



Board Diversity and Corporate Investment Efficiency: a Multi-Dimensional Analysis

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Abstract. This study systematically examines the multidimensional impact of board composition diversity on corporate investment efficiency. Drawing upon an annual sample of U.S.-listed companies from 1980 to 2022, a governance diversity index is constructed across four dimensions: gender, nationality, age, and cultural background. This index employs a dual measurement approach combining the Herfindahl–Hirschman Index (HHI) with the exact number of categories, while capital allocation effectiveness is assessed through Tobin’s Q and efficiency metric derived from Data Envelopment Analysis (DEA) method. The study employs a dual fixed-effects model for benchmark testing, subsequently identifying the relative explanatory power of each dimension through a competitive regression framework. Heterogeneity analysis is further conducted based on differences in firm size and growth opportunities. Core findings indicate that nationality and gender diversity significantly enhance investment efficiency, with the positive effect of gender diversity being particularly pronounced in large and high-growth firms. Cultural diversity primarily elevates Tobin’s Q, whereas age dispersion exerts a detrimental impact on operational efficiency. This study contributes by transcending the limitations of single-dimensional research in existing literature. Through a multi-level, synergistic examination and the effective separation of interference between dimensions via competitive design, it reveals the heterogeneous mechanisms and boundary conditions governing the role of diversity. This deepens theoretical understanding of board governance effectiveness, providing actionable empirical evidence and practical insights for listed companies to optimize director selection mechanisms and for regulators to refine diversity governance policies.

Keywords: Board Diversity, Tobin’s Q, Investment Efficiency, Panel Regression, Heterogeneity Analysis.

1 Introduction

In recent years, the trend towards greater diversity in corporate board structures has become increasingly pronounced, particularly in terms of gender, age, and cultural background. Historically, boards were typically dominated by older males, but over the past few decades, societal and legal pressures have driven significant shifts towards more diverse membership [1]. Data indicates that globally, the proportion of female

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board members has risen from 16.9% in 2018 to 23.3% in 2023 [2]. However, academic research on the relationship between board diversity and corporate investment efficiency has yielded inconclusive findings. One perspective holds that board diversity can bring specialized skills, knowledge, and experience from different fields to the company, thereby enhancing its ability to access critical resources, reducing information asymmetry, and improving the quality of investment decisions. Agency Theory posits that the core function of the board is to oversee management in order to safeguard shareholder interests [3]. Board diversity, by increasing the proportion of independent directors, can effectively reduce agency costs and thus enhance investment efficiency. Another perspective contends that diversity may provoke conflicts of values, cultural differences, and communication barriers, thereby increasing communication costs and diminishing decision-making efficiency [4]. Consequently, the precise relationship between board diversity and corporate investment efficiency warrants further empirical investigation.

To systematically examine the impact of board diversity on corporate investment efficiency, this study utilizes annual data from U.S.-listed companies spanning 1980 to 2022. A comprehensive panel dataset has been constructed, incorporating board diversity characteristics, investment efficiency metrics, and firm-level financial data. Methodologically, this study constructs a diversity metric across four dimensions, including gender, nationality, age, and cultural background, and employs a dual-measurement approaches, which are the Herfindahl-Hirschman Index (HHI) and category counts. This dual approach ensures the robustness of the research findings. Subsequently, Tobin's Q and a firm efficiency index based on Data Envelopment Analysis (DEA) are employed to collectively measure corporate investment efficiency. Finally, a multiple regression model controlling for industry and year fixed effects is utilized to empirically examine the independent and combined effects of various diversity dimensions on investment efficiency. Furthermore, a heterogeneity test, using gender diversity as an example, is conducted to investigate whether the effects of diversity are more pronounced in large-scale and high-growth firms. This approach strengthens the causal interpretation of the findings, deepens the understanding of the mechanisms through which diversity influences corporate investment efficiency, and provides practical implications.

Research findings indicate that national, gender, and cultural diversity within boards significantly enhance corporate investment efficiency, particularly exerting a pronounced positive effect on Tobin's Q. Conversely, age diversity demonstrates a significant negative impact, suggesting that dispersed age structures may incur communication costs and decision conflicts, thereby undermining internal operational efficiency. In a horse racing analysis encompassing all diversity dimensions, the effects of nationality and gender diversity prove most robust, emerging as core drivers of investment efficiency gains. Finally, a heterogeneity analysis using gender diversity as an example reveals that its positive impact on investment efficiency is particularly pronounced in larger and higher-growth companies.

Existing literature has confirmed that corporate investment efficiency arises from the combined influence of multiple internal and external factors. Internally, this encom-

passes dimensions such as corporate governance, managerial capability, and ESG performance, whilst externally it is constrained by elements including macroeconomic policies and the level of financial development [5-6]. Research has also examined the positive effects of board diversity on corporate innovation, risk levels, and social responsibility [7-8], though studies predominantly focus on singular dimensions such as gender or nationality. Conclusions regarding its impact on financial performance and investment efficiency remain inconclusive. Thus, the primary contribution of this paper lies in enriching the discourse on the relationship between board diversity and corporate investment efficiency. By examining the impact of four distinct dimensions of diversity on investment efficiency, it addresses the existing research gap concerning the insufficient exploration of diverse sub-dimensions. Secondly, through the introduction of a horse racing analysis, multiple diversity variables across dimensions are compared within a single model, effectively isolating the mutual interference between these dimensions. Thirdly, the study employs heterogeneity analysis to strengthen the causal inferences of its findings and provides evidence for understanding the operational mechanisms of diversity. Consequently, this research offers concrete, actionable guidance for companies seeking to optimize their board structures, thereby facilitating the realization of diversity's value.

2 Data and Methodology

This study selects annual data from U.S.-listed companies between 1980 and 2022 as the initial sample, constructing a comprehensive dataset encompassing diversification metrics, investment efficiency indicators, and financial data. Industry classifications adhere to the U.S. SIC standards. To ensure the reliability of the results, financial industry reports are excluded, and only statements denominated in U.S. dollars are selected.

2.1 Explained Variables – Investment Efficiency Measures

The metrics for measuring investment efficiency select Tobin's Q and the operational efficiency index proposed by Demerjian et al. (2012) [9]. Tobin's Q is an indicator measuring the ratio between a company's market value and its replacement cost, calculated as the following equation (1).

$$Tobin's\ Q = \frac{Market\ value\ of\ equity + Market\ value\ of\ liabilities}{Book\ value\ of\ assets} \quad (1)$$

Market value encompasses both the market value of equity and the market value of liabilities, while the book value refers to the book value of the company's total assets. Hence, a higher Tobin's Q ratio typically indicates that the company presents better investment opportunities and higher investment efficiency [10].

The Demerjian firm efficiency index is measured by using the DEA method to assess the efficiency of a company's output given its inputs [9]. A higher Demerjian firm efficiency score indicates that a company is more effective at transforming its resources

into outputs, thereby reflecting greater investment efficiency. To reduce the impact of outliers on regression results, the study applies truncated quantiles at the 1% and 99% percentiles for both indices.

2.2 Explanatory Variables – Diversity Measures

The *BoardEx* database is the main source of the board diversification data used in this study. *BoardEx* is a globally recognized platform for board information services that gathers specific personal traits and tenure data of board members from listed companies all around the world [11]. Based on raw data provided by *BoardEx*, this paper constructs a diversity metric across four dimensions: gender, nationality, age, and culture. It employs two metrics, the category count and the HHI, where a higher count and a lower HHI signify more diversity [12].

Taking gender as an example, the metric calculates the sum of squares of gender representation within each company's board for each year, along with the total number of genders represented on the board. The same approach applies to nationality, age, and culture. Age is grouped into intervals of ten years, while culture is determined by matching board members' surnames to their cultural origins. All raw indicators are computed at the board level, with data ultimately aggregated to the company-year level. For each HHI metric, the mean value (across all boards) is taken, while the count metric uses the maximum value (retaining the highest category count across all boards for that company in the year). This aggregation method preserves overall company diversity information while reasonably handling complex scenarios involving multiple boards. To ensure the authenticity of diversity metrics, tail effects are not used to exclude extreme outliers.

2.3 Control Variables - Financial Variables

All corporate financial data used in this study are sourced from the *Compustat North America* database, which provides comprehensive financial statement data for major publicly listed companies across North America. This paper controls for firm size (*Size*), profitability (*ROA*), leverage ratio (*Leverage*), cash holding ratio (*Cash Ratio*), and sales growth rate (*Sales Growth*) to account for other factors that may influence corporate investment efficiency. To ensure the reliability of the research findings, samples with missing total assets, missing sales, or zero sales would be excluded, and all continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers.

2.4 Descriptive Statistics

After the aforementioned variable processing, the study ultimately obtains a sample of 33,185 firm-year observations for analysis. A descriptive statistical analysis is conducted to examine the basic characteristics of the variables. Table 1 presents the descriptive statistics of the main variables, from which the following conclusions can be drawn.

Firstly, the mean *Tobin's Q* is 2.057, which is greater than its median of 1.596. Furthermore, the substantial gap between the 75th percentile value of 2.376 and the maximum value of 8.493 indicates a right-skewed distribution. This suggests that while the majority of firms have *Tobin's Q* values between 1.2 and 2.4, a small number of firms with extremely high values significantly elevate the average. This observation is further corroborated by the *Firm Efficiency* measure. Secondly, the *Gender HHI* and *Nationality HHI* are 0.866 and 0.929 respectively, indicating a high degree of concentration in both dimensions. Over 75% of the firms have boards composed entirely of members of a single nationality. Although most company boards include two genders, the high HHI values indicate that even when two genders are present, one gender is overwhelmingly dominant, specifically manifested as male dominance. Age and cultural diversity show better performance, with most firms having 3 to 4 different age groups and cultural types represented on their boards. The distributions of the other variables all fall within reasonable ranges.

Table 1. Descriptive statistical results.

Variable	Count	Mean	Std.	Min.	25%	50%	75%	Max.
<i>Tobin's Q</i>	33185	2.057	1.399	0.654	1.189	1.596	2.376	8.493
<i>Firm Efficiency</i>	33185	0.327	0.168	0.071	0.229	0.277	0.368	1.000
<i>Gender HHI</i>	33185	0.866	0.139	0.500	0.755	0.867	1.000	1.000
<i>Gender Count</i>	33185	1.549	0.498	1.000	1.000	2.000	2.000	2.000
<i>Nationality HHI</i>	33185	0.929	0.147	0.200	1.000	1.000	1.000	1.000
<i>Nationality Count</i>	33185	1.280	0.575	1.000	1.000	1.000	1.000	6.000
<i>Age HHI</i>	33185	0.392	0.111	0.160	0.313	0.375	0.440	1.000
<i>Age Count</i>	33185	3.446	0.829	1.000	3.000	3.000	4.000	7.000
<i>Culture HHI</i>	33185	0.376	0.158	0.107	0.265	0.337	0.440	1.000
<i>Culture Count</i>	33185	4.227	1.452	1.000	3.000	4.000	5.000	11.000
<i>Size</i>	33185	6.420	1.848	2.641	5.108	6.368	7.654	10.984
<i>ROA</i>	33185	0.090	0.154	-0.595	0.054	0.114	0.168	0.418
<i>Leverage</i>	33185	0.175	0.195	0.000	0.001	0.123	0.280	0.890
<i>Cash Ratio</i>	33185	0.209	0.217	0.001	0.041	0.130	0.308	0.891
<i>Sales Growth</i>	33185	0.160	0.426	-0.521	0.013	0.081	0.212	2.888

2.5 Empirical Model

To examine the impact of board diversity on corporate investment efficiency, this study employs a multiple regression analysis. This paper constructs the following benchmark regression model as equation (2).

$$Efficiency_{i,t} = \beta_0 + \beta_1 Diversity_{i,t} + \gamma * ControlVar'_{i,t} + \alpha_j + \delta_t + \varepsilon_{i,t} \quad (2)$$

Here, *Efficiency* represents the company's investment efficiency, with *Tobin's Q* and Demerjian *Firm Efficiency* used as the dependent variables in the regression

analysis. *Diversity* refers to the indicators of board diversity, including gender diversity, nationality diversity, age diversity, and cultural diversity. This paper will conduct regression analyses for each of these diversity indicators separately. *ControlVar* represents various control variables. Additionally, α_j denotes the industry fixed effects, δ_t represents the year fixed effects, and $\varepsilon_{i,t}$ is the error term.

To further substantiate the causal nature of the findings and deepen understanding of its operational mechanisms, subsequent analysis will focus on examining how gender diversity impacts investment efficiency across companies of varying complexity levels, thereby conducting heterogeneity tests. The formula is as follows (equation (3)).

$$Efficiency_{i,t} = \alpha_0 + \alpha_1 Gender\ Count_{i,t} * Moderator_{i,t} + \alpha_2 Gender\ Count_{i,t} + \alpha_3 Moderator'_{i,t} + \gamma * ControlVar'_{i,t} + \alpha_j + \delta_t + \varepsilon_{i,t} \quad (3)$$

3 Research Results and Analysis

This section aims to systematically present empirical findings on the impact of board diversity on corporate investment efficiency. The study first conducts benchmark regressions to examine the independent effects of nationality, gender, age, and cultural diversity on investment efficiency. Subsequently, a horse racing analysis integrates all diversity dimensions into a single model to identify which dimension demonstrates greater explanatory power. Finally, this paper conducts heterogeneity analyses to examine whether the effects of board diversity differ across firm size and growth context.

3.1 Baseline Regression

Regression models are constructed and reported in Tables 2–5. Industry fixed effects and year fixed effects are incorporated to account for industry-specific characteristics that do not change over time and macroeconomic shocks that are independent of industry.

Table 2 demonstrates the impact of board nationality diversity on investment efficiency. In columns (1) and (3), the coefficient for *Nationality Count* is significantly positive at the 1% level, at 0.077 and 0.013 respectively. This indicates that compared to boards with a single nationality, boards comprising multiple nationalities exhibit an average *Tobin's Q* 7.7% higher and *Firm Efficiency* 1.3% higher. In columns (2) and (4), the coefficient for *Nationality HHI* is significantly negative at the 5% level, at -0.211 and -0.025 respectively. This indicates that the richer the nationality background of the board, the higher the firm's investment and operational efficiency. Directors from diverse countries and regions bring broader international perspectives, diverse knowledge networks, and varied approaches to problem-solving, thereby aiding the firm in making superior investment decisions.

Tables 3 and 4 show that gender and cultural diversity similarly have a positive effect on investment efficiency. However, Table 5 reveals a different impact for age diversity. *Age Count* shows no significant correlation with *Tobin's Q* but has a significant negative effect on *Firm Efficiency*, while *Age HHI* shows no significant correlation

with *Tobin's Q* but has a significant positive effect on *Firm Efficiency*. A possible explanation is that investment efficiency does not focus on age distribution, but internal operational efficiency indeed benefits from age concentration. Boards with overly dispersed age structures may face communication barriers or decision-making conflicts, which to some extent impair daily operational efficiency. In contrast, teams with relatively concentrated age structures may make decisions more quickly and execute more effectively. Overall, the baseline regression results preliminarily confirm that board nationality and gender diversity have a robust positive impact on corporate investment efficiency. The positive effect of cultural diversity is mainly reflected in corporate value, while age diversity does not contribute positively to firm efficiency.

Table 2. Baseline regression results — Nationality.

	<i>Tobin's Q</i>		<i>Firm Efficiency</i>	
	(1)	(2)	(3)	(4)
<i>Nationality Count</i>	0.077*** (3.449)	/	0.013*** (3.416)	/
<i>Nationality HHI</i>	/	-0.211** (-2.558)	/	-0.025** (-2.309)
<i>Size</i>	-0.049*** (-6.243)	-0.045*** (-5.611)	0.039*** (20.800)	0.040*** (20.744)
<i>ROA</i>	1.948*** (6.219)	1.944*** (6.201)	0.294*** (10.659)	0.292*** (10.624)
<i>Leverage</i>	0.133 (1.250)	0.130 (1.217)	-0.039*** (-3.547)	-0.040*** (-3.577)
<i>Cash Ratio</i>	2.331*** (17.215)	2.334*** (17.213)	0.133*** (8.407)	0.114*** (8.430)
<i>Sales Growth</i>	0.521*** (6.400)	0.520*** (6.399)	0.024*** (8.102)	0.024*** (8.095)
<i>Year</i>	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes
<i>R-squared</i>	0.335	0.334	0.450	0.449
<i>N</i>	33185	33185	33185	33185

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

Table 3. Baseline regression results — Gender.

	<i>Tobin's Q</i>		<i>Firm Efficiency</i>	
	(1)	(2)	(3)	(4)
<i>Gender Count</i>	0.129*** (4.547)	/	0.004 (1.299)	/
<i>Gender HHI</i>	/	-0.403*** (-3.934)	/	-0.026** (-2.234)
<i>Size</i>	-0.056*** (-6.514)	-0.052*** (-6.002)	0.040*** (20.445)	0.040*** (20.419)

	<i>Tobin's Q</i>		<i>Firm Efficiency</i>	
	(1)	(2)	(3)	(4)
<i>ROA</i>	1.943*** (6.230)	1.940*** (6.214)	0.292*** (10.620)	0.292*** (10.618)
<i>Leverage</i>	0.143 (1.354)	0.143 (1.341)	-0.039*** (-3.548)	-0.039*** (-3.534)
<i>Cash Ratio</i>	2.329*** (17.110)	2.329*** (17.040)	0.114*** (8.377)	0.114*** (8.338)
<i>Sales Growth</i>	0.526*** (6.379)	0.524*** (6.371)	0.024*** (8.297)	0.024*** (8.359)
<i>Year</i>	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes
<i>R-squared</i>	0.335	0.335	0.449	0.449
<i>N</i>	33185	33185	33185	33185

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

Table 4. Baseline regression results — Culture.

	<i>Tobin's Q</i>		<i>Firm Efficiency</i>	
	(1)	(2)	(3)	(4)
<i>Culture Count</i>	0.036*** (3.827)	/	-0.000 (-0.067)	/
<i>Culture HHI</i>	/	-0.142* (-1.711)	/	-0.011 (-1.489)
<i>Size</i>	-0.054*** (-6.188)	-0.044*** (-5.363)	0.040*** (20.162)	0.041*** (20.456)
<i>ROA</i>	1.946*** (6.235)	1.938*** (6.200)	0.291*** (10.585)	0.291*** (10.576)
<i>Leverage</i>	0.131 (1.229)	0.128 (1.200)	-0.040*** (-3.577)	-0.040*** (-3.560)
<i>Cash Ratio</i>	2.323*** (16.959)	2.331*** (16.945)	0.114*** (8.353)	0.115*** (8.403)
<i>Sales Growth</i>	0.523*** (6.391)	0.521*** (6.390)	0.024*** (8.210)	0.024*** (8.168)
<i>Year</i>	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes
<i>R-squared</i>	0.335	0.334	0.449	0.449
<i>N</i>	33185	33185	33185	33185

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

Table 5. Baseline regression results — Age.

	<i>Tobin's Q</i>		<i>Firm Efficiency</i>	
	(1)	(2)	(3)	(4)
<i>Age Count</i>	0.022 (1.599)	/	-0.005*** (-2.973)	/
<i>Age HHI</i>	/	-0.118 (-1.213)	/	0.027** (2.592)
<i>Size</i>	-0.043*** (-5.357)	-0.042*** (-5.243)	0.041*** (20.997)	0.041*** (20.849)
<i>ROA</i>	1.936*** (6.191)	1.936*** (6.191)	0.291*** (10.539)	0.291*** (10.546)
<i>Leverage</i>	0.127 (1.187)	0.128 (1.198)	-0.039*** (-3.547)	-0.040*** (-3.564)
<i>Cash Ratio</i>	2.338*** (17.174)	2.338*** (17.168)	0.114*** (8.377)	0.114*** (8.388)
<i>Sales Growth</i>	0.521*** (6.391)	0.521*** (6.384)	0.024*** (8.228)	0.024*** (8.253)
<i>Year</i>	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes
<i>R-squared</i>	0.334	0.334	0.449	0.449
<i>N</i>	33185	33185	33185	33185

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

3.2 Horse Racing Analysis

To avoid potential interactions among different diversity dimensions and to examine which dimension possesses greater explanatory power, this study conducts a horse racing analysis by simultaneously including all four diversity proxy variables in the regression model. The results are shown in Table 6. In the models explaining *Tobin's Q* (columns (1) and (2)), the coefficients for *Nationality Count*, *Gender Count* and *Culture Count* remain significantly positive at the 1% level, and the coefficients for *Nationality HHI* and *Gender HHI* also remain significantly negative. This indicates that even under conditions of competition, nationality, gender, and cultural diversity still make independent and significant positive contributions to enhancing firm investment efficiency. In contrast, the coefficient for age diversity is insignificant.

In the model explaining *Firm Efficiency* (columns (3) and (4)), the coefficient for *Nationality Count* remains significantly positive (coefficient = 0.013), while the coefficients for *Nationality HHI* and *Gender HHI* are significantly negative (coefficients = -0.025 and -0.025, respectively). This reaffirms the robust effect of nationality and gender diversity on enhancing operational efficiency, while the coefficient for cultural diversity remains insignificant. The complex influence of age diversity persists in the horse racing analysis, manifesting as a significant negative correlation. In summary, the results of the horse racing analysis reinforce the benchmark regression findings:

board diversity in nationality and gender represents the most robust and core driver of enhanced corporate investment and operational efficiency. Cultural diversity also demonstrates a positive impact on investment efficiency, while age diversity shows a negative effect on operational efficiency.

Table 6. Horse racing analysis regression results.

	<i>Tobin's Q</i>		<i>Firm Efficiency</i>	
	(1)	(2)	(3)	(4)
<i>Nationality Count</i>	0.071*** (3.215)	/	0.013*** (3.385)	/
<i>Nationality HHI</i>	/	-0.212** (-2.605)	/	-0.025** (-2.327)
<i>Gender Count</i>	0.120*** (4.175)	/	0.004 (1.314)	/
<i>Gender HHI</i>	/	-0.408*** (-3.925)	/	-0.025** (-2.199)
<i>Age Count</i>	0.013 (1.037)	/	-0.005*** (-2.837)	/
<i>Age HHI</i>	/	-0.125 (-1.295)	/	0.025** (2.376)
<i>Culture Count</i>	0.029*** (3.108)	/	-0.000 (-0.118)	/
<i>Culture HHI</i>	/	-0.134 (-1.602)	/	-0.011 (1.393)
<i>Size</i>	-0.074*** (-8.141)	-0.057*** (-6.696)	0.039*** (20.232)	0.040*** (19.984)
<i>ROA</i>	1.967*** (6.327)	1.957*** (6.280)	0.293*** (10.685)	0.292*** (10.651)
<i>Leverage</i>	0.145 (1.388)	0.141 (1.334)	-0.038*** (-3.494)	-0.039*** (-3.511)
<i>Cash Ratio</i>	2.311*** (16.994)	2.318*** (16.877)	0.113*** (8.337)	0.114*** (8.383)
<i>Sales Growth</i>	0.527*** (6.406)	0.523*** (6.397)	0.024*** (8.333)	0.024*** (8.359)
<i>Year</i>	Yes	Yes	Yes	Yes
<i>Industry</i>	Yes	Yes	Yes	Yes
<i>R-squared</i>	0.337	0.336	0.451	0.450
<i>N</i>	33185	33185	33185	33185

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

3.3 Heterogeneity Analysis

The value of board diversity may not be uniform across all companies. For instance, in larger, more complex firms or in companies experiencing higher growth and greater uncertainty, diverse perspectives and experiences may yield greater impact [13]. Testing this helps substantiate that the main effect this study identified is more likely causal rather than merely correlational. It also deepens the understanding of the mechanisms through which board diversity functions, enhancing the study's practical relevance. Therefore, this study employs gender diversity, which is the most robust and easily achievable effect, as a case for further heterogeneity analysis.

Specifically, the study calculates the industry-year median for company growth rate (*Sales Growth*) as a benchmark for assessing the corporate life cycle. Industry-year samples exceeding the median (*High Sales Growth*) are assigned a value of 1, while others receive 0. Next, the industry-year median for firm size (*Size*) is calculated, assigning 1 to samples above the median (*Large Size*) and 0 otherwise. The interaction terms between the gender diversity indicator *Gender Count* and these two moderators are introduced into the regression. Results are presented in Table 7.

Column (1) of the table examine the heterogeneous effects of firm size. The coefficient for the interaction term *Gender Count * Large Size* is significantly positive at the 1% level (coefficient = 0.029). This clearly indicates that gender diversity exerts a more pronounced positive effect on enhancing investment efficiency within large firms. Typically characterized by more complex organizational structures and facing more diverse market environments, large companies can more effectively translate the broader perspectives and prudent decision-making styles fostered by gender-diverse boards into efficiency gains.

Columns (2) of the table examine the impact of firm growth. The coefficient for the interaction term *Gender Count * High Sales Growth* is significantly positive at the 5% level (coefficient = 0.008). This finding indicates that the positive effect of gender diversity on investment efficiency is amplified in high-growth companies. Such firms often require continuous exploration of new investment opportunities and adaptation to rapidly changing markets. Gender-diverse boards are more likely to stimulate innovation and avoid the pitfalls of groupthink, thereby supporting sustainable corporate growth.

In summary, the heterogeneity analysis provides deeper insights into the research. The economic benefits of board gender diversity are not uniform across the board but are significantly amplified in large companies and high-growth firms. This offers valuable practical implications for companies seeking to optimize their governance structures at different stages of development.

Table 7. Regression results for the heterogeneity test.

	<i>Firm Efficiency</i>	
	(1)	(2)
<i>Gender Count * Large Size</i>	0.029*** (5.714)	/
<i>Gender Count * High Sales Growth</i>	/	0.008** (2.367)
<i>Gender Count</i>	-0.008** (-2.475)	0.000 (0.030)
<i>Large size</i>	-0.048*** (-5.458)	/
<i>High Sales Growth</i>	/	-0.008 (-1.466)
<i>Size</i>	0.040*** (18.590)	0.040*** (20.387)
<i>ROA</i>	0.293*** (10.744)	0.290*** (10.673)
<i>Leverage</i>	-0.038*** (-3.416)	-0.039*** (-3.532)
<i>Cash Ratio</i>	0.115*** (8.540)	0.114*** (8.428)
<i>Sales Growth</i>	0.025*** (8.281)	0.022*** (8.889)
<i>Year</i>	Yes	Yes
<i>Industry</i>	Yes	Yes
<i>R-squared</i>	0.450	0.449
<i>N</i>	33185	33185

Note: The data in the table are regression coefficient and t-value of each variable, and ***, **, and * are significant at the significance level of 1%, 5% and 10% respectively.

4 Conclusion

This study systematically examines the impact of board diversity on corporate investment efficiency using panel data from U.S.-listed companies spanning 1980 to 2022. A diversity metric is constructed across four core dimensions: gender, nationality, age, and cultural background. Employing a dual-measurement approach alongside dual-perspective investment efficiency metrics, combined with horse racing analysis and heterogeneity tests, the research yields findings of both theoretical and practical significance. Key conclusions are as follows.

Firstly, the impact of board diversity on corporate investment efficiency exhibits significant dimensional heterogeneity. Nationality, gender, and cultural diversity all markedly enhance investment efficiency, with nationality and gender diversity demonstrating the most robust positive effects. These not only elevate Tobin's Q but also op-

optimize operational efficiency. The positive role of cultural diversity is primarily concentrated at the corporate investment efficiency level. Age diversity, however, exhibits a significant negative impact. A dispersed age structure tends to increase communication costs and decision-making conflicts, thereby undermining internal operational efficiency. This finding also reveals that diversity is not necessarily ‘the more, the better’; attention must be paid to the appropriateness of diversity dimensions.

Secondly, after controlling for the mutual interference among various dimensions of diversity, nationality and gender diversity continue to exert a significant positive influence on investment and operational efficiency, serving as the core drivers of efficiency enhancement. Cultural diversity maintains its positive impact on investment efficiency, while the negative effect of age diversity persists. This provides empirical support for distinguishing the relative importance of different diversity dimensions.

Thirdly, heterogeneity analysis indicates that the value effect of gender diversity is more pronounced in larger, higher-growth companies. Complex organizational structures and diverse market environments in large corporations necessitate a multi-perspective approach to better address management challenges. Meanwhile, high-growth firms confront greater investment opportunities and uncertainties; gender-diverse boards can effectively mitigate groupthink, stimulate innovative decision-making, and thereby underpin sustainable growth.

Based on the above conclusions, this paper proposes the following practical implications. Firstly, when optimizing board composition, enterprises should prioritize advancing nationality and gender diversity. By incorporating directors with diverse international backgrounds and gender perspectives, decision-making resources and oversight dimensions can be enriched. Concurrently, age distribution should be appropriately managed to minimize unnecessary communication friction. Secondly, large enterprises and high-growth companies should intensify efforts to advance gender diversity. By aligning with their developmental stage and business characteristics, they can establish governance teams that balance inclusivity with decision-making efficiency, thereby fully unlocking the value of diverse governance. Thirdly, policymakers should further refine guidelines on board diversity, encouraging companies to establish substantive diversity mechanisms rather than superficial structural adjustments. Concurrently, they should guide enterprises to focus on the cultural integration and communication mechanisms underpinning diversity, ensuring its value is fully realized.

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