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CEO confidence bias and strategic choice: a general framework

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ABSTRACT

An owner of a firm may choose to hire an unbiased CEO or one with confidence bias. We develop a model that demonstrates that the owner's optimal choice depends on whether the firm and rival choice variables are strategic substitutes or strategic complements. When choice variables are strategic substitutes or strategic complements for both firms, owners optimize by hiring overconfident CEOs. When choice variables are substitutes for one firm and complements for the rival firm, each firm optimizes by hiring an underconfident CEO. We show that the model applies to price and output competition, advertising, research and development spending, and product design.

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Behavioral economics; firm behavior; confidence bias; managerial overconfidence; strategic substitutes and complements

1. Introduction

Seminal studies by Malmendier and Tate (2005, 2008) show that many large corporations hire chief executive officers (CEOs) who are overconfident. Research further indicates that overconfident CEOs overpredict the likelihood of success, engage in more aggressive merger and borrowing behavior, and inflate estimates of future earnings.¹ Despite the attention paid to CEO overconfidence, evidence of underconfidence exists as well (Ben-David, 2013; Moore & Cain, 2007).² For example, Chen, Sau Leung, Song, and Goergen (2019) identify industry-specific CEO confidence levels and find that public utility and telecommunication industries hire relatively underconfident CEOs.

Early theoretical studies were designed to rationalize the presence of overconfident CEOs. For example, Goel and Thaker (2008) and Campbell, Gallmeyer, Johnson, Rutherford, and Stanley (2011) show how moderate CEO overconfidence can attenuate corporate risk. Englmaier (2010, 2011) and Englmaier and Reisinger (2014) investigate duopoly games that allow firm owners to hire CEOs who overestimate the effectiveness of various actions, such as spending on research and development, to increase firm demand. These studies demonstrate that an owner can increase profit by hiring an overconfident CEO in both Cournot and Bertrand product market games. This can occur when the

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¹See Malmender et al. (2011), Schrand and Zechman (2012), and Deshmukh et al. (2013). For reviews of the literature, see Armstrong and Huck (2010), Malmendier and Tate (2015), Dhami (2016), and Tremblay, Schroeder, and Tremblay (2018).

²CEO confidence also varies with experience (Bertrand & Schoar, 2003) and by gender (Huang and Kisgen, 2013).

action of an overconfident CEO profitably changes the behavior of competitors. More recent work proves that it can be profitable for owners to hire underconfident CEOs when there are strategic asymmetries (Schroeder et al., 2021a; 2021b).

As Malmendier and Tate (2015) point out, the overconfidence literature provides a different reason for the agency problem in which CEOs fail to maximize simple profits. In the classic principal-agent problem, this failure is due to the fact that CEO compensation is not aligned with profits. In the overconfidence literature, however, the source of failure is CEO confidence bias. In this case, CEOs can fail to maximize simple profits even when they are financially incentivized to do so. Thus, a contract that aligns CEO compensation with profit need not affect CEO behavior or benefit owners.³

The purpose of this study is to develop a general model that encompasses previous and new results regarding confidence bias for a broad class of strategic variables. The model identifies conditions under which it is optimal for owners to hire perfectly rational, overconfident, or underconfident CEOs. One determining factor is whether firms compete in a strategic or non-strategic setting. Another is whether the relevant choice variables are strategic substitutes or strategic complements. We develop the model in section 2. In section 3, we show how our model subsumes a wide range of economic applications that are relevant to CEO confidence bias. The study concludes in section 4.

2. Confidence bias and strategic behavior

In this section, we develop a general framework for identifying conditions that support an owner's decision to purposefully hire a CEO with confidence bias. In our model, costs are sufficiently low to assure firm participation. Profit functions are strictly concave and twice-continuously differentiable, such that the first- and second-order conditions of profit maximization are met for all choice variables.

Consider a market where two firms (1 and 2) compete in a sequential game. Subscript i will identify one firm, and subscript j will represent firm i 's competitor. In stage I, owners or boards of directors decide whether to hire CEOs who are perfectly rational, overconfident, or underconfident. The goal of each owner is to maximize the company's true profit, π . Once hired, all corporate decisions are delegated to CEOs.⁴ In stage II, the CEO of firm i chooses the value of the strategic variable $s_i \in S$, where $S \subseteq \mathbb{R}$ is the feasible choice set. s_i could represent a variety of choice variables, including output, price, product design, or research and development. Bias occurs when a CEO overestimates or underestimates the effectiveness of s_i to increase profit. The CEO of firm i maximizes expected profit, which is based on potentially biased beliefs about the effectiveness of strategic variables. In each stage, decisions are made simultaneously. Information is perfect and complete.

Potential CEO bias is indexed by parameter ϕ . For the perfectly rational CEO who has an accurate assessment of the effectiveness of s_i , $\phi_i = 0$. When overconfident, the CEO of firm i overestimates the effectiveness of s_i by $\phi_i \in (0, \infty)$. An underconfident CEO underestimates the effectiveness of s_i , such that $\phi_i \in (-\infty, 0)$. In our model, $\phi_i \in$

³We wish to thank an anonymous referee for pointing out that the classic principal-agent problem is another important reason for the agency problem.

⁴Strategic delegation theory was developed by Schelling (1960), and a review of the literature can be found in Sengul, Gimeno, and Dial (2012).

$(-\infty, \infty)$ and the level of overconfidence (underconfidence) increases (decreases) with ϕ_i . Owner search reveals the confidence level of each CEO candidate before hire. With this notation, firm i 's profit is $\pi_i(\phi_i, \phi_j, s_i, s_j)$.

Our main results depend upon the presence of strategic effects and whether s_i and s_j are strategic substitutes or complements (Bulow et al., 1985). At stage II, each firm has a unique best reply, denoted by $s_i^{BR} = \operatorname{argmax}_{s_i \in S} \pi_i(s_i, s_j)$. When s_i and s_j are strategic substitutes, the choice variables are combative – an increase in s_j imposes a negative externality on firm i by lowering its marginal profit (i.e., $\frac{\partial^2 \pi_i}{\partial s_i \partial s_j} < 0$), and firm i 's best-reply function has a negative slope. When strategies are complements, the choice variables are constructive – an increase in s_j produces a positive externality for firm i by raising its marginal profit (i.e., $\frac{\partial^2 \pi_i}{\partial s_i \partial s_j} > 0$), and firm i 's best-reply function has a positive slope.

Backward induction is used to identify the subgame-perfect Nash equilibrium (SPNE). In stage II, CEOs simultaneously choose s , based on the degree of confidence bias and given owner decisions in stage I. Firm i 's Nash equilibrium value in this subgame is $s_i^{NE}(\phi_i, \phi_j)$. In stage I, firm i 's profit depends on first-stage choices, ϕ_i and ϕ_j , and the anticipated actions in stage II. Thus, owner i maximizes $\pi_i(\phi_i, \phi_j, s_i^{NE}, s_j^{NE}) = \pi_i(\phi_i, \phi_j)$ with respect to ϕ_i .

If deviation from perfect rationality ($\phi_i = \phi_j = 0$) raises owner profit, then it is optimal for an owner to hire a biased CEO in stage I. When evaluated at $\phi_i = \phi_j = 0$, the total effect is:

$$\frac{d\pi_i(\phi_1 = \phi_2 = 0)}{d\phi_i} = \frac{\partial \pi_i(\phi_1 = \phi_2 = 0)}{\partial s_i} \frac{\partial s_i}{\partial \phi_i} + \frac{\partial \pi_i(\phi_1 = \phi_2 = 0)}{\partial s_j} \frac{\partial s_j}{\partial s_i} \frac{\partial s_i}{\partial \phi_i} \quad (1)$$

The first set of terms on the right-hand side of the equality is the direct effect on firm i 's profit of a marginal increase in ϕ_i (i.e., greater overconfidence). The second set of terms identifies the indirect or strategic effect that results from a change in the action of firm j . If Equation (1) is zero, then it pays to hire a perfectly rational CEO. If it is positive (negative), however, it is optimal to hire an overconfident (underconfident) CEO.

Equation (1) demonstrates that an owner will hire a perfectly rational CEO when strategic effects are absent. From the first-order condition of profit maximization, $\frac{\partial \pi_i}{\partial s_i} = 0$. For a monopolist, $\partial s_j / \partial s_i = 0$ because the firm has no competitors. In perfect competition, $\partial s_j / \partial s_i = 0$ because each firm is infinitesimally small and its action has no effect on rival demand or cost conditions. Thus, in the absence of strategic effects, $\frac{d\pi_i}{d\phi_i} = \frac{\partial \pi_i}{\partial s_i} = 0$ and an owner maximizes profit by hiring a perfectly rational CEO.⁵

In a strategic setting, an owner's commitment to hiring a biased CEO may change rival behavior and increase firm profit.⁶ The next three propositions identify conditions under which it is optimal for an owner to hire a CEO with confidence bias in a duopoly market.

⁵Schroeder et al. (2021a) illustrate this result for monopoly and competition markets, assuming linear demand and marginal cost functions.

⁶In essence, this action moves the equilibrium toward the Stackelberg solution, as described by Schroeder et al., (2021a).

The first two propositions consider the symmetric cases where the choice variables are either strategic substitutes or strategic complements for both firms. The third proposition treats the asymmetric case where the choice variables are strategic substitutes for one firm and strategic complements for the other firm.

Proposition 1: In the duopoly game where the choice variables, s_i and s_j , are strategic substitutes for both firms, it is optimal for each owner to hire an overconfident CEO ($\phi_i > 0$).

Proof: From Equation (1), the direct effect is zero because $\frac{\partial \pi_i(\phi_i = \phi_2 = 0)}{\partial s_i} = 0$ from the first-order condition of profit maximization. For strategic substitutes where s_i and s_j are combative, $\frac{\partial s_j}{\partial s_i} < 0$ (i.e., firm j 's best-reply function has a negative slope) and an increase in s_j lowers firm i 's profit ($\frac{\partial \pi_i(\phi_i = \phi_2 = 0)}{\partial s_j} < 0$). Because overconfidence leads to an overestimation of the effectiveness of s_i , $\frac{\partial s_i}{\partial \phi_i} > 0$. Thus, $\frac{d\pi_i(\phi_i = \phi_2 = 0)}{d\phi_i} > 0$, and it is optimal for the owner of firm i to hire an overconfident CEO ($\phi_i > 0$).⁷ Q.E.D.

Proposition 2: In the duopoly game where the choice variables, s_i and s_j , are strategic complements for both firms, it is optimal for each owner to hire an overconfident CEO ($\phi_i > 0$).

Proof: From Equation (1), the direct effect is zero because $\frac{\partial \pi_i(\phi_i = \phi_2 = 0)}{\partial s_i} = 0$ from the first-order condition of profit maximization. For strategic complements, where s_i and s_j are constructive, $\frac{\partial s_j}{\partial s_i} > 0$ (i.e., firm j 's best-reply function has a positive slope) and an increase in s_j raises firm i 's profit ($\frac{\partial \pi_i(\phi_i = \phi_2 = 0)}{\partial s_j} > 0$). Because overconfidence leads to an overestimation of the effectiveness of s_i , $\frac{\partial s_i}{\partial \phi_i} > 0$. Thus, $\frac{d\pi_i(\phi_i = \phi_2 = 0)}{d\phi_i} > 0$, and it is optimal for the owner of firm i to hire an overconfident CEO ($\phi_i > 0$).⁸ Q.E.D.

The next proposition considers the asymmetric case where the choice variables are strategic substitutes for one firm but strategic complements for the other firm. For concreteness, let s_1 and s_2 be strategic complements for firm 1 ($\frac{\partial^2 \pi_1}{\partial s_1 \partial s_2} > 0$) and strategic substitutes for firm 2 ($\frac{\partial^2 \pi_2}{\partial s_1 \partial s_2} < 0$). That is, s_1 is combative and s_2 is constructive, such that best-reply functions are positively sloped for firm 1 and negatively sloped for firm 2.⁹ Examples of this case will be discussed in the next section.

Proposition 3: In the duopoly game where the choice variables, s_i and s_j , are strategic complements for firm 1 and strategic substitutes for firm 2, it is optimal for each owner to hire an underconfident CEO ($\phi_i < 0$).

⁷This is not globally true, however, given that the profit function is concave. Firm i 's optimal level of ϕ_i is finite and occurs where $d\pi_i/d\phi_i = 0$.

⁸This is not globally true, however, given that the profit function is concave. Firm i 's optimal level of ϕ_i is finite and occurs where $d\pi_i/d\phi_i = 0$.

⁹For further detail, see Tremblay and Tremblay (2019).

Proof: For firm 1, Equation (1) becomes:

$$\frac{d\pi_1(\phi_1 = \phi_2 = 0)}{d\phi_1} = \frac{\partial\pi_1(\phi_1 = \phi_2 = 0)}{\partial s_1} \frac{\partial s_1}{\partial\phi_1} + \frac{\partial\pi_1(\phi_1 = \phi_2 = 0)}{\partial s_2} \frac{\partial s_2}{\partial s_1} \frac{\partial s_1}{\partial\phi_1} \quad (2)$$

The direct effect is zero because $\frac{\partial\pi_1(\phi_1=\phi_2=0)}{\partial s_1} = 0$ from the first-order condition of profit maximization. Given that s_1 is combative and s_2 is constructive, $\frac{\partial\pi_1(\phi_1=\phi_2=0)}{\partial s_2} > 0$ and $\frac{\partial s_2}{\partial s_1} < 0$. Because overconfidence leads to an overestimation of the effectiveness of s_1 , $\frac{\partial s_1}{\partial\phi_1} > 0$. Thus, $\frac{d\pi_1(\phi_1=\phi_2=0)}{d\phi_1} < 0$, and it is optimal for the owner of firm 1 to hire an underconfident CEO ($\phi_1 < 0$).¹⁰ For firm 2, Equation (1) becomes:

$$\frac{d\pi_2(\phi_1 = \phi_2 = 0)}{d\phi_2} = \frac{\partial\pi_2(\phi_1 = \phi_2 = 0)}{\partial s_2} \frac{\partial s_2}{\partial\phi_2} + \frac{\partial\pi_2(\phi_1 = \phi_2 = 0)}{\partial s_1} \frac{\partial s_1}{\partial s_2} \frac{\partial s_2}{\partial\phi_2} \quad (3)$$

The direct effect is zero because $\frac{\partial\pi_2(\phi_1=\phi_2=0)}{\partial s_2} = 0$ from the first-order condition of profit maximization. Given that s_1 is combative and s_2 is constructive, $\frac{\partial\pi_2(\phi_1=\phi_2=0)}{\partial s_1} < 0$ and $\frac{\partial s_1}{\partial s_2} > 0$. Because overconfidence leads to an overestimation of the effectiveness of s_2 , $\frac{\partial s_2}{\partial\phi_2} > 0$. Thus, $\frac{d\pi_2(\phi_1=\phi_2=0)}{d\phi_2} < 0$. That is, it is optimal for the owner of firm 2 to hire an underconfident CEO ($\phi_2 < 0$).¹¹ *Q.E.D.*

These results indicate that an owner's decision to hire a biased CEO requires there to be strategic effects and depends on whether the choice variables are strategic substitutes or complements. In the absence of strategic effects, as with perfect competition and monopoly, it is optimal for owners to hire perfectly rational CEOs. In strategic settings where both choice variables are either strategic complements or strategic substitutes, it is optimal for owners to hire overconfident CEOs. In the asymmetric setting where the choice variables are strategic substitutes for one firm but strategic complements for the other firm, it is optimal for owners to hire underconfident CEOs.

3. Common economic applications

In this section, we analyze several applications of CEO confidence bias in strategic settings. We consider specific choice variables and show how our model serves as an umbrella for several established and new results. Famously, the first duopoly models of non-cooperative oligopoly were developed by Cournot (1838) and Bertrand (1883). In the Cournot model, the choice variable is output (q), and two firms simultaneously choose output levels: $s_1 = q_1$ and $s_2 = q_2$. In the Bertrand model, the choice variable is price (p), and two firms simultaneously choose price levels: $s_1 = p_1$ and $s_2 = p_2$. In both cases, owners/managers are assumed to be profit maximizers who are unbiased (i.e., perfectly rational).

¹⁰This is not globally true, however, given that the profit function is concave. Firm 1's optimal level of ϕ_1 is finite and occurs where $d\pi_1/d\phi_1 = 0$.

¹¹This is not globally true, however, given that the profit function is concave. Firm 2's optimal level of ϕ_2 is finite and occurs where $d\pi_2/d\phi_2 = 0$.

Different results may emerge, however, when owners (or boards of directors) are different from managers. In this case, owners may commit to hiring managers who over- or under-estimate demand. In the Cournot model, the choice variables are strategic substitutes for both firms, and the choice variables are strategic complements for both firms in the Bertrand model. Thus, Propositions 1 and 2 indicate that the *SPNE* is for owners to hire overconfident CEOs. Several authors verify that it is profit maximizing for owners to hire overconfident CEOs in Cournot and Bertrand settings for linear demand and cost functions.¹² Schroeder et al. (2021b) prove this with more general demand and cost conditions.

A related model that assumes strategic asymmetry has also emerged in the literature, the Cournot-Bertrand model. This is a hybrid model where one firm competes in output, as in Cournot, and the other firm competes in price, as in Bertrand (Bylka and Komar, 1976; Tremblay & Tremblay, 2019). In this case, the choice variables, $s_i = q_i$ and $s_j = p_j$, are strategic substitutes for the Bertrand-type firm and are strategic complements for the Cournot-type firm. Consistent with Proposition 3, Schroeder et al. (2021b) prove that it is optimal for owners to hire underconfident CEOs with Cournot-Bertrand competition.

Real firms compete in a variety of other variables, including research and development (*R&D*), advertising, and product design. Models with these strategic options require an additional stage in the sequential game. With *R&D*, for example, owners choose the level of CEO confidence bias in stage I, firms compete in *R&D* in stage II, and firms compete in output (or price) in stage III. Confidence bias enters the model in stage II, where an overconfident (underconfident) CEO overestimates (underestimates) the effectiveness of *R&D* in increasing demand or decreasing costs. *R&D* can generate product innovations (i.e., create an improved product) or process innovations (i.e., reduce the cost of producing an existing product). *R&D* is combative when firm i 's product innovation steals customers from firm j . When this is true for both firms, $R\&D_i$ and $R\&D_j$ are strategic substitutes. In contrast, *R&D* is constructive if information about firm i 's process innovation (partially) spills over to firm j , thus benefiting firm j as well as firm i . In this case, $R\&D_i$ and $R\&D_j$ are strategic complements. Strategic asymmetry is also possible, where one firm focuses on product innovations and the other focuses on process innovations. In this instance, $R\&D_i$ and $R\&D_j$ would be strategic substitutes for one firm and strategic complements for the other firm.

As in the previous section, backward induction is used to identify the *SPNE*. In stage III, firm i 's Nash equilibrium output is $q_i^{NE}(\phi_i, \phi_j, R\&D_i, R\&D_j)$. In stage II, CEOs simultaneously make *R&D* decisions, given stage I realizations (ϕ_i and ϕ_j) and the anticipated best-replies in stage III, q_i^{NE} and q_j^{NE} . At this stage, firm i 's Nash equilibrium would be $R\&D_i^{NE}(\phi_i, \phi_j)$. Thus, in stage I, owners simultaneously make CEO decisions, given q_i^{NE} , q_j^{NE} , $R\&D_i^{NE}$, and $R\&D_j^{NE}$. In these games, Propositions 1 and 2 indicate that owners benefit from hiring overconfident CEOs when $R\&D_i$ and $R\&D_j$ are either strategic substitutes or strategic complements for both firms.

¹²For example, see Englmaier (2010, 2011), Englmaier and Reisinger (2014), and Pu et al. (2017).

Englmaier and Reisinger (2014) and Tondji (2021) consider such models of competition in $R\&D$. They assume linear demand and production cost functions and that both firms engage in process enhancing $R\&D$ with positive spillovers (strategic complements). Their results are consistent with Proposition 2: owners benefit from hiring overconfident CEOs. To date, no one has investigated the cases where $R\&D_i$ and $R\&D_j$ are strategic substitutes for both firms, which would support overconfidence (Proposition 1), or are strategic substitutes for one firm but strategic complements for the other firm, which would support underconfidence (Proposition 3).

Another important choice variable is advertising. In this case, bias enters the game in stage II when CEOs have a potentially biased view of advertising effectiveness. As discussed by Marshall (1890) and Friedman (1983), advertising can be expansionary (constructive) when it increases market demand or predatory (combative) when one firm's advertising steals customers from its competitor. When both firms engage in combative (constructive) advertising, these choice variables are strategic substitutes (complements) and owners benefit from hiring overconfident CEOs (Propositions 1 and 2). There also are real-world examples where a maverick firm engages in combative advertising and competes with a dominant firm that chooses more constructive advertising campaigns (Tremblay and Tremblay, 2012). In this case, Proposition 3 implies that owners will prefer to hire underconfident CEOs. Schroeder et al. (2021a) analyze advertising games with these characteristics and find results that are consistent with Propositions 1, 2, and 3.

As a final example, consider the case where firms compete in product design, as discussed in Johnson and Myatt (2006). Here, firms have the option of developing a product that appeals to the masses or to a niche set of consumers. For example, an economy sedan like a Honda Civic might have mass market appeal, while a performance sedan like a BMW 330 might appeal to a smaller set of performance enthusiasts. In this application, overconfidence (underconfidence) occurs when a CEO overestimates (underestimates) the appeal of a particular design to consumers. If firms 1 and 2 both compete in either economy sedans or performance sedans, these choices are combative. As a result, owners benefit from hiring overconfident CEOs (Proposition 1). On the other hand, if firm 1 chooses to produce an economy sedan and firm 2 chooses to produce a performance sedan, an asymmetry can result. The introduction of the economy sedan by firm 1 may attract a new set of potential consumers to the market and benefit firm 2, while firm 2's introduction of the performance sedan may steal sales from firm 1. In this case, the choice variables are strategic substitutes for firm 1 but strategic complements for firm 2. As a result, both owners benefit from hiring underconfident CEOs (Proposition 3). The issue of CEO confidence bias and product design has not been considered in the literature.

4. Concluding remarks

We develop a general duopoly model of CEO confidence and strategic choice that provides a unifying framework for the existing literature, as well as suggesting some new results. In the first stage of the model, owners or boards of directors choose the level of CEO confidence bias when hiring a CEO. In the second stage, this CEO chooses the value of the strategic variable, maximizing profit according to potentially biased beliefs. This model flexibly encompasses a wide range of specific models, given its general

demand and cost conditions and for a variety of possible strategic choice variables, including output, price, R&D, advertising, and product design. The model identifies conditions under which it is optimal for owners to hire CEOs who are overconfident, underconfident, or perfectly rational.

In perfect competition or monopoly, the absence of strategic effects leads to the conclusion that it is optimal for owners to hire perfectly rational CEOs. In strategic settings, the result depends on whether the choice variables are strategic substitutes or strategic complements. When the game is symmetric, in that the choice variables are either strategic substitutes for both firms or strategic complements for both firms, it is optimal for each owner to hire an overconfident CEO. When the choice variables are strategic complements for one firm and strategic substitutes for the other firm, however, it is optimal for both firms to hire underconfident CEOs.

These results shed light on a variety of findings in the theoretical and empirical literatures. Empirically, we have seen that both CEO overconfidence and underconfidence exist in the real world. Similarly, the theoretical literature provides examples of duopoly models in which overconfidence or underconfidence is optimal. Our general framework highlights the key feature of these models that are driving the differing results: whether the choice variables are strategic substitutes or complements.

Although there are advantages to a general model, welfare analysis is infeasible. The studies found in [Section 3](#) that used specific functional forms demonstrate that the effect of confidence bias on welfare varies across economic settings. For example, product market studies found that the presence of confidence bias increases welfare (i.e., consumer and total surplus) with Cournot competition, decreases welfare with Bertrand competition, and has an indeterminate effect on welfare with Cournot-Bertrand competition. When the choice variable is advertising, however, the welfare effect of confidence bias depends upon whether advertising is informative or persuasive, not on whether advertising is a strategic substitute or complement alone. These results further illustrate the inherent complexity of policy analysis regarding imperfectly competitive markets. An optimal policy would need to be case-specific.

This paper suggests several avenues for future research. First, analysis of alternative choice variables, using both general and specific models, may reveal additional instances in which confidence bias benefits owners and/or improves welfare. In addition, a future study might incorporate the classic principal-agent problem with confidence bias and allow CEO bias to influence the contract between owners and CEOs. Such a model would provide a more complete picture of agency problems and CEO bias.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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