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Impact of CEO perceived dominance on corporate financial performance: an empirical study based on facial feature extraction via deep learning

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Abstract

Perceived dominance, which can be formed on the basis of the facial features of a chief executive officer (CEO), can affect the behavior of other firm members (i.e., other executives and subordinates) and impact corporate outcomes. However, a consensus has yet to be reached on the association between CEO perceived dominance and corporate financial performance owing to limitations in sample representativeness, measurement errors, and empirical strategies of previous studies. This study investigates the impact of CEO perceived dominance on corporate financial performance through facial feature extraction via deep learning, which can provide robust and causal insights from a large dataset spanning a long time period of 30 years. Furthermore, this study explores the mechanism of the impact of CEO perceived dominance from the perspective of information flow and sharing by investigating the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments. The results indicate that the degree of CEO perceived dominance is negatively associated with corporate financial performance and that a CEO's high nonsalary compensation, large board size, and large number of business segments can attenuate the negative association. Our findings can deepen the theoretical understanding of the impact of CEO perceived dominance on corporate financial performance and provide managerial implications for the decision-making of investors.

Keywords: CEO perceived dominance, Corporate financial performance, Information flow and sharing, Facial feature extraction, Deep learning

Introduction

As the core of the management team, the chief executive officer (CEO) has the legal power and responsibility to lead and control the corporation. Studies have shown that CEOs play a vital role in a corporation's achievements, especially its financial performance (Schumacher et al. 2020; Mukherjee & Sen 2022). CEOs can make an impact by exhibiting their innate personality traits and impressing other firm members (Adebambo et al. 2024; Dietl et al. 2018). Psychological and neuroscientific research has demonstrated that people can immediately form impressions of and judge others by

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observing their facial features, which can influence their subsequent behavior (Willis & Todorov 2006; Rule et al. 2011). Therefore, this study focuses on one of the most important aspects of interpersonal perception (Oosterhof & Todorov 2008; Sutherland et al. 2013; Jones et al. 2021), namely, perceived dominance, and explores how CEO perceived dominance can affect other firm members (i.e., other executives and subordinates) and thus corporate financial performance.

In the context of corporate governance, CEO perceived dominance can be defined as other people's perceptions of a CEO's willingness to influence and control corporate decisions (Cheng et al. 2013; Hehman et al. 2019; Kakkar et al. 2020). According to implicit leadership theory, other executives and subordinates will perceive the dominance of CEOs by observing their facial cues and comparing them with dominant CEO prototypes (Kenney et al. 1994; 1996). For example, existing studies demonstrate that a short nose and a broad lower face of the CEO can enhance the perception of dominance (Windhager et al. 2011), and CEOs with high perceived dominance typically exhibit facial features such as low eyebrows, narrow eyes, and large chins (Toscano et al. 2014). On the basis of such facial cues, the impression of CEO dominance can be rapidly and implicitly formed and can continuously impact observers, leading to social consequences (Willis & Todorov 2006; Klapper et al. 2016; Shen et al. 2020). Thus, CEO perceived dominance can affect the reactions and behaviors of other firm members (Dietl et al. 2018) and hence corporate financial performance (Adebambo et al. 2024).

Although CEO perceived dominance has attracted research attention, empirical results on the impact of CEO perceived dominance on corporate financial performance are inconclusive. For instance, Rule and Ambady (2008) investigated the impact of the CEOs of Fortune 1000 companies and observed the positive effect of CEO perceived dominance on corporate profits. In contrast, Pillemer et al. (2014) validated the detrimental impact of CEO perceived dominance on corporate profits and rankings, and Re and Rule (2016b) identified a negative correlation between CEO perceived dominance and the financial performance of nonprofit organizations. In addition, some studies suggested that CEO perceived dominance may not significantly affect corporate financial performance (Graham et al. 2017; Canace et al. 2020).

The inconclusiveness of the research results can be explained from three aspects, the first of which is sample representativeness. Most existing studies conduct empirical analyses on cross-sectional data rather than panel data; thus, CEO samples are generally small in size and limited in representativeness. Moreover, the limited sample data can estimate corporate financial performance only for a short period (e.g., 1 year). The second aspect is measurement errors. Previous research has commonly recruited human raters to assess the degree of CEO perceived dominance on the basis of CEOs' facial photographs. However, owing to the high cost of manual rating, the derived data may encounter scale limitations and thus subjective bias. Potential bias may result from the raters' knowledge and experience and confounding factors (e.g., assessment of multiple impressions simultaneously from the same facial photo). The third aspect is empirical strategies. Related works construct regression models to test the association/correlation between CEO perceived dominance and corporate financial performance, but causal analyses are lacking. Owing to unobservable omitted variables, association models can

hardly support robust and cogent conclusions on the impact of CEO perceived dominance on corporate financial performance.

To address the identified limitations and challenges, this study investigates the impact of CEO perceived dominance on corporate financial performance through facial feature extraction via deep learning. Deep learning models have advantages in feature learning and large-scale data fitting (Mohamed et al. 2023; Yang et al. 2023); thus, we utilize a well-developed method (Vernon et al. 2014) to measure the degree of CEO perceived dominance automatically and rapidly. On the basis of the extracted facial features, CEO perceived dominance can be calculated using this method with the learned feature weights. Furthermore, this study explores the mechanism and boundary conditions of the impact of CEO perceived dominance on corporate financial performance from the perspective of information flow and sharing. Specifically, this study investigates the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments, which are closely related to information flow and sharing in the corporation (Windsperger 2009; Gormley et al. 2013; Zona et al. 2018) and thus may affect the association between CEO perceived dominance and corporate financial performance. To alleviate potential endogeneity issues owing to simultaneity, measurement errors, or unobservable omitted variables in causal analyses, empirical tests are conducted with two-way fixed effects models and difference-in-differences (DiD) models on a large dataset spanning the period of 1992–2022 and containing more than 1,400 United States-listed corporations and more than 2,200 CEOs. The results reveal that the degree of CEO perceived dominance is significantly and negatively associated with corporate financial performance. In addition, a CEO's high nonsalary compensation, large board size, and large number of business segments can attenuate the negative association between CEO perceived dominance and corporate financial performance. These findings remain consistent in the multiview robustness checks, such as alternative measurements of key variables and alternative fixed effects.

The main contributions of this work are twofold. First, this study examines the impact of CEO perceived dominance on corporate financial performance, on which prior research has failed to reach a consensus, by drawing on robust and causal insights. Specifically, to address the sample representativeness, measurement error, and empirical strategy limitations of previous works, this study conducts various tests on a large dataset spanning a long time period with two-way fixed effects models and DiD models, in which the degree of CEO perceived dominance is automatically and rapidly measured via deep learning. Second, to broaden the scope of previous research, this study explores the potential mechanism of the association between CEO perceived dominance and corporate financial performance from the perspective of information flow and sharing. Specifically, this study investigates the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments, which are related to corporate information flow and sharing. The empirical validation of the boundary conditions can provide evidence for our mechanism exploration. Our findings can deepen the theoretical understanding of the impact of CEO perceived dominance on corporate financial performance and provide managerial implications for investors' decision-making practices.

Literature review

CEO perceived dominance and corporate financial performance

In the context of corporate governance, CEO perceived dominance refers to people's perceptions of a CEO's willingness to influence and control corporate decisions (Cheng et al. 2013; Hehman et al. 2019; Kakkar et al. 2020). According to implicit leadership theory, other firm members (i.e., other executives and subordinates) can perceive the dominance of CEOs by observing their facial cues (e.g., eyebrow height, eye width, nose length) and comparing them with dominant CEO prototypes (Kenney et al. 1994; 1996). The CEO is the core of the corporate management team; thus, other firm members' perceived dominance of the CEO can subsequently affect their reactions and behaviors (Dietl et al. 2018), which may impact corporate financial performance (Adebambo et al. 2024). This impact route aligns with findings in psychological and neuroscientific research, which demonstrates that people can immediately form impressions of others by observing their facial features, which may influence the subsequent behavior of observers (Willis & Todorov 2006; Rule et al. 2011; Klapper et al. 2016; Shen et al. 2020).

In light of this route, several empirical studies have investigated the impact of CEO perceived dominance on corporate financial performance. For example, Pillemer et al. (2014) validated the detrimental impact of CEO perceived dominance on corporate profitability and rankings on the basis of CEO perceived dominance from facial photographs, and Re and Rule (2016b) demonstrated that CEO perceived dominance can negatively affect the financial performance of nonprofit organizations. However, some prior research has reached the opposite conclusion; that is, CEO perceived dominance has a positive effect on corporate financial outcomes (Rule & Ambady 2008; 2009). Specifically, Rule and Ambady (2011) confirmed that high perceived dominance of managing partners can benefit law firms in terms of their financial success. In addition, several studies found that CEO perceived dominance does not significantly affect corporate financial performance (Graham et al. 2017; Canace et al. 2020; Hopp et al. 2023).

Although research has explored the impact of CEO perceived dominance on corporate financial performance, related studies are fewer than those on other aspects of CEO impressions, such as attractiveness (Halford & Hsu 2020; Colombo et al. 2022; Ling et al. 2022) and trustworthiness (Duan et al. 2020; Hendrawan & Utama 2024). More importantly, the empirical results are inconclusive. Furthermore, existing work has not sufficiently explored the mechanism and boundary conditions of the impact of CEO perceived dominance on corporate financial performance or causal interpretations of such impact. Considering the limitations of previous studies, this study conducts empirical tests on a large dataset spanning a long time period with two-way fixed effects models and DiD models to obtain robust and causal insights. In addition, this study explores the mechanism of the association between CEO perceived dominance and corporate financial performance from the perspective of information flow and sharing and verifies the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments.

Measurement of CEO perceived dominance

As validated by existing studies, the social perception process through which people form impressions of others by observing their facial features is sufficiently stable for

statistical modeling and impression measurement (Hehman et al. 2019; Jaeger & Jones 2022). Prior studies reveal that such impressions can be consistent at the group level, even across cultures and demographics (Zebrowitz et al. 2012; Sutherland et al. 2020; Lin et al. 2021), and do not change significantly over time (Rule & Ambady 2011). Therefore, to directly measure the degree of CEO perceived dominance, related works commonly recruit human raters to assess CEO perceived dominance by looking at facial photographs of CEOs (Rule & Ambady 2008; 2009; 2011; Pillemer et al. 2014; Re & Rule 2016a; 2016b; Hopp et al. 2023). However, the method can result in a limited sample size with potential subjective bias owing to the high cost of manual rating, and confounding bias may exist if the raters are guided to assess multiple impressions simultaneously from the same facial photo (Giacomin & Rule 2020).

The rapid development of deep learning methods can pave the way for the automatic and time-efficient measurement of CEO perceived dominance. Owing to their outstanding advantages in complex pattern extraction/fitting (Mohamed et al. 2023; Yang et al. 2023), deep learning models have been widely applied in various managerial scenarios for supporting decisions (Heidari et al. 2022; Amiri et al. 2024). Although the relationship between CEOs' facial cues and perceived dominance is latent, deep learning-based methods can extract various facial features and fit the underlying relationship by using large-scale data. Vernon et al. (2014) developed an approach to extract crucial features from people's facial photographs, trained a linear neural network model to learn the weights of the facial features to determine the perceived dominance, and validated the superiority of the proposed approach's performance over that of baseline methods. Data experiments indicated that, through training with a large sample of photos with multiple independent judgments (i.e., alleviating the subjective bias and confounding factors), the learned model can rapidly predict peoples' perceived dominance on the basis of facial feature extraction, and the prediction is significantly and positively correlated with human ratings. In other words, the model can effectively capture the human mapping of people's facial cues to form an impression of their dominance. By using this valid and time-efficient method, some empirical studies assess perceived dominance with a large sample to further explore the impact of perceived dominance on political elections (Joo et al. 2015) and stock forecast accuracy (Peng et al. 2022).

In summary, facial feature extraction with deep learning methods can achieve automatic and time-efficient measurement/quantification of CEO perceived dominance, which is ideal for empirical analyses that require a large sample size to obtain robust insights. Hence, this study follows the identified route to extract crucial features from the collected facial photographs of CEOs via well-developed deep learning methods, calculates the degree of CEO perceived dominance with trained weights, and investigates the impact of CEO perceived dominance on corporate financial performance on the basis of large-scale data.

Hypotheses

Figure 1 depicts our conceptual model. As proposed, Hypothesis 1 examines the association between CEO perceived dominance and corporate financial performance, which remains inconclusive in existing studies. From the perspective of information flow and sharing, our moderation hypotheses explore the influence of CEOs' nonsalary

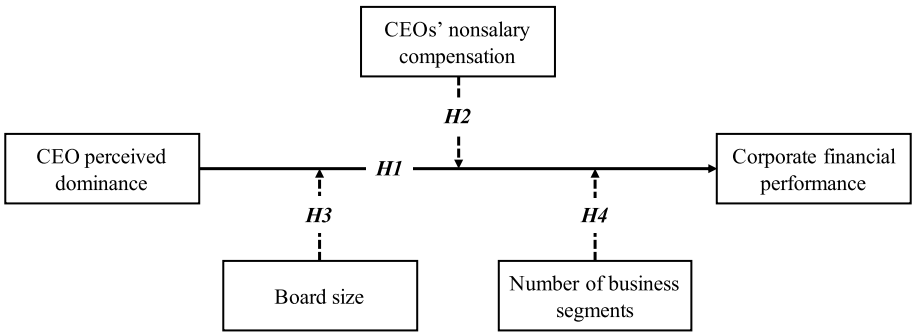

Fig. 1 Conceptual model

compensation (***H2***), board size (***H3***), and the number of business segments (***H4***) on this association. As these factors are closely related to information flow and sharing in the corporation, our exploration of their moderating effects may help explain the impact mechanism of CEO perceived dominance on corporate financial performance.

CEO perceived dominance and corporate financial performance

This study focuses on the corporate governance context, in which CEO perceived dominance can be defined as people's perception of a CEO's willingness to influence and control corporate decisions (Cheng et al. 2013; Hehman et al. 2019; Kakkar et al. 2020). Such an impression/perception is formed when other firm members (i.e., other executives and subordinates) observe the facial cues of CEOs, such as eyebrow height, eye width, and nose length (Windhager et al. 2011; Toscano et al. 2014), and compare them with dominant CEO prototypes (Kenney et al. 1994; 1996).

As indicated by the threat signal hypothesis, perceived dominance is generally interpreted as a signal related to threats and aggression (Cheng 2020; Fang et al. 2023), which can activate others' defensive responses, rather than closeness, in their cognitive process (Harber et al. 2011). In a corporation, the CEO is the core of the management team and naturally has the power to lead; thus, perceived dominance can aggravate the perceived threat of/aggression from the CEO's influence and control over corporate decisions (Maner & Mead 2010). Owing to defensive responses, other firm members may feel constrained and hesitant to share unfavorable news or express dissenting views (Hambrick & D'Aveni 1992; Gupta et al. 2019), which hinders their effective communication and collaboration with the CEO and thus impedes information flow and sharing in the corporation.

Previous research has emphasized that accurate information is necessary for effective corporate decision-making (Du & Budescu 2021; Pereira 2021). Adequate information flow and sharing are essential prerequisites for a corporation's financial success (Shin 2006; Gibson et al. 2007; Vazquez-Bustelo & Avella 2019); thus, CEO perceived dominance can pose a threat to corporate financial performance when the CEO acquires limited and biased information. For example, without sufficient information, a CEO may exhibit opportunistic behaviors or be inclined to explore new technologies/ventures with uncertain returns, which may result in financial losses for the corporation (Tang et al. 2011; Matsuo 2022).

Research has indicated that high CEO perceived dominance is associated with decreased corporate financial performance in various contexts (Bebchuk et al. 2011; Morse et al. 2011; Pillemer et al. 2014; Re & Rule 2016b; Tang 2021). In summary, considering that high CEO perceived dominance may restrict other firm members from expressing their opinions, hinder information flow and sharing in the corporation, and facilitate the CEO's risky corporate decision-making owing to insufficient information, we propose the following hypothesis:

H1 : The degree of CEO perceived dominance is negatively associated with corporate financial performance.

Moderating effect of CEOs' nonsalary compensation

According to agency theory, corporate investors and managers generally have conflicts of interest. To protect their own interests, investors trigger managers' efforts and obtain their desired outcomes by aligning financial incentives (e.g., compensation) with corporate performance (Jansen et al. 2009; Ntim et al. 2019; Chen et al. 2021). Generally, a CEO's total annual compensation can be divided into salary and nonsalary components, and the latter includes bonuses, stocks, and options-based incentives. To guarantee the CEO's base income, a corporation will explicitly determine the annual salary on the basis of the CEO's qualifications and experience (Canace et al. 2020; Schmid & Baldermann 2021). Unlike the salary, a CEO's nonsalary compensation consists of various performance-based rewards that depend highly on the corporation's financial performance, which can increase the income uncertainty of the CEO and thus motivate the CEO's efforts to a considerable extent (Gomez-Mejia & Wiseman 1997; Demski & Feltham 1978).

Related work implies that long-term incentives, such as high nonsalary compensation, which is linked with a corporation's financial performance, can encourage a CEO's long-term orientation (Gopalan et al. 2014; Ortiz-de-Mandojana et al. 2019). With a strong long-term orientation, the CEO tends to focus on and value the future, which reduces their short-sighted and opportunistic decisions to pursue temporary earnings (Lin et al. 2019; He & Hirshleifer 2022). Specifically, a high proportion of nonsalary compensation is generally associated with long pay durations; thus, a CEO can benefit only from the corporation's future outcomes, which can lead to increased investment in long-term strategies, such as innovation and stakeholder relationships (Souder & Shaver 2010; Flammer & Bansal 2017). Therefore, high nonsalary compensation can motivate a CEO to make deliberate decisions by seeking comprehensive information and diverse opinions from other executives and subordinates and fostering collaborative decision-making in the executive team for long-term success (Westphal 1999; Gormley et al. 2013). These practices then benefit information flow and sharing in the corporation and decrease the negative impact of CEO perceived dominance.

In summary, owing to the long-term orientation mechanism, high nonsalary compensation can encourage a CEO to exert the utmost effort to improve the corporation's long-term financial performance and widely collect information to protect his or her

own interests, which can mitigate the negative impact of CEO perceived dominance on corporate financial performance. Therefore, we propose the following hypothesis:

H2 : A CEO's high nonsalary compensation can attenuate the negative association between CEO perceived dominance and corporate financial performance.

Moderating effect of board size

In corporate managerial practices, the board of directors is responsible for making collaborative decisions on important operation and investment strategies (Mendiratta & Tasheva 2025). To implement their corporate management decisions, CEOs must first obtain the approval of the majority of board members (Boivie et al. 2021). As the board size (i.e., the number of board members) increases, the supervisory ability of the board can be enhanced by strong governance standards and high governance efficiency (Lehn et al. 2009; Jia & Zhang 2013). In other words, on the basis of their diverse perspectives and experiences, other board members are likely to express their concerns or raise questions about the CEO's opinions to protect their corporate interests (Anderson et al. 2004; Vaccaro et al. 2012), which may result in additional discussions among board members to reach a consensus (Jensen 1993). Although such coordination and communication may slow the decision-making process of the corporation, efforts can reduce the probability of the implementation of risky strategies to a considerable extent (Cheng 2008; Pathan 2009; Bhagat & Huyett 2013).

From the perspective of information flow and sharing, we posit that a large board size may result in enriched information sources and enhanced information sharing, which can be explained by the dual role of the board members as advisors and supervisors (Hillman & Dalziel 2003; Bezemer et al. 2023). On the one hand, to protect their benefits associated with corporate performance, other board members may intervene in the CEO's risky decisions on the basis of their acquired information (Fang et al. 2020) and be willing to seek external resources and diverse perspectives that may assist them in their corporate decision-making (Song et al. 2020; Simionescu et al. 2021). As the board size increases, the available pool of information and resources can be enriched for the CEO to make appropriate decisions (Wu et al. 2022). On the other hand, a large board can enhance oversight and increase accountability, which may imply high costs for the CEO to threaten corporate interests (Jermias 2007; Jain & Zaman 2020). Thus, the CEO tends to make decisions cautiously by actively collecting information from other executives and subordinates, which can counterbalance the negative effects of perceived dominance.

In summary, although a high degree of CEO perceived dominance can hinder information flow and sharing in a corporation, a large board of directors can make effective decisions on the basis of the members' enriched perspectives and enhanced supervision, which can mitigate the negative impact of CEO perceived dominance on corporate financial performance. Considering that a large board size can supplement resources and information to support corporate decisions and prevent CEOs from taking risks, we propose the following hypothesis:

H3 : A large board size can attenuate the negative association between CEO perceived dominance and corporate financial performance.

Moderating effect of the number of business segments

Prior research considers the number of business segments as a reflection of a corporation's complexity and diversification (Pinto & Morais 2019; Choi et al. 2021). As a corporation's business practices become increasingly complex and diversified, it will establish additional business segments to decentralize the management power (Zhang 2022) because understanding and controlling the entire corporation will be extremely costly for the CEO (Chang & Wang 2007). Thus, with more focus on planning, coordination, and appraisal (Yang et al. 2024), the CEO's control over business segments will change from direct strategic control to indirect financial control (Hoskisson & Hitt 1988), which can mitigate the CEO's excessive influence on corporate performance.

By delegating decision-making authorities to division managers, a corporation can benefit from the improved effectiveness of decentralized decisions owing to improved information flow and sharing within each segment (Harris & Raviv 2005; Windsperger 2009). As business segments are close to the source of data, decentralized decisions can be supported with accurate information that is processed and shared by segment experts (Aghion et al. 2021). Furthermore, the large number of business segments in a corporation can generally progress by frequently coordinating and communicating with one another rather than by directly reporting to the CEO (Kumar 2013). Such practices can reduce information loss and simplify the reporting and feedback process (Jensen & Heckling 1995; Bloom et al. 2014), which improve not only overall information flow and information-sharing efficiency in the corporation but also the corporation's responsiveness to varying market conditions for improved financial performance.

In summary, a large number of business segments can promote the decentralization of power, which can decrease the potential risky strategies developed by the CEO. Decentralized decisions are made on the basis of sufficient information flow and sharing within and across segments, which can further reduce the negative impact of CEO perceived dominance on corporate financial performance. Therefore, we propose the following hypothesis:

H4 : A large number of business segments can attenuate the negative association between CEO perceived dominance and corporate financial performance.

Data and methods

Sample

To investigate the impact of CEO perceived dominance on corporate financial performance, we accessed multiple data sources of U.S.–listed corporations, that is, the Execucomp database for CEO information (e.g., demographic characteristics and compensation), the Compustat database for corporations' accounting and segment information, and the Boardex database for board of directors' information.

We collected photographs of all the CEOs in the Execucomp database from 1992–2022 by conducting a Google search. To ensure the quality of the collected photos, we recruited three graduate students to assist in the data collection process. (1) The three research assistants searched for information on each of the CEOs on Google with the query "CEO name + corporate name". (2) The assistants clicked on the photo URLs in the search results to obtain rich information on the identities of the people in the photos. (3) The assistants cross-checked the tenure history of each CEO from their company websites with information from the database. (4) When more than one photo was available for a CEO, the assistants prioritized the colored photo of a single individual, the full-frontal-view photo, the high-resolution photo, or the photo taken and used during the CEO's tenure period.

With the collected high-quality CEO photos, we match the corresponding data in Execucomp with the Compustat database via *GVKEY* and then match the data with the Boardex database via the *CUSIP* number. Next, we exclude the financial corporations with an SIC code of 6000–6999, samples with missing values for any of the variables that would be used in the hypothesis testing or robustness checks, and samples with invalid values, considering the definition and range of each variable. The obtained panel dataset consists of a total of 16,038 corporation–year–CEO records from 1,455 corporations and 2,219 CEOs.

Measures

Dependent variable (DV)

In this study, we use the corporation's return on assets (ROA) to measure the DV, that is, corporate financial performance (Agle et al. 2006; Wong et al. 2011; Brigham & Houston 2016). As a common measure of corporate financial performance in existing finance research, ROA is calculated as the ratio of net income to total assets and reflects the ability of a corporation to obtain profits and use its assets (Jurkus et al. 2011). To measure the yearly financial performance of each corporation, we collect the corporate annual ROA data from Compustat.

Independent variable

To measure the degree of CEO perceived dominance, which is the independent variable, we adopt a well-developed deep learning-based method to extract CEOs' facial features from their photographs and then calculate perceived dominance by using the learned weights based on the method of Vernon et al. (2014). Figure 2 illustrates the main procedure for the measurement of CEO perceived dominance, which consists of four steps.

First, we import a pretrained multitask cascaded convolutional neural network (MTCNN) model from the facenet–pytorch library[1] in Python to detect the face of each CEO automatically from the collected high-quality facial photographs and then crop each photo to a unified size (i.e., 256 px × 256 px), with the CEO's face in the center. Second, we use the Dlib library in Python[2] to locate 68 crucial landmarks on the face of each CEO from the cropped photos. Third, we extract 65 facial features (e.g., head

[1] https://github.com/timesler/facenet-pytorch

[2] https://dlib.net

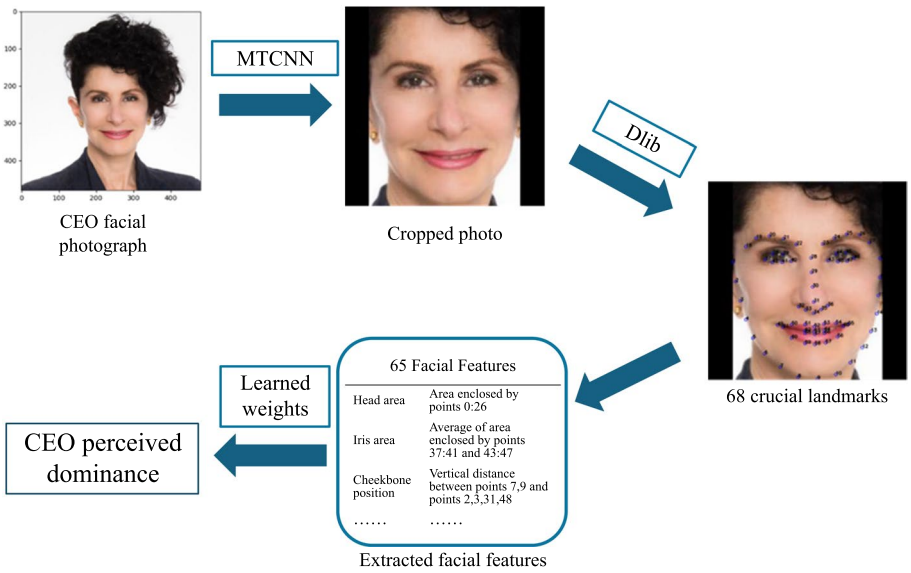

Fig. 2 Measurement procedure for CEO perceived dominance

area, iris area, and cheekbone position) on the basis of the coordinates of these landmark points, in which the calculation of each feature is proposed and validated by prior studies (Peng et al. 2022). Additionally, to ensure comparability across CEOs, we standardize the geometric and area measures by head size and linearly scale all the extracted facial features to the range of [−1, 1]. Fourth, we calculate the perceived dominance score of each CEO using the weights of the 65 facial features learned via a pretrained linear neural network model (Vernon et al. 2014), which can rapidly and accurately estimate perceived dominance on the basis of people's facial cues. Here, a high absolute value of the weight implies that the corresponding feature may affect perceived dominance to a large extent; for example, features with the highest absolute weights include the eye-to-eyebrow distance (−0.44), cheek gradient (0.37), eye line gradient (0.32), and iris area (−0.31). After calculation, the perceived dominance score of the CEOs in our sample ranges from −3.58–0.59, with an average of −1.92 and a standard deviation of 0.71, which indicates marked differences in CEO perceived dominance. Furthermore, we linearly scale each derived perceived dominance score to the range of [0, 1] because the independent variable is the degree of CEO perceived dominance (i.e., DOM).

Moderator variables

In this study, we examine the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments on the association between CEO perceived dominance and corporate financial performance.

To measure the CEO's nonsalary compensation, we utilize the available variables in Execucomp. Considering that a CEO's total annual compensation (TDC1) consists of salary (SALARY), bonuses, restricted stock awards, and granted stock options, we calculate the CEO's nonsalary compensation (NONSALARY) as the ratio of TDC1 minus SALARY to TDC1.

To measure board size (BOARD), we use the total number of board members in the corporation (Karavitis et al. 2021; Schopohl et al. 2021), which is available in Boardex.

To measure the number of business segments (SEGMENT), we count the number of business segments with positive annual sales volumes in the corporation, according to Compustat, on the basis of the literature on firm diversification (Hough 2006; Hinson et al. 2019).

Control variables

By referring to existing work on CEO perceived dominance and corporate financial performance, we adopt several control variables related to CEOs and corporations. For the CEOs, we control for their gender (GENDER), age (AGE), tenure (TENURE), annual salary (SALARY), and facial width-to-height ratio (fWHR), which is a facial feature of CEOs that may affect corporate financial outcomes (He et al. 2019; Kim et al. 2022; Amin et al. 2024). For the corporations, we control for their firm size (SIZE), book leverage (BLEV), growth options (GROWTH), and tax rate (TAX). In the variable calculations, we use log transformations for the skewed variables on the basis of their density distributions, namely, AGE, TENURE, SALARY, and SIZE, to ensure the robustness of the empirical analysis. Extreme outliers typically exist in corporations' accounting data and CEOs' salary-related data; thus, we winsorize the corresponding continuous variables in our dataset at the 1st and 99th percentiles. Table 1 presents the variable definitions and calculations.

Table 1 Variable definitions and calculations

Type	Variable	Definition and calculation
Dependent	ROA	Return on assets, calculated as the ratio of net income to total assets
Independent	DOM	Degree of CEO perceived dominance, calculated based on facial feature extraction by deep learning and scaled to [0, 1] range
Moderator	NONSALARY	CEO's nonsalary compensation, calculated as the ratio of total annual compensation minus salary to total annual compensation
	BOARD	Corporation's board size, calculated as the total number of board members in the corporation
	SEGMENT	Number of business segments in the corporation, calculated as the number of business segments with positive annual sales volumes in the corporation
Control (CEO)	fWHR	CEO's facial width-to-height ratio, calculated as the ratio of bizygomatic width to facial height and scaled to [0, 1] range
	GENDER	CEO's gender, which takes the value of one for female, and zero for male
	AGE	CEO's age, calculated as the natural logarithm of one plus age
	TENURE	CEO's tenure, calculated as the natural logarithm of one plus the time duration (in years) that the executive has served as the corporate CEO
	SALARY	CEO's annual salary (in millions), calculated as the natural logarithm of one plus the annual salary adjusted to 2022 constant dollars
Control (Corporation)	SIZE	Firm size, calculated as the natural logarithm of one plus the corporation's total assets (in billions)
	BLEV	Corporation's book leverage, calculated as the ratio of total liabilities to assets
	GROWTH	Corporation's growth options, calculated as the ratio of capital expenditures to assets
	TAX	Corporation's tax rate, calculated as the ratio of total income tax expenses to earnings before interest and taxes

Models

Equation (1) shows the two-way fixed effects model used to estimate the main effect of CEO perceived dominance on corporate financial performance on the basis of the panel data.

$$\begin{aligned} ROA_{i,t} =& \beta_0 + \beta_1 DOM_{i,t} + \beta_2 NONSALARY_{i,t} + \beta_3 BOARD_{i,t} + \beta_4 SEGMENT_{i,t} \\ &+ \beta_5 fWHR_{i,t} + \beta_6 GENDER_{i,t} + \beta_7 AGE_{i,t} + \beta_8 TENURE_{i,t} + \beta_9 SALARY_{i,t} \\ &+ \beta_{10} SIZE_{i,t} + \beta_{11} BLEV_{i,t} + \beta_{12} GROWTH_{i,t} + \beta_{13} TAX_{i,t} + \gamma_i + \delta_t + \varepsilon_{i,t}, \end{aligned} \tag{1}$$

where i represents the corporation, t represents the year; γ_i and δ_t represent the firm and year fixed effects, respectively; and $\varepsilon_{i,t}$ represents the error. Specifically, by referring to the literature (Rule & Tskhay 2014; Hopp et al. 2023), we use firm fixed effects to address the unobserved heterogeneity of corporations and year fixed effects to control for variations in the macroeconomic climate to alleviate potential endogeneity concerns. In addition, to increase the robustness of the estimation, we employ firm-clustered standard errors to address the cross-sectional correlations and time series autocorrelations. In ***H1***, we posit that the β_1 coefficient will be negative to imply a negative association between the degree of CEO perceived dominance (DOM) and corporate financial performance (ROA).

We evaluate the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments on the association between CEO perceived dominance and corporate financial performance by constructing additional regression models for the estimation, as shown in Eq. (2).

$$\begin{aligned} ROA_{i,t} =& \beta_0 + \beta_1 DOM_{i,t} + \beta_2 DOM_{i,t} \times MOD_{i,t} + \beta_3 NONSALARY_{i,t} \\ &+ \beta_4 BOARD_{i,t} + \beta_5 SEGMENT_{i,t} + \beta_6 fWHR_{i,t} + \beta_7 GENDER_{i,t} \\ &+ \beta_8 AGE_{i,t} + \beta_9 TENURE_{i,t} + \beta_{10} SALARY_{i,t} \\ &+ \beta_{11} SIZE_{i,t} + \beta_{12} BLEV_{i,t} + \beta_{13} GROWTH_{i,t} + \beta_{14} TAX_{i,t} + \gamma_i + \delta_t + \varepsilon_{i,t}, \end{aligned} \tag{2}$$

where MOD represents a moderating variable, that is, the CEO's nonsalary compensation, the board size, or the number of business segments. We focus on the β_2 coefficient of the interaction terms (i.e., DOM × NONSALARY, DOM × BOARD, and DOM × SEGMENT), which we hypothesize to be positive, as illustrated in ***H2***, ***H3***, and ***H4***, to imply that a CEO's high nonsalary compensation, large board size, or large number of business segments can attenuate the negative association between CEO perceived dominance and corporate financial performance.

Results

Descriptive statistics and correlation analysis

Table 2 presents the descriptive statistics of the variables. As shown in the table, the mean and standard deviation of ROA are 0.05 and 0.09, respectively, and the mean and standard deviation of DOM are 0.40 and 0.17, respectively. Regarding the moderator variables, the means of NONSALARY, BOARD, and SEGMENT are 0.77, 9.42, and 1.92, respectively.

Table 2 Descriptive statistics of the variables

Variable	Mean	SD	Min	P25	Median	P75	Max
ROA	0.05	0.09	−0.34	0.02	0.05	0.09	0.28
DOM	0.40	0.17	0	0.28	0.40	0.51	1
NONSALARY	0.77	0.19	0.02	0.72	0.83	0.89	0.99
BOARD	9.42	2.19	5	8	9	11	15
SEGMENT	1.92	1.16	1	1	2	2	6
fWHR	0.38	0.12	0	0.28	0.36	0.45	1
GENDER	0.04	0.20	0	0	0	0	1
AGE	4.03	0.13	3.40	3.95	4.04	4.11	4.50
TENURE	1.98	0.73	0.69	1.39	1.95	2.48	3.93
SALARY	6.89	0.49	4.72	6.64	6.96	7.21	7.91
SIZE	1.51	1.15	0.08	0.59	1.21	2.16	5.14
BLEV	0.24	0.18	0	0.09	0.24	0.36	0.77
GROWTH	0.05	0.04	0	0.02	0.03	0.06	0.25
TAX	0.19	0.41	−2.22	0.12	0.24	0.33	1.74

Note: N = 16,038; SD: standard deviation; P25: 25th percentile; P75: 75th percentile

The bivariate correlations of the variables are reported in Table 3. As shown in the table, the degree of CEO perceived dominance (DOM) and corporate financial performance (ROA) are significantly and negatively correlated ($r = -0.039$, $p < 0.01$). In addition, DOM is significantly negatively correlated with BOARD ($r = -0.026$, $p < 0.01$) and SEGMENT ($r = -0.024$, $p < 0.01$), and ROA is significantly positively correlated with NONSALARY ($r = 0.147$, $p < 0.01$) and BOARD ($r = 0.032$, $p < 0.01$). Furthermore, we calculate the variance inflation factors (VIFs) to address the potential issue of multicollinearity. The highest observed VIF value is 2.25, and the average VIF of all the variables is 1.31, which is well below the threshold of 10.0. The findings suggest that multicollinearity is not a major concern in this analysis (Cohen et al. 2002).

Hypothesis tests

For hypothesis testing, we estimate five two-way fixed effects regression models. The results are summarized in Table 4, in which each column refers to a distinct model specification. In the first column (i.e., Model 0), only the control variables are included in the regression. The coefficients reveal the significant effects of some of the control variables on the DV (i.e., ROA), namely, the CEO's nonsalary compensation, gender, tenure, and annual salary and the corporation's number of business segments, book leverage, and growth options.

In the second column (i.e., Model 1), the independent variable (i.e., CEO perceived dominance) is added to the regression to test ***H1***, as shown in Eq. (1). The results demonstrate that CEO perceived dominance has a negative and statistically significant effect on a corporation's ROA ($\beta = -0.022, p < 0.01$); thus, ***H1*** is supported. That is, the degree of CEO perceived dominance is negatively associated with corporate financial performance. Suppose that other variables take their fixed mean value; an increase in the DOM from one standard deviation below the mean to one standard deviation above the mean can result in a 13.32 % decline (from 0.0563 to 0.0488) in the predicted ROA.

Table 3 Correlation matrix of variables

	ROA	DOM	NONSALARY	BOARD	SEGMENT	fWHR	GENDER	AGE	TENURE	SALARY	SIZE	BLEV	GROWTH
DOM	−0.039***												
NONSALARY	0.147***	−0.001											
BOARD	0.032***	−0.026***	0.241***										
SEGMENT	−0.011	−0.024***	0.081***	0.324***									
fWHR	0.035***	−0.191***	−0.008	−0.044***	−0.044***								
GENDER	−0.007	0.227***	0.021***	0.018**	−0.004	0.139***							
AGE	0.043***	−0.087***	0.019**	0.091***	0.087***	0.002	−0.036***						
TENURE	0.062***	−0.031***	−0.124***	−0.180***	−0.061***	0.014*	−0.083***	0.395***					
SALARY	0.076***	0.003	0.225***	0.449***	0.240***	−0.016**	0.018**	0.190***	0.006				
SIZE	0.029***	−0.024***	0.404***	0.607***	0.352***	−0.042***	0.022***	0.141***	−0.139***	0.559***			
BLEV	−0.159***	0.051***	0.151***	0.281***	0.146***	−0.049***	−0.011	0.078***	−0.086***	0.264***	0.334***		
GROWTH	0.046***	−0.005	−0.007	−0.001	−0.008	−0.014*	0.030***	−0.008	−0.018**	−0.021***	0.033***	0.017**	
TAX	0.114***	−0.002	0.011	0.012	0.014*	0.006	−0.016**	0.009	0.016**	0.020**	−0.009	−0.091***	0.072***

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively

Table 4 Results of two-way fixed effects models

Variable	DV = ROA				
	Model 0	Model 1	Model 2	Model 3	Model 4
DOM		−0.022***	−0.086***	−0.097***	−0.043***
		(−2.59)	(−2.68)	(−2.74)	(−2.87)
DOM × NONSALARY			0.083**		
			(2.18)		
DOM × BOARD				0.007**	
				(2.34)	
DOM × SEGMENT					0.009**
					(2.04)
NONSALARY	0.077***	0.077***	0.043***	0.077***	0.077***
	(10.92)	(10.93)	(2.85)	(10.97)	(10.94)
BOARD	−0.000	−0.000	−0.000	−0.003**	−0.000
	(−0.25)	(−0.24)	(−0.20)	(−2.12)	(−0.23)
SEGMENT	−0.003**	−0.003**	−0.003**	−0.003**	−0.007***
	(−2.08)	(−2.06)	(−2.04)	(−2.07)	(−2.91)
fWHR	0.008	0.000	0.001	−0.002	−0.002
	(0.68)	(0.00)	(0.06)	(−0.15)	(−0.12)
GENDER	−0.011*	−0.007	−0.008	−0.008	−0.007
	(−1.96)	(−1.23)	(−1.40)	(−1.38)	(−1.25)
AGE	−0.019	−0.022	−0.021	−0.022	−0.022
	(−1.17)	(−1.36)	(−1.31)	(−1.36)	(−1.37)
TENURE	0.006***	0.006***	0.006***	0.006***	0.006***
	(2.77)	(2.88)	(2.87)	(2.90)	(2.87)
SALARY	0.017***	0.017***	0.017***	0.017***	0.017***
	(5.01)	(5.03)	(5.07)	(5.07)	(5.12)
SIZE	−0.006	−0.006	−0.006	−0.006	−0.006
	(−1.50)	(−1.50)	(−1.44)	(−1.46)	(−1.53)
BLEV	−0.143***	−0.143***	−0.143***	−0.143***	−0.143***
	(−12.49)	(−12.51)	(−12.49)	(−12.53)	(−12.48)
GROWTH	0.221***	0.223***	0.225***	0.224***	0.222***
	(5.95)	(5.99)	(6.08)	(6.03)	(5.97)
TAX	0.000	0.000	0.000	0.001	0.000
	(0.15)	(0.16)	(0.13)	(0.17)	(0.15)
Constant	−0.023	0.000	0.022	0.029	0.007
	(−0.35)	(0.00)	(0.32)	(0.43)	(0.11)
Firm fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
R^2	0.4879	0.4884	0.4889	0.4888	0.4886
Adj R^2	0.4355	0.4359	0.4365	0.4363	0.4361
Within R^2	0.0810	0.0818	0.0827	0.0825	0.0822
N	16,038	16,038	16,038	16,038	16,038

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively

Regarding ***H2***, in Eq. (2), we add the interaction term DOM × NONSALARY to the regression and find that the CEO's nonsalary compensation negatively moderates the association between CEO perceived dominance and corporate financial performance, as shown in the third column (i.e., Model 2). Specifically, the interaction term significantly

and positively affects a corporation's ROA ($\beta = 0.083, p < 0.05$). The result suggests that a CEO's high nonsalary compensation can attenuate the negative association between CEO perceived dominance and corporate financial performance; hence, ***H2*** is supported.

Regarding ***H3***, we explore the moderating effect of board size by including the interaction term DOM × BOARD in the regression, following Eq. (2). As shown in the fourth column (i.e., Model 3), the board size of the corporation negatively and significantly moderates the association between DOM and ROA ($\beta = 0.007, p < 0.05$). The statistically significant and positive coefficient suggests that a large board size can attenuate the negative association between CEO perceived dominance and corporate financial performance; therefore, ***H3*** is supported.

Regarding ***H4***, we examine the moderating effect of the number of business segments by adding the interaction term DOM × SEGMENT to the regression, following Eq. (2). The fifth column (i.e., Model 4) shows that the corporation's number of business segments significantly and negatively moderates the association between DOM and ROA ($\beta = 0.009, p < 0.05$). The statistically significant and positive coefficient indicates that a large number of business segments can attenuate the negative association between CEO perceived dominance and corporate financial performance; thus, ***H4*** is supported.

To further explain the mitigating effect of the moderating variables (i.e., NONSALARY, BOARD, and SEGMENT) on the association between CEO perceived dominance and corporate financial performance, we compare the decline in the predicted ROA brought about by the increase in DOM under a low (i.e., one standard deviation below the mean) versus a high (i.e., one standard deviation above the mean) level of each of the moderators. The results are summarized in Table 5.

In Table 5, suppose that other variables take their fixed mean value, the increase in DOM will lead to a slight decline in the predicted ROA when the moderating variables are at a high, rather than a low, level. Specifically, NONSALARY can mitigate the negative association between DOM and ROA by 82.95 % (from 0.0129 to 0.0022), BOARD can mitigate the association by 65.82 % (from 0.0158 to 0.0054), and SEGMENT can mitigate the association by 58.54 % (from 0.0123 to 0.0051). The results demonstrate that a high level of CEOs' nonsalary compensation, corporate board size, or number of business segments can decrease the negative impact of CEO perceived dominance on corporate financial performance, which echoes the significant moderating effects revealed in Table 4 and further supports ***H2***, ***H3***, and ***H4***.

Table 5 ROA predictions with different levels of DOM and moderators

Variable	Low level (L) High level (H)	DOM		ROA decline	Mitigation
		Low level	High level		
NONSALARY	L	0.0448	0.0319	0.0129	82.95 %
	H	0.0684	0.0662	0.0022	
BOARD	L	0.0575	0.0417	0.0158	65.82 %
	H	0.0514	0.0460	0.0054	
SEGMENT	L	0.0597	0.0474	0.0123	58.54 %
	H	0.0482	0.0431	0.0051	

Note: Low and high levels refer to one standard deviation below and above the mean, respectively

Causal analysis

In this study, we investigate the impact of CEO perceived dominance on corporate financial performance. Considering that two-way fixed effects models may suffer from endogeneity issues owing to simultaneity, measurement errors, or unobservable omitted variables, we supplement difference-in-differences (DiD) analyses to address potential concerns and enhance the causal interpretation of our conclusions.

Subsample construction

For the DiD analysis, we employ CEO turnover as the exogenous shock. To obtain the subsample, first, we select the corporations that satisfy two conditions: (1) those that experienced CEO turnover during the sample period and (2) those that retain complete annual records within a 5-year time window before and after turnover. Among the selected corporations, those in which CEO perceived dominance has increased significantly by more than one standard deviation (i.e., 0.17, as shown in Table 2) owing to turnover are included in the treatment group. We place the corporations that experienced CEO turnover but insignificant changes (i.e., not exceeding the threshold of 0.17) in CEO perceived dominance in the control group.

Parallel trends test

To validate the effectiveness of the exogenous treatment (i.e., increase in perceived dominance by CEO turnover), we conduct a parallel trends test to examine the dynamic effect of the increase in CEO perceived dominance on corporate financial performance. The parallel trends assumption requires the treatment and control groups to exhibit similar corporate financial performance trends (i.e., ROA) during the preshock period. Like existing studies (Rambachan & Roth 2023), we use a series of dummy variables to capture the timeline related to CEO turnover. Specifically, we define the CEO turnover year as *Current*; 5 years before the turnover as $Before^{-5}$, $Before^{-4}$, $Before^{-3}$, $Before^{-2}$, and $Before^{-1}$; and the years after the turnover as $After^{+1}$, $After^{+2}$, $After^{+3}$, $After^{+4}$, and $After^{+5}$. With $Before^{-5}$ as the benchmark year, Fig. 3 shows the two-way fixed effects regression results of the parallel trends test, with 90 % confidence intervals for the estimated coefficients.

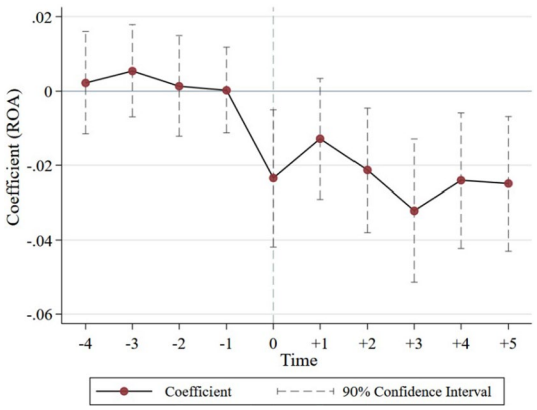

Fig. 3 Regression results of the parallel trends test

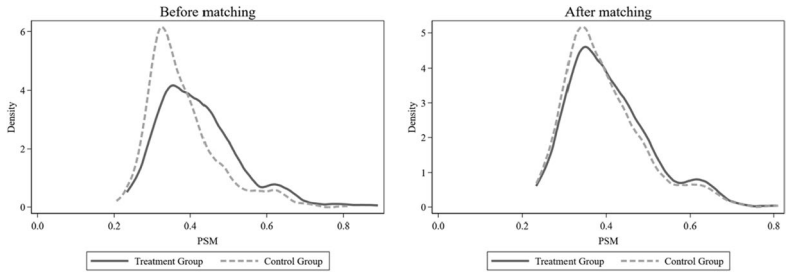

Fig. 4 Density curves of the propensity score before and after matching

As shown in Fig. 3, before CEO turnover, the estimated coefficients are positive and statistically insignificant at the 0.1 level, which suggests that no significant differences exist in ROA between the treatment and control groups. However, the estimated coefficients become negative and statistically significant (except for $After^{+1}$) after CEO turnover, which indicates a consistent gap in corporate financial performance between the two groups. That is, the ROA of the treatment group is significantly lower than that of the control group. The results generally satisfy the parallel trends assumption and demonstrate that the proposed exogenous treatment related to CEO turnover is valid, which can provide a basis for causal analysis of the impact of CEO perceived dominance on corporate financial performance.

Propensity score matching (PSM)

To further address potential selection bias, we conduct PSM to derive the treatment and control samples for the constructed DiD model (Meng et al. 2024; Fang et al. 2025). The covariates for the matching are the characteristics of the CEOs and the corporations (i.e., NONSALARY, SEGMENT, SALARY, SIZE, and GROWTH), which significantly differ between the two sample groups and play an important role in corporate financial performance. Studies have shown that a firm's size of assets, capital expenditures, and number of business segments can significantly affect its financial performance (Orlitzky 2001; George & Kabir 2012; Lovallo et al. 2020). Moreover, as direct financial incentives for the CEO, salary and nonsalary compensation can impact the CEO's motivation to a considerable extent and thus corporate performance (Jansen et al. 2009; Song & Wan 2019). Therefore, by referring to the literature (Jin & Yu 2022), we conduct one-to-two nearest neighbor matching with a caliper width of 0.01[3] to obtain pairwise treatment and control samples with similar propensity scores.

Figure 4 presents the density curves of the propensity scores of the treatment and control groups before and after matching. As shown in the left subfigure, significant differences exist between the two groups before the PSM, whereas in the right subfigure, the two curves nearly overlap after matching. The results indicate that, by conducting PSM, we can make the treatment and control samples similar in terms of the controlled characteristics of the CEOs and the corporations to overcome the problem of selection bias.

[3] We also implement three alternative matching methods, that is, one-to-one nearest neighbor matching with a caliper width of 0.01, kernel matching with a bandwidth of 0.01, and radius matching with a caliper distance of 0.01. The sample-matching results obtained by the four methods are consistent, and the average treatment effect on the treated remains statistically significant.

Table 6 Balance tests of covariates before and after matching

Variable	Unmatched (U) / Matched (M)	%bias	%reduct |bias|	*t* − test	
				t	*p*>|*t*|
SIZE	U	−19.9	75.8	−4.40	0.000
	M	4.8		1.00	0.320
GROWTH	U	18.1	74.1	4.13	0.000
	M	−4.7		−0.90	0.367
SALARY	U	−23.3	95.1	−5.07	0.000
	M	−1.1		−0.22	0.827
NONSALARY	U	−29.8	93.3	−6.82	0.000
	M	−2.0		−0.40	0.688
SEGMENT	U	14.1	71.1	3.10	0.002
	M	4.1		0.81	0.420

Table 6 summarizes the estimated bias of the controlled covariates before and after the PSM. Specifically, "%bias" measures the mean difference of the variable between the treatment group and the control group (Rosenbaum & Rubin 1985), and "%reduct |bias|" measures the reduction in such a difference after matching (Cochran & Rubin 1973).[4] The results of the balance test for each variable between the treatment group and the control group are also reported. As shown in the table, the absolute bias of all the covariates declines significantly after matching. Moreover, the *t* test results reveal that before the PSM, the treatment group and the control group are significantly different in terms of all five variables. In contrast, the matched treatment and control samples exhibit statistically insignificant differences in these variables. Therefore, the matched subsample can be valid for the DiD analysis.

DiD model estimation

By using the matched treatment and control samples, we estimate the DiD model shown in Eq. (3).

$$\begin{aligned} ROA_{i,t} =& \beta_0 + \beta_1 Treat_i \times Post_{i,t} + \beta_2 NONSALARY_{i,t} + \beta_3 BOARD_{i,t} + \beta_4 SEGMENT_{i,t} \\ &+ \beta_5 fWHR_{i,t} + \beta_6 GENDER_{i,t} + \beta_7 AGE_{i,t} + \beta_8 TENURE_{i,t} + \beta_9 SALARY_{i,t} \\ &+ \beta_{10} SIZE_{i,t} + \beta_{11} BLEV_{i,t} + \beta_{12} GROWTH_{i,t} + \beta_{13} TAX_{i,t} + \gamma_i + \delta_t + \varepsilon_{i,t}, \end{aligned} \tag{3}$$

where $Treat_i$ is a dummy variable that equals one if firm i is in the treatment group and zero otherwise, and $Post_{i,t}$ is a dummy variable that equals one if the firm–year observation is after CEO turnover and zero otherwise. As discussed in ***H1***, the β_1 coefficient is hypothesized to be negative, which implies that an increase in the degree of CEO perceived dominance can lead to a decrease in corporate financial performance (i.e., ROA).

[4] Let $\overline{x_T}$ and $\overline{x_C}$ denote the mean of variable x in the treatment group and the control group, respectively. $\sigma^2_{x_T}$ and $\sigma^2_{x_C}$ denote the variance of x in the two groups. %bias can be calculated as $(\overline{x_T} - \overline{x_C})/\sqrt{(\sigma^2_{x_T} + \sigma^2_{x_C})/2} \times 100\%$. Furthermore, let $|\overline{x_T} - \overline{x_C}|_U$ denotes the absolute difference between $\overline{x_T}$ and $\overline{x_C}$ before matching, and $|\overline{x_T} - \overline{x_C}|_M$ denotes the absolute difference after matching. %reduct |bias| can be calculated as $(|\overline{x_T} - \overline{x_C}|_U - |\overline{x_T} - \overline{x_C}|_M)/|\overline{x_T} - \overline{x_C}|_U \times 100\%$.

Table 7 Results of the DiD models

Variable	DV = ROA			
	(1)	(2)	(3)	(4)
Treat × Post	−0.023***	−0.020***	−0.023**	−0.016*
	(−3.07)	(−2.85)	(−2.14)	(−1.80)
Controls	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
R^2	0.5318	0.5550	0.6309	0.6255
Adj R^2	0.4515	0.4598	0.4871	0.4696
Within R^2	0.0965	0.0870	0.1419	0.0688
N	1,483	1,464	575	644

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively; Controls: all the CEO and corporation control variables, namely, NONSALARY, BOARD, SEGMENT, fWHR, GENDER, AGE, TENURE, SALARY, SIZE, BLEV, GROWTH, and TAX

The results of the PSM-DiD analysis are summarized in Table 7. In column (1), we present the estimation of Eq. (3). The coefficient of the interaction term Treat × Post is negative ($\beta = -0.023$) and statistically significant at the 0.01 level, which suggests that the corporation will suffer from a decline in its financial performance after it switches to a CEO with a higher degree of perceived dominance. To derive robust insights, in the subsample construction process, we change the observation time window before and after CEO turnover from 5 years to 4 years (i.e., column (2)), increase the threshold of CEO perceived dominance from 0.17 to 0.34 (i.e., column (3)), and change the two simultaneously (i.e., column (4)) to conduct PSM once again. As shown in Table 7, the robust DiD estimation results demonstrate that the degree of CEO perceived dominance significantly and negatively impacts corporate financial performance; thus, the causal tests further support ***H1***.

Additional discussion

Dynamic effect of CEO perceived dominance

To further examine how the impact of CEO perceived dominance on corporate financial performance may change over time, we investigate the potential moderating effect of CEO tenure in a fine-grained manner. Specifically, we divide all samples into five groups by equal intervals (i.e., 0.65) in the range of TENURE and define five dummy variables to denote whether a sample belongs to each group, that is, TENURE_1, TENURE_2, TENURE_3, TENURE_4, and TENURE_5, in ascending order of range. Taking the group with TENURE_5 = 1 as the reference group, we introduce the other four dummy variables and their interaction terms with DOM to the two-way fixed effects model in Eq. (1), and the regression results are shown in column (1) of Table 8. Analogously, we redivide all samples into four groups by equal intervals (i.e., 0.81) of the TENURE variable. Taking the group with TENURE_4 = 1 as the reference group, the corresponding regression results are reported in column (2) of Table 8.

As indicated in column (1), the estimated coefficients of DOM × TENURE_1, DOM × TENURE_2, and DOM × TENURE_3 are positive and statistically significant at the 0.1 level, whereas the moderating effect of TENURE_4 is insignificant. In column (2),

Table 8 Results of the moderating effect of tenure variables

Variable	DV = ROA	
	(1)	(2)
DOM	−0.081**	−0.093***
	(−2.39)	(−2.77)
DOM × TENURE_1	0.063*	0.075**
	(1.79)	(2.15)
DOM × TENURE_2	0.067*	0.078**
	(1.95)	(2.27)
DOM × TENURE_3	0.057*	0.064*
	(1.69)	(1.81)
DOM × TENURE_4	0.033	
	(1.01)	
Controls	YES	YES
Firm fixed effects	YES	YES
Year fixed effects	YES	YES
R^2	0.4887	0.4888
Adj R^2	0.4360	0.4362
Within R^2	0.0823	0.0826
N	16,038	16,038

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively; Controls: all the CEO and corporation control variables, namely, NONSALARY, BOARD, SEGMENT, fWHR, GENDER, AGE, SALARY, SIZE, BLEV, GROWTH, and TAX

the estimated coefficients of DOM × TENURE_1 and DOM × TENURE_2 are significantly positive at the 0.05 level, and the moderating effect of TENURE_3 is significant at the 0.1 level. The coefficients in both columns reveal a similar dynamic pattern; that is, the negative impact of DOM on ROA diminishes slightly over time and then becomes amplified as TENURE increases, which suggests a mixed and potentially nonlinear effect of CEO tenure on the association between CEO perceived dominance and corporate financial performance. The results echo the confounding mechanisms of time-varying impressions in the literature. On the one hand, as other executives and subordinates gain a deep understanding of the CEO's personality, their initial impression of the CEO's dominance on the basis of facial features will likely change (Wolf 1995; Berscheid & Regan 2005), which may mitigate the negative impact of the CEO's perceived dominance on information flow and thus benefit corporate financial performance. On the other hand, as the CEO's tenure extends, other firm members' initial impressions of the CEO's dominance gradually deepen, and they may form stereotypes (Sunnafrank & Ramirez Jr., 2004; Human et al. 2013, 2020). Thus, the deepened perceived dominance of the CEO may further restrict information flow and sharing in the corporation and thus impair its financial performance. The dynamic effect of CEO perceived dominance on corporate financial performance and its mechanism are complex but influential; thus, we believe that this research topic is worth exploring in the future.

Robustness checks

In this subsection, we conduct robustness checks on alternative measures of the key variables and alternative fixed effects to derive robust insights.

Alternative dependent variables: To check the robustness of the main effect, we adopt profitability and Tobin's Q as alternative variables to measure corporate financial performance. As a commonly used variable in prior studies to measure corporate financial performance and cash flow returns on assets, profitability is calculated as the ratio of operating income before depreciation to total assets (Cascio et al. 1997; Swift et al. 2019; Kozlowski 2021). Tobin's Q is a market-based measure of corporate financial performance, which is calculated as the ratio of total assets plus the market value of equity minus the book value of equity to total assets (Baker & Xuan 2016; Abdallah et al. 2020; Ishaq et al. 2021). As a widely adopted metric in the corporate governance literature, Tobin's Q can reflect the value of a firm adjusted to risks and is less susceptible to changes in accounting practices (Wernerfelt & Montgomery 1988; Jawad & Naz 2025). Table 9 shows the regression results. Specifically, the degree of CEO perceived dominance has a significantly negative association with corporate financial performance, measured by either profitability or Tobin's Q, which demonstrates that our conclusion for ***H1*** remains robust.

Alternative measures of the independent variable: As illustrated in Table 1, the degree of CEO perceived dominance is calculated on the basis of facial feature extraction via deep learning and scaled to the [0, 1] range. For the robustness checks, we adopt two alternative measures of the independent variable, that is, the raw CEO perceived dominance score derived by deep learning and that normalized by the *z*-score. Table 10 reports the re-estimated results of the four regression models, in which Models 1–4 with the raw perceived dominance score are shown in columns (1)–(4), and those with the *z*-score normalized perceived dominance are shown in columns (5)–(8). The results consistently demonstrate that the conclusions for the four hypotheses are robust across the different measures of the independent variable. Specifically, CEO perceived dominance has a significantly negative effect on corporate financial performance, and a CEO's high nonsalary compensation, large board size, and large number of business segments can significantly attenuate the negative association between CEO perceived dominance and corporate financial performance.

Alternative measures of moderator variables: To check the robustness of the moderating effects, we adopt alternative measures for the CEO's nonsalary compensation, the

Table 9 Robustness checks: alternative dependent variables

Variable	DV = Profitability	DV = Tobin's Q
DOM	−0.019**	−0.291**
	(−2.02)	(−2.30)
Controls	YES	YES
Firm fixed effects	YES	YES
Year fixed effects	YES	YES
R^2	0.5832	0.7099
Adj R^2	0.5405	0.6802
Within R^2	0.0679	0.0663
N	16,038	16,038

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively; Controls: all the CEO and corporation control variables, namely, NONSALARY, BOARD, SEGMENT, fWHR, GENDER, AGE, TENURE, SALARY, SIZE, BLEV, GROWTH, and TAX

Table 10 Robustness checks: alternative measures of the independent variable

Variable	DV = ROA							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DOM	−0.005***	−0.021***	−0.023***	−0.010***	−0.004***	−0.015***	−0.017***	−0.007***
	(−2.59)	(−2.68)	(−2.74)	(−2.87)	(−2.59)	(−2.68)	(−2.74)	(−2.87)
DOM × NONSALARY		0.020**				0.014**		
		(2.18)				(2.18)		
DOM × BOARD			0.002**				0.001**	
			(2.34)				(2.34)	
DOM × SEGMENT				0.002**				0.002**
				(2.04)				(2.04)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.4884	0.4889	0.4888	0.4886	0.4884	0.4889	0.4888	0.4886
Adj R^2	0.4359	0.4365	0.4363	0.4361	0.4359	0.4365	0.4363	0.4361
Within R^2	0.0818	0.0827	0.0825	0.0822	0.0818	0.0827	0.0825	0.0822
N	16,038	16,038	16,038	16,038	16,038	16,038	16,038	16,038

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively; Controls: all the CEO and corporate control variables, namely, NONSALARY, BOARD, SEGMENT, fWHR, GENDER, AGE, TENURE, SALARY, SIZE, BLEV, GROWTH, and TAX

Table 11 Robustness checks: alternative measures of moderator variables

Variable	DV = ROA			
	(1)	(2)	(3)	(4)
DOM	−0.032***	−0.032***	−0.027***	−0.025***
	(−3.02)	(−3.21)	(−2.92)	(−2.78)
DOM × NONSALARY	0.019*	0.021**		
	(1.82)	(2.17)		
DOM × BOARD			0.016**	
			(2.37)	
DOM × SEGMENT				0.011**
				(2.04)
Controls	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
R^2	0.4888	0.4887	0.4889	0.4886
Adj R^2	0.4363	0.4361	0.4364	0.4361
Within R^2	0.0826	0.0823	0.0827	0.0822
N	16,038	16,038	16,038	16,038

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively; Controls: all the CEO and corporate control variables, namely, NONSALARY, BOARD, SEGMENT, fWHR, GENDER, AGE, TENURE, SALARY, SIZE, BLEV, GROWTH, and TAX

board size, and the number of business segments. The regression results are summarized in Table 11. Specifically, for the CEO's nonsalary compensation, in column (1), we generate a binary variable that equals one if the CEO's absolute nonsalary compensation (i.e., total annual compensation minus salary) is above the median and zero otherwise.

In addition, considering that the CEO's total annual compensation may be divided into cash compensation (i.e., salary and bonuses) and stocks and options-based incentives, in column (2), we generate a binary variable that equals one if the CEO's noncash compensation (i.e., the ratio of total annual compensation minus salary and bonuses to total annual compensation) is above the median and zero otherwise. For board size and the number of business segments, we apply *z*-score normalization to the absolute values, and the regression results are shown in columns (3) and (4), respectively. As indicated in Table 11, the significantly positive coefficients of the interaction terms suggest that, under the different measurements, a CEO's high nonsalary compensation, large board size, and large number of business segments can weaken the negative impact of CEO perceived dominance on corporate financial performance; thus, ***H2***, ***H3***, and ***H4*** remain robust.

Alternative fixed effects: The alternative two-way fixed effects regression results are shown in Table 12 for the robustness checks. By acknowledging the potential nonlinear relationship between CEOs' facial features and years of tenure, which may not be sufficiently captured by the linear specification of TENURE in our regression models, we introduce tenure fixed effects. The effects are designed to control for tenure-specific influences that could affect the analysis, and the corresponding results are presented in columns (1)–(4). Furthermore, by recognizing that corporate financial performance (i.e., ROA) is influenced considerably by the industry in which a corporation operates, we incorporate industry fixed effects (by using the four-digit NAICS codes) in columns (5)–(8) to account for the industry-specific factors that may introduce bias to the model parameter estimation. The estimated coefficients and their statistical significance

Table 12 Robustness checks: alternative fixed effects

Variable	DV = ROA							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DOM	−0.021**	−0.086***	−0.099***	−0.042***	−0.015**	−0.143***	−0.066**	−0.034**
	(−2.38)	(−2.63)	(−2.77)	(−2.75)	(−2.04)	(−4.33)	(−2.05)	(−2.40)
DOM × NONSALARY		0.085**				0.165***		
		(2.19)				(4.14)		
DOM × BOARD			0.008**				0.005*	
			(2.42)				(1.80)	
DOM × SEGMENT				0.009**				0.010**
				(2.03)				(2.06)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES				
Tenure fixed effects	YES	YES	YES	YES				
Industry fixed effects					YES	YES	YES	YES
Year fixed effects					YES	YES	YES	YES
R^2	0.4743	0.4749	0.4748	0.4745	0.1977	0.2011	0.1982	0.1982
Adj R^2	0.4195	0.4200	0.4199	0.4196	0.1849	0.1883	0.1854	0.1854
Within R^2	0.0870	0.0880	0.0878	0.0874	0.0875	0.0914	0.0881	0.0880
N	16,038	16,038	16,038	16,038	16,038	16,038	16,038	16,038

Note: *, **, and ***: statistical significance at the 0.1, 0.05, and 0.01 levels, respectively; Controls: all the CEO and corporate control variables, namely, NONSALARY, BOARD, SEGMENT, fWHR, GENDER, AGE, TENURE, SALARY, SIZE, BLEV, GROWTH, and TAX

validate the robustness of our hypothesis testing conclusions when alternative fixed effects are considered.

Conclusion

In the context of corporate governance, perceived dominance acts as an important impression that is formed on the basis of a CEO's facial features, which can affect the behavior of other firm members (i.e., other executives and subordinates) and impact corporate outcomes. However, extant empirical results on the impact of CEO perceived dominance on corporate financial performance are inconclusive owing to limitations in sample representativeness, measurement errors, and empirical strategies. To derive robust and causal insights, this study investigates the impact of CEO perceived dominance on corporate financial performance on the basis of facial feature extraction via deep learning and conducts multiview hypothesis tests and robustness checks on a large dataset spanning a long time period of 30 years. Specifically, we use two-way fixed effects models to control for unobserved heterogeneity and variations and DiD models to further alleviate potential endogeneity concerns owing to simultaneity, measurement errors, or unobservable omitted variables. In addition, we explore the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments on the association between CEO perceived dominance and corporate financial performance.

We summarize the key findings of our empirical analysis. First, the degree of CEO perceived dominance is negatively associated with corporate financial performance, which is confirmed by two-way fixed effects models and DiD analysis. Second, a CEO's high nonsalary compensation, large board size, and large number of business segments can attenuate the negative association between CEO perceived dominance and corporate financial performance. The validated moderating effects identify the boundary conditions of the impact of CEO perceived dominance on corporate financial performance and provide evidence for the mechanism of the impact from the perspective of information flow and sharing.

This work can deepen the understanding of the impact of CEO perceived dominance on corporate financial performance and provide managerial implications for investors' decision-making practices. From a theoretical perspective, first, prior research has struggled to reach a consensus on the impact of CEO perceived dominance on corporate financial performance; however, our study demonstrates a significantly negative association between CEO perceived dominance and corporate financial performance, with robust and causal insights. Specifically, to address the limitations of existing studies in terms of sample representativeness, measurement errors, and empirical strategies, we conduct various tests on a large dataset spanning a long time period with two-way fixed effects models and DiD models. Second, to broaden the scope of previous work, our study explores the potential mechanism of the association between CEO perceived dominance and corporate financial performance from the perspective of information flow and sharing. Specifically, we investigate the moderating effects of CEOs' nonsalary compensation, board size, and the number of business segments, and the empirical results reveal that these factors may affect information flow and sharing in the corporation and thus moderate the negative impact of CEO perceived dominance on corporate financial

performance. From a practical viewpoint, we conduct an in-depth analysis of the perceptive reasons behind the impact of CEOs. The findings can provide investors with valuable insights to make informed investment decisions during CEO turnover, which can help them predict the impact of the new CEO on other firm members' information flow and sharing behaviors and thus on corporate financial performance and be aware of the potential risks brought about by the high perceived dominance of the CEO.

Future efforts may employ advanced deep learning methods to improve the measurement of CEO perceived dominance and enrich the methods with audio or video data of CEOs. From a dynamic perspective, future work may examine how the impact of CEO perceived dominance on corporate financial performance changes over time and explore the potential mechanism of such changes. Another direction is to investigate the impact of CEO perceived dominance on corporate performance in other aspects, such as innovation, customer satisfaction, and social responsibility.

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Author contributions
Baojun Ma developed the research conceptualization, formulated the research goals, designed the methodology, and performed the supervision. Lingyun Zhou performed the acquisition of data, conducted the validation and empirical analysis, and drafted the manuscript. Yao Mu designed the methodology, improved the implementation of experiments, and reviewed and edited the manuscript. Yi Chen designed the methodology and improved the implementation of experiments. Jian Zhang developed the research conceptualization and designed the methodology. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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