Natural disasters and internal capital market efficiency: evidence from multi-segment firms

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Abstract

In this study, we examine how natural disasters affect the allocation efficiency of internal capital markets using a sample of US firms from 2001 to 2020. We find that natural disasters, as an exogenous shock, lead firms to reduce the allocation efficiency of their internal capital market. Our findings suggest that when confronted with extreme uncertainty shocks, firms are more likely to adopt a more conservative financing policy. Our results further show that this inverse relationship between natural disasters and internal capital allocation efficiency is more pronounced among firms facing a greater threat of financial constraints. Intriguingly, we also find that the suboptimal capital allocation induced by natural disasters leads to an increase in firm value. This implies that, in the context of financial constraints arising from natural disasters, a conservative capital allocation policy, which prioritizes stability and resilience over short-term efficiency, would seem to be optimal, thus improving firm value. These insights carry significant implications for capital budgeting strategies.

JEL classification: Q54, G30, G31, G32
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1. Introduction

Climate-related natural disasters, such as hurricanes, floods, droughts, heatwaves, extreme weather events, and wildfires, have been attracting increasing public attention due to the high degree of uncertainty associated with them and their substantial economic and societal impacts. These catastrophic consequences are economically significant, involving substantial losses and adverse effects on the economics and welfare (Deryugina et al., 2018; Duqi et al., 2021; IPCC, 2012). According to data released by the World Meteorological Organization in its Atlas of Mortality and Economic Losses from Weather, Climate and Water-related Hazards (1970-2021)[2], over the last half century, 11,778 disasters attributed to weather, climate and water extremes were reported globally, causing 2,087,229 deaths and economic losses amounting to US$ 4.3 trillion[3].

Motivated by increasing concerns over climate change and its adverse effects, a growing number of studies have examined the impacts of natural hazards from different perspectives, such as the financial outcomes for disaster victims (Deryugina et al., 2018), banking markets (Duqi et al., 2021), insurance and credit (Billings et al., 2022; Hu, 2022), and corporate behaviors (Aretz et al., 2019; Dessaint & Matray, 2017; Huang et al., 2022; Le et al., 2023; Wang, 2023). Deryugina et al. (2018) show that hurricanes have a significant and persistent long-term economic impact on where people live, but only small and usually transitory impacts on wage income, employment, and total income. Duqi et al. (2021) demonstrate that the recovery is faster in less competitive banking markets following a disaster, as banks increase the supply of real estate credit by refinancing mortgage loans, although they do not extend additional lending to businesses or consumers in response to unexpected shocks. Billings et al.

[2] See the WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water-related Hazards (1970-2021) report: https://storymaps.arcgis.com/stories/8df884dbd4e849c89d4b1128fa5dc1d6.

[3] Specifically, the mortality has declined over time, largely due to the implementation of multi-hazard early warning systems, while economic losses have continued to rise. In the most recent decade (2010-2019), reported deaths dropped to 184,436, while economic losses surged to US$ 1,476.2 billion, with 39% of these losses occurring in the United States.

(2022) point out that flood insurance, compared to disaster assistance, could more effectively mitigate the inverse financial impact of flooding on credit-constrained households. Regarding the prospects for corporate behavior and financial strategy, Dessaint and Matray (2017) reveal that the occurrence of natural disasters leads to a large distortion between perceived and actual risk, inducing managers to increase cash holdings as a precautionary measure. Huang et al. (2022) suggest that heightened risk salience prompts managers to favour greater transparency, leading firms to increase their ESG disclosures over the period following the disaster as a result of increases in investors' risk perceptions. Wang (2023) finds that firms affected by natural disasters can secure post-disaster financing through operating leases without pledging additional assets as collateral. However, understanding of the effects of natural disasters on the internal capital market remains limited. This paper fills this gap by investigating the impact of natural disasters on the allocation efficiency of the internal capital market due to the central role that internal resources play in corporate decision-making, especially in the context of acute external financing frictions.

Prior research suggests that firms are more likely to rely on internal financing when it is challenging and costly to access external funds (Kim et al., 1998; Myers & Majluf, 1984). In the same vein, Matvos et al. (2018) argue that firms expand their scope and diversify their investment needs and cash flow in response to high external capital market frictions. Similarly, Bartram et al. (2022) claim that financially constrained firms reallocate emissions and resources within their internal production network in an effort to comply with environmental policies. More importantly, the availability of the internal capital market differentiates conglomerates from single-segment firms, enabling managers of conglomerates to transfer resources across different business segments to effectively bypass the allocative discipline of external capital markets (Iskenderoglu, 2021). Additionally, multi-segment firms are generally more resilient in the face of external capital market disruptions compared to single-segment firms (Matvos & Seru, 2014), as they can actively reallocate resources within their internal networks to better adapt to changing conditions (Giroud & Mueller, 2015).

The efficient internal capital market theory suggests that resource reallocation can result in greater excess value for multi-segment firms, as managers are motivated to direct more resources to segments with superior investment opportunities. In particular, company headquarters can create value by reallocating resources from segments with poor prospects to those with better prospects (Stein, 1997). Giroud and Mueller (2019) also reveal that firms respond to local economic shocks by propagating them through their internal networks, especially under tighter financial constraints. Similarly, Lamont (1997) demonstrates that internal capital markets provide a vehicle for transmitting shocks across sectors.

Moreover, some studies emphasize the contribution of internal capital markets to firm value (Bartram et al., 2022; Billett & Mauer, 2003; Matvos et al., 2018). These studies show that firms strategically shift resources internally to hedge against risks stemming from large dislocations in financial markets. Specifically, Billett and Mauer (2003) show that making subsidies to less financially constrained segments with favourable investment opportunities significantly heighten the excess value of a diversified firm, and transferring resources away from segments with relatively good investment opportunities significantly decreases excess value.

Building on these findings, we expect that natural disasters, by creating substantial disruption and uncertainty, may influence the efficiency of internal capital markets in two opposing ways. As previously mentioned, natural disasters create challenges in accessing external financing, making it more expensive and harder to obtain (Duqi et al., 2021). Moreover, they disrupt the operating cash flows of affected firms and cause widespread destruction of physical assets, which reduces corporate pledgeability, diminishes collateral values, and impairs repayment capacity (Wang, 2023). These factors collectively increase firms' financial constraints. On one hand, the heightened uncertainty and financial constraints caused by natural disasters could prompt firms to adopt more conservative capital allocation strategies aimed at maintaining stability and resilience against the shock. Consequently, firms may prioritize risk mitigation, asset preservation, and operational restoration to safeguard their business continuity, which is critical for short-term survival. In other words, internal capital budgets are likely to be tilted towards low-risk segments with stable cash flows, rather than towards higher-risk segments with expected higher returns. In this way, firms can also prevent even more excessive costs that could arise from making worse investment choices in underperforming segments (Rajan et al., 2000). However, by focusing on stability, firms may neglect opportunities for expansion, innovation, or strategic investments in high-growth areas. This approach may lead to inefficiencies in resource allocation, as capital is tied up in less productive or lower-return segments. In other words, while this conservative allocation strategy helps maintain short-term stability, it comes at the cost of the firm's long-term growth prospects and market competitiveness that could otherwise be achieved through more effective resource distribution.

Furthermore, some prior studies have emphasized the discounted value of diversification (Berger & Ofek, 1995; Rajan et al., 2000; Scharfstein & Stein, 2000). Internal capital markets are plagued by agency conflicts as they foster internal politics in relation to resource allocation, and agency conflicts between headquarter managers and segment managers tend to intensify when external capital market frictions increase. In this context, rent-seeking becomes more of a problem as managers of weaker segments face a lower opportunity cost when spending time and effort away from productive work to lobbying headquarters for extra resources (Scharfstein & Stein, 2000). Such lobbying behavior could reduce the productivity and incur indirect costs for firms. To alleviate these inefficient and costly lobbying activities, headquarters may find it optimal to redirect resources towards "corporate socialism" (Matvos & Seru, 2014; Rajan et al., 2000), whereby stronger segments cross-subsidize their weaker counterparts. While this strategy can reduce the internal politics, it may further impair internal capital allocation efficiency by directing resources towards segments with lower growth potential. Therefore, we predict that natural disasters diminish the efficiency of internal resource distribution within the firm.

On the other hand, in response to the heightened uncertainty and liquidity risks caused by natural disasters, firms may opt to prioritize recovery and growth rather than stability. When the external capital market freezes, internal capital markets may become more attractive, and firms need to reallocate resources more effectively. Instead of holding cash reserves, firms are incentivized to increase and diversify their scope, by actively pursuing high-value opportunities (Matvos et al., 2018). Diversification can help to reduce risk by spreading investment needs and cash flow across different segments, which may provide greater stability in periods of high uncertainty. By shifting funds away from less productive segments to those with more valuable investment opportunities, firms can direct internal resources toward the most valuable opportunities and thereby achieve higher returns even in the face of disruption, as argued by the "winner-picking" theory. Furthermore, the increased financial constraints may push firms to select higher-quality projects (Hovakimian, 2011) which, in turn, leads to a more efficient allocation of internal capital by spinning off underperforming segments and focusing more on those with superior growth potential. Consequently, we expect natural disasters to lead to more efficient internal capital allocation.

To explore these two competing hypotheses, we follow previous studies on natural disasters (e.g., Duqi et al., 2021; Wang, 2023) and employ a difference-in-difference (DID) approach using a sample of 1,261 US public firms from 2001 to 2020, containing 6,299 firm-year observations. We find that natural disasters have a negative and statistically significant effect on internal capital allocation efficiency. This supports the view that firms are more likely to adopt more conservative allocation strategies when confronted with an unexpected exogenous shock. This is consistent with the finding by Freund et al. (2021) that shifting internal capital toward less risky segments can reduce the overall firm risk and improve cash flow stability, thereby shielding companies from the threat of insolvency and inefficient liquidation. Our further analysis reveals that the adverse impact is more pronounced among firms facing tighter financial constraints, suggesting that these firms engage in risk-shifting by adopting a conservative capital allocation strategy. We also conduct a battery of robustness tests including the entropy balancing approach, placebo test, and alternative definitions of natural disasters, and the results further reinforce the causal interpretation of the negative correlation between natural disasters and internal capital allocation efficiency.

In addition, we delve deeper into assessing whether this risk-managing behavior affects the overall firm value as inefficient capital allocation may help to maintain corporate financial stability following exogenous shocks such as natural disasters. Our findings demonstrate that the effects of natural disasters on internal capital efficiency indirectly enhance firm value. It is plausible that when firms face the risk of bankruptcy, investors may view a conservative capital allocation policy as optimal, thereby increasing the likelihood of assigning a higher value to these firms (Freund et al., 2021). Furthermore, we find that this positive impact on firm value is stronger for firms with greater financial constraints. Finally, we observe a more pronounced effect of natural disasters on the allocation efficiency of internal capital for firms with better ex-ante performance and firms with lower CEO ownership due to the greater financial capacity and operational flexibility these firms possess and the greater misalignment of interest between the CEO and shareholders in such firms.

Our study makes a two-fold contribution to the literature. First, the study adds to a growing body of research focusing on the impact of natural disasters on corporate behaviors (Aretz et al., 2019; Dessaint & Matray, 2017; Huang et al., 2022; Le et al., 2023; Wang, 2023). To the best of our knowledge, this study represents the first attempt to assess the extent to which corporate managers effectively adjust internal capital resources within their firms to confront the adverse effects of natural disasters. Dessaint and Matray (2017) and Huang et al. (2022) highlight the role of managers' perception of salient risk in the corporate strategies of cash holdings and ESG disclosure in response to changes in investors' risk perceptions following the natural disaster, while our study shifts the focus to the "real" risk caused by natural disasters by extending research on the direct impact of natural disasters on risk-shifting behaviors (Aretz et al., 2019), innovation (Le et al., 2023), and operating leasing (Wang, 2023) to the domain of internal resource allocation.

Our findings show that firms are likely to adopt more conservative allocation strategies that promote resilience when they are exposed to short-term liquidity and uncertain shocks. This approach, however, comes at the cost of reduced allocative efficiency in internal capital markets. This supports Lamont's (1997) argument that the interdependence of corporate segments in diversified firms leads to cross-subsidization and overinvestment in underperforming segments facing cash flow shocks.

This paper also complements existing work related to internal capital (Barrot & Sauvagnat, 2016; Bartram et al., 2022; Giroud & Mueller, 2019; Lamont, 1997), which emphasizes the role of internal resources in response to economic and policy shocks by providing new insights into the impact of natural hazards on the allocative efficiency of internal capital. In particular, natural hazards not only disrupt operational stability but also create financial shocks that necessitate immediate adjustments in internal capital allocation. Our study extends the understanding of how disasters affect corporate capital utilization. Such insights are particularly important given the rising frequency of natural disasters, which pose substantial and unexpected risks to business operations and sustainability.

Second, our paper contributes to research examining the association between internal capital allocation and firm value. In contrast to Berger and Ofek (1995) and Rajan et al. (2000), who find that inefficient capital allocation reduces the value of diversified firms, our research presents a new perspective on the role of internal capital markets in response to exogenous shocks. Specifically, we uncover the novel finding that inefficient capital allocation, driven by natural disasters, can in turn increase firm value. This may be because such inefficiencies are positively valued by investors as a form of risk mitigation, signalling the firm's ability to adapt and enhance stability in the face of external crises.

In addition, various studies suggest that the contribution of internal capital markets to firm value becomes more pronounced as financial constraints intensify (Bartram et al., 2022; Billett & Mauer, 2003; Freund et al., 2021; Hovakimian, 2011; Matvos et al., 2018). Specifically, Hovakimian (2011) finds that firms facing more stringent financial constraints during recessions enhance the efficiency of internal capital markets' efficiency by shifting more funds towards higher growth segments, which can positively affect firm value. In contrast, our study aligns with Freund et al. (2021), who argue that firms experiencing financial constraints tend to adopt more conservative allocation strategies, directing scarce internal resources towards less risky segments. This strategy reduces the overall firm risk and enhances cash flow stability, which, in turn, protects firms from insolvency or inefficient liquidation and leads to a higher firm value. Moreover, our results echo Billett and Mauer's (2003) argument that financial constraints drive the relationship between the internal capital market and firm value.

The remainder of this paper is organized as follows. Section 2 discusses the literature and develops the hypotheses. Section 3 describes the data and empirical design. Section 4 discusses the empirical results. Section 5 presents the additional analysis, while Section 6 concludes.

2. Related literature and hypothesis development

2.1 Natural disaster

Since natural disasters (i.e., hurricanes, droughts, floods, etc.) caused by climate change result in considerable negative impacts and severe economic losses on businesses and societies, there is a growing body of research aimed at investigating the exact effects of these disasters from different perspectives. One series of studies concentrates on individual outcomes and local economic conditions (Billings et al., 2022; Deryugina et al., 2018; Duqi et al., 2021). For instance, Deryugina et al. (2018) examine the long-term economic impact of Hurricane Katrina on victims and show that the effects on income and wage earnings are small and transitory. The quick recovery of income and wage earnings suggests that federal disaster relief is sufficient to aid economic losses driven by the storm. Similarly, Billings et al. (2022) investigate whether disaster victims rely on insurance or disaster assistance in response to flood risks. They document that, for credit constrained households, flood insurance better mitigates the adverse financial effect of flood in comparison to disaster assistance. Furthermore, Duqi et al. (2021) find that economic growth recovers more quickly in counties with stronger bank market power after a hurricane. They emphasize the importance of bank market structure since banks with high market power are better able to support borrowers by providing new mortgage credit and refinancing existing mortgage loans. This is consistent with the view that market power allows financial institutions to facilitate the post-disaster recovery to avoid foreclosure.

Another stream of research focuses on the impact of natural disasters on corporate behaviors (Aretz et al., 2019; Dessaint & Matray, 2017; Huang et al., 2022; Le et al., 2023; Wang, 2023). Dessaint & Matray (2017) analyze how managers respond to hurricane events when their firms are located in the neighborhood of the disaster area and find that managers often rely on heuristics and make predictable risk assessment mistakes that may affect corporate decision-making. As a consequence, managers tend to overact by increasing more cash holdings as a buffer against sudden increases in perceived liquidity risk induced by hurricanes. Nevertheless, this increase is temporary, and cash holdings revert to pre-disaster levels over time. These findings align with salience theories of choice (Bordalo et al., 2012), which predict that transient salience of the event reshapes decision makers' risk attitudes and leads them to overweighs its probability. Analogously, Huang et al. (2022) study the effect of natural disasters on corporate environmental, social, and governance (ESG) disclosure policies of firms located close to disaster areas. They show that managers of nearby firms exhibit greater risk salience in the aftermath of a natural disaster, thereby increasing ESG disclosures. They also indicate that the increase in ESG disclosures is driven more by changes in investors' risk perceptions rather than managers' risk perceptions.

Rather than concentrating on the "perceived" disaster risk, Aretz et al. (2019), Le et al. (2023), and Wang (2023) aim to explore the "real" disaster risk spring from the occurrence of natural disasters. The "real" disaster risk refers to the actual risk a firm experiences when a disaster happens, while the "perceived" disaster risk is the risk that firms might have been affected by the near-miss disasters but were not by chance. Aretz et al. (2019) study whether industrial firms take on more risk to hedge against distress risk caused by hurricane strikes. They find that moderate distress risk levels drive managers of those firms to participate not only in risk-taking but indeed also in risk-shifting. Specifically, moderately distressed firms shift their asset mixes toward riskier segments by shutting down lower-risk segments and observe abnormally high failure rates after a hurricane strike.

Similarly, Le et al. (2023) explore how natural disasters affect corporate innovation and highlight the economic consequence of financial constraints due to natural disasters. They suggest that the negative impact of disasters on corporate innovation is driven by financial constraints, which reduce firms' incentive to innovate. Hence, firms with high levels of financial constraints have lower R&D investments and fewer subsequent innovation activities. In addition, Wang (2023) focuses on the crucial role of collateral leases in providing financing for disaster-affected firms. She emphasizes the unique role of operating leases in offering necessary post-disaster financing for collateral-constrained firms. Although natural disasters cause physical damage to firms' tangible assets, leading to collateral constraints and creating friction in obtaining external financing, affected firms can secure financing through operating leases to restore operations without pledging additional assets as collateral.

2.2 Internal capital allocation efficiency

The basic idea of the efficiency of internal capital allocation goes back to Rajan et al. (2000), who state that resources within diversified firms should ideally be allocated to segments with greater opportunities. The efficient internal capital market theory argues that diversification creates value since diversified firms can allocate resources to their best use by forming an internal capital market where the internally generated cash flows can be pooled and distributed optimally (Stein, 1997). If segments have similar levels of resources and confront similar opportunities, the internal capital market works efficiently, allocating resources to segments with greater opportunities. This efficient allocation is in line with "winner-picking" in Stein (1997), which suggests that diversified firm can enhance value by employing transfers to deserving divisions when stand-alone divisions encounter imperfect capital markets and cannot borrow as much as they need.

However, as diversity in resources and opportunities increases, internal resources will be allocated to the most inefficient division, leading to more inefficient investment and reduced firm value. Such misallocation explains why diversified firms trade at a discount on average (Berger & Ofek, 1995). The potential investment distortions in diversified firms could sometimes be explained by agency theories. As managers of weaker segments have an incentive to lobby headquarters for more resources, in an attempt to distort the resource allocation in a way that prioritizes their own benefit (Scharfstein & Stein, 2000). Due to increased project opportunities and potentially more resources available to top managers in diversified firms, especially when diversification eases constraints imposed by imperfect external capital markets, there is a risk of overinvestment (Matsusaka & Nanda, 2002; Stulz, 1990). This phenomenon could be seen as CEOs trying to entrench themselves within the firm.

As a result, relative to the best use, the diversified firm may misallocate some funds at the margin to prevent greater average investment distortions. Since incentives to undertake efficient investment are distorted away from the optimal by the diversity of opportunities and resources, capital will be transferred from divisions that are large and have good opportunities to divisions that are small and have poor investment opportunities (Rajan et al., 2000). Their results also indicate that headquarters are willing to channel large capital budgets to divisions with poor opportunities to avoid even more enormous costs associated with those departments making even worse investment choices.

In addition, Billett & Mauer (2003) assess the relationship between the diversified firm's excess value and internal capital market. By focusing on the various components of the internal capital market, they find that efficient subsidies to financially constrained segments significantly increase excess value. On the contrary, inefficient transfers from segments with good relative investment opportunities substantially decrease excess value, which is in line with the efficient internal capital market theory. Furthermore, consistent with the predictions of Rajan et al. (2000), they suggest that subsidies to financially constrained segments significantly increase excess value since managers can take this strategy to mitigate divisional managers' incentives to choose self-serving investments.

A body of research (Barrot & Sauvagnat, 2016; Bartram et al., 2022; Billett & Mauer, 2003; Giroud & Mueller, 2019; Matvos et al., 2018) on the relationship between financial frictions and the value of internal capital allocation shows that firms shift resources internally to hedge against risk stemming from large dislocations in financial markets. They highlight the contribution of internal capital markets to firm value. In the face of disaster-related losses, corporations must decide how to manage salience risk optimally, especially when external finance is hard to access. Barrot & Sauvagnat (2016) find that suppliers experiencing natural disasters-induced disruptions can significantly impact their customers, particularly when they provide specific inputs. These disruptions lead to substantial output losses and, in turn, significant declines in market value, and the effects spill over to affect other suppliers. Their finding suggests that firm-level idiosyncratic shocks from natural disasters can be propagated though production networks.

In line with this finding, Giroud & Mueller (2019) document that economic shocks can be transmitted through a firm's internal networks of establishments. They show that establishment-level employment is sensitive to shocks occurring in remote regions where the establishment's parent company operates, and this sensitivity is heightened with an increase in the firm's financial constraints. This finding supports the view that internal capital markets can serve as an optimal response to exogenous variation in external capital markets frictions (Matvos et al., 2018). Specifically, Matvos et al. (2018) indicates that increased frictions in external capital markets make internal capital markets more appealing, encouraging firms to expand their scope. Moreover, Bartram et al. (2022) demonstrate that financially constrained firms can mitigate the environmental regulatory shocks by reallocating their internal resources and pollutive activities within their internal production network. Although these studies have explored the impact of economic shocks on the internal capital market, little is known about the effect of natural disasters on the allocative efficiency of internal capital markets.

2.3 Hypotheses development

Previous climate literature (IPCC, 2012) shows that hurricanes which have been increasingly frequent in the United States, can inflict severe damage to local economies, and randomly affect an extensive number of firms. Because the probability of a hurricane occurring cannot be accurately predicted and its occurrence is independent of economic conditions, natural disasters are arguably unexpected exogenous shocks that lead to increased liquidity risk and local business uncertainty. In this sense, external funds are much more expensive for the affected firms since natural disasters can reduce credit supply by deteriorating collateral values and weakening a firm's repayment capacity (Brown et al., 2021). The widespread physical destruction of a firm's tangible assets, especially those potential pledgeable assets, creates collateral constraints, thereby weakening the ability of the enterprise to raise external financing (Wang, 2023). Additionally, evidence shows that banks increase the supply of real estate credit through mortgage refinancing but do not lend more to businesses or consumers following a disaster (Duqi et al., 2021), further emphasizing the increase in the limits of external funding in the aftermath of such events.

Economic theory posits that managers need to maximize a firm's profits via optimally allocating resources as long as they are financially unconstrained. However, firms with higher threats of financial constraints are more likely to rely on internal resources as it is much less costly (Kim et al., 1998; Myers & Majluf, 1984). This implies that internal capital markets become more valuable when external capital costs rise, particularly during economic downturns. As external capital markets frictions increase, capital allocation in internal capital markets becomes more favorable, providing incentives for firms to diversify their investment needs and cash flow across industries (Matvos et al., 2018). Since whether internal capital allocation makes companies more valuable or not depends on the efficiency of such allocation relative to that provided by the external capital markets (Billett & Mauer, 2003; Kuppuswamy & Villalonga, 2016; Matvos et al., 2018), it is conceivable that the hazard might increase the relative value of internal capital markets and thereby the value of corporate diversification. This is consistent with Stein (1997), who uncovers the fact that corporate headquarters can add the most value by actively reallocating scarce funds across projects when credit constraints are binding, further reinforcing the insurance role of internal capital markets against unexpected exogenous shocks. Therefore, whether and to what extent firms effectively allocate their internal capital markets in response to natural disasters is of interest in our study.

We conjecture that natural disasters may affect internal capital market allocation efficiency in two opposite directions. The first direction expects that natural disaster is associated with less efficient internal capital markets. This prediction is based on the argument that natural disasters can heighten liquidity risk and increase local business uncertainty. The increased uncertainty induced by natural disasters is negatively associated with the real economy (Bloom, 2009), leading to a dramatic drop in productivity, outputs, and employment, which in turn increases cash flow risk. Furthermore, natural disasters drive up the cost of external financing (Brown et al., 2021; Duqi et al., 2021), making it more difficult and expensive for firms to obtain external funds. As a result, firms tend to increase their cash reserves as an insurance mechanism against the risk of liquidity shocks (Bates et al., 2009; Dessaint & Matray, 2017). In other words, firms with greater exposure to natural disasters are more likely to adopt a conservative financial policy, prioritizing cash retention over investments in growth opportunities. Moreover, the incompleteness of the insurance market for natural disasters further explains the accumulation of cash holdings (Wagner, 2022). However, as firms opt to retain more cash as a buffer to against the impact of natural disasters, the internal resources available for segment investments are simultaneously reduced. This, in turn, diminishes the efficiency of internal capital allocation.

In addition, as mentioned by the prior studies (Billett & Mauer, 2003; Matvos et al., 2018), capital reallocation within a firm becomes more valuable when external markets tighten. In response to increased financial constraints caused by natural disasters, firms have greater motivation to reallocate their internal capital resources within various segments. However, as predicted by the model of Rajan et al. (2000), the diversity in investment opportunities across segments within firms leads to distorted investment allocations because managers are self-interested. As managerial agency conflicts are often exacerbated by frictions in external capital markets, managers of weaker segments have strong incentives to lobby headquarters for additional resources, attempting to channel capital budgets in their favor. This is because the opportunity cost of engaging in lobbying activities is lower compared to productive work. However, these lobbying efforts are costly for the firm because they reduce firm-wide productivity. To mitigate these costs from lobbying activities and alleviate the internal politics, there a general tendency towards socialism in internal capital markets, where stronger segments often subsidize weaker ones (Scharfstein & Stein, 2000). This practice, which can also prevent even larger costs arising from underperforming segments making even worst investments (Rajan et al., 2000), further undermines the effectiveness of internal capital allocation within the company.

Furthermore, as managers are generally risk-averse in the face of high uncertainty arising from natural disasters, firms may also pursue diversification for the purposes of corporate systematic risk reduction (Hann et al., 2013). This is because diversification is associated with more stable income streams and a lower likelihood of bankruptcy for firms (Amihud & Lev, 1981). As diversification decreases the volatility of the firm's cash flows, it lowers the need for liquidity, which aligns with Duchin's (2010) finding that multi-segment firms tend to maintain less cash compared to stand-alone firms. When cash is scarce, the risk management motive dominates and companies allocate more of their resources to the low-risk segment with stable cash flows (Dai et al., 2024), often at the expense of high-return but riskier segments.

Collectively, firms tend to adopt a more conservative financial strategy in response to natural disasters. This strategy, aiming at risk mitigation, asset preservation, and operational restoration, comes at the cost of the firm's long-term growth prospects and market competitiveness. Through the inefficient internal capital allocation - redirecting resources from high-opportunity segments to low-opportunity ones - firms may achieve short-term resilience in the face of the shock. That is, when facing the uncertainty and challenges posed by natural disasters, managers tend to prioritize short-term stability over long-term growth prospects. Hence, we propose the following hypothesis:

H1(a): The allocation efficiency of internal capital markets decreases following a hurricane.

The second direction predicts that natural disaster is associated with more efficient internal capital markets. This conjecture builds on empirical evidence that firms can propagate economic shocks through their internal networks (Barrot & Sauvagnat, 2016; Giroud & Mueller, 2019). Following the occurrence of natural disasters, managers may overreact to sudden increases in perceived liquidity risk and consequently accumulate cash holdings (Dessaint & Matray, 2017). While this decision provides a cushion against uncertainty, it may be suboptimal in terms of resource allocation as the increase in cash holdings is costly and inefficient, leading to decreases in the market value of cash following the hurricane. That is, rising cash holdings after natural disasters may be a waste of scarce internal funds, which in turn motivates managers to allocate internal funds in a more efficient manner.

Additionally, when faced with financial constraints, firms may be more motivated to expand and diversify their operations, actively seeking high-value opportunities to maximize returns (Matvos et al., 2018). Hovakimian (2011) provides supportive evidence that financial constraints improve the quality of project selection by reducing free cash flow and pressuring managers to fund more valuable investment opportunities. This is consistent with “winner-picking" theory (Stein, 1997), which argues that with a restricted amount of capital available, firms can utilize the flexibility provided by internal capital markets to reallocate funds from inferior quality projects to higher quality ones. By doing so, firms can prioritize segments with the greatest potential for return and improve overall capital efficiency.

Moreover, companies may opt to utilize their internal capital more effectively by closing these segments after natural disasters and reallocating more resources towards segments with superior opportunities, rather than protecting under-performing segments (Hovakimian, 2011). This is consistent with Scharfstein's (1998) finding that 33% of diversified firms refocused by selling their smallest segments at the end of 1994, thereby making capital allocation within the firms more efficient.

Taken together, firms are likely to optimize their internal resource allocation in the face of natural disasters. By shifting resources from underperforming segments to those with higher growth potential, firms may achieve higher returns, improve their long-term growth prospects and market competitiveness. Based on the above arguments, we state the competing hypothesis:

H1(b): The allocation efficiency of internal capital markets increases following a hurricane.

Building on the competing hypotheses regarding the impact of natural disasters on internal allocation efficiency, it is of interest to explore whether these changes translate into firm value. Prior research highlights the crucial role of internal capital markets in firm value, especially when external financial market is hard to access (Bartram et al., 2022; Billett & Mauer, 2003; Matvos et al., 2018). Internal capital markets provide firms with flexibility to reallocate resources and mitigate financial frictions during period of heightened uncertainty after natural disasters.

Theoretical arguments propose that diversification can produce either positive or negative effects on firm value. On the one hand, the efficient internal capital market theory suggests that diversification creates value by enabling managers to allocate resources optimally, channeling internal funds toward more productive segments (Stein, 1997). Such efficient allocation suggest that diversification maximizes firm returns and mitigate the risk from external shocks. On the other hand, Berger & Ofek（1995), Rajan et al. (2000) and Scharfstein & Stein (2000) argue that diversification may reduce firm value due to agency conflicts. Such conflicts between top managers and segment managers spur costly rent-seeking behavors in underperformance segments, leading headquarters to adopt 'corporate socialism' practices, therefore diminishing diversified firm value. This misallocation reduces the overall value of diversified firms, with the diversification discount intensifying as more resources are skewed toward low-opportunity segments (Berger & Ofek, 1995).

Given that allocating more internal capital to higher risk but deserving segments creates more value, we assume that if hypothesis H1b holds, there would be a positive relation between natural disasters and excess value of multi-segment firms would be observed. Conversely, if H1(a) holds, we anticipate a negative relationship due to inefficient resource allocation. However, as the conservative allocation policy that prioritize stability by distorting resources towards the less risky segments could help financially constrained firms prevent bankruptcy and inefficient liquidation, ultimately increase firm value (Freund et al., 2021). In other words, natural disasters motivate managers engage in risk-decreasing behaviors, which may align with investor preferences for lower uncertainty during volatile periods, resulting in a higher valuation being assigned to the firm.

Taken together, we propose that changes in internal capital allocation efficiency induced by natural disasters contribute positively to firm value. Specifically, we expect a positive association between natural disasters and excess value of firm. Therefore, our second hypothesis is as follows:

H2: The excess value of multi-segment firms increases following a hurricane.

3. Data and methodology

3.1 Measures of internal capital allocation efficiency

Following previous studies (Freund et al., 2021; Rajan et al., 2000), we use the industry-adjusted relative value added by allocation (RVIA) to measure internal capital allocation efficiency.

$$RVIA = \sum_{j=1}^{n} \omega_j (q_j - \bar{q})[\frac{Capex_j}{BA_j} - \frac{Capex_j^i}{BA_j^i}] \quad (1)$$

where w_j is the ratio of segments j's book value of assets to the firm's book value of assets and n is the total member of segments of the diversified firm. While q_j is the segment j's Tobin's q, measured by the asset-weighted average Tobin's q of all single-segment firms operating in the same three-digit SIC code industry as that of segment j, $\bar{q}$ is the asset-weighted average imputed q_j's of the multi-segment firm. Both w_j and q_j are measured as of the beginning of the period. $Capex_j$ is the segment j's capital expenditure, and BA_j is the segment j's book value of assets. $Capex_j/BA_j$ is the segment j's investment ratio, whereas $Capex_j^i/BA_j^i$ represents the asset-weighted average ratio of capital expenditure to assets for matched stand-alone firms operating in the same three-digit SIC industry as segment j.

The expression $(q_j-\bar{q})$ measures the segment's investment opportunities compared to the other segments of the firm. If allocations of internal sources are to be efficient, segments with better investment opportunities ($q_j-\bar{q}>0$) should obtain more resources, while segments with poor investment opportunities ($q_j-\bar{q}<0$) should get less resources. The term $[Capex_j/BA_j-Capex_j^i/BA_j^i]$ indicates the capital expenditure of the segment normalized by the book value of the segment's assets compared to the asset-weighted average equivalent measure for the industry-matched firms. It captures how the investment ratio of segment j differs from that of the corresponding asset-weighted ratio of single-segment peer firms within the same industry. This deviation works as a proxy for the "abnormal" investment ratio of the segment compared to the industry, indicating the transfer of resources.

Efficient transfers occur when the investment opportunity and the investment allocation both are above or below average, the weighted product $w_j(q_j-\bar{q})[Capex_j/BA_j-Capex_j^i/BA_j^i]$ will make a positive contribution toward the measure. However, if the investment opportunity and the associated allocation move in opposite directions, the weighted product will contribute to generating a negative measure. In other words, inefficient transfers happen when an above-average q segment receives below-average investment as well as a below-average q segment receives greater-than-average investment. Thus, our measure of internal capital allocation efficiency, $RVIA$, exhibits the correlation between investment and investment opportunities across different divisions within a diversified firm. The stronger the positive correlation, the more efficient the firm allocates internal resources. In other words, higher positive values of $RVIA$ imply higher allocation efficiency, while lower or negative values of that mean sub-optimal allocation efficiency.

3.2 Measures of firm excess value and diversification

Considering that the allocation of internal capital market can have two opposing impacts on firm value, we measure firm excess value following Berger & Ofek (1995), Datta et al. (2009) and Freund et al. (2021):

$$EV = \ln\left(\frac{MV}{I(MV)}\right) \tag{2}$$

where *MV* is the firm's market value calculated as book value of assets plus the difference between market value and book value of equity, *I(MV)* is the imputed value of the multi-segment firm defined as the sum of the stand-alone market values of the firm's n business segments:

$$I(MV) = \sum_{i=1}^{n} Sales_i * \left(Ind_i\left(\frac{Capital}{Sales}\right)_{mf}\right) \tag{3}$$

$Sales_i$ is the segment i's sales value, $Ind_i\left(\frac{Capital}{Sales}\right)_{mf}$ is the median industry multiple of total capital to sales of matched pure-play firms in the industry with the same three-digit SIC code.

Prior studies (Datta et al., 2009; Freund et al., 2021; Rajan et al., 2000) document that allocation efficiency is associated with a higher level of diversification. Therefore, in the spirit of these papers, we measure the degree of diversification by multi-segment firms using the inverse Herfindahl index, the inverse of a firm's sales-based Herfindahl index:

$$Inverse\ HI = \sum_{j=1}^{n}\left(\frac{Sales_j}{\sum_{j=1}^{n} Sales_j}\right)^2 \tag{4}$$

where j represents segment j and n is the total number of segments. It is calculated as of the beginning of the year.

3.3 Research framework

This study primarily concentrates on identifying how the real risk of natural disasters affects the allocative efficiency of the internal capital market. To examine the relationship between natural disasters and the allocative efficiency of internal capital market, we employ the difference-in-difference (DID) model following Duqi et al. (2021) and Wang (2023). Natural disasters, such as hurricanes, can work as an exogenous shock for the following reasons[4]. First, there is basically no warning when a hurricane strikes. Second, the timing and location of hurricanes are inherently difficult to predict and are exogenous to firm and manager characteristics. Third, hurricanes cause severe economic damage to affected areas. These features make hurricane events an ideal setting to estimate the causal effect of natural disasters on the internal capital allocation efficiency of a treatment group of directly affected firms

[4] We focus on hurricane events because, according to WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water-related Hazards (1970-2021), although flood-related disasters were the most prevalent, in terms of impact, tropical cyclones were the primary cause of both human and economic losses worldwide over the past 51 years. North America, Central America and the Caribbean also reported the most economic losses were due to storm-related disasters, and more specifically, to tropical cyclones.

relative to a control group. As natural disasters are inherently exogenous, variations in internal capital allocation efficiency observed after their occurrence cannot easily be attributed to unobserved heterogeneity or reverse causality. We use the following model:

$$RVIA_{i,c,t} = \alpha_0 + \alpha_1 Disaster_{i,c,t} + \alpha_2 X_{i,c,t} + \delta_i + \gamma_t + \varepsilon_{i,c,t} \tag{2}$$

where *i* indexes firm, c denotes the county location of the firm headquarter, and t indicates year. Our primary interest of dependent variable $RVIA_{i,c,t}$ measures internal capital allocation efficiency as defined in Eq.(5). $Disaster_{i,c,t}$ is a dummy variable that equals 1 if the firm located in the area hit by a hurricane in the three years ($t + 1$ to $t + 3$) following the disaster and 0 otherwise. Specifically, we require a gap of at least 7 years between the disaster strikes experienced by a treated firm. We do so to solve the problem that there is an overlap between the earlier hurricane's post-event period and the later hurricane's pre-event period. $X_{i,c,t}$ is a vector of control variables for firm characteristics. δ_i and γ_t are firm and year fixed effects, respectively; ε_t is the error term. We include firm and year fixed effects to control the effects of time-invariant unobservable firm-specific heterogeneity as well as the effects of common time trends. Standard errors are clustered at the firm level. The main coefficient of interest in Eq. (5) is α_1, which captures the effect of natural disasters on internal capital market allocation efficiency.

Based on Freund et al. (2021) and Iskenderoglu (2021), we control for a number of factors that are likely to be related to internal capital more generally, including firm size (*Size*, measured by the natural logarithm of total assets), capital expenditures (*Capex,* the ratio of capital expenditures to total assets), R&D expenditures (*R&D*, the ratio of research and development expense to total sales), Tobin's q (*Tobin's q*, calculated by the market value of assets divided by the book value of assets), leverage (*Leverage*, measure by the sum of long-term debt and debt in current liabilities divided by total assets), Age (*Age*, calculated by the natural logarithm of 1 plus the number of years since a firm first appeared in the Compustat), Sales growth (*Sales growth*, measured by the difference between the sales for the current fiscal year and the sales for the previous year divided by the sales for the previous year), and diversity (*Inverse HI,* the inverse of the sales-based Herfindahl Index).

We control for the impact of firm size because more well-established firms tend to have fewer growth opportunities but more available resources, which captures firm transparency (Datta et al., 2009). Furthermore, as Datta et al. (2009) documented, larger investments can lead to less efficient allocations, we include capital expenditures in the model. We also control for R&D expenditures in our model since R&D activities exhibit a high level of information asymmetry between divisions and corporate headquarters, impeding the effective allocation of the internal capital market (Seru, 2014). Following Rajan et al. (2000), we also include Tobin's q as an additional control variable. Tobin's q is used to reflect the firm's investment opportunities, which may also affect the internal capital market allocation efficiency.

Moreover, Lang et al. (1996) state that increased leverage diminishes both the current funds available for investment and the firm's capacity to raise additional funds for investment. In other words, highly leveraged firms confront more expensive external financing compared to internal financing; therefore, firms with higher leverage tend to adopt a more conservative financing policy to get rid of experiencing financial default. Regarding this concern, we control leverage in the model. We also control firm age and sales growth, which are potential determinants of internal capital allocation (Matvos et al., 2018). Older firms typically have more stable cash flows and well-established operations, which lead to more informed decision-making regarding capital allocation. In addition, companies experiencing high sales growth may allocate more capital internally to fund capacity expansion and investment strategies. As Rajan et al. (2000) predict that diversity in investment opportunities between segments within firms leads to distorted investment allocations, we include the inverse of the sales-based

Herfindahl Index (*Inverse HI*) to serve as a proxy for the diversity of investment opportunities in the firm as a control variable.

3.4 Sample construction and descriptive statistics

This section describes the sample construction process and data sources. We employed three sets of databases to form our sample and get the necessary data: Compustat database, Compustat historical segment database, and Spatial Hazard Events and Losses Database for the United States (SHELDUS) database. Data on natural disasters is available from the Spatial Hazard Events and Losses Database for the United States (SHELDUS) database. This database provides county-level information on the date, location, and losses caused by natural disasters (such as hurricanes, thunderstorms, floods, wildfires, and tornados) as well as perils (like flash floods, heavy rainfall, etc.). Similar to Duqi et al. (2021), we focus on major hurricanes, which are defined as those with presidentially declared disasters (PDD). Since a PDD indicates that the disaster is of such severity, the affected state does not have sufficient resources to respond effectively and requires Federal Government intervention. In addition, we obtain firm-level characteristics data from Compustat. Segment-level information comes from the Compustat historical segment files, which provide annual accounting data such as sales, capital expenditure, assets, income, and operating profits at the segment level since 1976.

To construct the sample, we process the below filters to the sample following the previous studies (Berger & Ofek, 1995; Freund et al., 2021; Iskenderoglu, 2021): (i) we exclude firms with missing segment information on sales, assets, and capital expenditures; (ii) we drop firms whose firm-level sales are $20 million or less; (iii) we delete firms whose sum of segment sales is more than 1% away from total firm sales and those whose sum of the segments' assets is more than 25% away from the firm's assets; (iv) we remove firms with segments operating in one-digit SIC codes of 0 (agriculture), 6 (financials), and 9 (public sector); (v) we require firms to have at least two segments operating in different three-digit SIC codes; (vi) for each segment of the diversified firms, we require to have at least five industry-matched single-segment firms based on three-digit SIC code; (vii) multiple-segment firms should have information available on Compustat to calculate control variables. Furthermore, we drop firms incorporated outside of the United States.

Our final sample is from 2001 to 2020 and includes 6,299 firm-year observations with 1,261 multi-segment firms. The detailed definitions of the variables used in this paper are presented in Appendix A. To mitigate the potential influence of outliers, all the continuous variables are winsorized at the 1st and 99th percentiles.

Table 1 presents the PDD hurricane events in the U.S. aggregated by county and year, including information on a number of affected counties, property damages (in $millions), and fatalities. In total, there are 1,591 PDD hurricane events from 2001 to 2020. The total financial cost of property damage of $313,323.16 million and the total number of fatalities of 2,334 indicate that hurricanes lead to considerable damage to local economies and lives.

[Insert Table 1 about here]

Table 2 reports the summary statistics for the allocation efficiency measure (*RVIA*), firm size (*Size*), capital expenditures (*Capex*), R&D expenditures (*R&D*), Tobin's q (*Tobin's q*), leverage (*leverage*), Age (*Age*), Sales growth (*Sales growth*), and diversity (*Inverse HI*). All continuous variables are winsorized at 1st and 99th percentiles to alleviate the potential impact of outliers. The detailed definition of each variable is provided in Appendix A. To facilitate the interpretation of estimation results, we multiply the original value of the internal capital allocation efficiency measure by 100.

The mean and median industry-adjusted relative value added (*RVIA*) are 0.1715 and 0.0370, respectively. The positive *RVIA* value indicates higher allocation efficiency. In other words, efficient transfers occur when the investment opportunities and the allocation move in the same direction. The average *Size* of the sample firm is 6.8807, and the average value of *Capex* is 0.0508. Furthermore, the sample firms have a mean value of *R&D* of 0.0284 and an average *Tobin's q* of 1.6184, which is comparable with that reported in Freund et al. (2021). In addition, the average sample value of *leverage* is 0.2990, and the firm's average age is 3.0948. The mean *Sales growth* and *Inverse HI* value of our sample are 0.1092 and 0.7388, respectively.

[Insert Table 2 about here]

Table 3 exhibits the correlation matrix among the key variables used in the empirical analysis. The correlation matrix shows that our dependent variable *RVIA* has a significant positive correlation with *Capex, Tobin's q, and Sales growth but a significant negative relationship with Size, Age,* and *Inverse HI*. This suggests that firms with higher *Capex* and *Tobin's q* allocate their internal capital more efficiently, but the larger firm size and higher diversification would reduce this efficiency (Datta et al., 2009). Firms with higher *Capex* and *Tobin's q* are generally associated with profitable investment opportunities, prompting managers to allocate resources towards projects that maximize firm value (Stein, 1997). However, as argued by Lang & Stulz (1994), large firm size and higher diversification can lead to inefficient capital allocation decisions across different segments due to managerial agency problems.

Moreover, older firms may face organizational rigidities and entrenched managerial practices (Loderer & Waelchli, 2011), leading to less optimal resource allocation. Firms with higher growth potential, on the other hand, are more likely to reallocate resources strategically toward areas with the greatest opportunity (Hovakimian, 2011). In addition, the correlations among the control variables are less than 0.5, suggesting that multicollinearity is not a major issue in our regression model. The untabulated statistics show that the mean variance inflation factor (VIF) is 1.05, further confirming that multicollinearity is not a concern in our empirical setting.

[Insert Table 3 about here]

4. Empirical results

4.1 The impact of natural disaster on internal capital market efficiency

Table 4 presents the estimated results of Eq. (5) using the measure of internal capital allocation efficiency (RVIA) as the dependent variable. Employing the difference-in-difference method, we examine the extent to which firms efficiently allocate their internal capital market following the hurricane. The key coefficient on the indicator variable Disaster captures changes in the efficiency of internal capital allocation following natural disasters. Columns (1) and (2) do not include any control variables. We incorporate firm fixed effects in column (1), (3) and (5), and further add year fixed effects in column (2), (4), and (6). In columns (3) and (4), we introduce control variables, including firm size (*Size*), capital expenditures (*Capex*), R&D expenditures (*R&D*), Tobin's q (*Tobin's q*), leverage (*leverage*), Age (*Age*), and Sales growth (*Sales growth*). Columns (5) and (6) further control for diversity (*Inverse HI*). The results across all model specifications consistently show significant and negative coefficients on *Disaster*, suggesting an adverse relationship between natural disasters and efficiency of internal capital market. The estimated coefficient of *Disaster* is -0.0475 (in column (6)), indicating that a 1% increase in *Disaster* is associated with approximately 0.0475% (= 0.01 * (-0.0475)) decrease in *RVIA*, which corresponds to a decrease of 27.7% relative to the sample mean (= 0.0475 / 0.1715). The negative relationship between natural disasters and internal capital allocation efficiency is statistically and economically significant, which aligns with our prediction that firms are more likely to adopt a more conservative capital allocation strategy to navigate adverse shocks induced by natural disasters.

With regard to the control variables, we find that *Capex* and *Sales growth* are positively and significantly correlated with *RVIA*, indicating that firms with larger investments and higher growth potential can allocate internal resources more efficiently (Freund et al., 2021). Larger investments and higher growth potential may enable diversification across a broader range of projects, which can help mitigate risks and allow firms to allocate resources more effectively to areas with the highest potential returns. Additionally, we observe that higher *Inverse HI* is associated with lower *RVIA*, consistent with the notion that greater diversity provides more opportunities for managers to misallocate internal capital and derive private benefits (Rajan et al., 2000). We also find that the coefficients on *Size*, *Age*, *Tobin's q*, *Leverage*, and *R&D* are insignificant, which resonates with previous studies (Datta et al., 2009; Freund et al., 2021).

[Insert Table 4 about here]

4.2 Parallel trend assumption test

The validity of the estimated results of the DID model depends on whether the parallel trend assumption is satisfied. The parallel trend assumption requires that prior to natural disasters, internal capital allocation efficiency in the treatment and control groups follow a similar trend. If pre-existing differences between disaster-affected and non-disaster-affected firms exist, the significant effect of natural disasters on internal capital allocation efficiency is likely to manifest before the occurrence of disasters. To address the concern that our findings may be influenced by pre-existing differences between firms affected by disasters and those unaffected by disasters, we conduct falsification tests by employing the dynamic effect model following Wang (2023). We replace the *Disaster* dummy with new time indicators $Disaster^{-3}$, $Disaster^{-2}$, $Disaster^{-1}$, $Disaster^{+1}$, $Disaster^{+2}$, and $Disaster^{+3}$ in Eq. (5), which refers to three years before, two years before, one year before, one year after, and two or more years after the natural disaster, respectively. The dummy variable $Disaster^{0}$, that is, the current year of the disaster occurrence, is considered as the base year and is therefore not included in this model.

The coefficients of these new time dummies capture the dynamic effect of natural disasters on internal capital allocation efficiency. If the pre-treatment parallel trends assumption is valid, the coefficients on $Disaster^{-3}$, $Disaster^{-2,}$ and $Disaster^{-1}$ will be indifferent from zero.

Table 5 presents the estimation results. As we do not find significant coefficients on $Disaster^{-3}$, $Disaster^{-2}$, and $Disaster^{-1}$, it suggests that the difference in internal capital allocation efficiency between affected and non-affected firms does not exhibit a remarkable change before the occurrence of disasters. In addition, the negative and statistically significant coefficients on $Disaster^{+1}$ and $Disaster^{+2}$ underpin our main finding that internal capital allocation efficiency is statistically and negatively related to natural disasters. Moreover, the insignificant coefficient on $Disaster^{+3}$ indicates that this negative impact is temporary. Turning to the control variables, we note that *RVIA* is positively and significantly related to *Capex* and *Sales growth* but negatively associated with *Inverse HI*, which is consistent with the findings of Freund et al. (2021) and Rajan et al. (2000).

[Insert Table 5 about here]

4.3 Entropy balancing method

To address the concern that our empirical results may be driven by the fundamental differences in characteristics between treatment and control groups, we employ an entropy balancing (EB) approach following Wang (2023). EB is a data pre-processing method that allows us to achieve balance on the higher moments of the covariate distributions (Hainmueller, 2012). This approach utilizes a maximum entropy reweighting scheme, which adjusts unit weights to ensure that both the treated and control groups meet a potentially large set of prespecified balance conditions. EB is superior to the propensity score matched (PSM) method because PSM results in a significant loss of observations. Additionally, compared to PSM, EB allows researchers to achieve a higher degree of covariate balance across measures such as mean, variance, and skewness by preserving valuable information in the processed data (McMullin & Schonberger, 2020).

Specifically, we use EB based on the first two moments (i.e., the mean and variance) of the firm-level covariates to match treated firms to control firms. Then, we repeat the regression model in Eq. (5) using the entropy-balanced sample. The results on Panel A in Table 6 compare the mean and variance of treated and control groups for different corporate characteristics. The matching variables are not significantly different in means and variances between treated and control groups, indicating that the entropy balance has been achieved. The Panel B of Table 6 reports estimated results. The negative and significant relationship between natural disasters and internal capital allocation efficiency remains consistent, further suggesting that our results are not driven by differences in characteristics between treatment and control groups.

[Insert Table 6 about here]

4.4 Placebo test

To rule out the concerns of spurious factors that may affect disaster-affected firms and disaster-unaffected firms similarly, we conduct a placebo test using pseudo-samples of treated and control firms following Wang (2023). We randomly assign treatment dummies to the whole sample and estimate the effect of pseudo natural disasters on internal capital allocation efficiency. The simulation is repeated 1,000 times. Table 7 reports the distribution of the coefficients and t-statistic of the placebo test. The average pseudo-coefficient of *Disaster* is 0.0003, with an average t-statistics of –0.0159. The probability of getting a pseudo-coefficient of *Disaster* greater than –0.0475 (our baseline regression results as shown in Table 4) is 0%. Furthermore, the probability of a pseudo-t-statistics of *Disaster* greater than –2.46 (the t-statistics of *Disaster* in our primary regression) is 0.6%. These findings show an insignificant relationship between the pseudo treatment event and internal capital allocation efficiency, suggesting that our baseline results are unlikely to be driven by confounding factors.

[Insert Table 7 about here]

4.5 The impact of natural disaster on firm excess value

In this section, we explore the effect of natural disasters on the value of multi-segment firms proxied by the excess value. As discussed in the previous section, natural disasters have a negative effect on allocation efficiency. This may be because firms redirect resources towards poorly segments to get rid of worse investments made in those segments (Rajan et al., 2000) and thus enhance the firm value. Furthermore, considering that a conservative investment policy can safeguard financially constrained firms from bankruptcy and inefficient liquidation, adopting a conservative capital allocation strategy would amplify the value of these distressed firms. We investigate the effect of natural disasters on excess value by using excess value as the dependent variable in our baseline regression. We estimate regressions separately for the full sample, financially distressed, and safe subgroups. The results are reported in Table 8. We find a positive and statistically significant association between natural disasters and firm excess value. Moreover, this positive effect is more apparent for those financially distressed firms. This finding suggests that the increased value could be a consequence of suboptimal capital allocation induced by natural disasters.

[Insert Table 8 about here]

5. Additional analysis

5.1 Different disaster windows

To further check the robustness of our baseline results, we vary the time window of the *Disaster* indicator following Huang et al. (2022). Instead of using a three-year window, we define a *Disaster* dummy to include the two-year (t+1 to t+2) or the four-year window (t+1 to t+4) subsequent to the disaster. We re-estimate the DID model using the new *Disaster* indicators and report the results in Table 9. The estimated coefficients on *Disaster* are consistently negative and statistically significant. This finding suggests that our main results are robust to the two alternative identifications of treated firms. In other words, our findings are not driven by the differential identification of the *Disaster* dummy.

[Insert Table 9 about here]

5.2 The potential channel: financial constraints

It is of interest to further exploit the potential channels through which natural hazards affect internal capital market allocation efficiency. As documented in prior literature (Baltas et al., 2022; Duqi et al., 2021; Le et al., 2023), natural disasters heighten friction in the external capital market and lead to higher financial constraints. As a consequence, multi-segment firms rely more on the internal capital market, especially those likely to face more binding financial constraints (Hovakimian, 2011). To validate this potential mechanism, we investigate the role of financial constraints in the adverse linkage between natural disasters and internal allocation efficiency in this section.

To measure the firm's financial constraint, we use the Kaplan-Zingales (KZ) index and the Whited-Wu (WW) index. Developed by Kaplan & Zingales (1997), as one proxy for financial constraints, a higher KZ index indicates that firms suffer from a higher risk of bankruptcy. Another proxy for financial constraints is constructed by Whited & Wu (2006). Similarly, a higher WW index implies that firms are more likely to confront higher levels of financial constraints. We divide firms into two groups based on the median value of the KZ

(WW) index. If the firm's KZ (WW) index is greater than the sample median, it is considered a highly constrained firm. Otherwise, it is a financially safe firm. Additionally, we define High KZ (WW) as a dummy variable equal to one if the firm has a KZ (WW) index that exceeds the median value and zero otherwise. We re-run our baseline regression using these subsamples.

Then, we try the regression results by including the interaction term between disaster and financial constraints dummies in the baseline model. Table 10 reports the estimated results. We find that the statistically negative relationship between natural disasters and internal capital allocation efficiency is more pronounced for firms with higher financial constraints. Our empirical results further show that natural disasters have a more substantial negative effect on the allocation efficiency of the internal capital market when firms experience greater financial constraints. This is consistent with the argument that financially distressed firms are more likely to follow a conservative capital allocation strategy (Freund et al., 2021).

[Insert Table 10 about here]

5.3 Cross-sectional analysis

5.3.1 Firm performance

One concern of our study is that the extent to which natural disasters affect internal capital allocation efficiency may depend on the ex-ante corporate performance. To mitigate this concern, we classify our sample into good performance subsample and poor performance subsample subgroups. We measure corporate performance by using annual stock returns. If a firm's stock return exceeds the median value of the sample in year t-1, it is categorized as a good performance firm; otherwise, it is classified as a poor performance firm. Table 11 shows the estimated results of Eq. (5) based on these two subsamples. The coefficient on *Disaster* is negative and statistically significant at the 1% level for the good performance group but insignificant for the poor performance group. This suggests that the negative correlation between natural disasters and internal capital allocation efficiency is more apparent for firms with better performance. That is, instead of allocating resources to segments with greater opportunities, managers of firms with higher performance are more likely to shift their scarce internal funds towards segments with fewer opportunities to prevent them from making even worse investment decisions. (Berger & Ofek, 1995; Rajan et al., 2000).

[Insert Table 11 about here]

5.3.2 CEO ownership

In this section, we further explore whether the negative relationship between natural disasters and allocation efficiency of internal capital market is heterogenous across cross-sectional variations in CEO ownership. Prior research suggests that higher CEO ownership strengthens the alignment of interest between CEO and shareholders (Raheja, 2005), as the CEO's wealth becomes closely tied to a firm's stock performance. This alignment reduces the potential of private benefit extraction by insiders and mitigates agency problems arising from costly monitoring (Demsetz & Lehn, 1985; Zhou, 2001). When interests are strongly aligned, the cost for the CEO to misallocate corporate resources by giving in to the rent-seeking and distortionary lobbying of the segment managers would be prohibitive compared to any potential private benefits the CEO might gain (Datta et al., 2009). As a result, firms with a high degree of CEO ownership are more likely to make more efficient capital allocation.

In contrast, lower CEO ownership exacerbates the misalignment of interest between the managers and shareholders, weakening the CEO's incentive to prioritize firm value over personal benefits. This misalignment increases the likelihood of managerial behaviors that lead to resource misallocation, such as overinvesting free cash flow for empire-building (Meckling & Jensen, 1976), engaging in inefficient cross-subsidization (Lamont, 1997; Scharfstein, 1998), and giving in to rent-seeking by segment managers (Scharfstein & Stein, 2000). Consequently, firm with lower CEO ownership are more susceptible to inefficient internal capital allocation.

We examine whether, and to what extent, the negative impact of natural disasters on allocation efficiency of internal capital market is more apparent for firms with a lower CEO ownership. We use CEO ownership, calculated as the percentage of shares owned by the CEO divided by total shares outstanding, to separate firms into two groups. If a firm's CEO ownership is greater than the sample median, it is regarded as a firm with high CEO ownership; otherwise, it is classified as a firm with low CEO ownership. We then re-estimate our baseline regression using subsamples. The results are presented in Table 12. The coefficient on *Disaster* is statistically significant and negative for low CEO ownership subsample, indicating that the negative effect of natural disasters on internal capital market efficiency is stronger for firms with lower CEO ownership.

[Insert Table 12 about here]

6. Conclusion

In this paper, we examine how natural disasters affect multi-segment firms' internal capital market efficiency. Our results suggest a negative impact of natural disasters on the allocation efficiency of the internal capital market. This indicates that the increased downside risk induces firms to adopt a more conservative financial policy. This inverse relationship is robust across different approaches that account for potential endogeneity. When natural disasters exacerbate external financial frictions and uncertainty, internal capital markets become crucial for firms to hedge against potential adverse impacts. Instead of solely aiming to maximize firm valuation, managers may be more motivated to reallocate internal resources from stronger segments to weaker ones to achieve stable cash flows and reduce overall risk. Our findings align with evidence given by Freund et al. (2021) that conservative capital allocation strategies appear to be optimal for financially distressed firms. Additionally, our results reinforce the findings of Giroud & Mueller (2019) that local economic shocks can be propagated through firms' internal networks, highlighting the critical role of internal capital markets in shaping firms' resilience to economic fluctuations.

In addition, we find that the adverse effect of natural disasters on internal capital allocation efficiency is more profound for firms facing higher levels of financial constraints. We further explore whether natural disasters, via influence internal capital allocation, affects the firm value. The results show the increase in firm value following natural disasters, especially for financially constrained firms. The increase in firm value reflects the argument that suboptimal capital allocation is seen as the best choice in the context of economic disclosure and, hence, improves firm value. Furthermore, our cross-sectional analysis shows that the negative influence of natural disasters on internal capital allocation efficiency is more pronounced for firms with greater pre-disaster corporate performance and those with lower CEO ownership.

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Table 1 US hurricanes over the 2001-2020 period

This table reports the number of counties affected by PDD hurricane events per year in the US mainland during the sample period. We include data on property damages (in $millions) and fatalities. Property damages are the total direct damage to property caused by hurricanes expressed in millions of dollars adjusted for the inflation to 2020. Fatalities are the total number of people directly killed by hurricanes.

Year	Number of counties Affected	Property damages (in $millions)	Fatalities
2001	22	7,640.00	22
2002	46	1,150.00	2
2003	107	2,330.00	10
2004	137	33,900.00	49
2005	254	128,000.00	2,020
2008	199	18,300.00	18
2010	6	0.57	0
2011	156	1,440.00	28
2012	85	287.00	17
2014	1	1.11	0
2015	3	6.08	0
2016	39	6,520.00	24
2017	245	55,200.00	100
2018	101	25,300.00	12
2019	37	48.40	0
2020	153	33,200.00	32
Total	1,591	313,323.16	2,334

Table 2 Summary statistics

This table reports firm-level summary statistics for key variables used in this paper over the 2001–2020 period. For each variable, number of observations, mean, standard deviation, median, and 25th and 75th percentiles are reported. We multiply the initial value of *RVIA* by 100 to ease interpretation. All continuous variables are winsorized at 1st and 99th percentiles to reduce the effects of outliers. Detailed definitions of variables are presented in Appendix A.

Variable	N	Mean	SD	p25	Median	p75
RVIA	6,299	0.1715	0.3834	0.0000	0.0370	0.1609
Size	6,299	6.8807	2.0311	5.5081	6.9243	8.3000
Capex	6,299	0.0508	0.0511	0.0191	0.0347	0.0651
R&D	6,299	0.0284	0.1299	0.0000	0.0000	0.0241
Tobin's q	6,299	1.6184	1.0042	1.0684	1.3442	1.8386
Leverage	6,299	0.2861	0.2417	0.1250	0.2630	0.3906
Age	6,299	3.0948	0.7881	2.4849	3.2189	3.7842
Sales growth	6,299	0.1092	0.4341	-0.0312	0.0577	0.1629
Inverse HI	6,299	0.7388	0.2416	0.5217	0.7394	1.0000

Table 3 Correlation matrix

This table presents correlation coefficients for the key variables used in this paper. Figures in bold indicate that the coefficient is significant at the 5% level.

	RVIA	Size	Capex	R&D	Tobin's q	Leverage	Age	Sales growth	Inverse HI
RVIA	1.0000								
Size	**-0.0290**	1.0000							
Capex	**0.4160**	**0.1230**	1.0000						
R&D	-0.0190	**-0.0840**	**-0.0350**	1.0000					
Tobin's q	**0.0430**	**-0.0560**	-0.0060	**0.1200**	1.0000				
Leverage	0.0130	**0.1420**	**0.0930**	**-0.0570**	**0.0430**	1.0000			
Age	**-0.1310**	**0.3200**	**-0.0920**	**-0.0450**	**-0.0380**	**-0.1080**	1.0000		
Sales growth	**0.0800**	**-0.0400**	**0.0650**	**0.0390**	**0.0870**	-0.0090	**-0.1730**	1.0000	
Inverse HI	**-0.2570**	-0.0110	-0.0110	**-0.0490**	0.0050	0.0030	0.0030	0.0170	1.0000

Table 4 Baseline regression: natural disaster and internal capital market efficiency

The table reports the preliminary results for the relationship between natural disasters and internal capital market efficiency based on Eq. (2). The dependent variable is the industry-adjusted relative value added by allocation (RVIA) measured using Eq. (1). The primary variable of interest is the indicator variable, Disaster, which takes a value of one if the county of the firm headquarters is in an area hit by a hurricane and is observed in the three-year period (t+1 to t+3) following the disaster. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	RVIA	RVIA	RVIA	RVIA	RVIA	RVIA
Disaster	-0.0908***	-0.0823***	-0.0538***	-0.0511**	-0.0504***	-0.0475**
	(0.0254)	(0.0243)	(0.0204)	(0.0208)	(0.0190)	(0.0193)
Size			0.0076	0.0102	0.0062	0.0007
			(0.0177)	(0.0179)	(0.0169)	(0.0170)
Capex			3.4348***	3.4098***	3.4468***	3.4222***
			(0.3623)	(0.3627)	(0.3562)	(0.3572)
R&D			0.0474	0.0485	0.0087	0.0082
			(0.0328)	(0.0314)	(0.0394)	(0.0390)
Tobin's q			0.0092	0.0072	0.0129*	0.0098
			(0.0070)	(0.0072)	(0.0066)	(0.0069)
Leverage			-0.0516	-0.0740	-0.0582	-0.0823
			(0.0528)	(0.0533)	(0.0510)	(0.0514)
Age			-0.0414	-0.0183	-0.0153	-0.0256
			(0.0357)	(0.0434)	(0.0336)	(0.0411)
Sales growth			0.0441**	0.0397*	0.0421**	0.0377*
			(0.0206)	(0.0210)	(0.0200)	(0.0204)
Inverse HI					-0.4361***	-0.4404***
					(0.0485)	(0.0486)
Constant	0.1780***	0.2508***	0.0707	0.0312	0.3180***	0.4238***
	(0.0018)	(0.0206)	(0.1126)	(0.1385)	(0.1082)	(0.1353)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	NO	YES	NO	YES	NO	YES
Observations	6,299	6,299	6,299	6,299	6,299	6,299
Adjusted R^2	0.005	0.026	0.148	0.154	0.193	0.199

Table 5 Dynamic effect of natural disasters on internal capital allocation efficiency

This Table presents the results of the dynamic treatment analysis, which tests the parallel trend assumption between treated and control groups before natural disasters. $Disaster^{-3}$, $Disaster^{-2}$, $Disaster^{-1}$, $Disaster^{+1}$, $Disaster^{+2}$, and $Disaster^{+3}$ are time indicator variables that indicate three years before, two years before, one year before, one year after, and two or more years after the natural disaster, respectively. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	RVIA	RVIA	RVIA	RVIA	RVIA	RVIA
$Disaster^{-3}$	-0.0018	-0.0155	-0.0117	-0.0205	-0.0097	-0.0205
	(0.0375)	(0.0386)	(0.0318)	(0.0331)	(0.0298)	(0.0310)
$Disaster^{-2}$	-0.0018	0.0082	0.0133	0.0145	0.0191	0.0188
	(0.0362)	(0.0363)	(0.0323)	(0.0328)	(0.0313)	(0.0318)
$Disaster^{-1}$	-0.0404	-0.0193	0.0058	0.0150	0.0052	0.0130
	(0.0341)	(0.0347)	(0.0275)	(0.0286)	(0.0268)	(0.0279)
$Disaster^{1}$	-0.0715**	-0.0567*	-0.0382	-0.0264	-0.0329	-0.0221
	(0.0317)	(0.0307)	(0.0273)	(0.0275)	(0.0257)	(0.0258)
$Disaster^{2}$	-0.1274***	-0.1169***	-0.0786***	-0.0742***	-0.0741***	-0.0695***
	(0.0321)	(0.0310)	(0.0266)	(0.0274)	(0.0254)	(0.0260)
$Disaster^{3}$	-0.0925***	-0.0857**	-0.0416	-0.0505	-0.0388	-0.0480
	(0.0350)	(0.0346)	(0.0310)	(0.0319)	(0.0296)	(0.0307)
Size			0.0077	0.0103	0.0063	0.0007
			(0.0176)	(0.0179)	(0.0169)	(0.0170)
Capex			3.4349***	3.4113***	3.4463***	3.4232***
			(0.3634)	(0.3636)	(0.3571)	(0.3580)
R&D			0.0477	0.0492	0.0089	0.0088
			(0.0327)	(0.0311)	(0.0394)	(0.0388)
Tobin's q			0.0093	0.0071	0.0131**	0.0097
			(0.0070)	(0.0072)	(0.0066)	(0.0069)
Leverage			-0.0512	-0.0737	-0.0577	-0.0820
			(0.0527)	(0.0531)	(0.0509)	(0.0513)
Age			-0.0415	-0.0187	-0.0154	-0.0261
			(0.0358)	(0.0434)	(0.0336)	(0.0412)
Sales growth			0.0447**	0.0402*	0.0428**	0.0382*
			(0.0206)	(0.0209)	(0.0200)	(0.0203)
Inverse HI					-0.4363***	-0.4405***
					(0.0485)	(0.0486)
Constant	0.1795***	0.2510***	0.0698	0.0316	0.3171***	0.4242***
	(0.0027)	(0.0207)	(0.1128)	(0.1385)	(0.1084)	(0.1353)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	NO	YES	NO	YES	NO	YES
Observations	6,299	6,299	6,299	6,299	6,299	6,299
Adjusted R^2	0.005	0.026	0.147	0.154	0.193	0.199

Table 6 Entropy balancing

The table reports the regression results of the effect of natural disasters on internal capital market efficiency using an entropy-balanced sample. Panel A tabulates the mean, variance, and skewness of firm characteristics for the treated and control firms of the entropy-balanced sample. We balance treated and control firms using the first two moments (i.e., the mean and variance) of all the firm-level control variables. Panel B shows regression results based on the entropy-balanced sample. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Entropy balanced sample

	(1)		(2)		(3)	(4)
	Treated group		Control group		Difference	Difference
	Mean	Variance	Mean	Variance	in Mean	in Variance
Size	6.965	4.259	6.965	4.259	0.000	0.000
Capex	0.058	0.003	0.058	0.003	0.000	0.000
R&D	0.021	0.004	0.021	0.004	0.000	0.000
Tobin's q	1.536	0.641	1.536	0.641	0.000	0.000
Leverage	0.299	0.047	0.299	0.047	0.000	0.000
Age	2.972	0.643	2.972	0.643	0.000	0.000
Sales growth	0.133	0.212	0.133	0.212	0.000	0.000
Inverse HI	0.739	0.062	0.739	0.062	0.000	0.000

Panel B: Regression results using Entropy balanced sample

	(1)	(2)
Dependent variable	RVIA	RVIA
Disaster	-0.082***	-0.040*
	(0.027)	(0.022)
Size		-0.001
		(0.022)
Capex		4.260***
		(0.491)
R&D		-0.278***
		(0.095)
Tobin's q		0.016
		(0.016)
Leverage		-0.173*
		(0.088)
Age		-0.003
		(0.055)
Sales growth		0.058**
		(0.023)
Inverse HI		-0.557***
		(0.079)
Constant	0.239***	0.439*
	(0.006)	(0.262)
Firm FE	YES	YES
Year FE	YES	YES
Observations	6,017	6,017
Adjusted R^2	0.614	0.707

Table 7 Placebo Test

This table reports the distribution of the placebo test coefficients and t-statistics. We randomly assigned treatment and control groups and repeated the simulation 1,000 times. All continuous variables are winsorized at 1st and 99th percentiles to reduce the effects of outliers. Detailed definitions of variables are presented in Appendix A.

Variable	N	Mean	SD	p25	Median	p75
Coef of pseudo *Disaster*	1,000	0.0003	0.0136	-0.0091	0.0000	0.0093
pseudo *T-stats*	1,000	-0.0159	1.0074	-0.6931	0.0011	0.6887
Probability of coef of pseudo *Disaster* >= -0.0475	0%					
Probability of pseudo *T-stats* <= -2.46	0.6%					

Table 8 Natural disasters, financial constraints, and firm excess value

The table regression results of firm excess value (*EV*) on natural disasters. Columns (2)-(3) and Columns (4)-(5) show the results for subsamples based on the firm's Kaplan-Zingales (*KZ*) index and the Whited-Wu (*WW*) index, respectively. If a firm's *KZ* index or *WW* index is above the sample median, it is classified as financially distressed. Otherwise, it is financially safe. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
Dependent variable	EV	EV	EV	EV	EV
	Full Sample	High KZ	Low KZ	High WW	Low WW
Disaster	0.1109*	0.1335**	0.1390	0.1642**	0.0037
	(0.0597)	(0.0622)	(0.1062)	(0.0702)	(0.1030)
Size	0.2399***	0.2214***	0.2108***	0.2129***	0.2814***
	(0.0428)	(0.0588)	(0.0775)	(0.0609)	(0.0717)
Capex	-0.3221	0.0406	-0.9336	0.5526	-1.3524**
	(0.5101)	(0.7390)	(0.7388)	(0.5578)	(0.5935)
R&D	0.7002***	0.6722***	0.5706	0.7033	0.7091***
	(0.0982)	(0.0723)	(0.7259)	(1.0380)	(0.0931)
Tobin's q	0.2485***	0.2438***	0.2771***	0.2336***	0.2672***
	(0.0285)	(0.0486)	(0.0384)	(0.0387)	(0.0386)
Leverage	-0.0177	-0.1290	-0.2123	0.1084	-0.0043
	(0.1024)	(0.1110)	(0.3171)	(0.1550)	(0.1356)
Age	0.0401	0.0280	0.0093	0.0307	0.0208
	(0.1019)	(0.1341)	(0.1909)	(0.1164)	(0.2021)
Sales growth	0.0061	0.0052	-0.0008	-0.0218	0.0112
	(0.0305)	(0.0415)	(0.0441)	(0.0563)	(0.0333)
Inverse HI	1.6688***	1.5976***	1.7919***	1.6563***	1.7157***
	(0.1148)	(0.1881)	(0.1624)	(0.1569)	(0.1662)
Constant	-2.9468***	-2.6943***	-2.7597***	-2.6943***	-2.7597***
	(0.4060)	(0.5554)	(0.6739)	(0.5554)	(0.6739)
Firm FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Observations	6,262	3,142	3,120	3,140	3,122
Adjusted R^2	0.196	0.183	0.205	0.182	0.224

Table 9 Different disaster windows

The table reports the relationship between natural disasters and internal capital market efficiency based on different disaster windows. Instead of using a three-year window, we also try different windows to define disaster. Disaster takes a value of one if the county of the firm headquarters is in an area hit by a hurricane and is observed in the two-year period (t+1 to t+2) or the four-year period (t+1 to t+4) following the disaster. The variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)
Dependent variable	RVIA	RVIA
	Disaster (2 years)	Disaster (4 years)
Disaster	-0.0419*	-0.0380**
	(0.0228)	(0.0190)
Size	0.0014	0.0006
	(0.0170)	(0.0171)
Capex	3.4311***	3.4291***
	(0.3583)	(0.3575)
R&D	0.0075	0.0075
	(0.0391)	(0.0395)
Tobin's q	0.0100	0.0100
	(0.0069)	(0.0069)
Leverage	-0.0825	-0.0834
	(0.0516)	(0.0513)
Age	-0.0257	-0.0252
	(0.0412)	(0.0412)
Sales growth	0.0381*	0.0383*
	(0.0204)	(0.0203)
Inverse HI	-0.4408***	-0.4421***
	(0.0488)	(0.0488)
Constant	0.4190***	0.4235***
	(0.1354)	(0.1350)
Firm FE	YES	YES
Year FE	YES	YES
Observations	6,299	6,299
Adjusted R^2	0.199	0.199

Table 10 Channel Test – Financial constraints

The table tests the channel that induces the relationship between natural disasters and internal capital market efficiency. Columns (1)-(2) and (4)-(5) show the relationship between natural disasters and internal capital market efficiency based on subsamples divided by financial constraints. Columns (3) and (6) show the regression results by including the interaction term between disaster and financial constraints. Financial constraints are measured by the Kaplan-Zingales (*KZ*) index and the Whited-Wu (*WW*) index. A firm is defined as a highly financially constrained firm if its *KZ* index or *WW* index is above the sample median. Otherwise, it is a lower financially constrained firm. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	(1) RVIA High KZ	(2) RVIA Low KZ	(3) RVIA Pool	(4) RVIA High WW	(5) RVIA Low WW	(6) RVIA Pool
Disaster	-0.0938***	-0.0172	-0.0118	-0.0488*	-0.0296	-0.0092
	(0.0317)	(0.0251)	(0.0256)	(0.0266)	(0.0296)	(0.0276)
High KZ			-0.0120			
			(0.0145)			
Disaster × High KZ			-0.0692*			
			(0.0396)			
High WW						-0.0284
						(0.0261)
Disaster × High WW						-0.0690*
						(0.0410)
Size	0.0164	-0.0321	0.0021	0.0098	0.0017	0.0083
	(0.0218)	(0.0368)	(0.0170)	(0.0228)	(0.0261)	(0.0173)
Capex	3.3427***	3.2077***	3.4216***	3.3191***	3.3873***	3.4136***
	(0.4332)	(0.6248)	(0.3574)	(0.4970)	(0.4533)	(0.3553)
R&D	0.0156	-0.1208	0.0076	-0.1240	0.0052	0.0087
	(0.0404)	(0.1792)	(0.0387)	(0.2264)	(0.0367)	(0.0385)
Tobin's q	0.0065	0.0214	0.0107	-0.0142	0.0074	0.0097
	(0.0098)	(0.0139)	(0.0070)	(0.0151)	(0.0074)	(0.0068)
Leverage	-0.0562	-0.0400	-0.0613	-0.1519	-0.0219	-0.0621
	(0.0618)	(0.1497)	(0.0555)	(0.1078)	(0.0485)	(0.0493)
Age	-0.0263	-0.0483	-0.0279	-0.0726	0.0030	-0.0248
	(0.0601)	(0.0494)	(0.0409)	(0.0536)	(0.0670)	(0.0412)
Sales growth	0.0503*	-0.0137	0.0370*	0.0538**	0.0283	0.0379*
	(0.0269)	(0.0327)	(0.0205)	(0.0271)	(0.0244)	(0.0205)
Inverse HI	-0.4104***	-0.4900***	-0.4421***	-0.3479***	-0.5066***	-0.4405***
	(0.0635)	(0.0790)	(0.0485)	(0.0549)	(0.0756)	(0.0487)
Constant	0.3108*	0.7340***	0.4216***	0.4795**	0.3975**	0.3792***
	(0.1740)	(0.2722)	(0.1363)	(0.2398)	(0.1681)	(0.1401)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Observations	3,160	3,139	6,299	3,150	3,149	6,299
Adjusted R^2	0.222	0.164	0.200	0.196	0.193	0.200

Table 11 Cross-sectional analysis: firm performance

The table reports the preliminary results for the relationship between natural disasters and internal capital market efficiency using subsamples divided by corporate performance. Corporate performance was measured by annual stock return. If a firm's stock return is above the sample median in year t-1, it is classified as a good performer. Otherwise, it is a poor performance firm. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable	(1) RVIA Good performance	(2) RVIA Poor performance
Disaster	-0.0797***	-0.0187
	(0.0275)	(0.0295)
Size	0.0203	-0.0118
	(0.0200)	(0.0263)
Capex	3.1507***	3.6104***
	(0.4690)	(0.4805)
R&D	-0.0754	0.0243
	(0.1317)	(0.0279)
Tobin's q	0.0093	0.0200
	(0.0074)	(0.0157)
Leverage	-0.0468	-0.1035
	(0.0557)	(0.0760)
Age	-0.0848*	0.0148
	(0.0515)	(0.0548)
Sales growth	0.0465*	0.0303
	(0.0255)	(0.0432)
Inverse HI	-0.4022***	-0.4429***
	(0.0519)	(0.0722)
Constant	0.4333***	0.3742*
	(0.1392)	(0.2161)
Firm FE	YES	YES
Year FE	YES	YES
Observations	3,433	2,866
Adjusted R^2	0.189	0.217

Table 12 Cross-sectional analysis: CEO ownership

The table presents the moderating effect of CEO ownership on the relationship between natural diesters and internal capital market efficiency using subsamples divided by CEO ownership. CEO ownership is calculated as shares held by CEO divided by total shares outstanding. If a firm's CEO ownership is above the sample median, it is classified as a firm with high CEO ownership. Otherwise, it is regarded as the firm with low CEO ownership. All the variables are defined in Appendix A. The standard errors shown in parentheses are clustered by firms. ∗∗∗, ∗∗ and ∗indicate significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)
Dependent variable	RVIA	RVIA
	High CEO ownership	Low CEO ownership
Disaster	-0.0529	-0.0458*
	(0.0324)	(0.0272)
Size	0.0179	-0.0001
	(0.0182)	(0.0276)
Capex	3.6151***	3.4155***
	(0.5707)	(0.4423)
R&D	0.0134	-0.1537*
	(0.0291)	(0.0896)
Tobin's q	0.0055	0.0119
	(0.0083)	(0.0112)
Leverage	0.0013	-0.1480
	(0.0616)	(0.0946)
Age	-0.1120	0.0140
	(0.0685)	(0.0613)
Sales growth	-0.0117	0.0552*
	(0.0148)	(0.0309)
Inverse HI	-0.3444***	-0.4879***
	(0.0643)	(0.0746)
Constant	0.4455**	0.4162**
	(0.2083)	(0.2112)
Firm FE	YES	YES
Year FE	YES	YES
Observations	2,670	3,629
Adjusted R^2	0.208	0.208

Appendix A. Variable descriptions

Variable	Description
RVIA	Industry-adjusted relative value added by allocation, see Eq. (1).
Disaster	A dummy variable, which equals to 1 if the firm headquarter is located in the disaster zone during the three-year period (t + 1 to t + 3) following a natural disaster, otherwise it is 0.
Size	Firm size, measured by natural logarithm of total assets.
Capex	Capital expenditure, the ratio of capital expenditures to total assets.
R&D	The ratio of research and development expense to total sales. we set missing R&D expenditure to zero.
Tobin's q	The market-to-book asset ratio, where market value is the sum of the market value of common equity and book value of assets minus book value of common equity minus accumulated deferred taxes.
Leverage	The sum of long-term debt and debt in current liabilities divided by total assets.
Age	Firm age, calculated by natural logarithm of 1 plus the number of years since a firm first appeared in the Compustat.
Sales growth	The difference between the sales for the current fiscal year and the sales for the previous year divided by the sales for the previous year.
Inverse HI	Inverse Herfindahl Index, see Eq. (4).
EV	Excess Value, see Eq. (2).
KZ index	Kaplan & Zingales (1997) index: *KZ = -1.002 × Cashflow + 0.283 × Tobin's q + 3.139 × Leverage - 39.368 × Dividend - 1.315 × Cash*, where *Cashflow* is defined as operating income before depreciation scaled by total assets, *Dividend* is calculated as common dividends divided by the book value of total assets, and *Cash* is measured as cash and cash equivalents scaled by total assets.
WW index	Whited & Wu (2006) index: *WW = -0.091 × Cashflow - 0.062 × Positive dividend dummy + 0.021 × Long-term debt - 0.044 × Size + 0.102 × Industry sales growth - 0.035 × Sales growth*, where *Positive dividend dummy* is a dummy variable equals one if a firm pays dividend and zero otherwise, and *Industry sales growth* is calculated at the three-digit SIC level.
Firm performance	Corporate performance, measured by annual stock return
CEO ownership	The percentage of shares owned by the CEO divided by total shares outstanding.