Who monitors climate risk of financial institutions? Evidence from catastrophe risks in insurance *

Christoph Basten Anastasia Kartasheva

June 9, 2025

Abstract

We assess the ability of the regulators and private monitors like credit rating agencies to evaluate and discipline the exposure of the insurance industry to natural catastrophe (NatCat) risks intensified because of climate change. We demonstrate that the rating agency A.M. Best is a more stringent monitor than the US insurance regulators in that it provides more adequate assessment of insurers' exposure to NatCat risk compared to regulatory risk-based capital standards; also, it has a long-lasting discipline effect by incentivizing insurers to improve their NatCat risk management. But A.M. Best's monitoring disciplines only a limited segment of the insurance market. We show that in response to stricter rating requirements for NatCat risks, many insurers accept the downgrades and become riskier. Meanwhile, the regulatory capital requirements are not capable of curtailing their excessive risk-taking.

Keywords: climate risk assessment, natural catastrophe insurance, regulatory capital requirements, credit rating agency.

JEL classification: G22, G32, L11.

*We are grateful to Shan Ge, Ralph Koijen, Tyler Leverty, Sojung Park, Joan Schmit, Stephane Verani and the audiences at the Bank for International Settlements, European Winter Finance Conference, FMA Annual Meeting, Swiss Finance Institute, Swiss Society for Financial Market Research Conference, Swiss Winter Conference on Financial Intermediation, University of St.Gallen, University of Wisconsin-Madison, University of Zurich for insightful feedback. Basten: European Central Bank, Christoph.Basten@ecb.europa.eu; Kartasheva: University of St.Gallen and Swiss Finance Institute, anastasia.kartasheva@unisg.ch.

1 Introduction

Insurers can play an important role in smoothing the climate change transition and adaptation, by providing risk transfer to firms and households and by producing information about the climate risk and communicating it through risk-sensitive insurance pricing. However, the ability of insurers to perform these functions critically depends on their own financial strength, which is also challenged by insurers' increasing exposures to natural catastrophes (NatCat) (Figure 1). Assessing the financial strength of insurers is a complex task for policyholders and investors and thus requires external certification. Hence, prudential regulation using tools like licensing and capital requirements is prevalent. Yet, besides regulators, private information providers like credit rating agencies (CRAs) also produce information about financial intermediaries. Who is a better monitor? Which source of information disciplines insurers? In the paper, we horse-race the relevance and performance of the public and private monitors, that is, regulators and CRAs, in assessing the exposure of the insurance industry to NatCat risks.

The context of our analyses is the response of the regulators, the CRA and insurance industry to hurricanes Katrina, Wilma and Rita in 2005, the most costly events for the US property-casualty industry in the last 50 years. Immediately after the hurricane season, in 2006 A.M. Best, the main credit rating agency publishing financial strength ratings of insurance companies, introduced a significant change to NatCat risks methodology in its capital model which is used to assign the financial strength ratings of insurers (A.M. Best, 2011). By contrast, the US insurance regulators took several years until 2017 to introduce catastrophe risk charges to the risk-based capital (RBC) formula which is the basis for the regulatory capital adequacy assessment of insurance companies (National Association of Insurance Commissioners, 2017). We analyse how insurers responded to the rating downgrade pressure from A.M. Best and compare it to insurers' ability to restore their impaired regulatory capital ratios in the aftermath of the 2005 hurricane season. Then we evaluate the long term effects of the rating standard change by A.M. Best and the slow response of the regulatory capital requirements updates, by looking at the resilience of insurers to NatCat risks during more recent years 2010-2022.

We demonstrate that the private monitor A.M. Best is more stringent (in addition to being faster) in that it provides more accurate assessment of insurers' exposure to NatCat risk compared to the regulatory RBC standards. But A.M. Best's better quality monitoring disciplines only a limited segment of the insurance market, namely, insurers that provide coverage to sophisticated corporate insurance buyers (commercial insurers, for short). In response to more stringent rating standards in 2006, commercial insurers adjust their capital and risk and reduce business volume in NatCat exposed states, which enables them to defend the rating. In the long-run, commercial insurers that were under the pressure of a rating downgrade in 2006 improve their risk management of NatCat risk which is indicated by the lower loss ratios during 2010-2022. By contrast, insurers that sell insurance to private unsophisticated buyers (private insurers, for short), such as homeowners or private auto insurance, accounted for most downgrade pressure from A.M. Best in 2006. However, private insurers chose not to defend their A.M. Best ratings and actually increased their NatCat risk exposure in the long-run. Meanwhile, private insurers had no issues to improve their RBC capital ratio after the hurricane which also confirms the low sensitivity of the regulatory RBC ratio to catastrophe risks.

We explain the divergent response and excessive risk taking by the difference in the elasticity of insurance demand to financial strength between private and commercial insurance buyers, particularly driven by the state guarantee fund protection of the private insurers. Facing the possibility of a rating downgrade, insurers trade off the decrease of insurance demand due to lower rating and the cost of raising capital. Highly rated commercial insurers favor defending the rating by raising capital and reducing risk by exiting the states with high NatCat exposure. By contrast, personal insurers increase the exposure in these states and accept the rating downgrades. However, since the regulatory capital standards are less responsive to NatCat risk, excessive risk taking by these insurers is not curtailed by the regulatory monitoring.

Our findings stress a lack of risk monitoring in large segments of the insurance market and have broader implications for the prudential regulation of insurers' NatCat exposures. While the original motivation of guarantee fund protection for personal insurance is to shelter unsophisticated policyholders from insurers' failures, the policy also reduces the sensitivity of insurance demand to an institution's financial strength, promotes risk-taking, and undermines the ability of the insurance industry to facilitate climate transition. These effects are reinforced by regulatory inertia. As insuring the exposure to catastrophic losses will require more capital, enhancing state-provided guarantee coverage of climate-related risks may further reduce the insurance industry's capacity to sustain the losses by promoting risk-taking in market segments with lower elasticity of demand with respect to financial strength.

Next we outline our main analyses and results. We start by building a theoretical model which explains how the rating criteria affect the risk management decisions of financial institutions. The model is used to explain how the change of the rating criteria can prompt a diverse response by intermediaries, depending on the benefits and the costs of defending the rating. Building on model predictions, we proceed to the empirical analysis.

The preliminary step in the empirical analysis is to establish that ratings have a differential impact on commercial and personal insurers. We estimate how the rating changes affect the direct premiums written (DPW) growth and the price markups of insurers. In response to one notch downgrade both commercial and personal insurers have about 4% lower DPW growth and 46 basis point (bpt) lower markups. Furthermore, these associations are insignificant for personal insurers alone but are as large as respectively 6%–6.7% and about 97 bps for commercial insurers. Then we examine the response of demand and price to the change in ratings and changes in the regulatory capital ratios (RBC) in a single specification and find that the response to ratings is stronger than the response to RBC changes. However, the result is driven by the response of commercial insurers. Our results confirm that commercial insurance demand and prices exhibit stronger financial strength elasticity compared to personal insurance.

The main empirical analysis consists of two parts. We first evaluate the downgrade pressure and the responses of insurers to the hurricane season losses and changes in the rating criteria. Then we analyse the long-term effect of the change of the rating criteria.

We start by analyzing the rating downgrade pressure on insurers with exposure to 2005 hurricane season affected areas. Furthermore, we decompose the downgrade pressure into the rating scale and incurred loss factors that enables to disentangle the relative contribution of the two concurrent effects on insurers' ratings. Then we analyze how the rating downgrade pressure manifested in the two segments of commercial and personal insurance. Recognizing that the estimated magnitude of the downgrade pressure already includes the impact of actions that insurers could have taken to protect their ratings, in the empirical analysis we consider a range of plausible mechanisms that insurers could use to preserve their ratings. We evaluate whether and how insurers have adjusted their liability exposure to NatCat risk, reinsurance coverage, capital policy, and asset allocation.

Our baseline estimation confirms that insurers with higher exposure to Katrina-affected regions experienced a rating downgrade pressure which on average translates in about 40% of a rating notch. Then we estimate the rating scale of insures in the Pre (2001-2005) and Post (2006-2008) period to explore whether other factors besides the NatCat exposure have gained more weight in the updated rating scale. We confirm empirically that a higher penalty for NatCat exposure is the main driver that changed under the updated rating scale. The estimation of the rating scales in the Pre and Post period also allows us to assess the relative contribution of the scale change and the impact of the incurred losses on insurers characteristics to rating downgrade pressure. We find that each of the two components contributed about a half to the rating downgrade pressure.

The next set of results concerns the differential effects of the 2005 events on personal and commercial insurers. Our analysis of the 2005 hurricane season losses and the rating scale change on commercial and personal insurers reveals that the rating downgrade pressure was particular for personal insurers but not for commercial insurers. Furthermore, we find that commercial insurers surmounted the changes better than personal insurers due to their financial strength characteristics differences. That is, commercial insurers' higher capital buffers, better diversified liability portfolios and more resilient risk management enabled them to sustain the shocks. This occurred either because of their initial stronger capitalization and risk management or because they were capable to overcome the impact of the extreme losses and the scale change better than personal insurers.

We also explore the differential rating downgrade pressure depending on the initial rating. Our analysis is motivated by the previous literature, e.g. Kisgen (2006) and Chernenko & Sunderam (2012), that shows that firms on the rating border may have stronger incentives to prevent the downgrade. While we find some evidence that firms on the border managed to experience lower downgrade pressure, we conclude that such differential incentives alone were sufficient to reverse the downgrade pressure arising from NatCat exposure.

Having identified the differential rating downgrade pressure on commercial and personal insurers, we analyze the drivers of the difference. Commercial insurers could have responded more effectively by changing their capital and risk management policies than personal insurers. But the differential effect could also occur because commercial insurers were initially better prepared to sustain extreme losses and thus on the margin did not need to implement significant changes to their corporate policy to maintain the rating. To explain the causes for the differential rating downgrade pressure, we analyze how insurers with NatCat exposure adjusted their capital and risk management, and whether the adjustment differed for commercial and personal insurers.

Using the regulatory and the rating agency risk-based capital scores, we assess whether insurers were able to improve their overall level of capitalization. Our analysis shows that insurers with exposure to hurricane affected regions had no issues to increase their regulatory capital RBC ratio. However, we find no evidence that insures with NatCat exposure managed to improve their risk-based capital ratio according to the rating agency capital model, the BCAR score. As BCAR became more sensitive to the catastrophe exposures under the updated rating methodology, we show that on average, insurers at best could only match the requirements under the new rating standards.

Then we explore several adjustment channels that could contribute to the change in the overall capitalization. In terms of the capital policy, we show that stock insurers with NatCat exposure were more likely to pay zero dividends. However, they were not issuing more capital or cutting dividends more often than the control group. We also find that Katrina-affected insurers have increased reinsurance coverage and thus reduced their exposure to NatCat tail risks. In terms of the investment portfolio, we find some evidence that insurers with larger NatCat exposure shifted their asset allocation to holding safer bonds in the bond portfolio and reduced their exposure to common stocks. For aforementioned channels, we find no evidence that commercial insurers exploited any of them stronger than personal insurers. By contrast, we find a divergent response of personal and commercial insures in terms of NatCat geographic exposures in the liability portfolio. Commercial insurers have shifted their NatCat exposures from the highest hurricane risk region in Florida to other regions, compared to personal insurers.

Overall, the summary and our interpretation of the empirical results on the downgrade pressure and the adjustment channels are as follows. The rating downgrade pressure on personal rather than commercial insurers shows that the latter were better prepared to sustain extreme losses of the 2005 hurricane season and on average were able to pass the stress tests under the updated rating methodology for NatCat exposures. Both personal and commercial insures exploited different channels to improve their regulatory capital RBC ratios, particularly by increasing the reinsurance coverage and shifting the investment portfolio to safer assets. However, these changes were not sufficient for the personal insures to avoid the downgrade pressure after the 2005 hurricane season, as measured by the BCAR score. Combined with the finding that personal insurers did not reduce their NatCat exposures, the results suggest that these insurers became more vulnerable to NatCat after the 2005 hurricane season.

Finally, we assess the long-term effect of the rating standard changes and the regulatory inertia on the insurance industry. The objective is to evaluate whether the rating standard change by A.M. Best disciplined the risk management of insurers and improved the resilience of the insurance industry. We regress the loss ratio, as a proxy for the firm's risk exposure on various measures of the downgrade pressure in 2006 and the interactions with the indicators for commercial and private insurers. We find that A.M. Best stricter rating criteria had a strong disciplining effect on the insurers that were facing the prospect of a rating downgrade, but only in the commercial insurance segment.

The new contribution to the literature (to the best of our knowledge) is that we are able to evaluate the feedback effect between rating standards and the capital and risk management policy of financial intermediaries. While previous literature provided convincing evidence that access to credit ratings or the ability to improve a rating reduce the cost of external capital and lead to more investment, e.g. Adelino & Ferreira (2016), Badoer et al. (2019), Faulkender & Peterson (2006), Kisgen (2006), Sufi (2007), Tang (2009), these studies are conducted in the environments where the CRA's rating methodology is stable. By contrast, our analysis includes a major revision of the rating methodology in assessing the impact of NatCat risks that caused higher risk-based capital requirements of the A.M. Best to maintain the same rating grade, i.e. ratings became more stringent.

In the recent literature on climate finance, there is growing evidence that external certification of firms ESG strategies is highly relevant to market participants. However, Berg et al. (2022), among others, finds that the information produces by the prominent ESG rating agencies is diverse. Azarmza and Shapiro (2024) develop a theory that explains how the differentiation of information can emerge in equilibrium. We contribute to this literature by analyzing how climate risk is reflected in CRA ratings of financial institutions, and how their standards shape the risk management policy of institutions with respect to climate risk.

More broadly, our analysis is related to the growing literature exploring how the risk management strategies of financial intermediaries are shaped by the financial market frictions and regulations, e.g. Ellul et al. (2011), Ellul et al. (2020), Foley-Fisher et al.

(2020), Koijen & Yogo (2016), Sen (2019).

Our analysis of the 2005 hurricane season, the major episode in the US property-casualty insurance industry, contributes to the recent literature analyzing how insurers respond to financial distress. Koijen & Yogo (2015) show that during the 2008 financial crisis, life insurers reduced the price of long-term policies below the actuarial value to improve their statutory capital. Berry-Stölzle et al. (2014) show that life insurers managed to raise external capital during the financial crisis. Ge (2022) shows that within the insurance group combining property-casualty and life insurance subsidiaries, life insurance divisions change product pricing in response to non-life divisions shocks. Ge & Weisbach (2021) find that insurers respond to losses by shifting to safer assets in their investment portfolios.

The rest of the paper is organized as follows. The next Section builds a simple theoretical framework that illustrates the possibility and drivers of the heterogeneous response to more stringent rating standards. Section 3 describes the institutional background. Section 4 presents the data and summary statistics. Then Section **??** shows the differential impact of ratings and regulatory RBC ratios on different segments of the insurance market. The following two sections contain the empirical analysis. Section 6 presents the analysis of the rating downgrade pressure after the 2005 hurricane season on different types of insurers. Section 7 evaluates the capital and risk management adjustment channels. Section 8 reports the analysis about the long term effects of rating criteria change. The conclusion follows.

2 A Simple Model

In this section, we develop a simple model that explains how the rating criteria can affect financial intermediaries' capital structure and risk management decisions, as well as how financial intermediaries react to a change of the rating criteria. We use the model to describe the best responses of intermediaries to changes in the rating methodology depending on the costs and benefits of maintaining a rating. We begin the section by describing the setup of the model and how the rating scale determines firm's choice of credit quality. We then show that a recalibration of the rating scale can induce divergent responses by firms: Some firms exert effort to improve their credit quality in order to defend the rating and others exert no effort while maintaining the current rating or accepting the downgrade. All proofs are presented in the Appendix.

2.1 Basic Setup

We consider a continuum of firms indexed by their intrinsic financial strength score q, $q \in [0, 1]$. A higher value of q corresponds to better quality. A credit rating agency (CRA) assesses the financial strength according to its rating methodology which translates the score q into a rating $R_i \in \{R_1, ..., R_N\}$, where R_N is the highest rating and R_1 is the lowest rating. Each rating R_i reflects some risk level according to the CRA's risk measure, e.g. probability of default or loss given default. The rating methodology of the CRA is a mapping $\alpha : q \to R$ such that all firms with $q \in [\alpha_i, \alpha_{i+1})$ are rated R_i, $i \leq N - 1$, where $0 = \alpha_1 < \alpha_2 < ... < \alpha_N < 1$, and firms with $q \in [\alpha_N, 1]$ are rated R_N. Assigning the same rating to firms with distinct scores q reflects the imperfection of the CRA's evaluation skills as well as CRA's strategic considerations. For simplicity, we assume that the rating scale parameters $\{\alpha_1, .., \alpha_N\}$ are fixed and known to all stakeholders, and the rating grades are of equal size, i.e. $\alpha_i - \alpha_{i-1} = \alpha_{i+1} - \alpha_i$. Further, we assume that all firms solicit a rating and we normalize the rating fee to zero.

Ratings matter to firms because of their effect on firms' profits and costs of access to the financial market. A firm rated R_i gains profits $\pi(R_i)$, and its profits increase in a rating, $\pi(R_{i+1}) > \pi(R_i)$. Furthermore, we consider two types of firms, $\theta \in \{H, L\}$, which cater to customers with different elasticity of demand to firm's financial strength. The marginal benefit of a higher rating to firms type θ_H is higher than to those type θ_L, i.e.

$$\pi_H(R_{i+1}) - \pi_H(R_i) > \pi_L(R_{i+1}) - \pi_L(R_i). \tag{1}$$

To model firms' pro-active capital and risk management, we assume that a firm has some flexibility to improve its initial financial strength score q. By exerting effort e, a firm can improve its financial strength from q to $q+e$. The effort can reflect raising more equity, hedging market risk with derivatives or transferring risk to third parties through reinsurance by insurers and through securitization by banks. The effort is costly, and the cost of participation in the financial market also depends on firm's rating. We assume that the cost of effort e equals to $eC(R_i)$ for a firm q that originally would be rated R_i, $q \in [\alpha_i, \alpha_{i+1})$.

The firm's strategy is the choice of effort e. In the status quo $e = 0$, a firm $q \in [\alpha_i, \alpha_{i+1}]$ is rated R_i and gains profits $\pi_\theta(R_i)$. To improve its rating by one notch, the firm needs to increase the financial strength score from q to at least α_{i+1} by exerting effort of $e = \alpha_{i+1} - q$. Then the firm obtains the payoff equal to $\pi_\theta(R_{i+1}) - (\alpha_{i+1} - q)C(R_i)$. For simplicity, we assume that changing the rating by more than one notch is prohibitively costly to the firm. Therefore, the choice of effort to improve financial strength depends on the following condition.

$$\pi_\theta(R_{i+1}) - (\alpha_{i+1} - q)C(R_i) > \pi_\theta(R_i). \tag{2}$$

If the inequality holds, a firm q improves its financial strength to α_{i+1} and obtains a rating R_{i+1}. Otherwise, it exerts no effort, maintains the initial quality score q and obtains a rating R_i.

In our setting, the firm's decision to exert effort depends on its quality type q and the rating scale of the CRA. Define

$$\widehat{q}_{\theta i} \equiv \alpha_{i+1} - \frac{\pi_\theta(R_{i+1}) - \pi_\theta(R_i)}{C(R_i)}. \tag{3}$$

In each rating grade R_i, firms type θ with the initial score $q \in [\widehat{q}_{\theta i}, \alpha_{i+1}]$ exert effort $e = \alpha_{i+1} - q$ and obtain a higher rating R_{i+1} than the one corresponding to their initial score; firms type θ with the initial score $q \in [\alpha_i, \widehat{q}_{\theta i})$ do not exert effort and obtain a rating R_i. The next proposition summarizes further implications.

Proposition 1 *Suppose the benefits of higher ratings are non-decreasing in rating,* $\pi_\theta(R_{i+1}) - \pi_\theta(R_i) \geq \pi_\theta(R_i) - \pi_\theta(R_{i-1})$. *Then firms with higher initial financial strength score are* *more prone to improve their financial quality by exerting the effort than firms with lower initial financial strength score, i.e.* $\alpha_{i+1} - \widehat{q}_{\theta i}$ *is increasing in* i.

Consider two firms with equal initial financial strength score. Firms catering to customers with higher elasticity of demand to financial strength are more prone to proactively improve their financial strength than those catering to customers with lower elasticity of demand, $\alpha_{i+1} - \widehat{q}_{Hi} > \alpha_{i+1} - \widehat{q}_{Li}$.

The decision to improve its credit quality depends on the marginal benefit of a higher rating $\pi_\theta(R_{i+1}) - \pi_\theta(R_i)$ and the marginal cost of effort $C(R_i)$. The higher is the marginal benefit and the lower is the marginal cost, the lager is the set of firms $[\widehat{q}_{\theta i}, \alpha_{i+1})$ which will proactively manage their financial strength to upgrade the rating from R_i to R_{i+1}. These observations also suggest that to the extent that firms' effort to improve financial strength has some persistency for future periods, firms with higher financial strength will grow stronger. Furthermore, firms facing higher elasticity of demand to financial strength will be differentially stronger compared to those catering to low elasticity of demand clients.

2.2 Recalibration of the rating scale

Suppose now that the CRA and the firms learn new information about the risk, e.g. the impact of climate change on the frequency and the severity of natural catastrophes, which forces a reassessment of the correspondence between firm's financial score q and the CRA's risk measure R_i. For simplicity, we consider a parallel shift in the rating scale. Under the updated rating scale a rating R_i is assigned to firms with score $q \in [\alpha_i + \Delta, \alpha_{i+1} + \Delta]$, where $0 < \Delta < \min_i(\alpha_{i+1} - \alpha_i)$ and thus the new rating scale consists of the same rating grades $R_1, ..., R_N$. Under this adjustment, all except the highest and the lowest ratings maintain the same width. We assume that the rating grades reflect the same risk under the new rating scale, and thus result in the same profits and costs. More stringent rating scale means that in order to achieve the same level of financial strength under the new loss distribution a firm needs to hold more capital, hedge more or select safer investment projects.

The firm's choice of effort under the new rating scale is driven by the same logic as above. In each rating interval $[\alpha_i + \Delta, \alpha_{i+1} + \Delta]$ there is a threshold $\overline{q}_i$ defined by

$$\overline{q}_{\theta i} \equiv \alpha_{i+1} + \Delta - \frac{\pi_\theta(R_{i+1}) - \pi_\theta(R_i)}{C(R_i)}, \tag{4}$$

such that firms $q \in [\alpha_i + \Delta, \overline{q}_{\theta i})$ exert no effort and obtain a rating R_i while firms $q \in [\overline{q}_{\theta i}, \alpha_{i+1} + \Delta)$ exert effort $e = \alpha_{i+1} + \Delta - q$ and obtain a rating R_{i+1}. Note that $\overline{q}_{\theta i} - \widehat{q}_{\theta i} = \Delta > 0$.

Given the firm's choice of effort under the original rating scale, we start by characterizing any changes in firm's choice of effort under the updated rating scale. For this purpose, consider an internal rating interval (α_i, α_{i+1}) that corresponds to the rating grade R_i under the original rating scale. Note that by construction $a_i < \alpha_i + \Delta < \widehat{q}_{\theta i} < \overline{q}_{\theta i} < \alpha_{i+1}$. Then firms' responses can be summarized as follows.

(a) Firms $q \in [\overline{q}_{\theta i}, \alpha_{i+1}]$ exert effort $\alpha_{i+1} - q$ and obtain a rating R_{i+1} under the original rating scale. After the recalibration these firms exert more effort $\alpha_{i+1} + \Delta - q$ to maintain their rating R_{i+1}.

(b) Firms $q \in [\widehat{q}_{\theta i}, \overline{q}_{\theta i}]$ exert effort $\alpha_{i+1} - q$ and obtain a rating R_{i+1} under the original rating scale. After the recalibration these firms exert no effort and are downgraded to R_i.

(c) Firms $q \in [\alpha_i + \Delta, \widehat{q}_{\theta i}]$ exert no effort and are rated R_i under the original rating scale. After the recalibration, these firms still exert no effort and maintain the rating R_i.

(d) Firms $q \in [\alpha_i, \alpha_i + \Delta]$ exert no effort and are rated R_i under the original rating scale. After the recalibration, these firms exert effort $\alpha_i + \Delta - q$ to defend their rating R_i and avoid the downgrade to R_{i-1}.

Firms with the quality score q in the highest rating R_N exert no effort and maintain their rating, either before or after the recalibration. However, fewer firms with the quality score in the lowest rating score R_1 exert the effort as $\overline{q}_{\theta i} > \widehat{q}_{\theta i}$. These responses lead to the following aggregate effect.

Proposition 2 *Recalibration reduces the average financial strength of firms due to lower mass of firms exerting effort in the lowest rating grade. The intermediate firms maintain the same average quality, despite some downgrades under the recalibrated rating scale.*

These results suggest that firms can increase, maintain or reduce their effort in response to the revision of the rating scale, even though they maintain the same rating. Firms' behavior in response to the new rating scale depends on the marginal costs of effort and marginal benefits of a higher rating, $\frac{\pi_\theta(R_{i+1})-\pi_\theta(R_i)}{C(R_i)}$. In particular, if the firms did not exert effort to improve their financial strength under the original rating scale either due to high costs $C(R_i)$ or due to lower marginal benefit, $\pi_\theta(R_{i+1}) - \pi_\theta(R_i)$, the recalibration of the rating scale does not reverse this choice. To the contrary, fewer firms with the lowest rating exert the effort to improve their financial strength.

3 Institutional background

There are several features of the property-casualty insurance market in the US that make it particularly suitable to identify and evaluate the role of private and public monitors, i.e. the CRA and the insurance regulators. First, demand for insurance (and insurers' ability to charge higher prices) is sensitive to insurers' financial strength ratings, and the sensitivity of demand varies across different types of insurance buyers. Another feature is that some (but not all) insurance business lines are exposed to losses from natural catastrophes like hurricanes, floods, tornadoes and earthquakes, and these exposures are reflected in insurers' financial strength ratings and regulatory capital requirements. The last but not least one is that in 2005 A.M. Best implemented a substantial revision of the rating methodology for the assessment catastrophe exposures. Though the revision of the methodology by A.M. Best was discussed for some years before 2006, accidentally there was a severe hurricane season in Fall 2005 that included hurricane Katrina. We now discuss these features and related institutional background, to the extent they are relevant for this paper.

3.1 Insurance coverage of catastrophe exposures

Insurance business lines that cover property damages or related business interruptions are exposed to natural catastrophes such as hurricanes, earthquakes, windstorms, floods and wildfires. According to the National Association of Insurance Commissioners (NAIC), the US regulator, twelve out of more than thirty distinct business lines have potential exposure to NatCat risks, including three personal lines and nine commercial ones.[1]

The frequency and severity of catastrophic events has been increasing globally in the recent several decades, including the US. Global warming is contributing to a fundamental shift in frequency expectations. Furthermore, the severity of losses from natural catastrophes is amplified by the growing demographic concentration in urban and suburban areas, rising property values in catastrophe-prone areas, and the expanding complexity of supply chains. Figure 1 depicts the economic costs of natural catastrophes in the US in 1980-2020. In addition to documenting the upward trend in losses caused by cat events, it reveals that a substantial share of losses remains uninsured.[2]

Fall 2005 hurricane season including hurricanes Katrina, Rita and Wilma was a major event for the US insurance industry. The economic losses of hurricane Katrina season account above $160 billion (inflation-adjusted to 2020 dollars). Around $85 billion of losses were insured and paid by insurers, depleting 11.3% of the aggregate equity capital

[1]The catastrophe exposed *personal business lines* are homeowners and farmowners multiple peril, and private passenfer auto physical damage. The catastrophe exposed *commercial business lines* include commercial auto physical damage, commercial multiple peril (non-liability), earthquake, federal flood, fire, inland marine, multiple peril crop, private crop and private flood.

[2]The growing insurance protection gap of natural catastrophes, i.e. the difference between the economic losses and the insured economic losses, is a growing challenge of building economic resilience to climate change. See Ito & McCauley (2019) and Swiss Re (2019) for discussion.

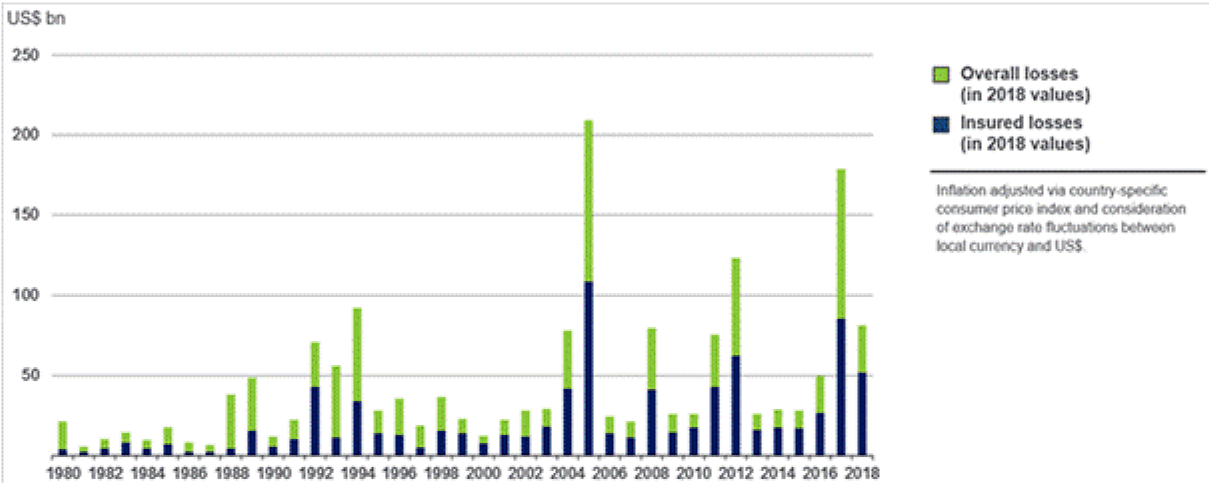

Figure 1: *Natural Catastrophe Loss Events in the US, 1980-2018*

of the US property-casualty insurance industry.[3]

3.2 Insurers' financial strength ratings

Insurers' ability to pay insured losses crucially depends on availability of financial resources upon realization of losses. As a consequence, demand for insurance increases in insurers' financial strength, which has been analyzes theoretically by Doherty & Schlesinger (1990) and documented empirically by Cummins & Danzon (1997), Epermanis & Harrington (2006) and Sommer (1996), among others. In the U.S. property-casualty insurance industry, financial strength ratings by A.M. Best are viewed as a benchmark indicator of insurers' financial strength. During the period of our study, A.M. Best provides almost full coverage of the property-casualty insurance industry in the U.S., rating 95% of insurers' in terms of assets. In addition to the use of ratings by insurance buyers, A.M. Best ratings are also used by insurance brokers to differentiate among insurers and are widely incorporated in various local, state and federal regulations related to insurance purchases. In Section 5 we analyze the role of ratings for personal and commenrcial insurers, and

[3]Estimates are according to Insurance Information Institute (2021) and Swiss Re (2020).

horse race the response to changes in ratings and changes in RBC ratios.[4]

3.3 Types of insurance buyers and state guarantee funds

A distinct feature of the property-casualty insurance industry is that there are two market segments, personal insurance and commercial insurance. The personal insurance business lines provide coverage for property and liability damages to individuals/households and small businesses, e.g., private passenger auto physical damage and liability, homeowners and farmowners multiple peril. These insurance contracts are highly standardized by insurance regulators and have low switching costs for insurance buyers. The main motive for contract standardization is that personal insurance policyholders are unsophisticated and need consumer protection. For the same reasons, personal insurance buyers are protected by insurance state guarantee funds in the scenario of insurer's insolvency. Though state guarantee fund provisions vary across states in the US, the maximum claim does not exceed $300,000 in most states and many states bar corporations and wealthy individuals from fund payments.[5]

The commercial insurance market segment includes business lines that provide property and liability damages coverage to sophisticated corporate buyers, e.g., commercial multiple peril, workers compensation or product liability. Underwriting commercial insurance requires insurer's efforts and substantial technical expertise about the corporate buyer's production process. Therefore, commercial insurance contracts are customized and involve substantial switching costs. An important feature of commercial insurance segment is that it is not protected by state guarantee funds, either because of explicit exclusions by states or because typical commercial insurance claims are significantly higher

[4]Although other well-known credit rating agencies - Moody's, Standard & Poor's and Fitch, also provide financial strength ratings of insurers, insurers usually obtain these ratings in addition to the A.M. Best rating (Doherty et al., 2012). In particular, only 1.95% of insurers do *not* have an A.M. Best rating but have at least one rating from the other three CRAs. Thus, for the purpose of our study we focus on A.M. Best ratings.

[5]Typically state guarantee funds are financed by ex-post assessment on surviving insurers operating in the state. Cummins (1988) analyzes the optimal design of the insurance guarantee fund protection. Downs and Sommer (1996) provide evidence that guarantee funds increase insurers' risk taking.

than the $300,000 limit.

The two types of insurance buyers provide the identification for differential benefits of defending a rating by an insurer. The divergence in underwriting needs, contract standardization, and guarantee fund protection imply that demand for commercial insurance is more sensitive to insurer's financial strength rating than demand for personal insurance, as previously documented by Epermanis & Harrington (2006). Consequently, insurers specializing in commercial lines have stronger motives to protect or improve their ratings compared to those with personal lines focus. We document it empirically in Section 5.

3.4 Change of rating methodology for catastrophe risks

A core element of the A.M. Best evaluation of insurer's balance-sheet strength is Best's Capital Adequacy Ratio (BCAR). BCAR calculates the net required capital to support insurer's underwriting, financial and asset leverage and compares it with the economic capital (adjusted surplus). The BCAR score is the ratio of the adjusted surplus to the net required capital. An absolute ratio below 100% implies that the insurer's indicated expected policyholder deficit is greater than 1%. A.M. Best publishes the guidelines that indicate the relationship between the insurer's BCAR score to its financial strength rating (A.M. Best, 2011, 2016).

A large catastrophe can have an extensive, rapid and unexpected impact on the financial conditions of an insurer. Therefore, charges for catastrophic exposures are significant components of the A.M. Best rating methodology. Up to the end of 2005, for companies with catastrophe exposures, A.M. Best performed a stress test which involved a reduction to surplus in the standard BCAR score using the larger of 1-in-100-year hurricane/windstorm probable maximum loss (PML), a 1-in-250-year per occurrence random time earthquake PML, or a large actual recent loss, net of reinsurance and of a 35% tax rate. For companies with catastrophe exposures, the stressed BCAR score was used as a ground for rating assignment (A.M. Best, 2011).

A significant change to the treatment of catastrophe exposures was introduced by A.M.

Best and other rating agencies and risk modelling firms in the end of 2005. In addition to the catastrophe risk stress test described above, A.M. Best introduced a second stress test, a 1-in-100-year hurricane/windstorms or 1-in-100-year earthquake. According to A.M. Best, the second stress test is designed to evaluate the financial conditions of an insurer after the first event and whether the insurer will have sufficient capital for the exposure remaining on its books. Following the second stress test, capitalization based on BCAR score is expected to be within 15 points of the minimum BCAR score compatible with the guidelines for its current rating.

A.M. Best announced that the stress testing changes were going to be implemented first to companies with major exposure to the 2005 hurricane events. The test would be applied to other companies during 2006 and completed for all companies before June 1, 2006 (Guy Carpenter, 2005). Interestingly, the US insurance regulators were much slower to reflect the natural catastrophe risk in capital charges to the NAIC Risk-Based Capital (RBC) score that determines the minimum regulatory capital requirements for insurers. After several years of development by NAIC, the catastrophe risk charge for hurricane and earthquake exposures in RBC was adopted and implemented in 2017 (National Association of Insurance Commissioners, 2017).

4 Data

4.1 Data sample and variables construction

We construct a sample of U.S. property-casualty insurance companies between 2001 and 2022. A.M. Best financial strength ratings are obtained from A.M. Best's annual Key Rating Guide. Insurers' balance sheet and exposure data are reported in the financial statements that insurers submit annually to the NAIC according to statutory accounting principles, obtained from S&P Market Intelligence Platform.

The sample consists of all property-casualty insurance companies in the U.S. rated by A.M. Best. The initial sample has 1'757 firms observed for up to 8 years between 2001-

2008. The panel is unbalanced as some firms enter or leave during our 8 years of study. However, there is neither a general time trend in the number of firms nor a decrease in the number of firms after hurricane Katrina. Therefore, our baseline analyses start with the full unbalanced sample of 11'190 observations and includes year fixed effects in most estimations. Robustness checks that balance the sample and thereby reduce its initial size to 8'216 observations, yield essentially the same results and are available on request. The sample size falls slightly from 11'190 to 11'044 when we include all controls.

Insurers companies report their direct premiums written, i.e. the volume of insurers sold to policyholders, for each line of business at the state level. To measure the exposure of insurers to Katrina-affected areas, we construct a variable $PCAT$ which is equal to the ratio of direct premiums written in NatCat prone lines of business in five states of Florida, Louisiana, Mississippi, South Carolina, and Texas that were severely affected by the 2005 hurricane season, to the total direct premiums written by an insurer in all states and all lines of business in a given year. In addition, we can construct similar ratios to measure exposures to more broad NatCat zones, also including other NatCat perils like earthquakes and tornados. The sample size reduces to 9'688 when we take into account not only state-level exposure to Katrina $PCAT$ but also to other natural catastrophe risks areas.

An insurance company can write premiums in both commercial and personal lines. However, the industry structure is such that insurers tend to specialize in either of the market segment. Table 1 shows the distribution of insurance business between personal and commercial lines. In particular, it shows that 32% of insurers have between 90%-100% of premiums in commercial insurance. Therefore, we define commercial insurers as those that write at least 50% of their premiums in commercial lines of business. For robustness, we also perform the analysis for alternative more narrow definitions of commercial insurers.

% DPW in Commercial Lines	Number of businesses	Total NPW (in $millions)	% Total NPW	Mean PCAT
0-10	209	17.1	0.59	0.434
10-20	187	15.8	0.54	0.291
20-30	181	34.7	1.19	0.149
30-40	418	119.2	4.09	0.108
40-50	750	464.5	15.92	0.060
50-60	1,161	363.4	12.46	0.024
60-70	1,405	569.7	19.53	0.021
70-80	1,003	181.8	6.23	0.033
80-90	864	218.9	7.50	0.034
90-100	4,732	931.8	31.94	0.020
All	10,910	2,916.9	100%	0.080

Table 1: *Distribution of commercial and personal insurance business*

Note: This table shows the distribution of commercial and personal lines of business for our sample insurers. Total NPW is the sum of all net premium written, % Total NPW is the percentage of the sum of the net premium written to aggregate total premium, Mean PCAT is the average PCAT for the insurers with corresponding proportion of commercial lines of business.

4.2 Summary statistics

Table 2 shows our summary statistics. Panel I starts with exposure to different natural catastrophe risks. While insurers' exposures range from 0% to 92% (Hurricane regions) or 100% (all other exposures) depending on the geographical distribution of each firm's direct premiums written (DPW), we see that the average firm in our sample has the largest exposures to Tornado regions (12%) and the North-East (10%). More importantly for our purposes, average exposure to the Gulf accounts for 4% and to Florida for 3% of DPW, adding up to 7% for the sum of the two which we deem Katrina region exposure. Not all South-East states were affected by Katrina and so we do not include the whole region for our baseline estimations, although robustness checks available on request show results under this alternative. It is worth noting that all of these NatCat risk factors have a far bigger between- than within-firm variation, reflecting that firms do not typically make significant business shifts from year to year.

Variable	Number	Mean	SD	Between SD	Within SD	Minimum	Maximum
PCAT	11,190	0.09	0.21	0.21	0.04	0.00	1.04
Exposure to Earthquakes	9,688	0.05	0.14	0.14	0.03	0.00	1.00
Exposure to the Caribbean	9,688	0.01	0.06	0.06	0.01	0.00	0.92
Exposure to the North-East	9,688	0.10	0.21	0.21	0.04	0.00	1.00
Exposure to Tornadoes	9,688	0.12	0.22	0.21	0.04	0.00	1.00
Exposure to Typhoons	9,688	0.00	0.04	0.04	0.01	0.00	1.00
Exposure to Low-Risk Regions	9,688	0.03	0.09	0.09	0.02	0.00	1.00
Exposure to Florida	9,688	0.03	0.11	0.12	0.03	0.00	1.00
Exposure to the Gulf	9,688	0.04	0.14	0.14	0.03	0.00	1.00
Exposure to the South-East	9,688	0.04	0.10	0.10	0.02	0.00	1.00
Investment Yield	11,190	4.10	1.70	1.31	1.29	-7.00	49.00
Combined Ratio	11,190	102.96	66.56	65.04	49.41	-599.00	1,660.00
Premium/Surplus	11,190	1.87	2.56	2.57	1.10	0.00	54.75
Net Premium Growth	11,044	17.84	90.52	80.70	77.09	-100.00	1,934.00
Reins. Recov. / Surplus	11,190	46.34	90.60	100.54	41.85	-95.00	976.00
Reserves/Surplus	11,190	88.20	75.20	76.52	33.27	-13.00	1,304.00
BCAR	11,190	242.10	152.59	143.94	72.13	21.30	999.90
RBC	11,067	1,326.81	2,059.13	2,080.86	972.68	39.00	15,346.00
Ln(Assets)	11,190	11.67	1.79	1.76	0.30	6.96	18.47
I(public)	11,190	0.31	0.46	0.46	0.00	0.00	1.00
I(single)	11,190	0.14	0.35	0.33	0.00	0.00	1.00
Rating	11,190	10.34	1.61	1.61	0.52	0.00	13.00
PDGs	9,505	0.89	0.32	0.32	0.00	0.00	1.00
PDGx	9,505	0.20	0.40	0.40	0.00	0.00	1.00
I(++ or - Rating last year)	11,190	0.37	0.48	0.42	0.24	0.00	1.00
I(A- or B++ Rating last year)	11,190	0.35	0.48	0.42	0.22	0.00	1.00
I($< P25$ or $> P75$ in 2004)	8,900	0.49	0.50	0.46	0.20	0.00	1.00
I($< P25$ or $> P75$ last year)	9,576	0.49	0.50	0.38	0.34	0.00	1.00
Retention Ratio (RR)	11,190	60.17	29.34	28.48	10.99	0.00	0.00
Low-Rated Bonds / C&S	11,183	2.11	5.62	5.21	3.26	1.00	100.00
Common St. / Unaff. Inv.	11,182	8.02	12.73	11.59	4.26	-2.69	89.76
Stocks / Unaff. Inv.	11,190	9.16	13.51	12.62	4.79	0.00	100.00
I (New Issuance)	11,190	0.11	0.32	0.17	0.27	0.00	1.00
I(Surplus Notes)	11,190	0.04	0.20	0.16	0.14	0.00	1.00
I(Dividend Cut)	11,190	0.28	0.45	0.26	0.41	0.00	1.00
I(Zero Dividends)	11,190	0.75	0.43	0.34	0.27	0.00	1.00

Table 2: *Summary Statistics*

Note: "SD" gives the total standard deviation, "Between SD" that between firms, "Within SD" that within firms across years.

Panel II reports firm characteristics starting with the quantification of A.M. Best rating. A.M. Best uses thirteen rating grades ranging A++ to D. We apply a numerical conversion from 13 for the highest rating A++ to 1 for the lowest rating D. An average rating of insurers is 10.34, or A-. Panel II shows that firms' investment yield averaged 4.1%, their Combined Ratio averaged about 103, premiums over surplus 1.87 and net premium growth (NPG) 17.84. Reinsurance recoverables over surplus averaged about 46%, reserves over surplus 88, the Best Capital Adequacy Ratio (BCAR) 242, and the log of assets 11.67. Finally, 31% of firms were publicly listed and 14% were single rather than member of a larger group.

Finally, Panel 4 explores some of firms' possible responses to counteract the downgrade pressure that we analyze in Section 7. It shows that on average firms retain about 60% of risks and reinsure the other 40%. On the asset side, investments into risky bonds rated 3-6 by the NAIC Securities Valuation Office (SVO) scale amounted to on average 2.11% of capital and surplus. Furthermore, common stocks amounted to on average about 8% of unaffiliated investments and total stock to about 9%. Finally, about 11% of firm-year observations are characterized by new capital issuance, 4% by the use of surplus notes, 28% by dividend cuts relative to the previous year, and 75% by zero dividends.

Table 3 displays the comparison between commercial and personal insurers. The last column shows differences, printing in bold letters all differences that are statistically significant at the 10% or lower confidence level. The table shows that commercial insurers have on average lower exposures to all natural catastrophes except typhoons (which is a relatively small market). Furthermore, commercial insurers buy more reinsurance and have more reserves over surplus, i.e. higher leverage, and lower BCAR values. Their own size does not differ significantly from that of personal policy focused firms. However, they tend to belong to larger groups and are more likely to be publicly listed.

	Personal			Commercial			Compared
	Mean	SD	Number	Mean	SD	Number	Difference
Rating Quantified	10.31	1.74	5,811	10.32	1.49	5,472	0.01
Investment Yield	4.11	1.76	5,811	4.09	1.64	5,472	-0.02
Combined Ratio	102.63	46.50	5,811	103.34	82.72	5,472	0.72
Premium/Surplus	2.13	2.45	5,811	1.60	2.64	5,472	**-0.52**
Net Premium Growth	14.95	87.16	5,811	20.44	92.75	5,472	**5.49**
Reins Recov / Surplus	31.28	68.06	5,811	62.35	107.32	5,472	**31.07**
Reserves/Surplus	74.07	64.14	5,811	103.16	82.80	5,472	**29.08**
BCAR	238.81	136.92	5,811	245.62	167.62	5,472	**6.81**
Assets	7.55×10^5	4.06×10^6	5,811	8.70×10^5	3.61×10^6	5,472	1.15×10^5
Group Assets	1.00×10^7	2.09×10^7	5,691	1.37×10^7	2.68×10^7	5,472	$\mathbf{3.70 \times 10^6}$
I(public)	0.26	0.44	5,811	0.37	0.48	5,472	**0.10**
I(single)	0.14	0.34	5,811	0.14	0.35	5,472	0.00
Earthquake Exposure	0.07	0.17	5,081	0.03	0.10	4,687	**-0.04**
Caribbean Exposure	0.01	0.06	5,081	0.01	0.06	4,687	0.00
Florida Exposure	0.03	0.13	5,081	0.02	0.07	4,687	**-0.02**
Gulf Exposure	0.05	0.15	5,081	0.03	0.12	4,687	**-0.01**
North-East Exposure	0.14	0.27	5,081	0.04	0.11	4,687	**-0.10**
South-East Exposure	0.05	0.13	5,081	0.02	0.07	4,687	**-0.03**
Tornado Exposure	0.18	0.26	5,081	0.06	0.15	4,687	**-0.12**
Typhoon Exposure	0.00	0.05	5,081	0.00	0.01	4,687	**0.00**
Low-Risk Exposure	0.04	0.11	5,081	0.01	0.05	4,687	**-0.02**
Katrina Exposure	0.08	0.20	5,081	0.05	0.14	4,687	**-0.03**
PCAT	0.12	0.24	5,811	0.06	0.16	5,472	**-0.06**

Table 3: *Commercial vs. Personal Policy Sellers*

Note: Differences in the rightmost column are in bold if statistically significant at 10% confidence or less.

5 Sensitivity of insurance markups and premiums to changes in ratings and RBC

As a preliminary step to the analysis of the impact of changes of NatCat assessment by the CRA, we start by analyzing the role of ratings and RBC ratios for insurers premiums and prices, as well as their relative importance.

Data. We use data at the firm * state * line of business * year level, covering firms in 50 US states and the District of Columbia. We consider four lines of business (LOB), commercial multiple peril, inland marine, homeowners multiple peril, and private passenger auto physical damage. The first two lines are classified as commercial lines and the last two as personal lines. All of these lines are exposed to NatCat risk.

The outcome variables are the volume of premiums and insurance markups. The insurance volume is measured as Direct Premiums Written (DPW). We use 20 years of data for years from 2001 until 2020. For this period, we start with a sample on DPW levels with 4'015*51*4*20, or 16'381'200 observations, or those on DPW growth with 19 years or 15'562'140 observations. In practice, not all insurers offer policies in all states, business lines and years so that the sample size reduces to 780'846 observations, further reduced to 715'069 observations if we drop cases with zero or (rarer) negative reported DPW levels. Including observations with zero or negative DPW levels yields qualitatively similar results available on request.

To calculate the markups, we follow the methodology described in Gründl et al. (2021). The markups are computed as the ratio between DPW and discounted losses. Since the payments of losses are reported for the ten years after the accident year, the calculation requires 10 years of data after the accident year which reduces the sample to years from 2001 until 2010.

For our baseline analyses we focus on year-on-year changes in the A.M. Best insurer rating. We observe the 16 values A++, A+, A, A-, ... , C-, D, E, F, and "not rated". Ignoring not rated cases and lumping together the bottom 3 categories leaves us with numerical values ranging from 0 (worst) to 13 (best). The first difference thereof takes value 0 in 90.98% of cases and values -1 or +1 in about 4% of cases each, but ranges from -9 through +9.

In addition to almost continuous measure of rating changes, we also generate an indicator for a downgrade, i.e. for any negative year-on-year change in ratings, and denominated "junk downgrade" for cases in which a firm's rating changes from an investment grade (IG) rating (above or equal to A-) to a sub-IG rating (below A-).

To analyse the impact of the regulatory capital on premiums and prices, we consider the RBC ratio, i.e. the ratio of actual "Total Adjusted Capital" (TAC) over required "Risk-Based Capital" (RBC) (Ellul et al., 2015). TAC consists primarily of capital and surplus, while RBC is the required capital that reflects both business and asset risks. NAIC regulation requires the RBC ratio to exceed a value of two.

Methodology. We relate both the percentage growth in DPW and the markup, at the firm*state*LOB*year level, to changes in firms' ratings. For both outcome variables, we start by treating all LOB equally. Then we include an interaction for the two commercial LOB. In a less conservative specification we include fixed effects for each firm and for each year, while in a more conservative one we include fixed effects for each firm*state and for each year. Following Bertrand et al. (2004), we cluster standard errors by whichever cross-sectional level we control for with fixed effects.

Empirical results. Table 4 shows our baseline results on demand responses to rating changes. Depending on the fixed effects used, we find each rating notch change, positive or negative, associated with on average 1.7%–1.9 % higher DPW growth (columns 5 and 6) and with an about 20 basis points higher markup (columns 1 and 2). Remarkably, these effects are insignificant or even slightly negative for the subset of observations from personal LOB but are as large as 3.5% higher DPW growth and about 250 bps larger markups for commercial business lines. This is consistent with personal insurance policy buyers caring much less about firm ratings given public guarantees.

	Markup				%ΔDPW			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔRating	20.388	20.812***	-187.950	-163.480***	1.708*	1.906***	-0.615	-0.356
	(20.073)	(4.089)	(242.898)	(38.404)	(0.964)	(0.305)	(1.217)	(0.435)
I(commercial)			-135.340	-138.826***			9.020***	7.399***
			(117.790)	(18.783)			(0.870)	(0.229)
I(comm)*ΔRating			283.869	251.061***			3.529**	3.438***
			(324.237)	(50.707)			(1.395)	(0.498)
Constant	78.204***	77.558***	167.408**	169.089***	16.625***	16.611***	10.553***	11.631***
	(1.119)	(0.227)	(79.413)	(12.638)	(0.016)	(0.005)	(0.585)	(0.154)
Observations	160,169	158,970	160,169	158,970	715,038	713,408	715,038	713,408
R^2	0.118	0.140	0.120	0.142	0.058	0.115	0.060	0.116
Cross-Sectional FE	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Std. Error Cluster	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State

Table 4: *Response to Rating Notch Change*

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	Markup				%ΔDPW			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I(Downgrade)	-45.488	-46.539***	34.854	17.714	-3.582**	-3.979***	0.245	0.292
	(44.899)	(7.125)	(194.052)	(30.020)	(1.751)	(0.562)	(2.272)	(0.777)
I(commercial)			-142.585	-145.314***			8.953***	7.411***
			(118.807)	(18.936)			(0.855)	(0.227)
I(comm)*I(DG)			-120.005	-96.161**			-5.984*	-6.666***
			(255.848)	(39.359)			(3.097)	(0.995)
Constant	76.983***	76.434***	172.732**	173.820***	16.829***	16.819***	10.860***	11.880***
	(3.167)	(0.502)	(81.878)	(13.008)	(0.066)	(0.021)	(0.568)	(0.152)
Observations	167,725	166,397	167,725	166,397	747,132	745,286	747,132	745,286
R^2	0.118	0.140	0.119	0.141	0.059	0.117	0.061	0.118
Cross-Sectional FE	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Std. Error Cluster	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State

Table 5: *Response to Downgrades*

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	Markup				%ΔDPW			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
%Δ(RBC Ratio)	16.238	14.292***	79.051	82.336***	-2.242***	-2.204***	-1.944**	-1.839***
	(23.508)	(3.631)	(114.445)	(17.714)	(0.623)	(0.185)	(0.783)	(0.250)
I(commercial)			-125.992	-132.852***			9.090***	7.368***
			(128.754)	(20.876)			(0.892)	(0.234)
I(comm)*%Δ(RBC Ratio)			-96.753	-106.457***			-0.437	-0.546*
			(170.608)	(26.634)			(0.999)	(0.313)
ΔRating	27.128	28.347***	-289.630	-239.646***	1.967**	2.171***	-0.447	-0.191
	(29.995)	(4.674)	(345.494)	(55.170)	(0.981)	(0.307)	(1.228)	(0.439)
I(comm)*ΔRating			427.920	362.144***			3.664**	3.584***
			(460.062)	(73.372)			(1.433)	(0.503)
Constant	79.505***	77.912***	161.056*	164.266***	17.925***	17.897***	11.814***	12.944***
	(1.353)	(0.225)	(86.480)	(14.001)	(0.055)	(0.016)	(0.597)	(0.157)
Observations	131,974	130,785	131,974	130,785	705,822	704,186	705,822	704,186
R^2	0.118	0.140	0.120	0.142	0.058	0.115	0.060	0.116
Cross-Sectional FE	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Std. Error Cluster	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State

Table 6: *Response to RBC Ratio (RBCR) Changes*

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

These results are confirmed by results in Table 5 which estimates the response of the DPW and markups to an indicator for a firm rating downgrade instead of a continuous rating change. On average across all business lines it shows a downgrade to be associated with 3.6%—4.0% lower DPW growth and 46% lower markups. Again these associations are insignificant for personal LOB alone, but are as large as respectively 6.0-6.7pp and about 97bps for commercial LOB.

Table 6 reports the results of the estimation that horse races the response to changes in the RBC ratio and changes in ratings. We find that a one standard deviation increase in RBC ratio implies a 0.41*14.3 higher markup, but also 0.4*2.2 lower demand. At the same time, a one standard deviation increase in ratings changes implies a 0.55*28.3 higher markup and 0.55*2.2 higher demand. So that direct comparison of effects controlling for the respective other shows ratings to affect profitability more than RBC. Furthermore, the personal versus commercial insurer comparison of responses to RBCR seems more informative when controlling for ratings (Columns 3 and 4). In this case, improvements in both dimensions lead firms to raise markups, and in both cases more for commercial than for personal insurers.

In sum, our results suggest that ratings are more relevant for commercial rather than personal insurers. Furthermore, we conclude that ratings changes prompt a more significant response of DPW and markups compared to RBC ratio changes. In the appendix, we report additional specifications on the responses to downgrade to junk and changes in RBC ratios that confirm our main conclusions.

6 Estimating rating downgrade pressure

To analyze the adjustment of insurers to more stringent rating standards, we proceed in two steps. In this section, we evaluate the extent of the rating pressure on NatCat exposed insurers after the 2005 hurricane season. In the following section, we explore how insurers adjusted their capital and risk management strategies depending on the costs and the benefits of maintaining the rating.

We start by exploring the effects of a rating standard change for NatCat and the 2005 hurricane season losses on firms ratings. In our baseline model, we estimate difference-in-difference specifications where the outcome variable is a rating and treated firms are those with NatCat exposure in Katrina affected regions of Florida and the Gulf. Then, recognizing that the estimated changes in ratings of treated firms combine the effects of the rating scale change as well as unprecedented losses incurred by insurers during Katrina hurricane season, we decompose the two components possibly driving the rating changes.

6.1 Methodology

Baseline specification. We start with Difference-in-Differences (DiD) estimations, where the treatment intensity is measured by PCAT, the insurer's fraction of 2005 direct premiums written (DPW) in Katrina-affected regions Florida and Gulf. We use annual data from 2001 till 2008. We estimate the following baseline equations:

$$Rating_{it} = \beta_1(Post \times PCAT_{it}) + \beta_2 Post + \beta_3 PCAT_{it} + \varepsilon_{it}, \tag{5}$$

$$Rating_{it} = \beta_1(Post \times PCAT_{it}) + v_i + \tau_t + \varepsilon_{it}. \tag{6}$$

The dependent variable $Rating_{it}$ is the numerical conversion of the A.M. Best rating of insurer i in year t, with a higher value indicating a higher rating. The variable $Post$ is a time dummy equal to 0 for all years 2001-2005 prior to Katrina hurricane season and equal to 1 for all years 2006-2008 after the hurricane season. The variable $PCAT_{it}$ is the share of direct premiums written in catastrophe exposed lines of business and regions by insurer i in year t. The terms v_i and τ_t represent insurer-fixed effects and yearly time-fixed effects, respectively. The interaction term $Post \times PCAT_{it}$ is positive if an insurer i has exposure to Katrina-affected states $PCAT$ during the post-Katrina period. The coefficient β_1 compares the change of a rating of insurers with PCAT exposure in post-Katrina period with the rating change of insurers without PCAT exposure. The term ε_{it} is the idiosyncratic error term. Standard errors are clustered at the insurer level, following Bertrand et al. (2004).

For robustness, we also estimate three alternative specifications. First, we estimate a variation of (6) where we include insurer's characteristics that are the main drivers of ratings. We include the A.M. Best risk based capital measure BCAR, the measures of insurers' profitability: combined ratio and net premium growth; the measures of leverage: premiums/surplus, reserves/surplus, reinsurance recoverables/surplus; the measure of size: logarithm of total assets; and the corporate structure indicators for publicly traded insurers and insurers that belong to an insurance group. We also include the insurer-year and time fixed effects. The latter controls matter only to the extent that they are time-varying for a given insurer.

The other two alternative models replace the linear probability model used in baseline with Ordered Probit and Ordered Logit estimations. These specifications better account for the fact that the number of possible rating outcomes is limited to 13. Due to the incidental parameter problem, these two specifications do not control for insurer and time fixed effects. Furthermore, their coefficients cannot be interpreted as the implied marginal effects directly. However, the estimated sign and the significance of β_1 coefficient in these two models confirm the robustness and the significance of the results.

All specifications rely on the identification assumption common to DiD estimations that trends in the outcome variables of interest would have been parallel between now differentially treated units if no treatment had occurred. This assumption cannot be tested explicitly because the underlying counter-factual scenario did not occur. However, its plausibility can be assessed by investigating whether differentially treated units did exhibit parallel trends in periods in which no treatment had occurred. Since we observe insurers over more than one pre-treatment period, we can interact the exposure to Florida and the Gulf hurricane regions with year fixed effects for each of years 2002-2008, using 2001 as the baseline. Doing so confirms that exposure to Florida and the Gulf did not affect ratings differentially in any of the pre-Katrina years 2001-2004. This reassures the plausibility of the identification assumption underlying our estimations.

Decomposition of downgrade pressure in rating scale change and incurred loss factors.

The estimation of the baseline model (5) and (6) combines the effect of two concurrent events on insurers' ratings: the change of the rating standard for NatCat exposures and the actual incurred losses of insurers with greater exposure to Florida and Gulf regions affected by Katrina. How much does each of these factors contribute to the rating change?

Distinguishing between the two factors requires estimation of the rating scale before and after the A.M. Best change of the rating methodology. We estimate such a model using the insurers' characteristics that are used by A.M. Best in evaluating their financial strength. Formally we estimate the following equation:

$$Rating_{it} = \gamma X_{it} + \varepsilon_{it}, \tag{7}$$

where X_{it} is a vector of insurer i characteristics in year t including its exposures to various NatCat regions, γ is a vector of parameters to be estimated and ε_{it} is the idiosyncratic error term. We use the linear probability model to estimate equation (7). We estimate separately two rating scale functions, for 2001-2005 (Pre) and 2006-2008 (Post). In addition, we estimate an alternative specification of (7) for 2001-2008 where we include the time dummies for the period 2006-2008 for each of the insurer's characteristics. The estimated dummies directly measure which risk factors gained in importance as A.M. Best updated its methodology.

The estimated rating scale functions are used to construct two variables, propensity to downgrade based on scale changes (PDGs) and propensity to downgrade based on losses and related changes of other firm characteristics (PDGx). To construct PDGs, we first predict each firm's baseline rating using both Pre period rating scale parameters and Pre period insurer characteristics, $\widehat{Rating}_{\text{Pre}}(X_{\text{Pre}})$. Then we evaluate how a firm with Pre period characteristics would be rated under the revised rating scale, $\widehat{Rating}_{\text{Post}}(X_{\text{Pre}})$. The difference between the two estimates measures the change in ratings based only on the scale changes. A firm that is predicted to obtain a lower rating under the updated rating scale and Pre period characteristics is assigned a PDGs score of one,

$$PDGs = \begin{cases} 1, \; if \;\; \widehat{Rating}_{\text{Post}}(X_{\text{Pre}}) < \widehat{Rating}_{\text{Pre}}(X_{\text{Pre}}), \\ 0, \; otherwise. \end{cases} \tag{8}$$

Similarly, we construct a variable PDGx to measure how the incurred losses alone would have affected an insurer's rating. It is equal to the difference between the predicted rating using the Pre period rating scale and the Pre period insurer characteristics, $\widehat{Rating}_{\mathrm{Pre}}(X_{\mathrm{Pre}})$, and the predicted rating using the Pre period rating scale and the Post period insurer characteristics that account for Katrina-related incurred losses, $\widehat{Rating}_{\mathrm{Pre}}(X_{\mathrm{Post}})$. A firm that is predicted to obtain a lower rating due to Katrina losses under the Pre period rating scale is assigned a PDGx score of one,

$$PDGx = \begin{cases} 1, & if \;\; \widehat{Rating}_{\mathrm{Pre}}(X_{\mathrm{Post}}) < \widehat{Rating}_{\mathrm{Pre}}(X_{\mathrm{Pre}}), \\ 0, & otherwise. \end{cases} \tag{9}$$

Using PDGs and PDGx as two alternative measures of treatment intensity, we estimate the following modification of the baseline model:

$$Rating_{it} = \beta_s(Post \times PDGs_{it}) + \beta_x(Post \times PDGx_{it}) + v_i + \tau_t + \varepsilon_{it}. \tag{10}$$

The coefficients β_s and β_x horse race the contribution of scale change and incurred losses to the downgrade pressure. We also include the estimation of the other four specifications of the baseline model described above. To further test the robustness of the results, we complement the analysis with an alternative measure of Katrina-related losses where we replace the $PDGx$ variable with a loss ratio LR in equation (10). It is the ratio of losses incurred in the Katrina-affected regions over the direct premiums written in those regions. Using LR instead of $PDGx$ isolates the effect of Katrina-related losses from possible changes in other firm's characteristics, and thus provides a direct test of the effect of the incurred losses on downgrade pressure.

Estimation of the differential effects on commercial and personal insurers. Our main interest is to evaluate to which extent the ratings downgrade pressure in the Post period was different for commercial and personal insurers. This analysis is necessary to reconcile the differential capital and risk management responses by these two types of insurers to alleviate the downgrade pressure. Therefore, we extend the baseline model by including a triple interaction of the $Post$ and $PCAT$ variables with a dummy variable $I(Comm)$ equal to one if an insurer's focused on commercial lines, fixed before the treatment occurred. We estimate the equation:

$$\begin{aligned} Rating_{it} = {} & \beta_1(Post \times PCAT_{it} \times I(Comm)) + \beta_2(Post \times I(Comm)) \\ & + \beta_3(PCAT_{it} \times I(Comm)) + v_i + \tau_t + \varepsilon_{it} \end{aligned} \tag{11}$$

as well as the other four alternative specifications of the baseline model. The coefficient β_1 shows whether the downgrade rating pressure for commercial insurers was different than for personal insurers. In addition, we estimate two modifications of the equation (11) to evaluate whether the scale change or the incurred losses and other insurer characteristics were driving the differential pressure for commercial and personal insurers. For this purpose, we replace the $PCAT$ variable in the equation (11) with variables $PDGx$ or $PDGs$.

Estimation of the differential effect depending on the initial rating. Following the analysis by Kisgen (2006) and Chernenko & Sunderam (2012), firms at the border of ratings, border of a broad rating categories, and firms at the investment grade border rating may have different incentives to counteract the downgrade pressure than other firms. To test whether similar effects are also relevant for our analysis, we estimate how the rating downgrade pressure varied across firms with different initial ratings. We consider three measures of the significance of a downgrade for an insurer. The first is an indicator $I(Border)$ for whether the firm was on the border of its broad rating A, B, C or D, i.e. whether it was rated A-, B++, B-, C++, or C- in the Pre period. The second is an indicator $I(IGBorder)$ of whether the firm was located just above or just below the border for an investment grade rating. According to the A.M. Best rating definitions and the industry practice, rating A- is the investment grade boundary rating for insurers. Therefore, we include the interaction with an indicator variable equal to one if an insurer was rated A- or BB+ in 2005. The last is an indicator $I(ScoreBorder)$ for whether the firm was in either the top or the bottom quantile of the underlying score of its rating in 2005. To identify these firms, we use the rating scale estimation (7) to identify the firms in the top and the bottom quantile of each rating. Then we define an indicator variable equal to one for firms in the border quantiles in the Pre period and zero otherwise. For each of the indicators $I(Border)$, $I(IGBorder)$ and $I(ScoreBorder)$, we estimate the triple interaction model akin to model (11).

6.2 Baseline estimation results

We present the results of the baseline DiD estimations of the total effect of exposure to Katrina-affected regions and the rating scale change on insurers' ratings in Table 7. Column (1) shows the most basic DiD regression including only the $Post$ time dummy equal to one for years 2006-2008, the $PCAT$ variable measuring the share of direct premiums written in Katrina-affected states, and their interaction $Post \times PCAT$. Column (2) shows the results for a specification with the insurer- and year-fixed effects and the interaction term $Post \times PCAT$. In both specifications, the coefficient of the interaction terms $Post \times PCAT$ is negative. However, it is significant only when one controls for firm- and year-fixed effects. The insignificance of the coefficient in column (1) is to be expected given that this specification does not control for any insurer characteristics that drive the rating assignment. The negative coefficient in column (2) shows that insurers with NatCat exposure in Katrina-affected regions experienced a downgrade pressure in the Post period compared with the control group.

The estimation in column (3) of Table 7 adds insurer's characteristics relevant for financial strength ratings to its firm- and time-fixed effects. The coefficient in column (3) is significant and is in the same range as in column (2) which reinforces the robustness of the result. The effect is also economically meaningful. We find that on average an insurer with the maximum possible exposure of 100% to the Katrina-affected states loses between 37% and 40% of a rating grade due to this exposure. Column (3) shows that insurer's capital, leverage and size are also relevant and statistically significant factors for the rating. Columns (4) and (5) replace the linear probability model (LPM) with Ordered Probit and Ordered Logit estimations, respectively. We find that the coefficient of the

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PCAT	-0.196	-0.406***	-0.367***	-0.239**	-0.382
	(0.186)	(0.119)	(0.114)	(0.114)	(0.238)
Post	0.131***			-0.132***	-0.235***
	(0.026)			(0.021)	(0.036)
PCAT	-0.194			-0.130	-0.136
	(0.241)			(0.166)	(0.328)
Investment Yield			0.007	0.036***	0.070***
			(0.004)	(0.012)	(0.025)
Combined Ratio			0.000	-0.000	-0.000
			(0.000)	(0.000)	(0.001)
Premium/Surplus			-0.004	0.053***	0.091***
			(0.009)	(0.007)	(0.013)
Net Premium Growth			0.000	0.000**	0.000**
			(0.000)	(0.000)	(0.000)
Reins Recov / Surplus			-0.001***	-0.002***	-0.004***
			(0.000)	(0.000)	(0.001)
Reserves/Surplus			-0.003***	-0.003***	-0.006***
			(0.000)	(0.000)	(0.001)
BCAR			0.000***	0.001***	0.003***
			(0.000)	(0.000)	(0.000)
Ln(Assets)			0.376***	0.392***	0.700***
			(0.052)	(0.017)	(0.031)
I(Public)				0.549***	1.023***
				(0.061)	(0.112)
I(Single)				-0.221***	-0.335***
				(0.060)	(0.108)
Constant	10.314***	10.474***	6.302***		
	(0.043)	(0.022)	(0.584)		
Observations	11,190	11,190	11,044	11,044	11,044
R^2	0.002	0.027	0.088		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm FE	No	Yes	Yes	No	No
Year FE	No	Yes	Yes	No	No

Table 7: *Difference-in-Differences (DiD) Analyses of the Effect of Katrina on Ratings*

Note: "Post" takes value 0 in 2001-5 and value 1 in 2006-8. "PCAT" denotes the firm's share of direct premiums written (DPW) going to the Katrina affected states. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

interaction term is negative and significant in the Ordered Probit specification, and the firm characteristics controls are significant and have economically expected signs.

In sum, the baseline results in Table 7 show that insurers experienced a downgrade pressure as a consequence of the rating scale change and Katrina-related losses. In what follows, we disentangles the two sources of the downgrade pressure, i.e. the rating scale change and the losses from the 2005 hurricane season. Then we evaluate the differences in the intensity of the rating downgrade pressure for the two segments of the insurance market, commercial and personal insurers. In addition, we estimate how the downward pressure varied depending on insurers' initial rating.

The estimation of the rating scale function (7) is reported in Table 8. Columns (1) and (2) report the estimated rating function for the pre-Katrina years 2001-5 and the post-Katrina years 2006-8, respectively. In addition, in Column (3) the estimation pools all years 2001-8 but interacts each single regressor with the time indicator for the post period. The left column of Column (3) reports the coefficients of the firm characteristics while the right column of Column (3) displays the coefficients of the interaction terms of firm characteristics and the time indicator dummies. The latter coefficients illustrate directly which marginal effects differ significantly in 2006-8 updated rating scale function from the 2001-5 rating function values. In line with the second stress-test design by A.M. Best under the updated rating methodology, we find that insurers' exposures to high hurricane risk zones in Florida and the Gulf deemed to warrant a lower rating under the updated rating scale. Hence, the same regional exposure after 2005 would imply a lower rating. Furthermore, the values of the other coefficients of the interaction terms are either statistically insignificant or small in magnitude, confirming empirically that the treatment of natural catastrophes exposures is the main factor that changed under the updated rating scale.

Using the rating scale function estimates for the Pre and Post periods reported in Table 8, we construct PDGs and PDGx variables for each insurer. To calculate PDGs, we predict a rating that an insurer would have obtained under the updated rating scale function in

	(1) Rating Scale	(2) Rating Scale	(3) Rating Scale	
	2001-5	2006-8	2001-5	2006-8
DPW share Florida	-0.862***	-1.382***	-0.862***	-0.520**
	(0.177)	(0.250)	(0.152)	(0.235)
DPW share Gulf	0.002	-0.442**	0.002	-0.444**
	(0.168)	(0.179)	(0.119)	(0.190)
DPW share Southeast	0.354*	0.115	0.354**	-0.240
	(0.199)	(0.193)	(0.152)	(0.242)
DPW Share Caribbean	-0.018	0.181	-0.018	0.198
	(0.193)	(0.211)	(0.280)	(0.422)
DPW share Earthquake regions	-0.322***	-0.422***	-0.322***	-0.100
	(0.107)	(0.113)	(0.113)	(0.187)
DPW share Northeast	0.448***	0.315***	0.448***	-0.133
	(0.071)	(0.087)	(0.076)	(0.123)
DPW share Typhoon regions	0.792***	-1.027	0.792*	-1.819***
	(0.290)	(0.673)	(0.415)	(0.689)
DPW share low-risk regions	-0.390**	-0.219	-0.390**	0.172
	(0.188)	(0.206)	(0.177)	(0.284)
Investment Yield	0.053***	0.031	0.053***	-0.022
	(0.014)	(0.020)	(0.009)	(0.019)
Combined Ratio	0.001*	-0.002***	0.001**	-0.002***
	(0.000)	(0.000)	(0.000)	(0.001)
Premium/Surplus	0.052***	0.071***	0.052***	0.019*
	(0.006)	(0.009)	(0.007)	(0.011)
Net Premium Growth	0.001***	-0.000	0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Reins Recov / Surplus	-0.003***	-0.003***	-0.003***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Reserves/Surplus	-0.004***	-0.004***	-0.004***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
BCAR	0.002***	0.002***	0.002***	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Ln(Assets)	0.452***	0.395***	0.452***	-0.057***
	(0.012)	(0.013)	(0.010)	(0.016)
I(Public)	0.607***	0.642***	0.607***	0.035
	(0.039)	(0.043)	(0.036)	(0.058)
I(Single)	-0.348***	-0.338***	-0.348***	0.010
	(0.050)	(0.056)	(0.050)	(0.080)
Constant	4.723***	5.551***	4.723***	0.829***
	(0.157)	(0.183)	(0.131)	(0.218)
Observations	5,911	3,665	9,576	
R^2	0.371	0.393	0.378	
Years	2001-5	2006-8	2001-5 & 2006-8	

Table 8: *Regressions Underlying the PDGs Measure of Scale Changed Based Downgrade Pressure*

Note: DPW are Direct Premiums Written. Standard errors in parentheses clustered by firm. * p < 0.1, ** p < 0.05, *** p < 0.01.

2006-8 but using its characteristics values of 2001-5. If the predicted rating is lower than the predicted rating obtained by keeping both rating scale and insurer's characteristics fixed at their 2001-5 values, the insurer is indicated to be subject to downgrade pressure based on the rating scale function change, and it is assigned a PDGs value equal to one. To calculate PDGx, we predict the firm rating using the rating scale function of 2001-5 for the insurer's characteristics in the Pre and Post period. If the predicted rating under 2006-8 characteristics is lower than the predicted rating under the 2001-5 characteristics, an insurer is predicted to have a downgrade pressure due to the change of its characteristics, and is assigned a PDGx value equal to one.

Table 2 Panel III displays our estimates of the indicator for a firm being under downgrade pressure when the scale changed from its 2001-5 to its 2006-8 version, $PDGs$ averaging a striking 89%. By contrast, only 20% of firms were under downgrade pressure when considering only changes in the firm characteristics $PDGx$.

The breakdown of the two sources of the downgrade pressure, i.e. the rating scale change and the 2005 hurricane season losses, are reported in Table 9. The table reports the estimation results of the horse race between the PDGs and PDGx in explaining the downgrade pressure in the Post period. We find that the coefficients of both interaction terms $Post \times PDGs$ and $Post \times PDGx$ are negative and significant in all five specifications. Therefore, we conclude that both the rating scale change and the incurred losses contributed to the downgrade pressure. Furthermore, for each of the specifications reported in Columns (1)-(5) we find that each of the two factors explains about half of the total downgrade pressure, with each being fully robust to controlling for the other.

In Table 10 we complement the analysis by reporting the results of the estimation that replaces PDGx with a loss ratio LR in Katrina-affected regions. The loss ratio accounts directly for the impact of Katrina on an insurer as it is the ratio of incurred losses in Katrina affected areas to the insurer's exposure to these areas measured by the direct premiums written. We find that the contribution of losses to downgrade pressure is negative and significant across all specifications. Furthermore, the impact of the scale

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PDGs	-0.337***	-0.212**	-0.161*	-0.160*	-0.230
	(0.110)	(0.090)	(0.091)	(0.092)	(0.201)
Post × PDGx	-0.240*	-0.266***	-0.055	-0.134	-0.289*
	(0.124)	(0.053)	(0.056)	(0.088)	(0.166)
PDGs	1.190***			0.203	0.516*
	(0.200)			(0.166)	(0.312)
PDGx	-0.214*			-0.245***	-0.504***
	(0.119)			(0.089)	(0.180)
Post	0.147***			-0.164***	-0.325***
	(0.030)			(0.028)	(0.052)
Constant	10.362***	10.535***	6.185***		
	(0.073)	(0.020)	(1.039)		
Observations	9,086	9,436	9,436	9,086	9,086
R^2	0.042	0.026	0.099		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm & Year FE	No	Yes	Yes	No	No
Controls	No	No	Yes	Yes	Yes

Table 9: *Horse Race of Scale (s)- vs. Characteristics (x)-Based Downgrade Pressures*

Note: Propensity to Downgrade from Scale Changes (PDGs) denotes continuous changes in underlying score due to moving from the 2001-5 scale to the 2006-8 scale but keeping firm characteristics fixed at their 2001-5 level. PDGx denotes instead continuous changes in firms' underlying rating score due to changing characteristics but keeping the scale fixed. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

change $Post \times PDGs$ remains negative and significant. Certainly, insurers' ability to sustain the same losses varies depending on their other characteristics included in PDGx. For this reason, in all specifications the coefficients of $Post \times LR$ terms are lower than either the coefficients of $Post \times PDGs$ terms reported in Table 10 or a contribution of $Post \times PDGx$ in the previous estimation reported in Table 9. However, the results of Table 10 confirm that Katrina-related losses were a significant shock for insurers' ratings.

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PDGs	-0.314	-0.268**	-0.210**	-0.343**	-0.530*
	(0.216)	(0.107)	(0.106)	(0.168)	(0.318)
Post × LR	-0.001*	-0.001***	-0.001***	-0.001***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
PDGs	0.005***	0.000**	0.000**	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
LR	0.230***			-0.072**	-0.169***
	(0.045)			(0.035)	(0.064)
Post	1.097***			0.269	0.660
	(0.230)			(0.239)	(0.481)
Constant	9.965***	10.508***	6.186***		
	(0.066)	(0.024)	(1.038)		
Observations	9,436	9,436	9,436	9,436	9,436
R^2	0.080	0.021	0.102		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm & Year FE	No	Yes	Yes	No	No
Firm Controls	No	No	Yes	Yes	Yes

Table 10: *Horse Race of Scale-Change-Based Downgrade Pressures with Incurred Loss Ratios*

Note: Propensity to Downgrade from Scale Changes (PDGs) denotes continuous changes in underlying score due to moving from the 2001-5 scale to the 2006-8 scale but keeping firm characteristics fixed at their 2001-5 level. Loss Ratio (LR) denotes incurred losses over direct premiums written in the Katrina regions in 2003. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6.3 Differential effect on commercial and personal insurers

In this section, we report the results of the analysis of the impact of the rating scale change and the Katrina losses on the two segments of the insurance market, commercial and personal insurers. We enhance the baseline model by adding the interaction term $Post \times PCAT \times I(Comm)$ that estimates whether and how the rating downgrade pressure occurred differently for personal and commercial insurers.

Table 11 presents the results of the triple-interaction estimation. The main result of Table 11 is that the coefficient of the triple interaction term $Post \times PCAT \times I(Comm)$ is positive and significant. Furthermore, its absolute value is higher than the value of the coefficient of the $Post \times PCAT$ term. Jointly, these results reveal that the rating downgrade pressure was experienced by personal insurers but not by commercial insurers. In addition, the coefficients of the $Post \times PCAT$ interaction term are negative and statistically significant in all specifications, which is consistent with the results of the baseline model results reported in Table 7. Better ability of commercial insurers to withstand the events could occur due to two non-exclusive reasons. First, commercial insurers could have had a higher initial capitalization level and better risk management prior to the rating change and Katrina events. Further, commercial insurers were more capable to counteract the rating downgrade pressure by changing their capital and risk management strategy. We explore these channels in detail in the following section.

To confirm that the differential response by personal and commercial insurers was driven by their capital and risk management rather than the divergent treatment of the two segments of the insurance market by the rating agency A.M. Best, we estimate two additional specifications. The first one estimates a model with a triple-interaction term $Post \times PDGs \times I(Comm)$ which evaluates whether the rating scale change was applied differently to commercial and personal insurers. The results are presented in Table 12. While the coefficient of $Post \times PDGs \times I(Comm)$ term is positive, it is statistically insignificant. However, the interaction term $Post \times PDGs$ is positive and significant in the two main specification reported in Columns (2) and (3) in Table 12. Together, these results imply that while the scale change put a downward pressure on insurers, the application of the rating scale was not differential for commercial and personal insurers.

The other specification estimates a model with a triple-interaction term $Post \times PDGx \times I(Comm)$. It evaluates whether the differential rating downgrade pressure stems from changes in the same characteristics having affected commercial firms less, either because

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PCAT	-0.414*	-0.597***	-0.640***	-0.501***	-0.804**
	(0.229)	(0.149)	(0.140)	(0.153)	(0.320)
Post × PCAT × I(Comm)	1.060***	0.785***	0.864***	0.731***	1.352***
	(0.396)	(0.233)	(0.217)	(0.234)	(0.507)
Post × I(Comm)	-0.031	-0.015	-0.041	-0.053	-0.096
	(0.057)	(0.036)	(0.033)	(0.039)	(0.069)
PCAT × I(Comm)	-0.372	-0.000	-0.115	-0.280	-0.522
	(0.538)	(0.169)	(0.158)	(0.353)	(0.727)
Post	0.178***			-0.094***	-0.204***
	(0.041)			(0.029)	(0.051)
PCAT	-0.138			-0.173	-0.193
	(0.283)			(0.213)	(0.444)
I(Comm)	0.003			-0.115**	-0.194*
	(0.085)			(0.056)	(0.100)
Constant	10.279***	10.416***	5.168***		
	(0.065)	(0.021)	(0.940)		
Observations	11,283	11,283	11,283	11,283	11,283
R^2	0.004	0.027	0.142		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm & Year FE	No	Yes	Yes	No	No
Firm Controls	No	No	Yes	Yes	Yes

Table 11: *Triple Difference Analysis on Katrina Pressure at Commercial vs Personal Policy Sellers*

Note: I(Comm) indicates firms with a share of policies going to commercial clients above the sample median of 82%. Standard errors in parentheses clustered by firm. * p < 0.1, ** p < 0.05, *** p < 0.01.

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PDGs	-0.304	-0.530***	-0.518***	-0.710***	-0.996**
	(0.380)	(0.167)	(0.160)	(0.255)	(0.435)
Post × PDGs × I(Comm)	-0.112	0.475**	0.583***	0.714**	0.877*
	(0.488)	(0.197)	(0.191)	(0.300)	(0.528)
Post × I(Comm)	0.095	-0.014	-0.046	-0.079	-0.094
	(0.097)	(0.050)	(0.047)	(0.062)	(0.107)
PDGs × I(Comm)	0.297	0.039	-0.063	-0.247	-0.580
	(0.499)	(0.193)	(0.250)	(0.325)	(0.660)
Post	0.128			-0.065	-0.186**
	(0.078)			(0.055)	(0.093)
PDGs	1.184***			0.297	0.825
	(0.362)			(0.297)	(0.609)
I(Comm)	-0.052			-0.096	-0.140
	(0.124)			(0.079)	(0.147)
Constant	10.239***	10.530***	6.167***		
	(0.097)	(0.024)	(1.042)		
Observations	9,436	9,436	9,436	9,436	9,436
R^2	0.032	0.021	0.103		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm & Year FE	No	Yes	Yes	No	No
Firm Controls	No	No	Yes	Yes	Yes

Table 12: *Triple Difference Analysis on Scale Change Pressure at Commercial vs Personal Policy Sellers*

Note: PDGs defined as in Tables 3 and 8, I(Comm) as in Table 9. Standard errors clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

commercial insurers had on average lower exposures and the marginal effect of the exposures is non-linear, or because commercial firms are capable to bear more exposure, e.g. due to their greater use of reinsurance. The results reported in Table 13 confirm that commercial insurers were more resilient to the changes. The coefficient of the triple interaction term $Post \times PDGx \times I(Comm)$ are positive and significant in all specifications while the coefficients of the interaction term $Post \times PDGx$ are negative and significant in the main specifications reported in Columns (2) and (3) of Table 13. The interpretation of these results is that while the Katrina-related losses were significant to all insurers with NatCat exposures, commercial insurers surmounted the changes better than personal insurers.

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PDGx	-0.480	-0.714***	-0.546***	-0.590**	-0.770
	(0.384)	(0.173)	(0.167)	(0.267)	(0.474)
Post × PDGx × I(Comm)	0.147	0.512**	0.676***	0.933***	1.142*
	(0.475)	(0.213)	(0.208)	(0.322)	(0.597)
Post × I(Comm)	0.064	0.007	-0.016	-0.043	-0.048
	(0.072)	(0.042)	(0.040)	(0.049)	(0.088)
PDGx × I(Comm)	0.225	-0.010	-0.071	-0.249	-0.440
	(0.513)	(0.220)	(0.242)	(0.343)	(0.702)
Post	0.133**			-0.127***	-0.277***
	(0.058)			(0.043)	(0.075)
PDGx	1.256***			0.309	0.841
	(0.373)			(0.314)	(0.669)
I(Comm)	-0.032			-0.114*	-0.197
	(0.103)			(0.068)	(0.124)
Constant	10.308***	10.533***	6.227***		
	(0.080)	(0.022)	(1.044)		
Observations	9,436	9,436	9,436	9,436	9,436
R^2	0.030	0.026	0.104		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm & Year FE	No	Yes	Yes	No	No
Firm Controls	No	No	Yes	Yes	Yes

Table 13: *Analysis on Characteristics Change Pressure at Commercial vs Personal Policy Sellers*

Note: Definitions as in prior tables. Standard errors in parentheses clustered by firm. Standard errors clustered by firm. * p < 0.1, ** p < 0.05, *** p < 0.01.

	(1) Rating		(2) Rating		(3) Rating	
	P	*C	P	*C	P	*C
Post × InvYield	-0.056	0.067	-0.056	0.064	-0.157***	0.172***
	(0.058)	(0.061)	(0.040)	(0.043)	(0.047)	(0.052)
Post × ComRatio	-0.013***	0.013***	-0.009***	0.009***	-0.025***	0.025***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Post × Premium/Surplus	-0.017	0.039*	-0.008	0.023*	-0.005	0.030
	(0.019)	(0.021)	(0.013)	(0.014)	(0.020)	(0.022)
Post × NPG	-0.001*	0.000	-0.001*	0.000	-0.001	0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
Post × RR/S	-0.004***	0.002*	-0.003***	0.002**	-0.006***	0.004**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Post × Res/S	-0.005***	0.001	-0.003***	-0.000	-0.005***	-0.000
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Post × BCAR	0.002***	-0.001	0.001***	-0.000	0.002***	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Post × Ln(Assets)	-0.081*	0.307***	-0.059*	0.205***	-0.059	0.319***
	(0.043)	(0.051)	(0.031)	(0.036)	(0.047)	(0.059)
Post × I(Public)	0.463***	-0.146	0.349***	-0.058	0.635***	-0.103
	(0.114)	(0.137)	(0.082)	(0.101)	(0.141)	(0.174)
Post × I(Single)	-0.780***	1.015***	-0.550***	0.773***	-0.795***	1.192***
	(0.152)	(0.196)	(0.095)	(0.120)	(0.157)	(0.203)
Post × LnGroupTA	0.202***	0.018	0.141***	0.030	0.283***	0.014
	(0.030)	(0.035)	(0.020)	(0.025)	(0.036)	(0.044)
Post × LowRatedBonds	0.005	-0.011	0.003	-0.004	0.000	-0.007
	(0.012)	(0.014)	(0.009)	(0.011)	(0.015)	(0.019)
Post × Stocks/UAI	0.008**	-0.004	0.006**	-0.000	0.009**	0.001
	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.006)
Post × PCAT	-1.084***	0.929**	-0.624***	0.550**	-1.048***	1.115**
	(0.254)	(0.386)	(0.162)	(0.252)	(0.296)	(0.438)
Constant	10.232***	-5.576***		-4.115***		-7.195***
	(0.041)	(0.304)		(0.198)		(0.352)
Observations	11,283		11,283		11,283	
Method	LPM		OProbit		OLogit	
Firm & Year FE	No		No		No	

Table 14: *Effect of Firm Characteristics on Ratings Post-Katrina by Business Model*

Note: Definitions as in prior tables. Double interactions of each characteristic with I(Comm) for the Pre period are also controlled for, but along with the constant not displayed to save space. Effects of interest are similar if we include also all triple and double interactions with PCAT. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PCAT	-0.930***	-0.440***	-0.445***	-0.984***	-1.725***
	(0.296)	(0.130)	(0.129)	(0.248)	(0.521)
Post × PCAT × I(Border)	0.673**	0.094	0.109	0.956***	1.637**
	(0.310)	(0.222)	(0.208)	(0.313)	(0.653)
Post × I(Border)	-0.014	0.040	0.021	-0.082*	-0.142*
	(0.062)	(0.028)	(0.028)	(0.045)	(0.078)
PCAT × I(Border)	-0.317	0.512	0.447	-0.404	-0.943
	(0.467)	(0.311)	(0.302)	(0.360)	(0.701)
Post	0.152***			-0.033	-0.053
	(0.041)			(0.034)	(0.060)
PCAT	0.024			-0.006	0.301
	(0.357)			(0.313)	(0.572)
I(Border)	-1.363***			-1.165***	-2.268***
	(0.067)			(0.070)	(0.160)
Investment Yield			0.001	0.018	0.036
			(0.003)	(0.013)	(0.023)
Combined Ratio			-0.000	-0.000	-0.001
			(0.000)	(0.000)	(0.001)
Premium/Surplus			-0.014*	0.045***	0.071***
			(0.008)	(0.008)	(0.013)
Net Premium Growth			0.000**	0.000***	0.001***
			(0.000)	(0.000)	(0.000)
Reins Recov / Surplus			-0.000	-0.002***	-0.004***
			(0.000)	(0.000)	(0.001)
Reserves/Surplus			-0.002***	-0.003***	-0.006***
			(0.001)	(0.000)	(0.001)
BCAR			0.000***	0.002***	0.003***
			(0.000)	(0.000)	(0.000)
Ln(Assets)			0.324***	0.360***	0.606***
			(0.052)	(0.020)	(0.039)
I(Public)				0.574***	0.994***
				(0.067)	(0.117)
I(Single)				-0.124*	-0.202
				(0.072)	(0.131)
Constant	10.917***	10.535***	6.733***		
	(0.056)	(0.019)	(0.617)		
Observations	8,121	8,121	8,109	8,109	8,109
R^2	0.197	0.028	0.078		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm FE	No	Yes	Yes	No	No
Year FE	No	Yes	Yes	No	No

Table 15: *PCAT Effects on Firms Previously Rated "++" or "-"*

Note: I(Border) takes value 1 if the firm was rated A-, B++, B-, C++, C- or D++ in the previous year. Results similar if measuring border status in 2003 only. Definitions of all other variables as before. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PCAT	-0.846***	-0.425***	-0.429***	-0.877***	-1.638***
	(0.304)	(0.132)	(0.130)	(0.241)	(0.516)
Post × PCAT × I(IGBorder)	0.519	0.087	0.097	0.837**	1.475**
	(0.330)	(0.187)	(0.175)	(0.357)	(0.697)
Post × I(IGBorder)	-0.073	0.042	0.025	-0.100**	-0.184**
	(0.047)	(0.029)	(0.028)	(0.041)	(0.072)
PCAT × I(IGBorder)	-0.002	0.602*	0.528	-0.176	-0.561
	(0.409)	(0.338)	(0.329)	(0.350)	(0.688)
Post	0.173***			-0.037	-0.049
	(0.039)			(0.032)	(0.058)
PCAT	-0.093			-0.122	0.129
	(0.407)			(0.309)	(0.602)
I(IGBorder)	-1.071***			-0.986***	-1.910***
	(0.066)			(0.069)	(0.157)
Investment Yield			0.000	0.021*	0.038
			(0.003)	(0.013)	(0.023)
Combined Ratio			-0.000	-0.000	-0.001
			(0.000)	(0.000)	(0.001)
Premium/Surplus			-0.014*	0.047***	0.074***
			(0.008)	(0.008)	(0.013)
Net Premium Growth			0.000**	0.000***	0.001***
			(0.000)	(0.000)	(0.000)
Reins Recov / Surplus			-0.000	-0.002***	-0.004***
			(0.000)	(0.000)	(0.001)
Reserves/Surplus			-0.002***	-0.003***	-0.006***
			(0.001)	(0.000)	(0.001)
BCAR			0.000***	0.002***	0.003***
			(0.000)	(0.000)	(0.000)
Ln(Assets)			0.322***	0.369***	0.619***
			(0.052)	(0.021)	(0.039)
I(Public)				0.576***	1.016***
				(0.069)	(0.119)
I(Single)				-0.152**	-0.238*
				(0.073)	(0.132)
Constant	10.794***	10.533***	6.761***		
	(0.064)	(0.019)	(0.615)		
Observations	8,121	8,121	8,109	8,109	8,109
R^2	0.124	0.029	0.079		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm FE	No	Yes	Yes	No	No
Year FE	No	Yes	Yes	No	No

Table 16: *PCAT Effects on Firms Previously on the Investment Grade Border (A- or B++)*

Note: I(IGBorder) takes value 1 if the firm was rated A- or B++ in the previous year. Results similar if measuring border status in 2003 only. Definitions of all other variables as before. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6.4 Differential effect depending on the initial rating

In the next set of results, we investigate whether insurers that were on the rating border and thus had more at stake to prevent the downgrade alleviated the downgrade pressure better than insurers that were not on the rating border. For this purpose, we estimate a model with a triple interaction term $Post \times PCAT \times I(Border)$ where the indicator variable $I(Border)$ is a dummy equal to one for insurers at the rating border. Consistent with previous literature, we consider three definitions of the rating border ranging from the most broad to the most narrow: the investment grade border $IGBorder$, the border of a broad rating category $CBorder$, e.g. B++ or B- for the B category, and the border of the rating $ScoreBorder$, i.e. the top and the bottom 25% estimated rating score in each rating grade. The interpretation of a positive and significant coefficient of the triple interaction terms is that firms at the rating border overcome the downgrade pressure better than those which are not on the border.

The summary statistics of the indicators are reported in Table 2 Panel III. On average, 37% of firms were in the border regions (++ or -) of the wider rating grades A, B, C or D, and 35% were more specifically rated A- or B++ the previous year. By definition 50% of firms were in the top or bottom quantile of their narrow rating notch both in 2004 and in each previous year.

The results of the estimations for the three definitions of the border variable dummy are reported in Tables 14, 15, and 16. The estimation results provide some evidence that firms starting from one of these more rating-critical positions managed to be downgraded less. However, the evidence is not robust to including firm fixed effects. Hence, we conclude that such differential incentives alone did not suffice to change the fact that more NatCat exposure per se increased the downgrade pressure.

7 Evaluating the adjustment channels post Katrina

In this section, we analyze whether and how insurers changed their capital and risk management in response to the more stringent rating scale and the Katrina hurricane season losses. We start by evaluating the changes in the overall level of capitalization, measured by the regulatory capital score RBC and the rating agency capital score BCAR. Then we investigate several plausible adjustment channels including the capital issuance and dividend policy, the riskiness of insurers investment portfolio, the risk transfer to reinsurers and the adjustment of the NatCat exposure in insurers' liability portfolio.

7.1 Methodology

Using the annual data for 2001-2008, we estimate the equation:

$$Outcome_{it} = \beta_1(Post \times Treatment_{it}) + \gamma X_{it} + v_i + \tau_t + \varepsilon_{it}, \tag{12}$$

where the $Outcome$ is one of the adjustment channels specified below and the $Treatment$ is either the exposure to Katrina-affected areas $PCAT$ or the insurer's downgrade pressure arising from the rating scale change $PDGs$ or the change in its financial strength characteristics $PDGx$. A vector X_{it} denotes characteristics for an insurer i in year t. The terms v_i and τ_t denote insurer- and time-fixed effects. The term ε_{it} is the idiosyncratic noise term. Out main interest is the coefficient β_1 which evaluates whether treated firms adjusted their corporate policy differently compared to the control group of untreated firms. The summary statistics of the outcome variables are reported Table 2 Panel IV. We estimate two model specifications, the linear probability model and the Logit model.

7.2 Risk-based capital

The rating standard change and the capital depleted to pay Katrina losses entailed the need to hold more capital for catastrophe exposures. Hence we start the analysis of the response of the insurance industry to 2005 hurricane season by evaluating the changes in the overall capitalization of NatCat exposed insurers. We consider two risk-based measures of capitalization, the Risk Based Capital ratio RBC used by the insurance regulators for setting the minimum capital requirements and the $BCAR$ score calculated by the A.M. Best and used for rating assignment. Though the two scores are calculated using the same principles, the main distinction between the regulatory and the rating agency approaches relevant for our analysis lies in their treatment of the NatCat exposures. As mentioned above, while A.M. Best responded to Katrina 2005 events by imposing a second stress test to the $BCAR$ score from early 2006, the NAIC introduced the NatCat exposure stress test for the RBC ratio only in 2013.

Table 17 presents the results of the estimation of the adjustment of the risk based capital for $PCAT$ exposed insurers. Columns (1)-(3) of Table 17 report the estimation results for the $BCAR$ score and columns (4)-(6) report the results for the RBC ratio. The results show a weak response of the BCAR of Katrina-affected insurers. The coefficient of the interaction term $Post \times PCAT$ is significant at 10% level only in one specification reported in Column (3) that includes both insurer- and year-fixed effects and a full set of additional controls. By contrast, the response of the RBC ratio reported in Columns (4)-(5) is positive and statistically significant at 5% or 1% level across all three specifications. That is, while insurers with PCAT exposure improved their regulatory capital score RBC, there is only weak evidence that increased their BCAR calculated by A.M. Best.

The difference in treatment of NatCat by A.M. Best and the regulators reconciles the inconsistency between the BCAR and RBC responses. Higher sensitivity of BCAR to NatCat exposures implies that the same risk reduction or capital adjustment by an insurer with NatCat exposures would lead to a weaker effect on its BCAR score than on its RBC score. For these reasons, the improvements in the RBC ratios of NatCat exposed insurers cannot be interpreted as stronger risk-based capital ratios for the insurance industry on average. Rather, they indicate the flexibility to improve the regulatory capital while maintaining the same NatCat exposure. In the unreported results, we also estimate whether the overall capitalization adjustments was different for commercial and personal insurers using the triple interaction regressions, and we do not find any significant difference in

	(1) Rating	(2) Rating	(3) Rating	(4) Rating	(5) Rating
Post × PCAT	-0.753**	-0.356**	-0.328**	-0.440*	-0.718*
	(0.351)	(0.155)	(0.149)	(0.240)	(0.433)
Post × PCAT × I(Scoreborder)	0.418	-0.059	-0.114	-0.016	-0.151
	(0.540)	(0.206)	(0.190)	(0.357)	(0.715)
Post × I(Scoreborder)	-0.147**	0.015	0.016	-0.057	-0.091
	(0.066)	(0.038)	(0.036)	(0.043)	(0.077)
PCAT × I(Scoreborder)	-1.335**	-1.263**	-1.162**	-0.787*	-1.276
	(0.579)	(0.554)	(0.532)	(0.421)	(0.813)
Post	0.173***			-0.118***	-0.210***
	(0.040)			(0.026)	(0.046)
PCAT	0.749			0.297	0.591
	(0.460)			(0.307)	(0.514)
I(Scoreborder)	0.166**			0.003	-0.019
	(0.084)			(0.060)	(0.108)
Investment Yield			0.006	0.030**	0.064**
			(0.005)	(0.014)	(0.032)
Combined Ratio			0.001***	-0.000	-0.001
			(0.000)	(0.000)	(0.001)
Premium/Surplus			-0.006	0.056***	0.094***
			(0.009)	(0.009)	(0.015)
Net Premium Growth			0.000	0.000**	0.000**
			(0.000)	(0.000)	(0.000)
Reins Recov / Surplus			-0.001**	-0.003***	-0.005***
			(0.000)	(0.000)	(0.001)
Reserves/Surplus			-0.002***	-0.003***	-0.006***
			(0.000)	(0.000)	(0.001)
BCAR			0.001***	0.002***	0.003***
			(0.000)	(0.000)	(0.000)
Ln(Assets)			0.385***	0.392***	0.695***
			(0.058)	(0.021)	(0.038)
I(Public)				0.635***	1.187***
				(0.073)	(0.134)
I(Single)				-0.234***	-0.356***
				(0.071)	(0.128)
Constant	10.355***	10.577***	6.106***		
	(0.066)	(0.029)	(0.662)		
Observations	8,887	8,887	8,887	8,887	8,887
R^2	0.007	0.030	0.084		
Method	LPM	LPM	LPM	OProbit	OLogit
Firm FE	No	Yes	Yes	No	No
Year FE	No	Yes	Yes	No	No

Table 17: *PCAT Effects on Firms Previously in the Top or Bottom 25% of their Rating Notch Score*

Note: I(Scoreborder) takes value 1 if the firm was in top or bottom 25% of the score underlying its rating notch in the previous year. Results similar if measuring border status in 2003 only. Definitions of all other variables as before. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

their responses.

These findings are consistent with the interpretation that initially commercial insurers were better prepared to sustain extreme events and the rating standard change than personal insurers. Personal insurers managed to improve the regulatory RBC ratios but these capital and risk management adjustments were not sufficient to alleviate the rating downgrade pressure under the new rating standard and rating agency BCAR ratios.

7.3 NatCat exposures

Reducing the exposure to NatCat lines of business by shifting to other geographic areas or refocusing the business on other lines of insurance not exposed to NatCat is another possible channel of adjustment. Certainly, insurers flexibility to adjust their liability portfolios along these dimensions can be limited by several factors. Other market segments may require a different type of expertise and be highly competitive to enter. Also, after the hurricane season, insurers have less capital to invest to enter new markets. Consistent with these arguments, the summary statistics Tables 2 and 3 show that most variation in regional exposures is between rather than within firms. That is, firms tend to maintain their business profile over time. Nonetheless, given the magnitude of the 2005 hurricane season and the followed rating standard change, it is plausible to expect some major revisions of insurers' liability portfolios. To assess the regional distribution of NatCat exposures by Katrina-affected insurers, we consider an outcome variables which measure exposures in various regions, and estimate whether Katrina-affected insurers changed their exposures differently than the control group.

The results of the baseline estimation are reported in Table 18. We find that overall insurers with NatCat exposure did not significantly change their regional exposures compared to the control group. The two exceptions are a small decrease in the Caribbean exposure (significant at 10%) and a small increase to Tornado-exposed regions (significant at 1%). However, when we distinguish between responses of personal and commercial insurers, we find that the results of the baseline estimation obtain due to the countervailing behavior of commercial and personal insurers. In Table 19, we report the estimation of the regional exposure responses using the triple interaction regression. Remarkably, we find that commercial insurers have decreased their exposure to the highest hurricane risk Florida region and increased their exposures to several other regions including Earthquake, North East, and Tornado regions compared to personal insurers. The divergent behavior between the two groups contributed to the differences in the downgrade pressure after the hurricane 2005 season between personal and commercial insurers.

Part (A)	(1) EQ	(2) EQ	(3) EQ	(4) CAR	(5) CAR	(6) CAR
Post × PCAT	0.001	-0.001	0.001	-0.002*	-0.001	-0.001
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
Post	-0.001	-0.000	-0.001	0.001*	0.000	0.001
	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
PCAT	-0.054***			-0.011***		
	(0.010)			(0.003)		
Constant	0.056***	0.052***	0.016	0.006***	0.006***	0.014**
	(0.004)	(0.000)	(0.039)	(0.002)	(0.000)	(0.007)
Observations	9,617	9,617	9,507	9,617	9,617	9,507
R^2	0.004	0.000	0.005	0.001	0.001	0.005
Firm & Year FE	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes
	FL	FL	FL	Gulf	Gulf	Gulf
Post × PCAT	0.024	0.002	0.008	-0.021	-0.007	-0.007
	(0.035)	(0.015)	(0.011)	(0.035)	(0.016)	(0.016)
Post	-0.001	-0.000	-0.000	0.002	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
PCAT	0.353***			0.589***		
	(0.060)			(0.061)		
Constant	0.003	0.026***	0.026	0.003	0.040***	0.009
	(0.002)	(0.000)	(0.041)	(0.002)	(0.000)	(0.024)
Observations	9,617	9,617	9,507	9,617	9,617	9,507
R^2	0.340	0.000	0.005	0.543	0.001	0.005
Firm & Year FE	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes

Part (B)	(1) NE	(2) NE	(3) NE	(4) SE	(5) SE	(6) SE
Post × PCAT	0.010	0.010	0.005	-0.002	-0.004	-0.005
	(0.010)	(0.013)	(0.009)	(0.006)	(0.004)	(0.004)
Post	0.001	0.001	0.002	0.001	0.003***	0.003***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
PCAT	-0.146***			-0.007		
	(0.014)			(0.010)		
Constant	0.106***	0.096***	0.125***	0.038***	0.037***	0.043*
	(0.007)	(0.001)	(0.040)	(0.003)	(0.000)	(0.026)
Observations	9,617	9,617	9,507	9,617	9,617	9,507
R^2	0.013	0.001	0.003	0.000	0.003	0.008
Firm & Year FE	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes
	TO	TO	TO	TY	TY	TY
Post × PCAT	0.019***	0.002	-0.000	0.001	0.002	0.001
	(0.007)	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)
Post	-0.009***	-0.005***	-0.003*	-0.000	-0.001	-0.000
	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
PCAT	-0.148***			-0.005*		
	(0.015)			(0.002)		
Constant	0.134***	0.123***	0.167***	0.003**	0.003***	0.030
	(0.007)	(0.001)	(0.051)	(0.001)	(0.000)	(0.026)
Observations	9,617	9,617	9,507	9,617	9,617	9,507
R^2	0.013	0.003	0.009	0.000	0.000	0.005
Firm & Year FE	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes

Table 18: *Geographical Distribution Responses*

Note: Outcomes are the shares of DPW going respectively to regions exposed to Earthquakes (EQ), Carribbean (CAR), Florida (FL), Gulf, Northeast (NE), Southeast (SE), Tornados (TO) or Typhoons (TY). Other definitions as above. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	(1) Ret. Ratio	(2) Ret. Ratio	(3) Ret. Ratio
Post × PCAT	-5.187*	-6.526***	-3.948**
	(2.988)	(2.215)	(2.001)
Post	0.053		
	(0.538)		
PCAT	-12.977***		
	(3.664)		
Investment Yield			0.251**
			(0.101)
Combined Ratio			-0.024***
			(0.005)
Premium/Surplus			-3.339***
			(0.370)
Net Premium Growth			0.016***
			(0.002)
Reserves/Surplus			0.069***
			(0.006)
BCAR			0.003
			(0.004)
Ln(Assets)			6.981***
			(1.083)
Constant	61.562***	60.443***	-18.207
	(0.759)	(0.391)	(12.567)
Observations	11,190	11,190	11,044
R^2	0.011	0.005	0.170
Method	LPM	LPM	LPM
Firm & Year FE	No	Yes	Yes

Table 19: *Reinsurance Responses*

Note: The outcome Retention Ratio is the fraction of premiums and risk retained on the firm's own balance sheet, i.e. not reinsured. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

7.4 Reinsurance

Reinsurance is an essential risk-sharing mechanism in the insurance industry. It involves the transfer of risk by insurers to other insurers or reinsurers which are specialized intermediaries that facilitate risk transfer between insurers. Shifting a part liability exposure to reinsurers allows insurers to reduce the volatility of incurred losses. In case of non-proportional reinsurance, i.e. an option-type contract which is in the money if the losses exceed a specified amount, reinsurance reduces the exposure to extreme events, e.g. Froot

(2008). To assess whether insurers transferred more risk to reinsurers in response to 2005 events and to protect their ratings, we analyze the changes of the insurers' retention ratio. The retention ratio, $Ret\ Ratio_{it}$, is defined as the ratio of the Net Premiums Written to the Direct Premiums Written. It measures the percentage of the liability exposure that an insurer retains on its books. A lower retention ratio means that an insurer transfers more risks to reinsurers.

	(1) I(Issuance)	(2) I(Issuance)	(3) I(Issuance)	(4) I(Issuance)	(5) I(Div Cut)	(6) I(Div Cut)	(7) I(Div Cut)	(8) I(Div Cut)
Post × PCAT	0.002	0.178	0.007	0.173	-0.019	-0.244	-0.001	-0.017
	(0.030)	(0.361)	(0.030)	(0.371)	(0.036)	(0.312)	(0.034)	(0.327)
Investment Yield			0.002	0.026			-0.005*	-0.036
			(0.003)	(0.023)			(0.002)	(0.023)
Combined Ratio			0.000**	0.005***			0.000	-0.000
			(0.000)	(0.001)			(0.000)	(0.001)
Premium/Surplus			0.002	0.027			0.004	0.039
			(0.003)	(0.037)			(0.003)	(0.035)
Net Premium Growth			0.000***	0.001**			0.000***	0.002***
			(0.000)	(0.000)			(0.000)	(0.000)
Reins Recov / Surplus			0.000	-0.000			-0.000	-0.000
			(0.000)	(0.001)			(0.000)	(0.001)
Reserves/Surplus			0.000	0.001			0.000*	0.003**
			(0.000)	(0.001)			(0.000)	(0.001)
BCAR			-0.000	-0.001**			0.000	-0.000
			(0.000)	(0.001)			(0.000)	(0.000)
Ln(Assets)			0.075***	0.541***			-0.059***	-0.606***
			(0.016)	(0.137)			(0.014)	(0.140)
Constant	0.001		-0.888***		1.014***		1.673***	
	(0.005)		(0.181)		(0.005)		(0.157)	
Observations	11,190	4,581	11,044	4,506	11,190	10,886	11,044	10,634
R^2	0.040		0.049		0.462		0.481	
Method	LPM	Logit	LPM	Logit	LPM	Logit	LPM	Logit
Firm & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	(9) I(Div=0)	(10) I(Div=0)	(11) I(Div=0)	(12) I(Div=0)
Post × PCAT	0.067*	1.065***	0.066*	1.044***
	(0.038)	(0.346)	(0.037)	(0.362)
Investment Yield			-0.015***	-0.109***
			(0.003)	(0.026)
Combined Ratio			0.000	0.002*
			(0.000)	(0.001)
Premium/Surplus			0.003	0.015
			(0.004)	(0.039)
Net Premium Growth			0.000*	0.001
			(0.000)	(0.000)
Reins Recov / Surplus			0.000	-0.000
			(0.000)	(0.001)
Reserves/Surplus			-0.000	-0.001
			(0.000)	(0.001)
BCAR			-0.000	-0.002***
			(0.000)	(0.001)
Ln(Assets)			-0.004	-0.089
			(0.017)	(0.134)
Constant	0.744***		0.861***	
	(0.008)		(0.193)	
Observations	11,190	4,476	11,044	4,344
R^2	0.021		0.028	
Method	LPM	Logit	LPM	Logit
Firm & Year FE	Yes	Yes	Yes	Yes

Table 20: *Capital Policy Responses*

Note: I(Issuance) = 1 if capital increased by >=2% year-on-year. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results of the estimation of the reinsurance policy responses are presented in Table 20. The estimation of the main specification of the model with firm controls and fixed effects is reported in Column (3). It shows that the interaction term $Post \times PCAT$ is negative and significant at the 5% level. The estimation of the specification with the interaction term and firm- and year fixed effects reported in Column (2) is also negative and significant at the 1% level. The estimated coefficients of these models show that the Katrina-affected insurance increased the reinsurance coverage by about 4%-7%. The baseline specification without fixed effects is also negative and significant at the 10% level. Jointly, the estimation reported in Table 20 shows that post-Katrina insurers responded to the growing NatCat risks by increasing the reliance on reinsurance. In unreported estimation, we also explore to which extent the intensity of this channel was different for commercial and personal insurers, and we do not find that the behavior of the two groups was significantly different.

7.5 Capital policy

Property-casualty insurers accumulate capital mainly through retained earnings or investment income. The two important elements of their capital policy are new capital issuance and, for insurers organized as stock companies, dividend cuts. To construct measures of capital issuance, we follow the approach of Berry-Stölzle et al. (2014) and the capital structure literature, e.g. Hovakimian et al. (2001), Korajczyk & Levy (2003) and Leary & Roberts (2005). In particular, the outcome variable $I(Issuance)_{it}$ is the indicator variable equal to one if the amount of new paid-in capital and new surplus notes[6] of an insurer i in year t, normalized by total capital and surplus of the previous year, exceeds 2%. As Berry-Stölzle et al. (2014), the amount of new paid-in capital is calculated using the sum

[6]Surplus notes is a form of subordinated debt often used by mutual insurers that do not have direct access to external capital market. Limited access to capital market is the main driver of the demutualization, i.e. the trend of mutual companies to convert to stock companies, as discussed in Viswanathan & Cummins (2003).

of operations of the NAIC filings.[7]

For stock insurers, the dividend payment to shareholders is an important element of capital policy. Cutting dividends after a major loss can help to recoup the depleted capital. In order to investigate this channel, we define two indicator variables related to dividend policy of stock insurers. A variable $I(Div\ Cut)_{it}$ is an indicator variable equal to one if insurer i decreases dividends paid in year t compared to year $t-1$ and the insurer paid positive dividends in year $t-1$. A variable $I(Div = 0)_{it}$ is an indicator variable equal to one if insurer i pays no dividends in year t, regardless of its dividend payment in the previous year.

Table 21 reports the results of the estimation for the capital policy outcomes. We do not find strong responses via capital issuance or dividend cuts. The only significant response of Katrina-affected insurers is an increase in the propensity to pay zero dividends by about 7% for a firm with maximum exposure to Katrina-affected regions, as reported in Columns (9) and (11). Overall, the results reported in Table 21 suggest that there was limited adjustment of the capital policy by insurers. In unreported estimations, we extend the analysis by including a triple interaction term with an indicator $I(Comm)$ for commercial insurers, and find that there is no significant differential response between the two segments.

[7]New paid-in capital equals to the sum of "50.1 Capital changes paid in" and "51.1 Surplus adjustments paid in" minus increases in "45 Changes in treasury stock." Surplus notes are reported in "48 Changes in surplus notes."

	(1) BCAR	(2) BCAR	(3) BCAR	(4) RBC	(5) RBC	(6) RBC
Post × PCAT	-2.643	4.734	20.433*	705.919**	668.621**	750.805***
	(20.830)	(16.876)	(12.353)	(320.523)	(260.899)	(231.213)
Post	33.966***			93.983*		
	(3.186)			(47.928)		
PCAT	21.370			431.685		
	(20.042)			(294.649)		
Investment Yield			1.396**			-6.425
			(0.658)			(8.640)
Combined Ratio			-0.005			-0.760
			(0.032)			(0.839)
Premium/Surplus			-4.929***			-66.079**
			(1.184)			(26.553)
Net Premium Growth			-0.044*			-0.280
			(0.024)			(0.271)
Reins Recov / Surplus			-0.168***			-2.077***
			(0.031)			(0.450)
Reserves/Surplus			-0.478***			-3.985***
			(0.063)			(0.727)
Ln(Assets)			16.307***			-455.157***
			(5.033)			(106.926)
Constant	227.010***	41,581.682***	105.001*	1,224.429***	-168,786.746***	7,295.403***
	(3.847)	(4,277.234)	(59.328)	(53.095)	(59,933.965)	(1,278.945)
Observations	11,190	11,084	11,044	11,067	10,963	10,921
R^2	0.012	0.050	0.095	0.008	0.013	0.084
Method	LPM	LPM	LPM	LPM	LPM	LPM
Firm & Year FE	No	Yes	Yes	No	Yes	Yes

Table 21: *BCAR and RBC Responses*

Note: Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In sum, the estimation results in Tables 17 and 21 suggest that the Katrina-affected insurers improved their RBC ratios. However, the change in their risk based capital did not occur via the capital policy channel of issuing new capital or cutting dividends. In interpreting these findings, it is necessary to consider the analysis reported in Section 6.3 which reveals that the rating downgrade pressure was concentrated in the personal insurance segment. Given that these insurers are smaller, have a weaker initial rating and belong to smaller insurance groups, issuing new capital or cutting dividends could be costlier for these firms. At the same time, the commercial insurers affected by Katrina had a higher initial level of capital in the Pre period and thus were better prepared to sustain the extreme losses and to maintain the rating under the updated rating scale. Thus for neither market segment we observe a significant change in their capital policy.

7.6 Asset quality

Investment returns are a valuable source of income to fund insurers' operations and liabilities. We explore whether and how insurers adjust their asset allocation in response to the rating downgrade pressure after 2005 hurricane season. In particular, we analyze whether insurers decrease the risk of their asset portfolio by reducing their exposure to lower rated bonds in the bond portfolio and by reducing the holdings of stocks in the investment portfolio. To measure the risk of the bond portfolio, we consider the share of low-rated bonds to all bond holdings and the share of low-rated bonds to capital and surplus of insurer i in year t. We use the Securities Valuation Office (SVO), a department in the NAIC, six grade classification of bonds and follow their guidelines and classify bonds rated 3-6 as lower rated/risky. In addition, we consider a share of stocks in unaffiliated investments and a share of preferred stocks in affiliated investments as two outcome variables measuring the exposure to stocks relative to exposure to bonds. The four outcome variables are obtained directly from the annual regulatory filings of insurers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(Low-Rated Bonds) / (Bonds)			(Low-Rated Bonds) / (C & S)			Stocks / (UAI)		
	PCAT	PDGs	PDGx	PCAT	PDGs	PDGx	PCAT	PDGs	PDGx
Post × Treatment	-0.060	0.779*	0.998**	-0.368	0.973**	0.973**	-1.631**	1.738**	1.144
	(0.342)	(0.448)	(0.459)	(0.446)	(0.427)	(0.465)	(0.766)	(0.861)	(0.899)
Constant	0.968	-4.035	-4.467	-2.507	-10.910**	-11.281***	-6.129	-6.250	-6.552
	(2.946)	(2.902)	(2.906)	(4.519)	(4.265)	(4.276)	(7.113)	(7.900)	(7.881)
Observations	11,237	9,416	9,416	11,283	9,436	9,436	11,283	9,436	9,436
R^2	0.014	0.016	0.016	0.055	0.069	0.069	0.042	0.046	0.045
Firm & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Full Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 22: *Asset Quality Responses*

Note: "UAI" are unaffiliated investments. All other definitions as above. Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

As for the measures of treatment intensity, we consider $PCAT$, $PDGs$ and $PDGx$ to investigate whether the response was robust across these sources of downgrade pressure.

The results of the estimation are presented in Table 22. Columns (2) and (4) show that the scale-based downgrade pressure $PDGs$ motivates insurers to reduce investment in risky bonds scaled either by the size of the bond portfolio or by the capital and surplus amount. However, the response is not significant for the other two measures of treatment intensity, $PCAT$ and $PDGx$. Furthermore, in Column (10) we find that the exposure to Katrina-affected regions $PCAT$ prompts insurers to reduce their investments in common stocks. By contrast, changes in preferred stock investments reported in Columns (7)-(8) are not significant. However, since common stocks account for most stock investments the change in common stocks translates also into a significant reduction in total stock investments (for brevity, the results are not displayed). Overall, these results provide some evidence that insurers with higher downgrade pressure due to $PCAT$ or $PDGs$ have reduced the risk of their asset portfolio. This is consistent with the analysis of Ge & Weisbach (2021) who find that insurers that are more financially constrained due to their operating losses shift towards safer bonds.

Table 23 investigates whether asset quality responses differ between personal and commercial insurers. For this purpose, we estimate the model with a triple interaction $Post \times Treatment \times I(Comm)$. While some differences are statistically significant when we either drop all fixed effects or do not cluster standard errors by firm, differences cease to exist with fixed effects and clustering. This remains the case also when we balance the sample to make cluster size more homogeneous, or when we bootstrap standard errors. Following Bertrand et al. (2004) and given a large number of clusters, clustering seems more appropriate and so we conclude that the two types of firms are not found to differ in terms of asset side responses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	(Low-Rated Bonds) / (Bonds)			(Low-Rated Bonds) / (C & S)			Stocks / (UAI)		
	PCAT	PDGs	PDGx	PCAT	PDGs	PDGx	PCAT	PDGs	PDGx
Post × Treat	0.116	1.077*	1.033	-0.336	1.316*	1.085	-2.166**	1.196	0.769
	(0.428)	(0.630)	(0.629)	(0.563)	(0.677)	(0.676)	(0.926)	(1.349)	(1.366)
Post × Treat × I(Comm)	-0.289	-0.331	0.164	0.112	-0.530	-0.164	1.918	1.131	0.759
	(0.688)	(0.900)	(0.904)	(0.810)	(0.852)	(0.902)	(1.623)	(1.682)	(1.745)
Post × Comm	0.282*	0.365	0.278	0.124	0.251	0.139	0.001	-0.036	0.034
	(0.170)	(0.245)	(0.199)	(0.200)	(0.270)	(0.230)	(0.350)	(0.429)	(0.368)
Treat × I(Comm)	0.090	-1.114	-0.556	-0.773	-1.069	0.495	-0.699	1.918	3.245
	(0.915)	(1.040)	(1.239)	(1.222)	(1.206)	(1.551)	(1.875)	(2.010)	(2.250)
Constant	1.445	-3.475	-3.978	-2.312	-10.598**	-11.098**	-6.289	-6.053	-6.632
	(3.063)	(3.003)	(3.008)	(4.623)	(4.339)	(4.399)	(7.168)	(7.978)	(7.915)
Observations	11,237	9,416	9,416	11,283	9,436	9,436	11,283	9,436	9,436
R^2	0.014	0.017	0.017	0.055	0.069	0.069	0.042	0.046	0.046
Firm & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Full Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 23: *Asset Side Responses by Commercial vs. Personal Policy Sellers*

Note: Standard errors in parentheses clustered by firm. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

8 Long term effects

Our final analyses concerns the long term effects of the rating standard change on the behavior of commercial and personal insurers. The objective is to evaluate whether the rating standard change by A.M. Best disciplined the risk management of insurers and improved the resilience of the insurance industry. For this purpose, we estimate how insurers loss ratios of the insurers has changed in the long run in response to the downgrade pressure in 2006.

Data. We use that data at firm*year level for years 2001-22. The outcome variable is the loss ratio. We include a set of explanatory variables of interest. The first is an indicator for whether the firm's rating in 2004 was on a rating border, i.e. whether it was a "++" or "-". The second is an indicator for whether the firm was focused on commercial policies. The third is an indicator for whether the firm's 2004 rating was on the investment grade border, i.e. rated B++ or A-. The fourth is an indicator for firms who in 2004 were in terms of the underlying continuous rating score rated in the top or bottom quartile of whatever their grade.

Methodology. We regress the loss ratio, as a proxy for the firm's risk exposure on the three different measures of the downgrade pressure in 2006 and the interactions with the indicators for commercial and private insurers. We also consider different period subsambples and a set of year fixed effects.

Results. Being on a rating border or on an investment grade border is associated with the firm experiencing a lower loss ratio. But across both rating dummies and across all specifications this is only for those firms focused on commercial clients, not for those focused on personal clients.

	Loss Ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
I(Border in 2004)	-0.93			0.50		
	(1.41)			(1.82)		
I(Comm)	-10.46***	-10.04***	-13.87***	-7.75***	-7.61***	-13.42***
	(0.88)	(0.87)	(1.00)	(1.13)	(1.12)	(1.28)
I(Border in 2004)*I(Comm)	-6.79***			-9.74***		
	(1.54)			(1.98)		
I(IG Border in 2004)		0.91			2.71	
		(1.42)			(1.84)	
I(IG Border in 2004) *I(Comm)		-8.75***			-11.20***	
		(1.55)			(2.00)	
I(Score Border in 2004)			-0.87			-1.45
			(1.38)			(1.77)
I(Score Border in 2004) * I(Comm)			-1.24			-0.91
			(1.52)			(1.95)
Constant	53.54***	52.98***	56.77***	50.69***	50.03***	56.87***
	(0.79)	(0.78)	(0.92)	(1.01)	(1.01)	(1.18)
Observations	28,380	28,380	24,618	16,770	16,770	14,547
Years	2001-22	2001-22	2001-22	2010-22	2010-22	2010-22
Fixed Effects	None	None	None	None	None	None

	Loss Ratio					
	(7)	(8)	(9)	(10)	(11)	(12)
I(Border in 2004)	4.85			0.50		
	(8.83)			(1.82)		
I(Comm)	-4.02	-4.63	-13.84*	-7.75***	-7.61***	-13.42***
	(5.47)	(5.42)	(5.93)	(1.13)	(1.12)	(1.28)
I(Border in 2004)*I(Comm)	-16.50			-9.74***		
	(9.59)			(1.98)		
I(IG Border in 2004)		7.31			2.71	
		(8.91)			(1.83)	
I(IG Border in 2004) *I(Comm)		-16.34			-11.20***	
		(9.69)			(1.99)	
I(Score Border in 2004)			-4.28			-1.45
			(8.19)			(1.77)
I(Score Border in 2004) * I(Comm)			2.75			-0.91
			(9.02)			(1.94)
Constant	53.40***	52.70***	62.59***	50.69***	50.03***	56.87***
	(4.91)	(4.88)	(5.43)	(1.01)	(1.00)	(1.17)
Observations	1,290	1,290	1,119	16,770	16,770	14,547
Years	2017	2017	2017	2010-22	2010-22	2010-22
Fixed Effects	None	None	None	Year	Year	Year

Table 24: *Loss Ratio Responses*

Note: The outcome is the CatRisk loss ratio at the firm*year level, obtained as the weighted average of all CatRisk loss ratios at the firm*year*state level, weighted with the share of all (all business lines) DPW of that firm*year allocated to each of the 56 states or regions. The border indicator marks firms rated ++ or - in 2004, the IG border indicator marks firms rated more specifically B++ or A- in 2004, and the score border indicator marks firms who in 2004 were in terms of the underlying continuous rating score rated in the top or bottom quartile of whatever their grade. I(Comm) is an indicator for firms selling more than 50% of their policies to commercial clients, as used also in other analyses. Years and fixed effects as indicated at the bottom. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

9 Conclusion

In this paper we explore the effect of more stringent rating standards on firms' strategic choice of capital and risk management. We develop a theoretical framework to show that more stringent rating standards lead to varying reactions driven by the trade-off between the costs and the benefits of defending a rating. We use a natural experiment of the 2005 hurricane seasons that prompted credit rating agencies to increase the stringency of rating standards for catastrophic risks. Consistent with the theoretical framework, the empirical analysis reveals that more stringent standards put no downgrade pressure on well-capitalized commercial insurers that have higher benefits and lower costs of maintaining the rating. At the same time, lower-rated personal insurers experienced a significant downgrade pressure and did not manage to improve their overall capitalization.

The results of the analysis contribute to understanding of the role credit ratings in the insurance industry. We find that rating standards have a significant effect on risk-taking behavior of insurers.

More broadly, our results show that the exact design of public guarantees may shape the extent to which the market disciplines insurers' management of NatCat risks and their choice of financial strength, and therewith their ability to help society cope with the consequences of climate change.

References

A.M. Best. (2011). *A.M. Best Methodology: Catastrophe Analysis in A.M. Best ratings.* (Oldwick, NJ: A. M. Best Company, Inc.)

A.M. Best. (2016). *A.M. Best Methodology: Understanding BCAR For Property/Casualty Insurers.* (Oldwick, NJ: A. M. Best Company, Inc.)

Adelino, M., & Ferreira, M. A. (2016). Bank ratings and lending supply: Evidence from sovereign downgrades. *Review of Financial Studies*, 29(7), 1709–1746.

Azarmsa, E., & Shapiro, J.D. (2023). The Market for ESG Ratings. Available at SSRN: https://ssrn.com/abstract=4236912 or http://dx.doi.org/10.2139/ssrn.4236912

Badoer, D. C., Demiroglu, C., & James, C. M. (2019). Ratings quality and borrowing choice. *Journal of Finance*, 74(5), 2619-2665.

Berg, F., Kölbel, J.F., & Rigobon, R. (2022). Aggregate Confusion: The Divergence of ESG Ratings. Review of Finance, 26(6), 1315–1344. https://doi.org/10.1093/rof/rfac033

Berry-Stölzle, T. R., Nini, G. P., & Wende, S. (2014). External financing in the life insurance industry: Evidence from the financial crisis. *Journal of Risk and Insurance*, 81(3), 529-562.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust Differences-in-Differences estimates? *Quarterly Journal of Economics*, 119(1), 249–275.

Chernenko, S., & Sunderam, A. (2012). The real consequences of market segmentation. *Review of Financial Studies*, 25, 2041-2070.

Cornaggia, J., Cornaggia, K. J., & Israelsen, R. D. (2018). Credit ratings and the cost of municipal financing. *Review of Financial Studies*, 31(6), 2038–2079.

Cummins, J. D. (1988). Risk-based premiums for insurance guarantee funds. *Journal of Finance*, 43, 823-839.

Cummins, J. D., & Danzon, P. M. (1997). Price, financial quality, and capital flows in insurance markets. *Journal of Financial Intermediation*, 6, 3-38.

Cummins, J. D., Grace, M., & Phillips, R. (1999). Regulatory solvency prediction in property-liability insurance: risk-based capital, audit ratios, and cash flow simulation. *Journal of Risk and Insurance*, 66, 417-458.

Cummins, J. D., Harrington, S. E., & Klein, R. W. (1995). Insolvency experience, risk-based capital, and prompt corrective action in property-liability insurance. *Journal of Banking and Finance*, 19, 511-527.

Doherty, N. A., Kartasheva, A. V., & Phillips, R. D. (2012). Information effect of entry into credit ratings market: The case of insurers' ratings. *Journal of Financial Economics*, 106, 308-330.

Doherty, N. A., & Schlesinger, H. (1990). Rational insurance purchasing: Consideration of contract nonperformance. *Quarterly Journal of Economics*, 105(1), 243-253.

Downs, D. H., & Sommer, D. W. (1999). Monitoring, ownership, and risk-taking: The impact of guaranty funds. *Journal of Risk and Insurance*, 66(3), 477–497.

Ellul, A., Jotikasthira, C., & Lundblad, C. (2011). Regulatory Pressure and Fire Sales in the Corporate Bond Market. *Journal of Financial Economics*, 101(3), 596-620.

Ellul, A., Jotikasthira, C., Lundblad, C.T., & Wang, Y. (2015). Is Historical Cost Accounting a Panacea? Market Stress, Incentive Distortions, and Gains Trading. The Journal of Finance, 70, 2489-2538. https://doi.org/10.1111/jofi.12357

Ellul, A., Jotikasthira, C., Kartasheva, A., Lundblad, C., & Wagner, W. (2020). Insurers as asset managers and systemic risk. CEPR Working paper no. DP12849.

Epermanis, K., & Harrington, S. E. (2006). Market discipline in property/casualty insurance: Evidence from premium growth surrounding changes in financial strength ratings. *Journal of Money, Credit and Banking*, 38, 1515-1544.

Faulkender, M., & Peterson, M. A. (2006). Does the source of capital affects capital structure? *Review of Financial Studies*, 19, 45-79.

Foley-Fisher, N., Narajabad, B., & Verani, S. (2020). Self-fulfilling Runs: Evidence from the U.S. Life Insurance Industry. *Journal of Political Economy*, 128(9), 3520-3569.

Froot, K. A. (2008). The intermediation of financial risks: Evolution in the catastrophe reinsurance market. *Risk Management and Insurance Review*, 11(2), 281-294.

Froot, K. A. (2007). Risk management, capital budgeting, and capital structure policy for insurers and reinsurers. *Journal of Risk and Insurance*, 74, 273-299.

Froot, K. A., Scharfstein, D. S., & Stein, J. C. (1993). Risk management: Coordinating corporate investment and financing policies. *Journal of Finance*, 48, 1629-58.

Froot, K. A., & Stein, J. C. (1998). Risk management, capital budgeting, and capital structure policy for financial institutions: an integrated approach. *Journal of Financial Economics*, 47, 55-82.

Ge, S. (2022). How do financial constraints affect product pricing? Evidence from weather and life insurance premiums. *Journal of Finance*, 77(1), 449-503.

Ge, S., Lam, A., & Lewis, R. (2022). The Costs of Hedging Disaster Risk and Home Prices in the Face of Climate Change. Available at SSRN: https://ssrn.com/abstract=4192699 or http://dx.doi.org/10.2139/ssrn.4192699

Ge, S., & Weisbach, M. (2021). The role of financial conditions in portfolio choices: The case of insurers. *Journal of Financial Economics*, 142(2), 803-830.

Guy Carpenter. (2005). Shifting winds: A review of recent changes in the direction of modelers and rating agencies. Specialty Practice Briefing, December 2005.

Guy Carpenter. (2006a). Rating agency update: Stepping up to new criteria.

Guy Carpenter. (2006b). The world catastrophe reinsurance market: Steep peaks overshadow plateaus.

Gründl, H., Guxha, D., Kartasheva, A., & Schmeiser, H. (2021). Insurability of pandemic risks. J Risk Insur. 88, 863–902. https://doi.org/10.1111/jori.12368

Hovakimian, A., Opler, T., & Titman, S. (2001). The debt-equity choice. *Journal of Financial and Quantitative Analysis*, 36(1), 1-24.

Ito, H., & McCauley, R. N. (2019). A disaster (re)insurance puzzle: Home bias in disaster risk-bearing. *BIS Working Paper No. 808.*

Insurance Information Institute. (2021). Facts and Statistics: US Catastrophes.

Kisgen, D. J. (2006). Credit ratings and capital structure. *Journal of Finance*, 61, 1035-1072.

Kisgen, D. J., & Strahan, P. E. (2010). Do regulations based on credit ratings affect a firm's cost of capital? *Review of Financial Studies*, 23, 4324-4347.

Koijen, R., & Yogo, M. (2015). The cost of financial frictions for life insurers. *American Economic Review*, 105(1), 445–75.

Koijen, R., & Yogo, M. (2016). Shadow insurance. *Econometrica*, 84(3), 1265-1287.

Korajczyk, R. A., & Levy, A. (2003). Capital structure choice: Macroeconomic conditions and financial constraints. *Journal of Financial Economics*, 68, 75-109.

Kunreuther, H. C., & Michel-Kerjan, E. O. (Eds.). (2009). *At War with the Weather*. MIT Press.

Leary, M. T., & Roberts, M. R. (2005). Do firms rebalance their capital structure? *Journal of Finance*, 60(6), 2575-2619.

National Association of Insurance Commissioners. (2017). NAIC enhances P/C RBC formula for catastrophe risk charges. *NAIC CIPR Newsletter*, August 2017.

Sen, I. (2019). Regulatory Limits to Risk Management. The Review of Financial Studies. Available at SSRN: https://ssrn.com/abstract=3345880 or http://dx.doi.org/10.2139/ssrn.3345880

Sommer, D. W. (1996). The impact of firm risk on property-liability insurance prices. *Journal of Risk and Insurance*, 63, 501-514.

Stulz, R. M. (1990). Managerial discretion and optimal financing policies. *Journal of Financial Economics*, 26, 3-27.

Sufi, A. (2007). The real effects of debt certification: Evidence from the introduction of bank loan ratings. *Review of Financial Studies*, 22, 1659-1691.

Sastry, P., Sen, I., & Tenekedjieva, A.-M. (2023). When Insurers Exit: Climate Losses, Fragile Insurers, and Mortgage Markets. Available at SSRN: https://ssrn.com/abstract=4674279 or http://dx.doi.org/10.2139/ssrn.4674279

Swiss Re. (2019). Indexing resilience: A primer for insurance markets and economics. Swiss Re Institute, Sigma 05/2019.

Swiss Re. (2020). 15 years after Katrina: The tale of the changing risk landscape. Swiss Re Institute, 08/2020.

Tang, T. T. (2009). Information asymmetry and firms' credit market access: Evidence from Moody's credit rating format refinement. *Journal of Financial Economics*, 93(2), 325-351.

Viswanathan, K. S., & Cummins, J. D. (2003). Ownership structure changes in the insurance industry: An analysis of demutualization. *Journal of Risk and Insurance*, 70(3), 401-437.

Appendix

Proof of Proposition 1

By definition, $\alpha_{i+1} - \widehat{q}_{\theta i} = \frac{\pi_\theta(R_{i+1}) - \pi_\theta(R_i)}{C(R_i)}$. Thus conditions $\pi_\theta(R_{i+1}) - \pi_\theta(R_i) \geq \pi_\theta(R_i) - \pi_\theta(R_{i-1})$ and $C(R_{i+1}) < C(R_i)$ imply the monotonicity condition in the first part of the proposition. The second part follows immediately from condition (1) that the marginal profit is increasing in firms' types.

Proof of Proposition 2

Consider the original rating scale. Given the firms' choice of effort, the set of firms rated R_i contains a mass of firms that had the original score $q \in [\widehat{q}_{\theta i-1}, \alpha_i]$ and exerted effort to improve it to α_i. Also it contains firms $q \in [\alpha_i, \widehat{q}_{\theta i}]$ that exert no effort and maintain their score q. Therefore, the average quality of firms with the original score $q \in [\alpha_i, \alpha_{i+1}]$ is

$$\frac{1}{2}(\widehat{q}_{\theta i} + \alpha_i)\frac{\widehat{q}_{\theta i} - \alpha_i}{\alpha_{i+1} - \alpha_i} + \alpha_{i+1}\frac{\alpha_{i+1} - \widehat{q}_{\theta i-1}}{\alpha_{i+1} - \alpha_i}.$$

Note also that rating R_i does not contain any firms with the original score $q \in [\widehat{q}_{\theta i}, \alpha_{i+1}]$ because these firms exert effort to improve their quality to α_{i+1} and obtain a rating R_{i+1}.

Under the new scale, firms in the interval $q \in [\alpha_i, \alpha_{i+1}]$ adjust their effort as explained in Section 2.2, resulting in the average quality equal to

$$\begin{aligned}
&\frac{\alpha_i + \Delta - \alpha_i}{\alpha_{i+1} - \alpha_i}(\alpha_i + \Delta) + \frac{1}{2}(\alpha_i + \Delta + \overline{q}_{\theta i})\frac{\overline{q}_{\theta i} - (\alpha_i + \Delta)}{\alpha_{i+1} - \alpha_i} \\
&+ \frac{\alpha_{i+1} - \overline{q}_{\theta i}}{\alpha_{i+1} - \alpha_i}(\alpha_i + \Delta) \\
&= \frac{1}{2}(\widehat{q}_{\theta i} + \alpha_i)\frac{\widehat{q}_{\theta i} - \alpha_i}{\alpha_{i+1} - \alpha_i} + \alpha_{i+1}\frac{\alpha_{i+1} - \widehat{q}_{\theta i}}{\alpha_{i+1} - \alpha_i}.
\end{aligned}$$

Thus firms with an original score in an internal rating maintain their average quality. Because $\overline{q}_{\theta i} > \widehat{q}_{\theta i}$, less firms in the lowest grade exert the effort.

Additional results on sensitivity of insurance markups and premiums

	Markup				%ΔDPW			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I(Junk Downgrade)	42.307	19.027	2,425.751	2,134.440***	-1.763	-2.172	5.794	5.117***
	(40.066)	(39.288)	(2,286.958)	(350.309)	(5.552)	(1.549)	(5.128)	(1.916)
I(commercial)			-130.927	-133.990***			8.802***	7.230***
			(109.585)	(17.560)			(0.848)	(0.225)
I(comm)*I(Junk DG)			-3,687.598	-3,299.736***			-12.657*	-12.170***
			(3,387.881)	(522.524)			(6.664)	(2.503)
Constant	73.577***	73.069***	161.026**	162.718***	16.704***	16.682***	10.837***	11.865***
	(0.188)	(0.181)	(73.370)	(11.760)	(0.033)	(0.009)	(0.564)	(0.150)
Observations	167,725	166,397	167,725	166,397	747,132	745,286	747,132	745,286
R^2	0.118	0.140	0.124	0.145	0.059	0.116	0.061	0.118
Cross-Sectional FE	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Std. Error Cluster	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State

Table 25: *Response to Downgrades to Junk*

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	Markup				%ΔDPW			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔRBCR	6.570	4.638	24.011	31.025**	-2.200***	-2.147***	-1.772***	-1.669***
	(20.125)	(3.234)	(99.756)	(15.394)	(0.427)	(0.113)	(0.549)	(0.159)
I(commercial)			-150.185	-152.755***			12.569***	11.952***
			(125.287)	(20.411)			(1.038)	(0.257)
I(comm)*ΔRBCR			-33.176	-47.594*			-0.619	-0.700***
			(161.461)	(25.187)			(0.694)	(0.191)
Constant	75.788***	74.280***	176.244**	176.220***	6.845***	6.899***	-1.528**	-1.060***
	(1.007)	(0.164)	(83.674)	(13.617)	(0.062)	(0.016)	(0.689)	(0.172)
Observations	137,409	136,092	137,409	136,092	817,500	815,939	817,500	815,939
R^2	0.113	0.114	0.114	0.115	0.068	0.125	0.072	0.128
Cross-Sectional FE	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Std. Error Cluster	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State	Firm	Firm*State

Table 26: *Response to RBCR Levels Changes*

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.