

ONLINE APPENDIX

Behavioral CEOs – The role of managerial overconfidence

Ulrike Malmendier and Geoffrey Tate

This Online Appendix contains (A) the model referred to in the paper, (B) a full version of Table 1 in the main paper.

Ulrike Malmendier is Edward J. and Mollie Arnold Professor of Finance at the Haas School of Business and Professor of Economics, University of California, Berkeley, California. Geoffrey Tate is Associate Professor of Finance, Kenan-Flagler Business School, University of North Carolina, Chapel Hill, North Carolina. Their email addresses are ulrike@berkeley.edu and Geoffrey_Tate@kenan-flagler.unc.edu.

(A) Model on how managerial overconfidence affects corporate investment:

1. Model Set-up

Consider a firm with existing assets A and s shares outstanding. At time 1, cash flow C is realized. The CEO chooses the level of (internal or external) investment $I \in [0, \infty)$ and a means of financing – internal cash flow or external capital. The investment generates a (weakly positive) stochastic future return, realized at time 2. We denote the expected return to investment I as $R(I)$, with $R' > 0$ and $R'' < 0$ for all I . To guarantee interior solutions, we also assume that $R'(I) \geq 1$ for some I . The risk-free rate is normalized to zero. An overconfident CEO overestimates future returns by a percentage $\Delta_R > 0$ and overestimates the value of existing assets by a percentage $\Delta_A > 0$, with $\Delta_R = \Delta_A = 0$ embedding the benchmark case of a rational CEO. For all levels of investment I , the CEO expects the return to be $R(I) \cdot (1 + \Delta_R)$.

In terms of the source of financing, we consider the choice between cash (including non-diluting assets such as risk-free debt) and equity, and ignore alternative sources of risky external financing, such as risky debt, for simplicity. New shareholders demand an equity stake equal in value to the amount of capital they provide. Hence, in this setting, equity is the only financial instrument for which the CEO's overestimation results in disagreement about the appropriate price.

2. Maximization Problem

Let c denote the amount of cash financing and s' is the number of new shares issued to finance the investment. Then the CEO solves the following problem to maximize the current shareholder value in an efficient market:

$$\max_{I, s', c} \frac{s}{s + s'} [A(1 + \Delta_A) + C + R(I)(1 + \Delta_R) - c] \quad (1)$$

$$\text{s.t. } \frac{s'}{s + s'} (A + C + R(I) - c) = I - c \quad (2)$$

$$c \leq C, c \leq I \quad (3)$$

$$c \geq 0, I \geq 0 \quad (4)$$

Let (I^*, c^*) be the solution to the CEO's maximization problem (1) – (4). Further, let \hat{I} be the level of investment such that $R'(\hat{I}) = \frac{1}{1+\Delta_R}$, and I_{FB} be the level of investment that satisfies $R'(I_{FB}) = 1$. As we will see, \hat{I} and I_{FB} are the levels of investment an overconfident CEO and, respectively, a rational CEO desire to implement if not faced with any frictions. The following proposition characterizes the financing choice of non-overconfident and overconfident CEOs.

PROPOSITION 1. *A rational CEO is indifferent between all available sources of capital for an investment project. An overconfident CEO first exhausts internal (or other riskless) sources of financing before turning to risky external financing.*

Proof of Proposition 1. Solving equation (2) for s' yields $s' = s \frac{I-c}{A+C+R(I)-I}$. Substituting into the objective function, we can rewrite the maximization problem as follows¹:

$$\begin{aligned} \max_{I,c} & A(1 + \Delta_A) + C + R(I)(1 + \Delta_R) - (I \\ & - c) \frac{A(1 + \Delta_A) + C + R(I)(1 + \Delta_R) - c}{A + C + R(I) - c} - c \end{aligned} \quad (\text{A1})$$

$$\text{s.t } c \leq C, c \leq I \quad (\text{A2})$$

$$c \geq 0, I \geq 0 \quad (\text{A3})$$

For simplicity, we ignore the non-negativity constraints $c \geq 0$ and $I \geq 0$, and show instead that the optimal solution to the unconstrained problem satisfies them. (See also Lemma 1.) Let λ and ν be the Lagrange multipliers on the constraints $c \leq C$ and $c \leq I$, respectively. Then, the following conditions determine the optimal investment and financing plan:

$$\begin{aligned} R'(I^*)(1 + \Delta_R) - \frac{A(1 + \Delta_A) + C + R(I^*)(1 + \Delta_R) - c^*}{A + C + R(I^*) - c^*} - (I^* - c^*) \\ \cdot \frac{(A + C + R(I^*) - c^*)R'(I^*)(1 + \Delta_R) - R'(I^*)[A(1 + \Delta_A) + C + R(I^*)(1 + \Delta_R) - c^*]}{(A + C + R(I^*) - c^*)^2} \\ + \nu = 0 \end{aligned} \quad (\text{A4})$$

¹ Notice that we need $A + R(I^*) > I^* - C$ for this problem to be well defined, i.e., the value of the company (including the returns to the investment project) cannot be less than the amount of external financing needed. The condition is implied if $R(I^*) > I^*$, or even just $R(I^*) > I^* - C$.

$$\frac{A(1 + \Delta_A) + C + R(I^*)(1 + \Delta_R) - c^*}{A + C + R(I^*) - c^*} - \frac{(\Delta_R R(I^*) + \Delta_A A)(I^* - c^*)}{(A + C + R(I^*) - c^*)^2} - 1 \quad (\text{A5})$$

$$- \lambda - \nu = 0$$

$$\lambda(c^* - C) = 0, \nu(c^* - I^*) = 0 \quad (\text{A6})$$

$$\lambda \geq 0, \nu \geq 0.$$

By (A1), a CEO maximizes

$$G = A(1 + \Delta_A) + C + R(I)(1 + \Delta_R) - (I - c) \frac{A(1 + \Delta_A) + C + R(I)(1 + \Delta_R) - c}{A + C + R(I) - c} - c.$$

Then $\frac{\partial G}{\partial c} = \frac{(\Delta_A A + \Delta_R R)(A + C + R(I) - I)}{(A + C + R(I) - c)^2} > 0$ for an overconfident CEO since $A + R(I^*) > I^* - C$

and $\Delta_R > \Delta_A > 0$. Thus an overconfident CEO maximizes the value for original shareholders after the realization of the investment on $c \in [0, I]$ by setting c as high as possible (which also guarantees the non-negativity constraints). Yet for rational CEOs, $\frac{\partial G}{\partial c} = 0$ since $\Delta_R = \Delta_A = 0$. **Q.E.D.**

The following Lemma summarizes the resulting investment choices of rational and overconfident CEOs.

LEMMA 1. (i) A rational CEO chooses the first-best level of investment, $I^* = I_{FB}$, regardless of the available cash flow. (ii) An overconfident CEO overinvests if he is cash-rich ($C \geq \hat{I}$), $I^* = \hat{I} > I_{FB}$, but curbs the overinvestment if he is cash-poor ($C < \hat{I}$), $\hat{I} > I^*$. If cash-poor, he still overinvests, $\hat{I} > I^* > I_{FB}$, if he overestimates the returns of the new investment more than those of the existing assets ($\Delta_R > \Delta_A > 0$). He may underinvest relative to the rational benchmark if instead $\Delta_A > \Delta_R > 0$, i.e., if he overestimates returns to the existing firm more, namely, in cases where he has to issue new equity to implement the desired financing.

Proof of Lemma 1.

(i) If the CEO is rational, i.e., $\Delta_R = \Delta_A = 0$, then conditions (A4) and (A5) simplify to

$$R'(I^*) - 1 + \nu = 0 \quad (\text{A7})$$

$$-\lambda - \nu = 0 \quad (\text{A8})$$

From (A8), we must have $\lambda = -\nu$. But, since the multipliers must be non-negative, we conclude that $\lambda = \nu = 0$. Thus, from (A7), $R'(I^*) = 1$ and $I^* = I_{FB}$. Further, all financing plans c^* satisfying (A2) and (A3) at I^* are optimal.

(ii) If the CEO is rational, i.e., $\Delta_R > 0$ and $\Delta_A > 0$, we need to distinguish the cases $\nu = 0$ and $\nu > 0$.

If $\nu = 0$, the constraint $c \leq I$ does not bind at I^* . Thus, this case includes all optimal plans in which the CEO issues shares ($s' > 0$). From conditions (A5),

$$\lambda = \frac{(A + C + R(I^*) - c^*)^2 + (\Delta_R R(I^*) + \Delta_A A)(A + C + R(I^*) - I^*)}{(A + C + R(I^*) - c^*)^2} - 1 \quad (\text{A9})$$

Then, since $A + R(I^*) > I^* - C$, $\lambda > 0$. Thus, $c^* = C$ from (A6), and (A3) is satisfied.²

From condition (A4),

$$\begin{aligned} R'(I^*) &= \frac{1}{1 + \Delta_R \frac{(A + C - c^*)(A + C + R(I^*) - I^*)}{[A(1 + \Delta_A) + C + R(I^*)(1 + \Delta_R) - c^*](A + C + R(I^*) - c^*)} - \Delta_A \frac{A(A + C + R(I^*) - I^*)}{[A(1 + \Delta_A) + C + R(I^*)(1 + \Delta_R) - c^*](A + C + R(I^*) - c^*)}} \end{aligned} \quad (\text{A11})$$

And, substituting $c^* = C$,

$$R'(I^*) = \frac{1}{1 + (\Delta_R - \Delta_A) \frac{A(A + C + R(I^*) - I^*)}{[A(1 + \Delta_A) + R(I^*)(1 + \Delta_R)](A + R(I^*))}} \quad (\text{A12})$$

Notice that $c^* = C$ and $c^* \leq I^*$ imply $C \leq I^*$. With $R(I^*) \geq 0$, $A > 0$, $C \leq I^*$, and $A + R(I^*) > I^* - C$, we have $\frac{1}{1 + \Delta_R} < R'(I^*) < 1$ if $\Delta_R > \Delta_A > 0$ and $\frac{1}{1 + \Delta_R} < 1 < R'(I^*)$ if $\Delta_A > \Delta_R > 0$. Thus, as $R'' < 0$, when an overconfident CEO overestimates the return of the investment to a greater extent than the overestimation of current asset ($\Delta_R > \Delta_A > 0$), he overinvests ($\hat{I} > I^* > I_{FB}$). However, when an overconfident CEO overestimates the current assets more than the return of the investment ($\Delta_A > \Delta_R > 0$), he perceives external financing as overly costly and therefore underinvests ($\hat{I} > I_{FB} > I^*$). Note that overinvestment is mitigated by the perceived external financing cost ($\hat{I} > I^*$) when $\Delta_R > \Delta_A > 0$. By implication, $C < \hat{I}$ in both cases.

Now, suppose $\nu > 0$. Then $c^* = I^*$, and the optimal financing plan does not include equity ($s' = 0$). Using (A5),

² Notice that all cash and debt capacity is exhausted before the CEO will issue equity, as shown in Proposition 1.

$$\lambda = \frac{A(1 + \Delta_A) + C + R(I^*)(1 + \Delta_R) - c^*}{A + C + R(I^*) - c^*} - 1 - \nu \quad (\text{A13})$$

Solving for ν and substituting in (A4) gives

$$R'(I^*)(1 + \Delta_R) - 1 - \lambda = 0 \quad (\text{A14})$$

First, consider $\lambda = 0$. Then, $R'(I^*) = \frac{1}{(1 + \Delta_R)}$, which implies $I^* = \hat{I} > I_{FB}$. Further, as $c^* \leq C$, we have $C \geq \hat{I}$. All financing plans c^* satisfying $0 \leq c^* \leq C$ and $c^* = I^*$ are optimal.

Next, consider $\lambda > 0$. Then, from (A6), $c^* = C$ and (A3) is satisfied. Further, $R'(I^*) = \frac{1 + \lambda}{(1 + \Delta_R)} > \frac{1}{(1 + \Delta_R)} = R'(\hat{I})$. Thus, as $R''(I^*) < 0$, $I^* < \hat{I}$ and, by implication, $C < \hat{I}$. Hence even if the overconfident CEO does not issue any new equity to finance the investment, the level of (over)investment is still lower than the level of investment for non-cash constrained overconfident CEOs due to the perceived cost of external finance. Finally, by (A13) and (A14), $R'(I^*) = \frac{A(1 + \Delta_A) + R(I^*)(1 + \Delta_R)}{A(1 + \Delta_R) + R(I^*)(1 + \Delta_R)} - \frac{\nu}{A(1 + \Delta_R) + R(I^*)(1 + \Delta_R)}$. Since $\nu > 0$, $R'(I^*) < \frac{A(1 + \Delta_A) + R(I^*)(1 + \Delta_R)}{A(1 + \Delta_R) + R(I^*)(1 + \Delta_R)} < 1$ and $I_{FB} < I^*$ if $\Delta_R > \Delta_A > 0$. The overconfident CEO overinvests when overestimating the return more than current assets. On the other hand, if $\Delta_A > \Delta_R > 0$, then $R'(I^*) = 1 + \frac{A(\Delta_A - \Delta_R)}{A(1 + \Delta_R) + R(I^*)(1 + \Delta_R)} - \frac{\nu}{A(1 + \Delta_R) + R(I^*)(1 + \Delta_R)}$. Thus the CEO overinvests ($R'(I^*) < 1$ and $I_{FB} < I^*$) if $0 < A(\Delta_A - \Delta_R) < \nu$, and underinvests ($R'(I^*) > 1$ and $I_{FB} > I^*$) if $A(\Delta_A - \Delta_R) > \nu > 0$.

PROPOSITION 2. (i) If the CEO is rational, the level of investment I^* is independent of internal cash flow C . (ii) If the CEO is overconfident, I^* is increasing in the amount of available cash flow C .

Proof of Proposition 2.

(i) For $\Delta_R = \Delta_A = 0$, $R'(I^*) = 1$ implies that I^* is independent of C .

(ii) For $\Delta_R > 0$, $\Delta_A > 0$, we first consider the case $\nu = 0$. (A12) gives

$$\frac{dI^*}{dC} = - \frac{(\Delta_R - \Delta_A)AR'(I^*)}{R''(I^*)[(A(1 + \Delta_A) + R(I^*)(1 + \Delta_R))(A + R(I^*)) + (\Delta_R - \Delta_A)A(A + C + R(I^*) - I^*)] + 2R'(I^*)(R'(I^*) - 1)(1 + \Delta_R)(A + R(I^*))}$$

Then, with $A > 0$ and $A + R(I^*) > I^* - C$,

$$0 < R'(I^*) < 1, C \leq I^*$$

and $R''(I^*) < 0$ imply $\frac{dI^*}{dC} > 0$.

Note that $C < \hat{I}$.

We now consider the case $\nu > 0$. Since $I^* = \hat{I}$ it is independent of C over the subset $C \geq$

\hat{I} . For $C < \hat{I}$, we have instead $I^* = C$ and thus $\frac{dI^*}{dC} = 1 > 0$.

Q.E.D.

(B) Full Version of Table 1

CEO Overconfidence and the Sensitivity of Corporate Investment to Cash Flow

	Full Sample		Speculative Grade and Unrated Debt		Investment Grade Debt	
	(1)	(2)	(3)	(4)	(5)	(6)
Q	0.046 *** (0.004)	0.036 *** (0.005)	0.046 *** (0.005)	0.034 *** (0.007)	0.038 *** (0.005)	0.035 *** (0.006)
Size	-0.046 *** (0.007)	-0.042 *** (0.008)	-0.059 *** (0.009)	-0.050 *** (0.012)	-0.025 *** (0.007)	-0.015 (0.010)
Stock Ownership	0.054 (0.049)	-0.018 (0.061)	0.033 (0.053)	-0.056 (0.065)	0.150 (0.095)	0.177 (0.163)
Vested Options	0.273 (0.284)	0.226 (0.348)	0.217 (0.332)	0.273 (0.446)	0.528 (0.516)	-0.083 (0.534)
Efficient Board Size	-0.001 (0.006)	-0.007 (0.007)	-0.010 (0.014)	-0.031 (0.022)	-0.001 (0.006)	-0.005 (0.006)
Longholder	-0.006 (0.007)	-0.006 (0.008)	-0.011 (0.011)	-0.029 * (0.015)	-0.002 (0.007)	0.005 (0.009)
Cash Flow (CF)	0.057 ** (0.022)		0.036 (0.035)		0.056 * (0.031)	
Efficient Board Size * CF	-0.004 (0.007)	0.004 (0.010)	-0.001 (0.012)	0.022 (0.023)	-0.002 (0.008)	0.006 (0.010)
Stock Ownership * CF	0.016 (0.035)	0.073 (0.049)	0.001 (0.035)	0.088 * (0.048)	0.067 (0.090)	0.112 (0.156)
Vested Options * CF	-0.183 (0.265)	0.022 (0.355)	-0.232 (0.379)	-0.019 (0.509)	0.097 (0.274)	0.607 (0.453)
Size * CF	0.000 (0.002)	-0.007 (0.008)	0.000 (0.003)	-0.005 (0.010)	0.001 (0.003)	-0.014 (0.011)
Q * CF	-0.003 * (0.002)	-0.006 ** (0.003)	-0.002 (0.002)	-0.004 (0.004)	-0.004 * (0.003)	-0.010 * (0.005)
Longholder * CF	0.012 ** (0.006)	0.020 * (0.011)	0.019 ** (0.008)	0.046 *** (0.015)	0.000 (0.008)	-0.004 (0.019)
Year Fixed Effects	yes	yes	yes	yes	yes	yes
Year * Cash Flow Fixed Effects	yes	yes	yes	yes	yes	yes
Firm Fixed Effects	yes	yes	yes	yes	yes	yes
Firm * Cash Flow Fixed Effects	no	yes	no	yes	no	yes
R ²	0.195	0.447	0.189	0.473	0.233	0.440
N	14,615	14,615	9,088	9,088	5,527	5,527
Number of Firms	2,341	2,341	1,808	1,808	858	858

The sample consists of firms in Compustat's Execucomp database between 1997 and 2012. The table reports linear regression coefficients. The dependent variable is investment, measured as capital expenditures scaled by the lag of net property plants and equipment. Q is the market value of assets scaled by the book value of assets. Stock Ownership (Vested Options) is the CEO's holdings of company stock (vested options) scaled by common shares outstanding. Efficient Board Size is an indicator variable equal to 1 if the firm's board has between 4 and 12 members. Cash Flow is the sum of earnings and depreciation scaled by the lag of net property plants and equipment. Longholder is an indicator variable equal to 1 if the CEO during his tenure held an option to the last year before expiration, provided it was at least 40% in-the-money entering its final year. We define the Longholder variable using exercise data from the Thomson Reuters insider filings database. All standard errors are adjusted for firm-level clustering. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.