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Strategic resilience: Exploring diversification's impact on R&D investment during economic crises

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ABSTRACT

Background: This paper aims to investigate the impact of diversification on decisions regarding strategic and technological choices during the global financial crisis. Specifically, we examine how the sudden changes in the macroeconomic environment impact research and development (R&D) investment decisions in diversified firms compared to stand-alone firms during the crisis.
Methods: This study uses a panel sample of US firms from 2004 to 2009, which includes the crisis years (2007–2009). The final sample has 3232 firm-year observations. We use cross-sectional time-series feasible generalized least squares regression models.
Results: Our findings show that firms with a higher degree of diversification are more likely to sustain or even increase R&D investment during economic crises, contrary to the general trend of R&D cuts. The negative relationship between diversification and R&D becomes weaker in the crisis period compared to the pre-crisis period.
Conclusion: Our research reveals a distinctive advantage conferred by diversification in the realm of financing and investment. It allows firms not only to withstand turbulent economic conditions, but also to actively augment their value creation by amplifying R&D investment during profound uncertainty. This highlights the strategic acumen of diversified firms, which position themselves not merely as passive entities enduring crises but as proactive creators of value in the midst of adversity. In the continuously shifting terrain of corporate economics, these insights serve as a guiding light, directing firms towards strategies that not only shield them from crises, but also empower them to flourish and innovate, even during the most formidable challenges.

1. Introduction

The external business environment oscillates between intervals of relative stability and bouts of volatility. Abrupt external changes have the potential to significantly affect a firm's strategic decisions [1]. Financial crises in particular give rise to financial constraints that influence investment choices [2,3]. These crises notably affect decisions related to research and development (R&D) investment, a process highly dependent on available financial resources [4,5]. Investment in R&D is an important strategy for firms for several reasons. Firms that maintained R&D investment during crises may have developed innovations crucial to their survival and subsequent recovery, thus offering valuable lessons on resilience [6]. Prioritizing R&D during a crisis can enable firms to emerge stronger, with new products, processes, or technologies that distinguish them from competitors [7]. Moreover, economic crises can serve as catalysts for innovation, as firms seek novel approaches to cope with reduced demand and financial constraints [8,9]. Investigating R&D

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investment during the financial crisis can uncover patterns of innovation that facilitated the recovery and growth of firms and economies post-crisis [10–12]. Moreover, analysing R&D investment decisions from this period provides insights into how firms manage risk and allocate resources under severe constraints, guiding future strategic decision-making in similar situations [13]. Finally, the ability of firms to adapt and reconfigure resources during crises is crucial for their long-term success. Examining R&D investment during the financial crisis illuminates the development of dynamic capabilities, enabling firms to respond to and leverage opportunities arising from economic shocks.

However, the financial crisis precipitates a decrease in credit supply, compelling banks and financial institutions to curtail investment in uncertain and risky ventures, including R&D projects. Consequently, companies encounter formidable challenges in securing external capital to fund critical investments like R&D. As a result, a significant number of firms find themselves compelled to reduce their R&D expenditures during periods of economic crisis. Yet research indicates that the behaviour of firms regarding R&D investment during recessions varies between diversified firms and stand-alone firms. These disparities stem from the financial and investment advantages inherent in diversified firms [14–16].

Despite extensive research on the impacts of diversification and economic crises on firm performance (e.g., Ref. [14,15]), there is a paucity of studies examining the interplay between diversification strategies and R&D investment decisions during economic downturns. Previous studies primarily focus on either diversification (e.g., Ref. [17–19]) or crisis impact (e.g., Ref. [6,20–22]) on R&D investment in isolation. However, little is known about the role of diversification in R&D investment during unstable periods. To bridge this research gap, our study uses the 2008 financial crisis as a unique natural experiment, offering a valuable opportunity to delve into the combined influence of the crisis and diversification on a firm's innovation initiatives. In particular, this study offers a more nuanced understanding of the impact of diversification on R&D investment in current economic crises.

From a resource-based perspective, diversification strengthens a firm's capacity for R&D investment by optimizing resource distribution, minimizing risks, and providing greater stability in cash flow. This strategy allows firms to maintain competitive advantages and sustain long-term innovation. Particularly in times of external financial constraints, such as during economic crises, diversified firms benefit from internal capital markets, which provide flexibility and mitigate reliance on external credit [23–25]. These internal resources enable diversified firms to sustain R&D investments, even when stand-alone firms may face financial constraints. Consequently, we hypothesize that R&D investment in diversified firms tends to increase during crisis periods compared to pre-crisis periods.

To test our hypotheses, we analyse panel data from 3232 firm-year observations. We use cross-sectional time-series feasible generalized least squares (FGLS) regression models. Our findings show that firms with a higher degree of diversification are more likely to sustain or even increase R&D investment during economic crises, contrary to the general trend of R&D cuts. Our study contributes to the literature by providing empirical evidence that supports the resource-based view of diversification, suggesting that diversified firms have a competitive advantage in maintaining innovation during economic downturns. Moreover, our research offers valuable guidance for managers on the importance of maintaining R&D investment during crises to sustain long-term competitiveness and growth. In particular, diversified firms should exploit their financial advantage to enhance R&D investment during downturns to increase their competitive advantage during upturns.

2. Literature review

Previous studies extensively examine the differences in R&D investment behaviour between multiproduct firms and stand-alone firms (Peyrefitte, 2004; [16,26]). Scholars argue that high diversification in multiproduct firms exacerbates agency problems. The presence of multiple divisions or segments in highly diversified firms stretches managerial capacities, leading to increased complexity and information asymmetries [27,28]. These information asymmetries and agency problems among various stakeholders within diversified firms result in inefficient investments, translating into lower R&D intensity compared to stand-alone firms. Empirical studies validate the notion that diversification often leads to reduced firm performance, evidenced by the "diversification discount" [29–32]. Agency problems are a primary cause of this value-reducing diversification [33,34]. Researchers such as Yun and Kim [35] demonstrate that diversified firms in Korea experience decreased firm value due to agency problems, and these problems intensify during crises, as observed by Kim and Lee [36]. The crisis amplifies agency costs, leading to diminished performance in diversified firms.

On the other hand, according to internal capital theory, certain studies argue that financial crises can enhance the value of diversified firms by amplifying the benefits of internal capital markets. Campello [23] points out that financially diversified corporations mitigate liquidity constraints faced by smaller bank members through internal capital markets. Billett and Mauer [37] illustrate how cross-subsidies among businesses within conglomerates contribute to their value when external financial constraints arise. Dimitrov and Tice [24] investigate whether corporate diversification alleviates financial constraints by providing "more money", finding that during recessions, growth rates decrease more for focused firms than for diversified firms. Empirical studies, such as Kuppuswamy and Villalonga's [15] research on the 2007–2009 financial crisis, highlight how diversified firms managed to reduce the diversification discount due to the benefits of "more money" and the efficiency of internal capital markets. Hovakimian [14] finds that, during recessions, when external capital costs escalate, diversified firms exhibit better internal financial capacity due to the efficient allocation of internal capital. However, previous studies primarily focus on the effects of external changes on the separate advantages or disadvantages of diversification concerning firm performance. The precise influence of abruptly changing markets and corporate governance structures on a firm's strategic choices, particularly in R&D investment decisions, remains a topic that lacks comprehensive understanding.

Numerous studies delve into R&D behaviours in the face of recessions, yet the role of diversification in shaping R&D spending amid financial uncertainty remains largely unexplored. For instance, Cincera et al. [10] observes diverse corporate responses to the 2008

crisis: while some companies reduced innovation investments, others sustained their innovative activities, and a few even increased R&D spending. The authors note a general trend of increased R&D and innovation activities post-crisis (2009–2012). Similarly, Osiyevskyy et al. (2015) argue that high R&D intensity firms cut R&D expenditures, whereas non-R&D-intensive firms experienced no changes or even rises in R&D spending following the 2008 financial crisis. Scholars highlight the vulnerability of innovation activities in new ventures and small firms during crises [38,39]. In contrast, Antonioli et al. [40], analysing Italian firms, find that small and medium-sized enterprises (SMEs) outperformed larger firms in innovation investments during the recent crisis (2008–2009). While these studies shed light on R&D behaviours in times of economic uncertainty, the intricate interplay between diversification and R&D spending in such contexts remains an area ripe for exploration. Understanding how diversification influences the strategic choices of firms, particularly in R&D investment decisions during financial uncertainty, is vital for comprehending the nuanced dynamics of corporate responses to economic crises. While previous studies focus on the impact of diversification on R&D investment (e.g., Ref. [17–19]), little is known about the relationship of diversification and R&D investment in dynamic periods such as the financial crisis. Diversified firms with both financial and investment advantages according to the resource-based view theory and internal capital market theory may foster R&D investment in high turbulence compared to a stable period.

3. Hypothesis development

According to the resource-based view theory, diversification can significantly enhance a firm's R&D investment capabilities. By enabling better resource allocation, mitigating risks, stabilizing cash flow, providing strategic flexibility, facilitating unique resource combinations, and increasing market power, diversification supports sustained and effective R&D activities. These factors contribute to building a firm's competitive advantage and fostering long-term innovation and growth. Thus, from the resource-based view, diversification is a valuable strategy for firms aiming to enhance their R&D investment and achieve superior performance in the marketplace. In contexts where external credit resources are difficult to access, the competitive advantage of a diversified firm, particularly its financial prowess, assumes greater significance in facilitating consistent investment in research and development (R&D). According to the theory of internal capital markets, diversified firms possess internal capital markets that gain value when external markets are constrained [23–25]. These internal markets allow firms to reallocate resources efficiently within the organization, which becomes particularly advantageous during periods of external financial constraints.

Recent empirical studies show that internal capital markets can enhance firm value by providing financial flexibility and mitigating the impacts of external market frictions [14,15,25,37]. For instance, during financial crises, firms with robust internal capital markets are better positioned to sustain investment and operational activities compared to those reliant solely on external financing. These insights underline the strategic importance of internal capital markets in diversified firms, especially in times of economic uncertainty. Firms can leverage these internal markets to support R&D investment and other critical operations, ensuring stability and fostering long-term growth despite external financial challenges. Firms with stable financial capacities may avoid value-depleting actions, while those with weaker financial positions might curtail productive activities such as R&D investment. Moreover, diversified firms with financial advantages can finance new R&D opportunities for a quicker recovery from economic downturns, gaining a competitive edge during the subsequent upturn. Consequently, we anticipate that diversification will alleviate the negative impact of credit shocks on R&D investment during crises. This suggests that diversified firms experience fewer detrimental effects related to financial constraints during crises, allowing them to maintain or even increase their R&D investment. Based on these premises, we hypothesize that R&D investment in diversified firms tends to be greater during crisis periods compared to pre-crisis periods, especially in comparison to stand-alone firms.

Hypothesis: Diversified firms are likely to increase their R&D investments during periods of economic crisis compared to pre-crisis periods.

4. Research methodology

4.1. Data sources and sample selection

We use a sample of 694 US firms within a panel dataset, with information gathered from Compustat, focusing on financial and segment data. To ensure the consistency of our results with previous research, we follow the sample selection criteria outlined by Reuer and Tong [41]. First, we limit our dataset to the period 2004 to 2009 to compare the impact of diversification on R&D during the crisis years (2007–2009) and the pre-crisis years (2004–2006). Second, our analysis concentrates exclusively on manufacturing firms, identified by Standard Industrial Classification (SIC) codes 2000 to 3999. We use a manufacturing sample for several reasons. First, it allows for comparability with previous studies on R&D investment. Second, R&D data in the manufacturing sector are systematically recorded and more comparable across firms. Finally, manufacturing firms exhibit more consistent accounting practices than firms in other sectors. Additionally, we set a criterion for total sales, requiring firms to have sales equal to or above $5 million. This criterion is intended to exclude startup firms from the sample, aligning with the methodology employed by Hitt et al. [42] and Peyrefitte and Jeff [43]. After applying these criteria, our final dataset for estimation comprises 3232 firm-year observations.

4.2. Measures

4.2.1. Dependent variables

We quantify R&D intensity as the ratio of research and development expenditures to total sales. This measure is used in previous

research [43–45].

4.2.2. Independent variables

We adopt three metrics to quantify the extent of corporate diversification: the count of segments, the Herfindahl index [46], and the entropy measure [47]. The count of segments is determined at the granular 4-digit SIC code level (NSEG_4d). The Herfindahl index (HERF_4d) is computed, show as Eq. (1)

$$HERF = 1 - \sum_{s=1}^{n} P_s^2 \tag{1}$$

where n signifies the number of a firm's segments, categorized at the 4-digit SIC code level; and P_s represents the fraction of the firm's sales derived from business s. Focused firms exhibit a HERF_4d value of 0, while a value nearing 1 indicates an elevated level of diversification.

The entropy measure is captured, show as Eq. (2)

$$Entropy = \sum_{s=1}^{n} P_s * ln\left(\frac{1}{P_s}\right) \tag{2}$$

where Ps denotes the ratio of a firm's sales attributed to business s within a corporate structure encompassing n distinct 4-digit SIC segments. Focused firms show entropy equal to 0. The higher the entropy, the greater the degree of diversification. This index has no upper boundary.

We drop firm-year observations in the year 2008, the peak of the US crisis. We use the declaration of a crisis of the National Bureau of Economic Research (NBER) Business Cycle Expansions and Contractions [48]. We construct the binary variable crisis, assigning a value of 1 to years falling within the crisis period (2007–2009) and 0 otherwise.

4.2.3. Control variables

We consider several control variables that might influence R&D intensity. These variables include a firm's size, leverage, cash reserves, average industry R&D intensity, and technological opportunity. To measure the size of a firm, we take the natural logarithm of its assets, using data from Compustat. We factor in a firm's leverage, since its debt policy could affect investment decisions and the value of its growth options due to potential underinvestment agency problems [49]. Leverage is calculated as the ratio of a firm's total debt to its total assets. We control for a firm's cash position, measured as the ratio of total cash to total assets. Cash reserves play a crucial role in a company's investment decisions and can affect its ability to fund R&D activities. Average industry R&D intensity is calculated as the ratio of R&D expenditure to total sales, averaged across all companies within a particular industry. It provides insights into the R&D spending patterns within the industry as a whole. Technological opportunities are incorporated using a dummy variable. A value of 1 is assigned if a firm belongs to industries with the highest level of technological opportunity, encompassing sectors such as chemicals, computers, drugs, aerospace industry, electrical equipment, precision instruments, photographic industry, and supplies [50]. Conversely, the value is set to 0 if the firm belongs to other industries. By incorporating these control variables, we aim to account for various factors that could affect a firm's R&D intensity, allowing for a more nuanced analysis of the relationship between diversification and R&D investment.

4.3. Statistical model and analysis method

To test our hypotheses, we test a regression model as follows, show as Eq. (3):

$$\begin{aligned} \text{R\&D Intensity}_t = {} & \alpha + \alpha 1 \text{Diversification}_t + \alpha 2\ \text{Crisis} + \alpha 3\ \text{Diversification}_t * \text{Crisis} + \alpha 4\ \text{Size}_t + \alpha 5\ \text{Leverage}_t + \alpha 6\ \text{Cash}_t \\ & + \alpha 7 \text{Average industry R\&D intensity}_t + \alpha 8 \text{TO}_t + n + v \end{aligned} \tag{3}$$

In our analysis, we employ three distinct methods – segment count, the Herfindahl index, and the entropy measure – to assess diversification, as delineated in the measures section. We use a pooled time-series cross-sectional dataset. There exists the possibility of cross-sectional variables and within-unit serial correlation. Thus, we adopt cross-sectional time-series feasible generalized least squares (FGLS) regression models [51,52]. FGLS allows the analysis to control for auto-correlation and cross-sectional variables [53,54]. This approach ensures that our analysis accurately accounts for both temporal and cross-sectional variations in the data, leading to more reliable and valid inferences.

5. Results

5.1. Main results

In Table 1, we provide an overview of the descriptive statistics and correlations for the variables. The mean value of the dependent variable, R&D intensity, is calculated at 0.08 for all firms, signifying the average allocation of resources towards R&D. The mean value of the independent variable entropy is 0.79, signifying the level of diversification within the sample firms. Firms in our dataset exhibit

a maximum value of 15 segments at the 4-digit level (NSEG_4d), illustrating the complexity of organizational structures. Furthermore, the mean values for related diversification and unrelated diversification stand at 0.55 and 0.23, respectively, reflecting the extent of diversification strategies pursued by the firms. To assess potential issues of multicollinearity, we calculate the variance inflation factors (VIF) for all variables. The results indicate VIF values lower than 2, well below the recommended cutoff of 10 [55]. This suggests that multicollinearity is not a significant concern in our analysis.

In Table 2, we present the coefficients of the FGLS panel estimations. In our analyses, we include firm size, leverage, cash reserves, average industry R&D intensity, and technological opportunity as control variables, all of which are significant across all models. To explore the impact of diversification on R&D investment following the economic crisis, we conduct regression analyses using three measures of diversification for the entire sample. Our aim is to understand how diversification strategies influenced R&D investments during this critical period of economic upheaval.

The results presented in Table 2 corroborate the theoretical underpinnings outlined in the preceding sections. As posited by the resource-based view theory, the positive and significant coefficient estimates of the interaction terms between diversification measures and the crisis variable affirm the notion that diversified firms are better equipped to maintain or increase their R&D investment during economic downturns. Specifically, the significant and positive association observed between the degree of diversification (measured by entropy, Model 1) and R&D intensity during crises lends support to the contention that diversified firms possess enhanced resource-allocation capabilities and strategic flexibility, enabling them to sustain innovation initiatives even in adverse economic conditions. Moreover, the findings pertaining to the interaction terms involving the number of segments (in Model 2) and the Herfindahl index (in Model 3) further underscore the resilience of diversified firms in maintaining R&D investments during crises. These results align with the premise that diversified firms, by virtue of their internal capital markets and diversified revenue streams, are less susceptible to external financial constraints and thus exhibit a greater propensity to sustain or augment R&D activities when confronted with economic turmoil. Furthermore, the observed positive associations between diversification and R&D intensity post-economic crises underline the enduring benefits of diversification in fostering long-term innovation and growth. This echoes the resource-based view's assertion and the internal capital market theory that diversification enhances a firm's competitive advantage and R&D investment capabilities, thereby facilitating sustained innovation initiatives beyond the immediate aftermath of economic downturns. In essence, the empirical findings substantiate the theoretical proposition that diversification serves as a strategic mechanism for mitigating the adverse effects of economic crises on R&D investment, thereby contributing to the resilience and competitive advantage of diversified firms in the marketplace.

5.2. Robustness analysis results

Our robustness analysis, aimed at checking the consistency of our main findings, confirms that the results hold up well. We wanted to see if the pattern we observed in the primary results remained the same when we used a different method. In our robustness analysis, we examine the difference in R&D behaviour between diversified and stand-alone firms during the crisis by employing a dummy diversification variable instead of continuous variables in the model.

The outcome of this check, in Table 3, aligns closely with what we found in the main results, showing that our findings are reliable. This strengthens our confidence in the validity of our study. Connecting these results with the theories we discussed earlier, we see that diversification continues to play a crucial role in how firms invest in R&D during tough economic times. Even when we simplify our analysis, the basic picture remains the same: diversified firms are better at maintaining their R&D investment during crises. This consistency supports what we expected based on theories about how diversification helps firms manage resources and adapt to challenging situations. It confirms that diversified firms have built-in advantages that allow them to keep investing in innovation, even when times get tough. In summary, these robustness check results reinforce our main findings and underline the importance of diversification in guiding firms through economic uncertainty. They provide further evidence for the strategic value of diversification in sustaining R&D investments during difficult times.

In addition, to address potential endogeneity in the decision to diversify, we use Heckman's two-step method. In the first step, we apply a probit model, regressing diversification on firm characteristics such as dividend payments and minority interest (MI), along with industry characteristics and control variables. We include industry attractiveness, dividend, and MI in the selection equation but exclude them in the second step, as required by the Heckman method. The second step uses the Inverse Mills Ratio, derived from the first-stage model, as an instrumental variable to control for endogeneity in the main regression. Our findings, after incorporating the Inverse Mills Ratio, provide strong support for our hypothesis (please see in our supplementary file for details).

6. Discussion

6.1. Theoretical implications

Our study significantly enhances our understanding of how firms make decisions regarding R&D investment, particularly during periods of economic turmoil such as the global financial crisis. Unlike previous research that overlooks the nuanced impact of external factors such as financial crises, our investigation explores the intricate relationship between diversification and R&D intensity, both before and during the crisis. This focus aligns with the theoretical framework we discussed earlier. The resource-based view theory suggests that diversified firms possess advantages that enable them to maintain or even increase their R&D investment during crises. Our findings support this notion, highlighting the strategic advantage held by diversified firms in intensifying their R&D efforts during economic uncertainty. Moreover, our research bridges a gap in understanding by encompassing both diversified and non-diversified

Table 1
Descriptive statistics and correlation matrix.

		Mean	SD	1	2	3	4	5	6	7	8	9
1.	R&D	0.081	0.131									
2.	Entropy	0.787	0.633	−0.199[a]								
3.	NSEG_4d	3.166	2.449	−0.167[a]	0.912[a]							
4.	H_4d	0.437	0.300	−0.200[a]	0.957[a]	0.775[a]						
5.	Size	5.822	2.226	−0.133[a]	0.371[a]	0.410[a]	0.298[a]					
6.	Leverage	0.422	0.214	−0.210[a]	0.173[a]	0.181[a]	0.142[a]	0.323[a]				
7.	Cash	0.135	0.129	0.256[a]	−0.145[a]	−0.130[a]	−0.137[a]	−0.183[a]	−0.337[a]			
8.	Average industry R&D intensity	0.057	0.046	0.307[a]	−0.193[a]	−0.179[a]	−0.174[a]	−0.163[a]	−0.283[a]	0.298[a]		
9.	Technological opportunity	0.789	0.408	0.195[a]	−0.047[a]	−0.045[a]	−0.048[a]	−0.093[a]	−0.189[a]	0.211[a]	0.508[a]	
10.	Crisis	0.322	0.467	0.011	0.008	0.006	0.010	0.005	−0.013	0.028[a]	0.037[a]	0.018

***$p < 0.01$, **$p < 0.05$.
[a] $p < 0.1$. For the dummy variable *crisis*, 45.51 % corresponds to the crisis years (2007–2009), while the remaining 54.49 % pertains to non-crisis years.

Table 2
Results of regression analysis.

Dependent variable: R&D intensity			
Independent variables	Model		
	(1)	(2)	(3)
Crisis	−0.004[a]	−0.005[a]	−0.010[a]
	(0.001)	(0.001)	(0.001)
Entropy	−0.018[a]		
	(0.001)		
NSEG_4d		−0.003[a]	
		(0.0002)	
H_4d			−0.050[a]
			(0.001)
Entropy × Crisis	0.002[b]		
	(0.001)		
NSEG_4d × Crisis		0.0004[b]	
		(0.0002)	
H_4d × Crisis			0.012[a]
			(0.002)
Size	0.002[a]	0.001[a]	0.002[a]
	(0.000)	(0.000)	(0.000)
Leverage	−0.041[a]	−0.036[a]	−0.044[a]
	(0.002)	(0.002)	(0.001)
Cash	0.110[a]	0.114[a]	0.109[a]
	(0.005)	(0.006)	(0.005)
Average industry R&D intensity	0.648[a]	0.651[a]	0.600[a]
	(0.014)	(0.014)	(0.013)
Technological opportunity	0.016[a]	0.014[a]	0.016[a]
	(0.001)	(0.001)	(0.001)
Wald χ^2 (p-value)	0.000	0.000	0.000
Observations	3232	3232	3232
Number of firms	694	694	694

Standard errors in parentheses.
[a] $p < 0.01$, **$p < 0.05$.
[b] $p < 0.1$.

Table 3
Results of regression analysis (using dummy variable diversification).

Dependent variable: R&D intensity	
Independent variables	Model
	(1)
Diversification	−0.039[a]
	(0.001)
Crisis	−0.016[a]
	(0.002)
Diversification × Crisis	0.015[a]
	(0.002)
Size	0.0001
	(0.000)
Leverage	−0.038[a]
	(0.002)
Cash	0.135[a]
	(0.005)
Average industry R&D intensity	0.545[a]
	(0.012)
Technological opportunity	0.018[a]
	(0.001)
Constant	0.051[a]
	(0.002)
Wald χ^2 (p-value)	0.000
Observations	3232
Number of firms	694

Standard errors in parentheses.
[a] $p < 0.01$, **$p < 0.05$, *$p < 0.1$.

firms. This approach provides a comprehensive view of how diversification influences R&D investment decisions, especially when external financial sources become constrained during economic downturns. It underscores the importance of internal capital markets, as theorized earlier, in facilitating R&D investment within diversified firms, even when faced with external financial constraints. Furthermore, our study extends previous research by employing a more comprehensive approach to measure corporate diversification. By incorporating multiple diversification measures – entropy, the number of segments, and the Herfindahl index – we enhance the precision and depth of our analysis. This methodological refinement aligns with the theoretical framework, as it allows for a more nuanced understanding of how diversification influences R&D investment behaviour.

Previous studies have separately analysed the impacts on firms of diversification (e.g., Ref. [17–19]) and financial crises (e.g., Ref. [6,20–22]). For instance, Dang et al. [17] focus on how diversification enhances firm performance but do not examine its role during economic downturns. Similarly, Orlando et al. [18] investigate the influence of diversification strategies on innovation outputs without considering the moderating effects of financial crises. Ziyadin et al. [19] explore the overall benefits of corporate diversification but not how these benefits might vary in the face of financial instability. Many studies also concentrate on investment behaviours without delving into the role of diversification. Chung [20] assesses the general impact of economic crises on corporate investment without differentiating between diversified and non-diversified firms. Filippetti and Archibugi (2011) and Archibugi et al. [6] analyse the effects of financial crises on innovation and yet do not account for diversification's potential moderating role. Ferrando and Ruggieri [21] explore the implications of financial constraints on R&D activities during crises but do not focus on how diversification might mitigate these constraints. Roper and Turner [22] examine the effects of financial crises on R&D investment without addressing the differential impacts on diversified versus non-diversified firms. Our study bridges these two areas by investigating how diversification affects R&D investment during financial crises. This integration fills a significant gap in the literature, offering empirical evidence that diversification can buffer firms against the negative impacts of financial crises on R&D investment. Our findings suggest that diversified firms are better positioned to sustain or even increase their R&D investment during financial crises compared to their non-diversified counterparts. This supports the notion that diversification enhances firm stability and strategic flexibility in adverse economic conditions. Our research therefore contributes to the discourse on strategic management and innovation, particularly under the stress of economic downturns. By highlighting the protective role of diversification during financial crises, we provide a nuanced understanding that advances both the diversification and crisis-management literature. In summary, our findings not only provide empirical support for the theoretical propositions discussed earlier, but also advance our understanding of the strategic role of diversification in guiding firms through economic uncertainty. By elucidating the mechanisms through which diversification influences R&D investment decisions, our study contributes both theoretical knowledge and practical insights for firms navigating turbulent economic landscapes.

6.2. Practical implications

Our study's practical implications resonate deeply with the theoretical foundations we established earlier. By shedding light on the important role of diversification strategies in strengthening R&D investments during economic downturns, our findings underscore the real-world significance of the resource-based view theory and the theory of internal capital markets. The theoretical premise that diversified firms possess inherent advantages in navigating economic uncertainties finds concrete validation in our research. Diversified firms emerge as key beneficiaries, leveraging their varied revenue sources and internal financial systems to sustain or even increase R&D spending during financial crises. This aligns with the resource-based view theory, which suggests that diversification enhances a firm's competitive advantage by providing access to diverse resources and capabilities.

Moreover, our findings carry practical implications for both managers and policymakers. For managers, understanding the protective role of diversification during economic uncertainties becomes critical. This knowledge empowers them to make informed strategic decisions, ensuring their companies remain resilient and adaptable in challenging times. It echoes the theoretical premise that diversification enhances a firm's ability to adapt and innovate in response to changing market conditions. Similarly, policymakers armed with the knowledge of diversification's pivotal role can formulate policies that encourage diversified investment strategies. This aligns with the theory of internal capital markets, which underlines the importance of efficient resource allocation within firms. By fostering an environment conducive to diversified investment, policymakers can stimulate innovation and sustainable growth, consistent with the theoretical proposition that diversification contributes to long-term firm performance. In essence, our study underscores that diversification is not merely a strategic choice but a financial stronghold that enables firms to weather crises, sustain investments, and emerge stronger in dynamic market conditions. This practical insight reinforces the theoretical foundations of our research, highlighting the interplay between theory and practice in guiding strategic decision-making and policy formulation.

6.3. Limitations and future research

While our study provides valuable insights into the relationship between diversification and R&D investment during financial crises, it is important to acknowledge its limitations. One significant limitation lies in the geographical scope of our research, which was confined to the United States, a developed nation. To enhance the depth of our understanding, future studies could expand the investigation to the role of diversification in R&D investment in the context of recessions in developing countries. This comparative analysis could offer nuanced insights into how diversification strategies vary across different economic landscapes, shedding light on unique challenges and opportunities faced by firms in diverse global settings. Moreover, the unprecedented events of the COVID-19 crisis have reshaped the business landscape in ways previously unimagined. Considering the profound impact of this global crisis on businesses worldwide, it would be intriguing for subsequent research to delve into the role of diversification in R&D investment

specifically in the context of the COVID-19 years. Exploring how diversification strategies have evolved or adapted in response to the unique challenges posed by this ongoing crisis could provide invaluable insights for businesses aiming to build resilience in the face of future pandemics or similar disruptive events.

Furthermore, while our study primarily focuses on R&D investment, future research could explore the impact of diversification on other vital areas of investments. For instance, understanding how diversification influences firms' decisions regarding fixed investments or advertising expenditures during recessions could unravel additional layers of strategic decision-making. By delving into these diverse facets of corporate investments, researchers can paint a more comprehensive picture of the multifaceted role diversification plays in shaping a firm's financial strategies during economic uncertainties. Thus, while our study paves the way for a deeper comprehension of diversification's impact on R&D investment during financial crises, these limitations and potential avenues for future research underscore the dynamic nature of this field. Continued exploration and analysis in these areas are essential not only for academic enrichment, but also for providing practical guidance to businesses navigating the intricate landscape of strategic decision-making during turbulent economic times.

7. Conclusion

The primary objective of our research is to dissect the intricate interplay between the financial crisis and corporate governance structures to examine how the sudden changes in the macroeconomic environment impact R&D investment decisions in diversified firms compared to stand-alone firms during the crisis period. Leveraging a robust dataset comprising a wide array of US firms, our study seeks to unravel the nuances of diversified firms' R&D investment behaviour vis-à-vis focused firms in the aftermath of the 2008 financial crisis. Additionally, we delve into the dichotomy between R&D expenditures in related versus unrelated firms during the post-crisis period. Our comprehensive analysis spans various industries, excluding financial service organizations, and encompasses multiple years in both pre-crisis and post-crisis contexts.

The outcomes of our investigation offer compelling insights. In the crucible of financial upheaval, diversified firms have advantages in R&D investment compared to their stand-alone counterparts. This finding carries substantial implications, given the conventional wisdom that diversification typically bears a negative correlation with R&D spending under normal circumstances. However, our research illuminates a fascinating shift during the financial crisis: diversification emerged as a potent catalyst, fostering a positive relationship with R&D intensity. This nuanced revelation underlines the strategic advantages inherent in diversification, particularly during periods of heightened uncertainty.

Our findings point to diversification offering a unique advantage in financing and investments, enabling firms to not merely weather the storm but to actively enhance their value creation by intensifying R&D investment under conditions of extreme uncertainty. This underscores the strategic prowess of diversified firms, positioning them not as mere survivors but as proactive architects of value in the face of adversity. As the corporate landscape navigates ever-changing economic tides, these insights serve as a beacon, guiding firms towards strategies that not only buffer them against crises, but also empower them to thrive and innovate, even in the most challenging of times.

CRediT authorship contribution statement

Thi Bao Chau Nguyen: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Quoc Nghi Nguyen:** Writing – review & editing, Validation.

Data availability statement

The generated data that support the findings of this study is available at: Nguyen, Thi Bao Chau (2024), "Database: HELIYON-D-23-49174", Mendeley Data, V1, doi: 10.17632/7dg5grf7bk.1.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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References

[1] S. Sarkar, O. Osiyevskyy, Organizational change and rigidity during crisis: a review of the paradox, Eur. Manag. J. 36 (1) (2018) 47–58.
[2] P. Balduzzi, E. Brancati, F. Schiantarelli, Financial markets, banks' cost of funding, and firms' decisions: lessons from two crises, J. Financ. Intermediation 36 (2018) 1–15.
[3] S. Ghosh, Does R&D intensity influence leverage? Evidence from Indian firm-level data, J. Int. Enterpren. 10 (2) (2012) 158–175.
[4] C. Flammer, I. Ioannou, Strategic management during the financial crisis: how firms adjust their strategic investments in response to credit market disruptions, Strat. Manag. J. 42 (7) (2021) 1275–1298.
[5] B. Hardy, C. Sever, Financial crises and innovation, Eur. Econ. Rev. 138 (2021) 103856.
[6] D. Archibugi, A. Filippetti, M. Frenz, The impact of the economic crisis on innovation: evidence from Europe, Technol. Forecast. Soc. Change 80 (7) (2013) 1247–1260.
[7] K.Z. Zhou, G.Y. Gao, H. Zhao, State ownership and firm innovation in China: an integrated view of institutional and efficiency logics, Adm. Sci. Q. 62 (2) (2017) 375–404.
[8] D. Archibugi, The social imagination needed for an innovation-led recovery, Res. Pol. 46 (3) (2017) 554–556.
[9] A. Secchi, F. Tamagni, C. Tomasi, Financial constraints and firm exports: accounting for heterogeneity, self-selection, and endogeneity, Ind. Corp. Change 25 (5) (2016) 813–827.
[10] M. Cincera, C. Cozza, A. Tübke, P. Voigt, Doing R&D or not, that is the question (in a crisis…), JRC: IPTS working paper on corporate R&D and innovation 12 (2010).
[11] H. Park, T. Kang, J.D. Lee, R&D dynamics and firm growth: the importance of R&D persistency in the economic crisis, Int. J. Innovat. Manag. 23 (5) (2019) 1950049.
[12] T. Mitze, T. Makkonen, Can large-scale RDI funding stimulate post-crisis recovery growth? Evidence for Finland during COVID-19, Technol. Forecast. Soc. Change 186 (2023) 122073.
[13] G.D. Sharma, A. Thomas, J. Paul, Reviving tourism industry post-COVID-19: a resilience-based framework, Tourism Manag. Perspect. 37 (2021) 100786.
[14] G. Hovakimian, Financial constraints and investment efficiency: internal capital allocation across the business cycle, J. Financ. Intermediation 20 (2) (2011) 264–283.
[15] V. Kuppuswamy, B. Villalonga, Does diversification create value in the presence of external financing constraints? Evidence from the 2007–2009 financial crisis, Manag. Sci. 62 (4) (2016) 905–923.
[16] S. Komera, P.J. Jijo Lukose, S. Sasidharan, Does business group affiliation encourage R&D activities? Evidence from India, Asia Pac. J. Manag. 35 (4) (2018) 887–917.
[17] R. Dang, L. Houanti, A. Bonnand, Exploring the effect of diversification strategy on R&D intensity using quantile regression: evidence from France, Appl. Econ. Lett. 23 (18) (2016) 1317–1320.
[18] B. Orlando, A. Renzi, G. Sancetta, N. Cucari, How does firm diversification impact innovation? Technol. Anal. Strat. Manag. 30 (4) (2018) 391–404.
[19] S. Ziyadin, A. Omarova, R. Doszhan, G. Saparova, G. Zharaskyzy, Diversification of R&D results commercialization, Probl. Perspect. Manag. 16 (4) (2018) 331–343.
[20] H. Chung, R&D investment, cash holdings and the financial crisis: evidence from Korean corporate data, Appl. Econ. 49 (55) (2017) 5638–5650.
[21] A. Ferrando, A. Ruggieri, Financial constraints and productivity: evidence from euro area companies, Int. J. Finance Econ. 23 (3) (2018) 257–282.
[22] S. Roper, J. Turner, R&D and innovation after COVID-19: what can we expect? A review of prior research and data trends after the great financial crisis, Int. Small Bus. J. 38 (6) (2020) 504–514.
[23] M. Campello, Internal capital markets in financial conglomerates: evidence from small bank responses to monetary policy, J. Finance 57 (6) (2002) 2773–2805.
[24] V. Dimitrov, S. Tice, Corporate diversification and credit constraints: real effects across the business cycle, Rev. Financ. Stud. 19 (4) (2006) 1465–1498.
[25] R. Santioni, F. Schiantarelli, P.E. Strahan, Internal capital markets in times of crisis: the benefit of group affiliation, Rev. Finance 24 (4) (2020) 773–811.
[26] J.L. Stimpert, I.M. Duhaime, Seeing the big picture: the influence of industry, diversification, and business strategy on performance, Acad. Manag. J. 40 (3) (1997) 560–583.
[27] Hoskission Hitt, D. Ireland, A mid-range theory of the interactive effects of international and product diversification on innovation and performance, J. Manag. 20 (2) (1994).
[28] R.E. Hoskisson, M.A. Hitt, C.W.L. Hill, Managerial incentives and investment in R&D in large multiproduct firms, Organ. Sci. 4 (2) (1993) 325–341.
[29] P.G. Berger, E. Ofek, Diversification's effect on firm value, J. Financ. Econ. 37 (1) (1995) 39–65.
[30] D. Hoechle, M. Schmid, I. Walter, D. Yermack, How much of the diversification discount can be explained by poor corporate governance? J. Financ. Econ. 103 (1) (2012) 41–60.
[31] J.D. Stowe, X. Xing, Can growth opportunities explain the diversification discount? J. Corp. Finance 12 (4) (2006) 783–796.
[32] G.C. Smith, J.M. Coy, Corporate diversification: can the observed diversification discount shed light on management's choice to diversify or re-focus? Rev. Account. Finance 17 (3) (2018) 405–424.
[33] K.V. Lins, H. Servaes, Is corporate diversification beneficial in emerging markets? Financ. Manag. (2002) 5–31.
[34] R. Rajan, H. Servaes, L. Zingales, The cost of diversity: the diversification discount and inefficient investment, J. Finance 55 (1) (2000) 35–80.
[35] Y.-S. Yun, S.-P. Kim, The value impacts of business diversification and agency problems, The Korean Journal of Finance 12 (1999) 1–37.
[36] B. Kim, I. Lee, Agency problems and performance of Korean companies during the Asian financial crisis: chaebol vs. non-chaebol firms, Pac. Basin Finance J. 11 (3) (2003) 327–348.
[37] M.T. Billett, D.C. Mauer, Cross-subsidies, external financing constraints, and the contribution of the internal capital market to firm value, Rev. Financ. Stud. 16 (4) (2003) 1167–1201.
[38] F. Eggers, Masters of disasters? Challenges and opportunities for SMEs in times of crisis, J. Bus. Res. 116 (2020) 199–208.
[39] K.Y. Hao, A.B. Jaffe, Effect of liquidity on firms' R&D spending, Econ. Innovat. N. Technol. 2 (4) (1993) 275–282.
[40] D. Antonioli, M. Mazzanti, P. Pini, Productivity, innovation strategies and industrial relations in SMEs. Empirical evidence for a local production system in northern Italy, Int. Rev. Appl. Econ. 24 (4) (2010) 453–482.
[41] J.J. Reuer, T.W. Tong, Corporate investments and growth options, Manag. Decis. Econ. 28 (8) (2007) 863–877.
[42] M.A. Hitt, R.E. Hoskisson, R.A. Johnson, D.D. Moesel, The market for corporate control and firm innovation, Acad. Manag. J. 39 (5) (1996) 1084–1119.
[43] J.B. Peyrefitte, Jeff, Product diversification and R&D investment: an empirical analysis of competing hypotheses, Organ. Anal. 12 (4) (2004) 379–394.
[44] T.Y. Leung, P. Sharma, Differences in the impact of R&D intensity and R&D internationalization on firm performance–Mediating role of innovation performance, J. Bus. Res. 131 (2021) 81–91.
[45] S. Tyagi, D.K. Nauriyal, R. Gulati, Firm level R&D intensity: evidence from Indian drugs and pharmaceutical industry, Review of Managerial Science 12 (2018) 167–202.
[46] A.O. Hirschman, The Stability of Neutralism: a geometrical note, Am. Econ. Rev. 54 (2) (1964) 94–100.
[47] A.P. Jacquemin, C.H. Berry, Entropy measure of diversification and corporate growth, J. Ind. Econ. (1979) 359–369.
[48] R. Srinivasan, G.L. Lilien, S. Sridhar, Should firms spend more on research and development and advertising during recessions? J. Market. 75 (3) (2011) 49–65.
[49] S.C. Myers, Determinants of corporate borrowing, J. Financ. Econ. 5 (2) (1977) 147–175.
[50] B. Baysinger, R.E. Hoskisson, Diversification strategy and R&D intensity in multiproduct firms, Acad. Manag. J. 32 (2) (1989) 310–332.
[51] W. Greene, Econometric Analysis, second ed., Macmillan, New York, NY, 1993.
[52] J.M. Wooldridge, Econometric analysis of cross section and panel data MIT press, Cambridge, ma 108 (2) (2002) 245–254.

[53] T.E. Dielman, Pooled cross-sectional and time series data: a survey of current statistical methodology, Am. Statistician 37 (2) (1983) 111–122.
[54] S. Gulnaz, H. Manglani, Does gravity work in the context of India and ASEAN bilateral trade? An application of the FGLS method, Theoretical & Applied Economics 29 (1) (2022) 143–160.
[55] S. Chatterjee, A.S. Hadi, B. Price, Regression Analysis by Example, third ed., Wiley, New York, 2000.