higher than zero.

shareholders' reserve price by $F(r|v_i^*)$, using intentionally the same notation as for the distribution of competitors' valuations in the two previous auction contexts discussed above.

Equilibrium bidding function

In such a setup, the acquiring CEO *i* maximizes:

$$\begin{aligned}&\underset{b}{\text{Max}}\ \ \pi(v_i^* - b)\\ &= \underset{b}{\text{Max}}\ \ U_i(v_i^* - b)F(b|v_i^*)\end{aligned}. \tag{A2.9}$$

As with sealed-bid first price auctions, taking the log and writing the first-order condition, we obtain the equation characterizing the optimal CEO *i* bid:

$$\frac{U'_i(v_i^* - b)}{U_i(v_i^* - b)} = \frac{f(b|v_i^*)}{F(b|v_i^*)}. \tag{A2.10}$$

The same arguments used in the case of sealed-bid first-price auctions still hold: the utility function is assumed to log supermodular, the CEO expected surplus therefore satisfies the single crossing difference conditions. By monotonic selection, the CEO optimal bidding function is non-decreasing in his reservation value. Only the arguments used to prove the strictly increasing behavior of the optimal bidding function change. The intuition is as follows:

- assume the optimal bidding function is not strictly increasing. Then, there would exist a range of reservation values v_i^* for which CEOs would offer a constant bid *b*;
- but, over this range of constant bids, the probability of doing the deal is constant while v_i^* is increasing. So, increasing by some *ε* the bid would be like buying partial insurance providing a higher probably of succeed in the deal. Since risk averse decision makers value positively insurance contracts, such a decision would have a positive impact on the expected surplus of the CEO.
- this is incompatible with optimality. The CEO bidding function must therefore be strictly increasing in v_i^*.

Expected payment conditional on winning

As for the case of the sealed-bid first-price auctions, the ex-post observable acquisition price (the price conditional on a successful deal attempt) is the acquirer's bid. It is therefore strictly increasing in v_i^*.