Real Effects of Changing Rating Standards for Catastrophic Risks*

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Abstract

The paper analyzes how the standards employed by the rating agencies affect the behavior of firms. In the aftermath of hurricane Katrina in 2005, the major rating agencies have increased the amount of capital that an insurer selling coverage for catastrophic events needs to hold to maintain its current rating. In this paper we demonstrate, theoretically and empirically, that new standards have a heterogeneous effect on the credit quality of insurers. The insurers' choice of capital and targeted rating obtains as a tradeoff between the benefits of higher rating due to the ability to sell insurance at higher price and the cost of raising capital. Thus the decision to maintain the rating depends on the elasticity of demand with respect to credit quality. While insurers facing higher elasticity of demand and lower cost of capital improve their credit quality, the others find the standard too costly, accept the downgrade and become more risky.

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1 Introduction

In this paper we analyze the link between the standards used by the rating agencies to assign the ratings and the behavior of firms. In the aftermath of hurricane Katrina the major rating agencies has increased the amount of capital that insurers necessary to satisfy a given credit rating. Have the new standards decreased the insurers insolvency risk? We show that they produced a heterogeneous effect. While some insurers increase the amount of capital and improve the credit quality, others find the new standard too costly. In the later case the insurers either reduce the exposure to catastrophic risk by selling fewer policies, or reduce the capital and become more risky.

In order to understand the impact of new standards on the capital structure choices of companies, we build a model that derives the optimal targeted rating for the insurance firm. The unique feature of an insurance policy is that insurance buyers care about the credit risk of the insurer and are willing to pay a higher price for the policy that has lower risk. The buyer uses the credit rating of the insurer to assess its financial strength. Holding more capital increases the credit rating and allows charging higher prices. The amount of capital needed to satisfy a particular rating standard depends on the volatility of insurer's liabilities. Since capital is costly, more volatile companies are more likely to admit lower rating. Ultimately, the capital structure decision depends on the cost of capital and the elasticity of aggregate demand for insurance with respect to financial quality.

Since the rating agency pools heterogeneous companies in one rating grade, the new standard will have asymmetric effect on companies with the same credit rating. For companies close to the lower boundary of the rating bin the new standard is binding and they need to raise more capital to maintain it. At the same time, companies on the top of the rating bin do not need to adjust their capital structure to maintain the rating. If the cost of raising new capital is too high relative to the benefits of maintaining the same rating under more stringent standards, the firm is better off admitting the rating downgrade and reducing the amount of capital.

We use the theory to empirically investigate the reaction of insurers to the change of the rating criteria after 2004-2005 hurricane seasons. The main hypothesis that follows from the theoretical analysis is that companies have an asymmetric reaction to new standards. The closer is the insurer to the lower boundary of the rating, the more likely it is to increase the amount of capital to maintain the current rating. At the same time, the decision to maintain the rating depends on the elasticity of demand with respect to credit quality. The results support the main hypothesis. Insurers that are close to the lower boundary of a given rating standard have increased their capital more compared to insurers close to the higher boundary of the standard. Also the behavior changes across the rating categories. Companies with higher ratings were more likely to increase the amount of capital relative to companies with lower ratings. Also the propensity to defend the rating is higher form insurers selling commercial insurance that has higher sensitivity of demand to credit risk. The difference in firm's behavior is especially pronounced around the A- rating which is viewed as an "investment grade" analog in insurance.

Overall, our results suggest that the standards used by the credit agencies have an important effect on firms' capital structure and pricing decisions. At the same time, tighter standards need not imply higher credit quality for all companies and thus lead to an ambiguous aggregate effect.

The rest of the paper is organized as follows. In the next section we analyze the model of pricing, capital and rating decisions of a firm. We use the model to derive the reaction of the industry to new standards in Section 3. Section 4 discusses the institutional setup and reviews the main changes that have been introduced by major credit rating agencies regarding the capital requirements for catastrophic exposures in 2006. Section 5 provides the econometric analysis of the change in the US property-casualty industry using the data between 2001 and 2008.

2 How do insurers choose a target rating?

2.1 The model

In this section we build a model of insurance pricing that is used to analyze how the rating standard determines the capital structure decisions of the insurance firm. The model is grounded on two basic assumptions. First, buyers of insurance are sensitive to insolvency risk. The higher is the financial quality of the insurance firm, the higher is the price consumers are willing to pay per dollar of insurance. Second, insurance buyers do not directly observe the financial quality of the firm and rely on the insurer's rating to assess its financial strength.

Consider a market with insurance firms, insurance buyers and a rating agency. The insurance firm operates in two periods. In the first period, it faces the demand function $Q(p, R)$, where p is the price charged per one dollar of insurance, $p \geq 1$, and R is the rating. The demand function is assumed to be continuous, decreasing and concave in price, $Q_p < 0$, $Q_{pp} > 0$. The firm sells insurance in the beginning of the period, and pays the realized losses in the end of the period. If realized losses exceed insurer's internal resources, the firm becomes insolvent and is liquidated. If the firm survives till the second period, it obtains the fixed gain G. The value of G summarizes the future growth opportunities of the insurance firm when it remains solvent. For simplicity we assume that the growth opportunities do no depend on firm's decision in the first period.

The insurer's equity is the difference between its assets and liabilities. Assets are composed of the revenue from selling insurance, $pQ(p, R)$ and the capital, K. The liabilities are the payments for insured losses.

Raising capital K reduces the likelihood of insolvency. Normalizing the economy discount rate to zero, the opportunity cost of K units of equity capital is K. However, we assume that there are additional deadweight costs to the insurer's capital. These costs arise from a number of sources. First, they could be due to the direct and indirect costs of bankruptcy and financial distress. Second, such costs could be due to the agency problems between the firm's managers and outside investors. Higher insolvency risk leads to higher deadweight costs. Raising one unit of capital by an insurer with rating R yields $1 - r_R$, $1 < r_R < 1$ units at company's disposal.

The assets of a company that raises K units of capital are

$$A = pQ(p, R) + (1 - r_R)K.$$

The liabilities L are random. The industry is composed of heterogeneous insurance firms that differ with respect to the variance of liabilities. The firms are indexed by type $\theta \in [\underline{\theta}, \overline{\theta}]$.

The liabilities of firm type θ are

$$L_\theta = (1 + v_\theta)Q(p, R).$$

The volatility parameter v_θ is distributed uniformly on an interval $[-\theta, \theta]$. Hence, the expected value of liabilities,

$$E[L_\theta] = E[(1 + v_\theta)Q(p, R)] = Q(p, R),$$

does not depend on firm's type and equals to the amount of sold insurance, $Q(p, R)$. In contrast, the variance of liabilities is unique for each type,

$$Var[L_\theta] = (Q(p, R))^2 E[(v_\theta)^2] = \frac{1}{3}\theta^2(Q(p, R))^2.$$

Higher type θ insurance firm has higher volatility of liabilities. Formally, the random variables $\{v_\theta\}_{\theta \in [0,1]}$ are ordered according to the second order stochastic dominance. That is, for any $\theta_1, \theta_2 \in [\underline{\theta}, \overline{\theta}]$ with $\theta_1 < \theta_2$ and any non-decreasing concave function $U(-L_\theta)$, the following condition is satisfied.

$$\int U(-L_{\theta_1})dv_{\theta_1} \geq \int U(-L_{\theta_2})dv_{\theta_2}.$$

It means that the insurance firm θ_2 is more risky than the insurance firm θ_1. Thus the type θ also refers to the insurer's risk characteristics.

The realized value of equity depends on the distribution of liabilities of type θ,

$$\max\{A - L_\theta, 0\} = \max\{pQ(p, R) + (1 - r_R)K - L_\theta, 0\}.$$

The type θ probability of default can be written as

$$d(\theta) = \Pr(pQ(p, R) + (1 - r_R)K - L_\theta < 0). \tag{1}$$

It implies that the insurer increases its financial strength by holding more capital K. Given the distribution of liabilities of type θ, the probability of default is

$$d(\theta) = \begin{cases} 0 & if \;\; \theta < p - 1 + \frac{(1-r_R)K}{Q(p,R)}, \\ \frac{1}{2}(1 - \frac{1}{\theta}(p - 1 + \frac{(1-r_R)K}{Q(p,R)}) & if \;\; \theta > p - 1 + \frac{(1-r_R)K}{Q(p,R)}. \end{cases}$$

We make a parametric assumption that the lowest risk insurer has a positive probability of default in the absence of capital. That is, if $p_R^* \in \arg\max_p \, (p-1)Q(p, R)$ then $\underline{\theta} > p_R^* - 1$ for all R.

The CRA evaluates insurer's type θ probability of default $d(\theta)$ and assigns it one of the three ratings[1], $R \in \{a, b, c\}$,

$$R = \begin{cases} a \text{ if } d(\theta) < \alpha, \\ b \text{ if } \alpha \leq d(\theta) < \beta, \\ c \text{ if } d(\theta) \geq \beta, \end{cases} \tag{2}$$

where $0 < \alpha < \beta < 1$ are the boundaries of ratings. There are several explanations for coarse information disclosure by credit rating agencies.[2] The focus of this paper is the analysis of the capital structure and pricing decisions for a given rating standard, and hence we treat the rating boundaries α and β as exogenous. Denote ρ the maximum probability of default that permits to obtain rating R, $\rho \in \{\alpha, \beta\}$. The demand function is assumed to be increasing in rating, $Q(p, a) > Q(p, b) > Q(p, c)$ for any $p \geq 1$. The deadweight cost of capital is decreasing in rating, $r_a < r_b < r_c$. The rating fee paid by the insurance firm to the CRA is normalized to zero.

The insurer chooses the price p and the capital K to maximize the expected firm value net of the investment costs K. The two-period profit of the insurer type θ is

$$\begin{aligned} \pi(R) &= E_\theta[\max\{A - L_\theta, 0\}] - K + (1 - d(\theta))G \\ &= \frac{1}{2}(p - 1 + \theta)Q(p, R) - \frac{1}{2}(1 + r)K \qquad (3) \\ &+ \frac{1}{2}G(1 + \frac{1}{\theta}(p - 1 + \frac{(1 - r)K}{Q(p, R)})) \qquad (4) \end{aligned}$$

The expression of the first period expected profit (3) indicates that its higher for higher volatility types θ. Indeed, the limited liability implies that the insurer benefits from volatility. While higher volatility types gain when the realized liabilities are below their expectations, their first period profit never falls below zero when the realized liabilities exceed the assets. As a consequence, in the absence of future profits, $G = 0$, the optimal strategy of the firm is to hold the minimum amount of capital necessary to satisfy a given rating standard. However, when the value of future profits G is substantial, the firm has incentives to hold extra capital in order to

[1] In practice, the major rating agencies use rating scales with 15-18 rating categories. Using three ratings is a simplification that does not affect the qualitative prediction of the model.

[2] Doherty, Kartasheva and Phillips (2010) analyze the optimal rating scale of a monopoly CRA by applying the optimal information disclosure framework developed by Lizzeri (1999). Their explanation of the coarse rating scale is based on the trade-off between the benefits and costs of pooling different types to one rating grade. The benefits are due to the increased willingness to pay of the lowest rated type. The cost of pooling are due to the lower rating precision. Goel and Thakor (2010) develop a dynamic reputation model with cheap talk and show that increasing legal liability for "misrating" leads to more coarse ratings.

decrease the likelihood of insolvency and maximize the second period expected profits (4). Next section derives the optimal choice of capital structure that builds on this trade-off.

2.2 Optimal pricing and capital choice

The rating standard (2) and the insurer's probability of default (1) imply that the minimum amount of capital that an insurer must hold to obtain rating R is defined by the condition $d(\theta) \leq \rho$, or

$$K_R \geq \frac{Q(p,R)}{1-r_R}(\theta(1-2\rho)-(p-1)),\ \ R=a,b,\rho=\alpha,\beta \tag{5}$$
$$K_c \geq 0.$$

The optimal choice of capital and price maximizes the expected value of firm's equity $\pi(R)$ subject to the constraint that firm's rating is R. The properties of the solution are summarized below.

Proposition 1 *The optimal choice of price and capital has a threshold structure. There is a type $\widehat{\theta}_R$ such that lower risk types $\theta < \widehat{\theta}_R$ hold capital above the minimum amount necessary to satisfy the rating requirement. For these types the optimal amount of capital is determined by the trade-off between the marginal cost of capital in the current period and the marginal benefit of higher expected future opportunities due to lower insolvency probability. Higher risk types $\theta > \widehat{\theta}_R$ hold the minimum capital amount necessary to satisfy the rating requirement.*

The optimal price per unit of insurance for lower risk types $\theta < \widehat{\theta}_R$ is implicitly defined by

$$\frac{p-1+[\theta-(\frac{G}{\theta Q})^2\frac{(1-r)^2}{1+r}\frac{1}{(Q(p,R))^2}]}{p} = (-\frac{1}{\varepsilon_p})(1+\frac{G}{\theta Q}), \tag{6}$$

where $\varepsilon_p = Q_p\frac{p}{Q}$ denotes the price elasticity of demand. The optimal price per unit of insurance for higher risk types $\theta > \widehat{\theta}_R$ is implicitly defined by

$$\frac{p-1+[\theta-\frac{1+r}{(1-r)^2}pQ(\theta(1-2\rho)-(p-1))^2]}{p} = (-\frac{1}{\varepsilon_p})(1+\frac{1+r}{(1-r)^2}Q(\theta(1-2\rho)-(p-1))^2). \tag{7}$$

There are two considerations that govern the firm's choice of capital. First, it holds capital in order to satisfy a rating standard implied by R. Second, capital reduces the insolvency risk and thus increases the expected value of future gains. For high volatility firms the first consideration is binding. However, as volatility θ decreases, the second consideration becomes more important, and the firms choose to hold more capital than is required by the rating standard.

The pricing strategy of the firm reflects the interaction between the risk-taking preferences in the current period and the incentives to reduce the insolvency risk to realize future gains. In the absence of future opportunities, $G = 0$, and uncertainly about liabilities, $\theta = 0$, the firm charges a monopolist price where the cost of a unit of insurance is equal to one. If liabilities are uncertain, but there is no future opportunities, limited liability implies that the firm has risk taking preferences. In this case the price is lower than the benchmark price of the monopolist. In the presence of future opportunities and uncertainty of liabilities, the optimal price can be below or above the benchmark depending on the volatility of liabilities, the value of future gains, the cost of capital and the demand for insurance in the current period. The next proposition provides further comparative statics results.

Proposition 2 *The price charged by lower risk types $\theta < \widehat{\theta}_R$ is decreasing in volatility of liabilities, $\frac{dp}{d\theta} < 0$; decreasing in the cost of capital, $\frac{dp}{dr} < 0$; and increasing in the size of the future opportunities, $\frac{dp}{dG} > 0$. The price of the higher risk types $\theta > \widehat{\theta}_R$ is increasing in the cost of capital, $\frac{dp}{dr} > 0$.*

The capital choice of the lower risk types $\theta < \widehat{\theta}_R$ is decreasing in the volatility of liabilities, $\frac{dK}{d\theta} < 0$, decreasing in the cost of capital, $\frac{dK}{dr} < 0$, and increasing in the size of the future opportunities, $\frac{dK}{dG} > 0$.

A firm obtains capital by writing insurance policies and raising equity capital. Increasing cost of capital r makes raising equity capital relatively more costly. Raising capital by writing insurance policies becomes more attractive. If the rating standard constraint is not binding, the price of insurance goes down, $\frac{dp}{dr} < 0$. However, when the rating standard constraint is binding, the price is increasing in the cost of capital in order to reduce the insolvency risk. Higher future profits G increase the incentives to reduce the insolvency risk, and thus increase the price.

2.3 Optimal rating

The optimal targeted rating of type θ is the one that obtains the highest expected payoff,

$$\max_R \pi(R) = \frac{1}{2}(p_R(\theta) - 1 + \theta)Q(p_R(\theta), R) - \frac{1}{2}(1+r)K_R + \frac{1}{2}G(1 + \frac{1}{\theta}(p_R - 1 + \frac{(1-r_R)K_R}{Q(p_R, R)}))$$

The firm thus will set the price and capital to target rating A rather than rating B if and only if $\pi(A) > \pi(B)$. The benefits and cost of higher rating can be seen from the following expression

$$\begin{aligned}
&\pi(A) - \pi(B) \\
&= \frac{1}{2}(p_A(\theta) - 1 + \theta)Q(p_A(\theta), A) - [\frac{1}{2}(p_B(\theta) - 1 + \theta)Q(p_B(\theta), B)] \\
&- \frac{1}{2}((1 + r_A)K_A(\theta) - (1 + r_B)K_B(\theta)) \\
&+ \frac{1}{2}G(1 + \frac{1}{\theta}[(p_A - 1 + \frac{(1-r_A)K_A}{Q(p_A, A)}) - (p_B - 1 + \frac{(1-r_B)K_B}{Q(p_B, B)})])
\end{aligned}$$

It shows that the choice of a rating depends on three factors. First, higher rating has a positive effect on profits becasue it allows to sell insurance at a higher price. Second, the rating affects the amount of capital that an insurance firm needs to hold. The magnitude of this effect depends on the cost of capital and the volatility of firm's liabilities. Higher volatility types will need more capital to satisfy a given rating standard. Third, higher rating reduces the insolvency risk and increases the expected value of future opportunities.

The next proposition derives two important properties of the expected value function $\pi(R)$.

Proposition 3 *The expected value of firm's equity is decreasing in volatility of the firm's liabilities,* $\frac{d\pi(R,\theta)}{d\theta} < 0$.*Also it satisfies a single crossing property,* $\frac{d\pi(A,\theta)}{d\theta} < \frac{d\pi(B,\theta)}{d\theta}$.

The main properties of the optimal rating choice are summarized below.

Proposition 4 *There are threshold volatility types* θ_A *and* θ_B *such that types* $\theta \leq \theta_A$ *target rating A, types* $\theta_A < \theta \leq \theta_B$ *target rating B, and types* $\theta > \theta_B$ *target rating C. The number of companies that obtain the highest rating is (i) increasing in the elasticity of demand with respect to financial quality, (ii) decreasing in the cost of capital, (iii) decreasing in the stringency of the rating standard that corresponds to higher* α *and* β.

In the next section we analyze how the optimal pricing and capital choices are adjusted when a rating agency changes the rating standards.

3 Adjustment of the rating standard

The increase of the standard stringency has been justified by the increased frequency and severity of losses. Indeed, the concentration of high value properties in the coastal areas has been increasing over the last several decades. The climate change lead to more frequent and pronounced events. At the same time, major hurricanes are rare events that leads to abrupt reassessment of the probability distribution of losses. Hurricane Katrina indicated that the insurance industry has to be prepared to sustain substantial losses.

In terms of the model, the new information about the probability of losses can be viewed as the shift of the original distribution to the right by some constant. Denote the new adjusted distribution by $\widehat{F}_\theta$. We assume that it satisfies all the properties of the original distribution F_θ. Higher risk will increase the assets needed to attain the same solvency levels α and β. Thus it will be the case that $\widehat{F}_\theta^{-1}(1-\alpha) > F_\theta^{-1}(1-\alpha)$ and $\widehat{F}_\theta^{-1}(1-\beta) > F_\theta^{-1}(1-\beta)$. The new distribution will lead to the following adjustment of the targeted ratings by insurance firms.

Proposition 5 *Under the new standard derived from distribution $\widehat{F}_\theta$, there are threshold volatility types $\widehat{\theta}_A$ and $\widehat{\theta}_B$ such that types $\theta \leq \widehat{\theta}_A$ target rating A, types $\widehat{\theta}_A < \theta \leq \widehat{\theta}_B$ target rating B, and types $\theta > \widehat{\theta}_B$ target rating C. The number of firms that target higher rating deceases, $\widehat{\theta}_A \leq \theta_A$ and $\widehat{\theta}_B \leq \theta_B$.*

The change of the rating standard thus has a heterogeneous effect on firms decisions regarding the targeted rating. For low risk types $\theta < \widehat{\theta}_A$ the new standard is not binding and they maintain the original high rating A. However, for the intermediate firms $\theta \in (\widehat{\theta}_A, \theta_A)$, the cost of the new rating is too high and the optimal targeted rating reduces to B. Similarly, firms $\theta \in (\theta_A, \widehat{\theta}_B)$ maintain the original rating B but lower quality firms $\theta \geq \widehat{\theta}_B$ reduce the targeted rating.

How the new standards of the industry will affect the insurance firm behavior in the presence of price regulation? Our analysis suggests that one of the major benefits of higher rating is that the insurer can charge higher price per dollar of insurance. Since selling more insurance at higher price is a substitute for raising external capital, withdrawing the opportunity to charge higher prices increases the need for external capital. If external capital is scares, the price regulation will increase the likelihood of targeting lower ratings.

4 Ratings in insurance and reinsurance market

4.1 Major rating agencies

Several credit rating agencies (CRAs) assess the financial strength of the U.S. insurance companies. Four CRAs, A.M. Best, Fitch, Moody's and Standard and Poor's (S&P), have NRSRO status and together provide coverage of 97.48% of the insurance market measured by asset size.

Among the NRSRO CRAs, the insurance industry views A.M. Best as a benchmark CRA rating insurance companies. A.M. Best ratings are widely incorporated in various local and state regulations. During the period of this study, A.M. Best provided ratings of 75.65% of insurance companies. Though on average insurers have ratings from 1.31 CRAs, A.M. Best rating is the first choice for the majority of companies. Indeed, the number of companies that do *not* have A.M. Best rating but have at least one rating from the other three NRSRO CRAs is only 1.95%.

The prominent role of A.M. Best is due to its monopoly position in the U.S. insurance market for most of the 20th century till late 1980s. Beginning 1990s, the monopoly of A.M. Best was challenged by Standard and Poor's (S&P). S&P established a solid position on the market of insurers ratings during the 1990s. The entry of S&P was followed by the entry of the other two agencies, Moody's and Fitch. In 2009, the market shares of A.M. Best, Fitch, S&P and Moody's were 95.36%, 47.93%, 51.13% and 24.88%, respectively. These CRAs have overlapping market coverage. About 41% of insurers have ratings from at least two CRAs. The most widespread ratings portfolio was composed of two ratings from A.M. Best and Fitch, accounting for 10.95% of insurance companies. Table 1 provides further details on the ratings portfolios in the insurance industry.

4.2 The role of ratings

Both practitioners and academics agree that ratings are important for insurers and reinsurers. The main reason is that the value of an insurance policy to the buyer depends on the insurer's insolvency risk. Often financial strength ratings are the main source of buyers' information about the credit quality of insurers. As a result, buyers are willing to pay higher prices for an insurance policy sold by an insurer with higher ratings.

Several studies has found empirical support for the demand sensitivity to insurer's insolvency risk. Epermanis and Harrington (2006) analyze the relationship between premium growth and changes in A.M. Best financial strength ratings for a large sample of property/casualty insurers during 1992-1999. They provide evidence of premium declines for downgraded insurers following the downgrades. The size of the effect depends on demand sensitivity to credit risk. Indeed, declines were concentrated in commercial lines that exhibit high sensitivity due to the lack of the state guarantee funds support and substantial customizing of individual policies. Also the premium declines were especially pronounces for companies that initially had A- rating that the insurance industry views as a threshold between high and average quality companies. Cummins and Danzon (1997) develop a model of price determination in insurance markets. They show that imperfect price elasticity of demand and sensitivity of demand to credit risk imply that insurer will optimally choose the level of credit risk. The analysis of liability insurance industry during 1976-1987 reveals that the price of insurance is positively related to financial quality, measured by the ratio of equity to liabilities. Also price is inversely related to loss shocks to prior liabilities. Sommer (1996) uses the measures of insolvency risk implied by the option-based model of insurance (Doherty and Garven 1986, Cummins 1988) and finds a negative relationship between insolvency risk and insurance prices in the property-liability insurance market for the period between 1979 and 1988.

4.3 Adjustment of rating standards for catastrophic risk exposures

Catastrophic losses have a significant, rapid and unexpected impact that can impair the financial strength of P&C insurers. The exposure to these losses has been increasing due to high demographic concentration and increasing property values in catastrophe prone areas. Higher frequency and severity of losses are the main two reasons that CRAs use to justify the higher capitalization needed to support catastrophic risks.

In the aftermath of hurricane Katrina in 2005, the major rating agencies have revised the property catastrophe insurance criteria resulting in the increased amount of capital that an insurer needs to hold in order to maintain the current rating. The changes of the rating methodology had a significant impact on the amount and composition of capital and reinsurance needed to achieve a particular rating.

Ratings standards can also have impact on the capital allocation and cost of capital in the reinsurance market. In order to diversify the large catastrophic exposures associated with hurricane and earthquake in the US, rating agencies encourage reinsurers to spread their capital across Japanese, European and Australian wind and earthquake exposures. Diversification results in inadequate capital left for the US market where the need is the highest. Froot (2008) provides the evidence on capacity shortage in the U.S. exposures and suggests that the S&P "forced diversity" is one of the factors that would explain the large increase in the costs of reinsurance from 2005 to 2006.

5 How did insurance companies react to new rating standards?

In this section we empirically investigate the reaction of insurers to the change of the rating criteria after 2004-2005 hurricane seasons. For the purpose of this study, we focus on the ratings of A.M. Best.

5.1 Empirical implications

The main prediction of the theoretical model developed in the previous section is that insurers with exposure to catastrophic risks will have an asymmetric reaction to new standards. The direction of change will depend on (i) the extent to which the new standard is binding upon the insurer, and (ii) the sensitivity of the demand for insurance to rating. Future investment opportunities will prevent a firm from holding the minimum capital necessary to obtain a given rating. However, (i) will depend on how close the insurer is to the lower boundary of the rating and how much hurricane risk exposure the insurer has. The closer the distance is to the lower boundary, the more likely it is that the new standard may trigger the rating change. Thus, insurers who are closer to the lower rating boundary and desire to maintain their rating level are more likely to increase their capital. The decision to maintain the rating will depend on (ii). If the demand for insurance has low sensitivity to demand and capital is costly, an insurer can decide to accept the rating downgrade instead of raising the capital. Thus, we also predict that the propensity of an insurer to defend its current rating differs among different groups of insurers. For example, commercial insurers will be more concerned about the rating change because the demand for commercial insurance is more sensitive to the insurers' rating than is the demand for personal insurance. We can write the regression model corresponding to the aforementioned empirical implication as

$$\Delta Capital = E[\Delta Capital | no\ rating\ standard\ change] + \beta BINDING + \varepsilon \tag{8}$$

BINDING is a variable that captures the extent to which the new standard is binding upon an insurer. We expect the coefficient of BINDING to be positive if insurers increase capital to maintain current ratings. The extent to which the new standard is binding will depend on how close the insurer is to the lower boundary of the rating and how much hurricane risk exposure the insurer has. In order to construct a BINDING variable, we first run a rating process estimation model to estimate the distance of each insurer's rating score from the lower boundary of each rating bin. Catastrophic risk exposure can be measured by the proportion of catastrophic risk premiums written to total premiums written. Based on the distance to the lower boundary and the catastrophic risk exposure, we construct a BINDING variable and run a regression to examine the relationship between this BINDING variable and the capital change of a firm.

We expect the magnitude of the coefficient to be greater among those insurers whose demands are more sensitive to credit ratings than insurers with less sensitive insurance demands. In order to compare the coefficients of heterogeneous propensity to defend their current ratings, we compare the coefficient estimates of the BINDING variable on several subgroups of insurers.

5.2 Data

Our empirical work uses a sample of US Property/Casualty insurance companies between 2001 and 2008. Our sample data are collected from two different databases. The first database is A.M. Best rating data collected from Best's annual Key Rating Guide. The rest of the variables used in this study are extracted from SNL Financial database, which is based on the annual regulatory statements on insurance companies provided by the National Association of Insurance Commissioners (NAIC).

We use all PC insurance companies in U.S. who have A.M. Best rating in the rating process estimation model. The initial sample has 15,703 firm-year observations. We lose 4,859 observations for which explanatory variables in the rating model regression were unavailable. The final sample has 10,844 firm-year observations. We only include the PC insurance companies with hurricane risk exposures in the capital change regressions. We define the hurricane risk prone line of business as direct premium written in homeowners, farm owners, auto physical damage, commercial multiperil (non-liability), or inland marine in the following five southeastern coastal states: Florida, Louisiana, Mississippi, South Carolina, and Texas. The number of firm-year observations for this hurricane exposed sample is 5,801. We lose some observations due to the unavailable right hand side variables in the regression. The final sample consists of 3,067 firm-year observations.[3]

5.3 Variable definitions and model specifications

5.3.1 Modeling rating process

In this section, we define a variable that estimates the likelihood of rating standard changes being a binding condition for a firm's capital structure decision. Since the rating standard changes must have a heterogeneous effect depending on how likely it will be downgraded, we estimate the location of each insurer within the rating bin that insurer belongs to. In order to measure that location, we first model a rating process using an ordered probit regression where the dependent variable of this model is the numerical conversion of the A.M. Best financial strength rating and

[3] Most of the sample is lost due to the A.M. Best rating and Best's Capital Adequacy Ratio (BCAR) availability.

the explanatory variables are the variables related to the insolvency probability of the firm.[4] The ordered probit regression model allows us to estimate the unobserved continuous latent rating score of each insurer as a linear function of the set of explanatory variables. We can also observe the cut-off point of each rating bin from the ordered probit regression result. We use this estimated latent score and the rating boundaries to construct the relative location of each insurer within each rating bin.

For the explanatory variables, we include a set of variables that are mentioned in the Best's Credit Rating Methodology (2009) and other insurer insolvency and rating studies (Cummins et al., 1995; Doherty and Phillips, 2002; Doherty et al., 2009). Our explanatory variables can be categorized into capital adequacy, profitability, catastrophic risk, and other corporate structure variables.

The first capital adequacy measure is the Best's Capital Adequacy Ratio (BCAR). BCAR is a quantitative score that A.M. Best assigns to each rated insurer based on the capital adequacy of an insurer relative to the overall asset and liability risk profile. This variable is the single most important quantitative variable that A.M. Best uses in their rating process analyzing capital adequacy according to the Best's Credit Rating Methodology (2009). In addition to BCAR, we include change in net premiums written, Kenny ratio (premium surplus ratio), reserve surplus ratio, and reinsurance recoverable surplus ratio, all of which are traditional sets of capital adequacy variables used in insurance insolvency studies and also mentioned in the capital adequacy analysis part of the "Best's Credit Rating Methodology" (Cummins et al., 1999; Doherty and Phillips, 2002; Doherty et al., 2009).[5]

The next set of variables is included to control for profitability and catastrophic risk. We include the combined ratio for underwriting profitability and investment yield for investment profitability. We include a proportion of premiums written in hurricane risk-exposed lines of business to total direct premium written (PCAT) as an estimate of catastrophic risk exposure. Including the catastrophic risk variable is particularly important in the rating process during our sample period of 2001 to 2008 because both the anticipated and the realized catastrophic

[4] A complete numerical conversion of ratings is available in the Appendix.
[5] In the insurance industry, the term "surplus" is often used instead of "capital."

risk were very high during this time. We expect PCAT to be negatively related to Best's ratings.

As explained in the previous sections, there was a rating standard change for catastrophic risk, and this change corresponds to the change in the coefficient of the PCAT variable from 2006. In order to examine whether our model can capture the rating standard change on catastrophic risk, we run two regressions on the sub-sample periods of before (2001-2005) and after (2006-2008) the rating standard change. The more stringent rating standards on catastrophic risk implies that the coefficient of PCAT should be more negative in 2006-2008 than 2001-2005.

The rest of the explanatory variables are controls for the qualitative assessment of risk and capital. A.M. Best incorporates other factors, such as the ability of raising capital, corporate stability, and risk management. We include firm size and firm age, expecting larger and older companies to be assigned higher ratings. We also include two dummy variables: public company and single unaffiliated insurer. Affiliated subsidiary insurers are likely to get capital aid from their affiliated company or holding company when an unexpected loss occurs, whereas a single unaffiliated insurer will have to find external financing. And if the holding company is a publicly traded stock company, external capital-raising costs can be lower than for a private company that does not have a readily available major financing source. Therefore, we expect the public dummy to be positively related and the single dummy to be negatively related to the firm's rating.

We also considered other variables not listed in this section, such as a mutual insurer dummy, a Risk Based Capital (RBC) ratio, and all Financial Analysis and Surveillance Tracking (FAST) scores. The RBC ratio and FAST scores are sets of variables used by insurance regulators to provide an early warning of insurer insolvency. Most variables included in our model are FAST scores. However, we did not include all of these variables in our final model because the correlations between these variables are very high. Therefore, we only select one variable which shows higher statistical significance if the two closely related variables have very high correlation as can be found in net premium written surplus ratio and direct premium written surplus ratio. We then include all other variables and keep only those statistically significant variables, as the purpose for this regression is to get an estimate of ratings scores; an inclusion of insignificant variables may only create noise. Excluding the insignificant variables did not affect the coefficients of remaining variables, resolving the possible omitted variable problem.

5.3.2 Capital adjustment to the rating standard change

We now investigate whether there was the predicted heterogeneous capital adjustment after the rating standards change, using the equation (8). The specific regression model used is the following.

$$SARC_{t,t+1} = \alpha + \beta_1 DISTANCE_t + \beta_2 CATDIS05 + \beta_3 CATDIS06 + \beta_4 CAT05 + \beta_5 CAT06 + \sum_i \gamma_i X_{i,t} + \varepsilon$$

The Hausman test rejects no fixed effect hypothesis, so we run a fixed effect regression. We utilize the annual surplus asset ratio change (SARC) as a dependent variable in this model. For the BINDING variable in the equation (8), we construct two variables, CATDIS05 and CATDIS06. We first assign a location variable that measures an unobserved underlying rating score location within each rating bin to each firm-year observation using the ordered probit model results from the previous section. This variable, DISTANCE, is defined as a distance from the estimated upper boundary latent score of each rating bin to the estimated score of each insurer. A larger DISTANCE means the insurer is closer to the lower boundary of each rating bin. We then construct CATDIS06 by multiplying DISTANCE by the year 2006 dummy and the proportion of premiums written in hurricane risk-exposed lines of business to total premiums, in order to measure the effect of the ratings standard change on hurricane risk between 2006 and 2007. It is possible that insurers could expect the ratings standard change in 2005 because the ratings standard for reinsurance companies occurred in 2005, although the ratings standard change for insurers occurred in 2006. Therefore, we construct a parallel variable for year 2005 to capture the capital adjustment due to the anticipated ratings standard change. We expect the coefficient of CATDIS06 to be positive if insurers increase their capital to defend their current rating and negative if insurers reduce their capital to admit downgrades. We expect that this reaction to be heterogeneous but not random. That is, the coefficient will be positive among the insurers which have stronger incentives to defend their current ratings, such as commercial line insurers and those insurers at the margin of strong ratings and weak ratings. If insurers adjusted their capital in 2005, expecting the rating change in future years, we will find positive or negative effect on CATDIS05 as well.

The anticipated hurricane risk has been modified upward after hurricane seasons. This change on the anticipated risk itself may lead hurricane risk-exposed insurers to increase their surplus asset ratio regardless of the rating standard change. Without controlling this effect, the main variable of our interest, CATDIS05 and CATDIS06, will capture the capital adjustment due to the anticipated risk change as well. Therefore, we control for the level of hurricane risk exposure by adding the proportion of catastrophic risk premium to total premium in 2005 and 2006, CAT05 and CAT06. If the ratings standard change influences insurers' capital decisions, the CATDIS05 and CATDIS06 will remain significant even after controlling for the degree of the catastrophic risk exposure itself.

Similarly, we include DISTANCE in order to control the capital adjustment behavior for a firm seeking to maintain their current rating in any year regardless of the ratings standard change. Kisgen (2006) finds that firms issue more capital than debt when they are closer to the bottom of each rating bin in order to secure their current rating. This can be the case for insurers in our sample as well. With an absence of DISTANCE in the model, CATDIS05 and CATDIS06 will also capture the general capital adjustment behavior without any rating standard changes. Because insurers close to the lower boundary of each rating bin may increase their surplus to safely secure their current rating, we expect DISTANCE to be positively related with surplus change even without the ratings standard change.

Lastly, we include the following control variables that may impact the surplus asset ratio change in the regression model. The most important consideration for insurer capital decision is its risk. Higher risk will require more capital in order to maintain the same default probability. The overall credit risk profile of an insurer depends on various factors, not limited to the premium written in hurricane-related lines of business. Asset portfolio change, underwriting line of business changes, reinsurance, and other strategic changes will all influence an insurer's overall risk. Therefore, we control for the overall risk profile change of insurers. In order to capture the overall risk change of each insurer, we add Risk Based Capital change from year t to $t + 1$.

As one of their solvency prediction methods, NAIC requires all insurers to report their Risk Based Capital (RBC) ratio. RBC is an overall risk "charge" which outlines the following four areas: asset risk, credit risk, underwriting risk, and growth and other form of off-balance sheet risk. NAIC provides guideline formulas for RBC, which is designed such that RBC increases as risks in each category increase. For example, an investment in U.S. government bonds has zero charge, whereas junk bonds require an RBC factor up to 30 percent. Similarly, underwriting in catastrophic risk-prone lines of business or commercial liability has a higher factor than auto property. When aggregating each charge into one RBC, covariance structure is also considered (Cummins, Grace, and Phillips, 1999; NAIC, 1993). Therefore, we can expect that the RBC provides a summary of the overall risk profile of the insurer. We use RBC change itself as a proxy for the risk profile change of each insurer instead of RBC ratio change because RBC measures the size of the risk, whereas RBC ratio is related with capital adequacy. We expect this variable to be positively correlated with capital ratio change.

The next control factor is a variable regarding loss experience. A loss shock in year t can reduce the surplus asset ratio because raising or recouping the depleted capital to the target level may take time. We include change in combined ratio to control this effect. Combined ratio is defined as a ratio of total loss and expense to net premium written, and it is a standard underwriting profitability measure in the insurance industry. We also control for BCAR (Best Capital Adequacy Ratio) change from year $t-1$ to year t. BCAR is a direct capital adequacy measure that Best's rating provides. It is possible that an insurer may adjust capital upward when a decreased BCAR ratio is observed. If an insurer adjusts its capitals to improve the BCAR ratio, this variable can be positively related to surplus asset ratio change. In addition to the aforementioned controls, we include log asset in year t, the A.M. Best rating in year t, and year dummy variables in the regression model. Table 2 presents the definition of variables used in this analysis.

The propensity to defend a current rating may vary depending on the line of business and the insurance company's rating. Epermanis and Harrington (2006) find that insurance demand sensitivity is more concentrated in commercial lines than personal lines. Epermanis and Harrington attribute this finding to commercial lines' more limited access to state guarantee funds as compared to personal lines. Therefore, we expect that commercial lines have a higher sensitivity to insolvency risk.

The current ratings of insurers may also matter if there is a threshold rating that triggers a demand change. Conventional wisdom and previous literature suggests that this threshold rating is A- (Bradford, 2003; Souter, 2000; Epermanis and Harrington, 2006). Brokers and policyholders generally view A- and higher rating to be acceptable and a rating B++ and below to be unacceptable. Consistent with this conjecture, Epermanis and Harrington find that the insurance demand sensitivity is highest when an insurer is downgraded from A- to B++. In addition, commercial insurance buyers could be most sensitive to insurers with a rating near the boundary of secure rating and vulnerable rating (A- and B++, respectively). Nini and Cheyne (2010) find that the majority of commercial insurance demand is associated with insurance requirements placed in loan and debt. Many insurance requirements specify that insurance companies must have a Best's Rating of A-. Therefore, commercial line demands are expected to be sensitive to the downgrade from A- to B++, and this provides a strong incentive for commercial insurers to defend an A- rating.

Following this logic, we subdivide insurers based on the propensity to defend a current rating after the ratings standard change, and we run regressions using the subgroups of insurers. We run regressions on commercial insurers and personal insurers. We define an insurer as a commercial insurer if the direct premiums written in commercial lines of business are more than 50% of the insurer's total premiums written. We then further proceed to make the following six subgroups based on their ratings and line of business combination in order to compare the effects of rating: The first group is commercial insurers with A and higher ratings, the second group is commercial line insurers with an A- rating, the third group is commercial insurers with a B++ or lower rating, the fourth group is personal insurers with A and higher ratings, the fifth group is personal insurers with an A- rating, and the last group is personal insurers with a B++ and lower. Therefore, we expect the coefficients of CATDIS05 and CATDIS06 are the most significantly positive in the A- rated commercial insurer subgroup regression because these insurers have the most incentive to defend A-.

5.3.3 Financial Strength of Insurers with Hurricane Risk Exposure

This section provides a descriptive overview of our sample insurers' financial strength during the sample period. Table 3 and Figure 1 show the financial strength change of commercial and personal property casualty insurers with hurricane risk exposures from 2002 to 2008. Panel A of Table 3 shows the number of insurers by lines of business and A.M. Best Rating. Both the numbers of commercial and personal insurers with ratings greater than or equal to A are stable during the sample period, but the number shows a quite different trend in non-rated insurers or insurers with ratings of A- or lower. The number of commercial insurers with A- or lower rating decreased from 2002 to 2006, then somewhat increased in 2007 and 2008. The number of insurers without ratings or with a rating of A- or lower has been increasing steadily.

After the 2004-2005 hurricane seasons, a few insurers went bankrupt and many others came into the market with new capital. Therefore, the trend found in Panel A of Table 3 could be due to the new insurers entering the market with no rating or an initially low rating. In order to examine the existing insurers' financial strength, we limit our attention to those insurers which have continuous ratings during the entire 2002-2008 sample period. Figure 1 presents average A.M. Best ratings changes for this sample. As can be seen here, the rating patterns of commercial insurers and personal insurers differ. The average ratings for personal insurers dropped in 2004 and 2005, but they do not recover from this downgrade in the following years. On the other hand, commercial insurers are not downgraded as much as personal insurers to start with, and their average rating increases until 2007. It seems that the average ratings for all groups decrease in 2008, possibly due to the recent financial crisis in 2007-2008. As a comparison, we also provide an average rating for the entirety of rated property casualty insurers in U.S. - a rating not limited to insurers exposed to hurricane risks. The rating change trend for all U.S. insurers is almost the same as the trend for commercial insurers.

Panel B of Table 3 presents a rating distribution of commercial and personal insurers and hurricane risk exposure for each insurer group. 97% of commercial insurers have an A.M. Best rating, whereas only 80% of personal insurers are rated, indicating that many personal insurers are either new or choose not to be rated by A.M. Best.[6] Both groups of insurers have a greater presence in the A rating category, followed by the A- rating. About 88% of commercial insurers have a rating equal to or greater than A-, whereas the percentage of personal insurers is 65%. The third and sixth column of Panel B in Table 3 shows the average ratio of hurricane risk gross premiums written to total gross premiums written, PCAT. As is expected, insurers with stronger financial strength ratings are less concentrated in the hurricane exposed lines of business than insurers with weaker ratings. The trend is striking in personal lines - the average PCAT of insurers with B++ and lower rating or no rating is more than 50%. It is also noteworthy that the commercial insurers are far less concentrated in the hurricane exposed risk than personal insurers.

5.4 Empirical results

5.4.1 Modeling rating process

Table 5 and Table 6 present the rating model results using the ordered probit model. Table 4 reports descriptive sample statistics for the variables used in the regression models. The second column of Table 4 shows a whole sample result, and the third and fourth column shows the regression for the subsample period before and after the ratings standard change. All coefficients are significant and have expected signs. When an insurer has a higher investment yield, lower premium surplus ratio, lower reserve surplus ratio, higher premium growth, lower reinsurance recoverable, fewer junk bonds, a higher BCAR, and more catastrophic risks, it has a better rating. The variables added to capture the qualitative characteristics also have predicted signs. Larger and older insurers have a higher rating. A subsidiary of a publicly traded insurance company has a higher rating, and single non-affiliated companies have lower ratings, indicating that the ability to acquire and cost of raising capital is an important rating factor.

The coefficient estimates of the PCAT variable in the two subsample regression results are consistent with the ratings standard change. That is, the model penalizes more for the hurricane

[6] Most non-rated insurers are rated by Demotech, a relatively small and new insurance rating agency.

risk exposure after the 2004-2005 seasons than before. The PCAT coefficient is -0.19 for the pre-standard change period and -0.72 after the standard change period. Table 6 shows summary statistics for the estimated latent score by the actual A.M. Best rating category. The mean and median score difference between rating bins is about 0.3 to 0.6. Therefore, the -0.19 and -0.72 coefficient of PCAT implies that, holding everything else equal, an insurer with 100% hurricane exposed lines of business after 2005 will be assigned a rating two to three notches lower than a 0% hurricane risk-exposed insurer, whereas the same hurricane risk insurer would have been assigned a rating only one step lower before this ratings standard change.

Table 6 also shows that as a rating becomes stronger, the estimated score monotonically increases. The significant coefficients and monotonic estimated estimate suggest that the ordered probit model yields solid explanatory power.

5.4.2 Capital adjustment to the rating standard change

Table 7 presents the surplus ratio change regression results. Panel A reports the regression results of all property casualty insurers with hurricane risk exposure, divided into commercial insurers only and personal insurers only. Panel B presents the coefficient estimate of CATDIS05 and CATDIS06 from the six rating-line of business subsample regressions. Our main variable of interest, CATDIS06, is not significant in the whole sample regression, implying that, on average, between 2005 and 2006, insurers did not adjust their capital after the rating standard change. Furthermore, CATDIS05 is significantly negative, meaning that insurers affected by the ratings standard change decreased rather than increased their capital between 2005 and 2006. In the second and third regression in Panel A, we can see this negative result of CATDIS05 is mostly due to personal line insurers. When we run the same regression on a commercial group, the coefficient of CATDIS06 is insignificant. On the other hand, CATDIS05 and CATDIS06 have significant negative coefficients in the personal line insurer group.

To further examine the different behavior of different types of insurers depending on their propensity to defend ratings, we compare the coefficients of CATDIS05 and CATDIS06 of six ratings-lines of business groups. The results are shown in Panel B of Table 7. It shows that there are dramatic differences among these groups, meaning that the current rating matters in addition to the line of business. Commercial insurers with an A- rating are expected to have the strongest incentive to defend their current A- rating: to keep their policyholders. The results support this conjecture. The commercial A- group is the only group which has a significantly positive CATDIS06 coefficient. It implies that there was an upward capital adjustment when commercial insurers with A- ratings were affected by the ratings standard change. The coefficient of 0.16 means that an insurer very close to the bottom of the A- rating increased the surplus asset ratio about 1.32% more compared to an insurer very close to the top of the A- rating, if both of them have the same 8.84% hurricane risk exposure. If both of the insurers had 20% hurricane risk exposure, the insurer at the bottom of the rating bin increased approximately 5.6% more than the top A- rated insurer.[7]

Other than the A- group, commercial insurers did not respond to the ratings standard change. On the other hand, personal line insurers show negative response to the ratings standard change, save for those insurers with an A- rating. A or better rated personal insurers significantly reduced their capital between 2006 and 2007 when they were close to the bottom of their ratings categories. B++ and lower rated insurers also reduced their surplus asset ratio between 2005 and 2006.

The regression results are also consistent with the actual ratings change over the sample period shown in Table 3 and Figure 1. Some personal line insurers were downgraded, but commercial line insurers were not downgraded after the hurricane seasons. Overall, commercial insurers, which have more sophisticated consumer demands and limited guaranteed fund access, are expected to have a higher propensity to defend a better rating than personal line insurers, which have a less elastic demand. Commercial insurers close to the bottom of their current ratings category indeed adjusted their capital upward more than personal line insurers after the ratings standard change. This was especially the case among A- rated insurers.

Other coefficients are generally consistent with the prediction. DISTANCE is always very

[7] The summary statistics of the latent rating score of the A- group is shown in Table 6. The difference between p99 and p1 in the A- rating is 2.76. So we assume that the DISTANCE difference between the top and bottom insurer is 2.76 in this computation.

strongly negative in all regression models. It implies that firms adjust their capital upwards when they are close to the bottom of each rating bin in any year. The positive sign of CAT05 and CAT06 means that insurers with more hurricane risk exposure increased their capital more than insurers with less hurricane risk exposure after the 2004-2005 hurricane seasons. The coefficient of the combined ratio change is significant and negative. It means that as insurers experience more losses in year $t + 1$ than year t, the surplus in year $t + 1$ is reduced compared to the surplus year t. The asset coefficient shows that larger insurers generally increased their surplus asset ratios more than smaller insurers during this sample period. Overall, the results provide persuasive evidence that rating is one of the decision factors of optimal surplus, and rating agencies standard change affect insurers' surplus level after the hurricane season of 2004-2005.

6 Conclusion

In this paper we build a model of insurer pricing, capital and target rating decision. The analysis of the model suggests that adjustment of rating standard must have a heterogeneous effect on insurers' target rating. The econometric analysis of the reaction to new standards for catastrophic risks mainly supports this hypothesis.

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Appendix

Proof of Proposition 1. The optimal (p, K) for a given rating is a solution of the optimization problem

$$\max_{p,K} \frac{1}{2}(p-1+\theta)Q(p,R) - \frac{1}{2}(1+r)K + \frac{1}{2}G(1+\frac{1}{\theta}(p-1+\frac{(1-r)K}{Q(p,R)}))$$
$$s.t.\ K \geq \frac{Q(p,R)}{1-r}(\theta(1-2\rho)-(p-1)).$$

Denote $\lambda \geq 0$ the Lagrangian multiplier of the constraint. The first order conditions of the problem are

$$p: \quad \tfrac{1}{2}(p-1+\theta)Q_p + \tfrac{1}{2}Q + \tfrac{1}{2}\tfrac{G}{\theta}(1-\tfrac{(1-r)K}{Q^2}Q_p) - \lambda(\tfrac{Q_p}{1-r}(\theta(1-2\rho)-(p-1)) - \tfrac{Q}{1-r}) = 0, \tag{9}$$

$$K: \quad -\tfrac{1}{2}(1+r)K + \tfrac{1}{2}\tfrac{G}{\theta}\tfrac{1-r}{Q} + \lambda = 0, \tag{10}$$

where Q_p denotes the derivative of demand with respect to p, and the arguments of the demand functions are omitted to save on notations. We consider the two possible cases, $\lambda = 0$ and $\lambda > 0$.

Case $\lambda = 0$**.** (10) implies that

$$K = \frac{1}{\theta}\frac{1-r}{1+r}\frac{G}{Q}.$$

Thus (9) can be written as

$$(p-1+\theta)Q_p + Q + \frac{G}{\theta}(1-\frac{G}{\theta}\frac{(1-r)^2}{1+r}\frac{Q_p}{Q^3}) = 0,$$

and the optimal price in this case is a solution to this equation. It is immediate to derive the following comparative statics results.

The price is decreasing in type θ and cost of capital r, and increasing in growth opportunities G,

$$\frac{dp}{d\theta} = -\frac{Q_p - \frac{G}{\theta^2} + \frac{2G^2}{\theta^3}\frac{(1-r)^2}{1+r}\frac{Q_p}{Q}}{L_{pp}} < 0,$$

$$\frac{dp}{dr} = -\frac{(\frac{G}{\theta})^2\frac{(1-r)(2(1+r)+1-r)}{(1+r)^3}\frac{Q_p}{Q^3}}{L_{pp}} < 0,$$

$$\frac{dp}{dG} = -\frac{\frac{1}{\theta} - \frac{2G}{\theta^2}\frac{(1-r)^2}{1+r}\frac{Q_p}{Q^3}}{L_{pp}} > 0,$$

where L_{pp} denotes the second order derivative of the Lagrangian with respect to p. $L_{pp} < 0$ due to second order condition.

The capital is decreasing in type θ and cost of capital r, and increasing in growth opportunities G,

$$\frac{dK}{d\theta} = \frac{1-r}{1+r}G(-\frac{1}{\theta^2}\frac{1}{Q} - \frac{1}{\theta}\frac{Q_p}{Q^2}\frac{dp}{d\theta}) < 0,$$
$$\frac{dK}{dr} = \frac{G}{\theta}(-\frac{2}{(1+r)^2}\frac{1}{Q} - \frac{1-r}{1+r}\frac{Q_p}{Q^2}\frac{dp}{dr}) < 0,$$
$$\frac{dK}{dG} = \frac{1}{\theta}\frac{1-r}{1+r}(\frac{1}{Q} - G\frac{Q_p}{Q^2}\frac{dp}{dG}) > 0.$$

$\lambda = 0$ is a solution if the constraint is not binding at the optimum, that is,

$$G > \frac{1+r}{(1-r)^2}\theta Q^2(\theta(1-2\rho) - (p-1)).$$

It occurs when the future profits are high, cost of capital is low, the firm is less risky and the rating standard is more lax.

Case $\lambda > 0$**.** The binding constraint implies

$$K = \frac{Q}{1-r}(\theta(1-2\rho) - (p-1)).$$

Solving (10) for λ obtains

$$\lambda = \frac{1}{2}\frac{1+r}{1-r}Q(\theta(1-2\rho) - (p-1)) - \frac{1}{2}\frac{G}{\theta}\frac{1-r}{Q}.$$

Thus (9) implies

$$(p-1+\theta)Q_p + Q - \frac{1+r}{(1-r)^2}Q_pQ(\theta(1-2\rho) - (p-1))^2 + \frac{1+r}{(1-r)^2}Q^2(\theta(1-2\rho) - (p-1)) = 0,$$

and the optimal price in this case solves the equation. Similarly to the previous case, we derive the following comparative statics results.

The optimal price p is increasing in r and decreasing in ρ. It does not depend on G.

$$\frac{dp}{d\theta} = -\frac{Q_p - \frac{1+r}{(1-r)^2}Q_pQ(1-2\rho)(\theta(1-2\rho)-(p-1)) + \frac{1+r}{(1-r)^2}Q^2(1-2\rho)}{L_{pp}}$$
$$\frac{dp}{dr} = -\frac{\frac{(1-r)(2(1+r)+1-r)}{(1-r)^4}(Q^2(\theta(1-2\rho)-(p-1)) - Q_pQ(\theta(1-2\rho)-(p-1))^2)}{L_{pp}} > 0,$$
$$\frac{dp}{dG} = 0,$$
$$\frac{dp}{d\rho} = -\frac{2\theta\frac{1+r}{(1-r)^2}(Q_pQ(\theta(1-2\rho)-(p-1)) - Q^2)}{L_{pp}} < 0.$$

The optimal capital K has the following comparative statics.

$$\frac{dK}{d\theta} = \frac{1}{1-r}(Q_p(\theta(1-2\rho)-(p-1)) - Q)\frac{dp}{d\theta} = -sign\frac{dp}{d\theta},$$
$$\frac{dK}{dr} = \frac{Q}{(1-r)^2}(\theta(1-2\rho)-(p-1)) + \frac{1}{1-r}(Q_p(\theta(1-2\rho)-(p-1)) - Q)\frac{dp}{d\theta},$$
$$\frac{dK}{d\rho} = -2\theta\frac{Q}{1-r} + \frac{1}{1-r}(Q_p(\theta(1-2\rho)-(p-1)) - Q)\frac{dp}{d\rho}.$$

$\lambda > 0$ is a solution when

$$G < \frac{1+r}{(1-r)^2}\theta Q^2(\theta(1-2\rho)-(p-1)).$$

It occurs when the future profits are low, cost of capital is high, the firm is more risky and the rating standard is strict. ■

Table 1. Ratings Coverage

Table 1 shows the ratings coverage of Property Casualty insurers by the four major rating agencies.

	All PC companies			Hurricane risk-exposed PC companies		
	Number	% DPW	% Asset	Number	% DPW	% Asset
A.M. Best	14,613	95.36%	93.29%	5,853	87.43%	86.37%
S&P	3,430	47.93%	48.13%	1,923	48.43%	46.48%
Fitch	4,237	51.13%	59.37%	2,049	48.03%	54.16%
Moody's	1,346	24.88%	33.49%	811	25.77%	32.61%
A.M. Best and at least one more rating from a major agency	5,956	73.36%	69.87%	3,061	69.14%	71.25%
At least one rating from one of the major four agencies	14,990	97.48%	97.37%	5,975	87.51%	86.42%

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Table 2. Variable Names and Definitions

Table 2 displays variable names used in the analysis and their definitions.

Variable Name	Definition
Asset	Net Admitted Asset [in regression: log[asset]]
Investment yield	Annualized investment returns based on average invested assets
Combined ratio	Combined ratio is loss and loss adjustment expense ratio plus expense ratio plus policyholder dividend ratio. This is the primary indicator of underwriting profitability.
RBC	Risk Based Capital
BCAR	Best's Capital Adequacy Ratio
Reinsurance Recoverable/Surplus	Reinsurance recoverable as a percent of surplus
Reserve/Surplus	Loss and loss adjustment expense reserves as a percent of surplus
Single dummy	Dummy=1 if this firm is non-affiliated single company
Public dummy	Dummy=1 if the ultimate parent of this company is publicly traded company
AMBEST	AM Best rating
Net premium growth	1 year net premium written growth
Premium/Surplus	Proportion of direct premiums written to surplus
Junk bonds/Asset	Proportion of junk bonds [NAIC 4-6] to total assets
Firm age	Firm age
PCAT	Proportion of premiums written in hurricane risk-exposed lines of business to total direct premiums written
SARC	Surplus/Asset ratio change from year t to year t+1
DISTANCE	Estimated latent rating score distance from the upper boundary of each rating bin: the larger the value, the closer the company to the lower boundary
CATDIS05	If year=2005, then DISTANCE * PCAT in 2005, zero otherwise
CATDIS06	If year=2006, then DISTANCE * PCAT in 2006, zero otherwise
CAT05	If year=2005, then PCAT in 2005, zero otherwise
CAT06	If year=2006, then PCAT in 2006, zero otherwise

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Table 3. Hurricane Risk-Exposed Insurers' Rating Changes from 2002 to 2008 by Line of Business

Table 3 shows the number of insurers in hurricane risk-exposed states by lines of business and by A.M. Best Rating. We define an insurer as a commercial insurer if the direct premiums written in commercial lines of business are more than 50% of the insurer's total premiums written. A strong rating is a rating greater than or equal to A and a weak rating is a rating less than or equal to A-. A weak rating also includes those insurers without A.M. Best rating information.

Panel A. Number of insurers by type and rating from 2002 to 2008

Year	Commercial Strong	Commercial Weak	Personal Strong	Personal Weak
2002	397	241	89	72
2003	372	234	91	84
2004	377	222	85	89
2005	383	201	80	96
2006	386	191	77	101
2007	400	198	81	103
2008	414	208	85	109

Panel B. Median ratio of hurricane risk gross premiums written to total gross premiums written

Rating	Commercial			Personal		
	N	N (Percentage)	PCAT	N	N (Percentage)	PCAT
A++	256	6.06%	2.21%	64	5.15%	10.91%
A+	946	22.40%	2.13%	192	15.46%	6.12%
A	1527	36.15%	2.68%	332	26.73%	18.66%
A-	949	22.47%	2.71%	225	18.12%	36.40%
B++	186	4.41%	5.28%	46	3.70%	67.63%
B+ and below	237	5.61%	3.43%	137	11.03%	81.36%
Not Rated	123	2.91%	8.48%	246	19.81%	87.80%

Table 4. Summary Statistics of Variables Used in the Regression Analysis

Table 4 shows the summary statistics of the variables used in the regression analysis. Sample includes Property Casualty insurers with an A.M. Best rating in the U.S. during 2001-2008.

Variable Name	N	Mean	Median	STD	P1	P99
Panel A. Variables used in ratings model ordered probit regression						
Investment Yield	10,910	4.11	4.00	1.72	1.00	8.00
Combined Ratio	10,910	103.41	98.00	67.14	8.00	258.00
Premium/Surplus	10,910	109.68	98.00	75.61	1.00	337.00
Net Premium Growth	10,910	19.56	5.00	100.53	-80.00	404.00
Reinsurance Recoverable/Surplus	10,910	46.12	12.00	89.75	-2.00	461.00
Reserve/Surplus	10,910	88.96	73.00	75.79	0	323.00
Junk Bonds/Asset	10,910	2.12	0	5.67	0	24.00
BCAR	10,910	0.31	0	0.46	0	1.00
Log[Asset]	10,910	241.05	198.20	152.00	73.20	999.90
Public Dummy	10,910	11.67	11.55	1.79	8.06	16.00
Single Dummy	10,910	0.31	0	0.46	0	1
Firm Age	10,910	0.14	0	0.35	0	1.00
PCAT	10,910	51.59	34.00	41.19	8.00	177.00
Investment Yield	10,910	0.044	0	0.14	0	0.92
Panel B. Variables used in capital ratio change regression						
Surplus/Asset ratio change	3,055	.0026	.0047	.0665	-.2068	.1854
DISTANCE	3,055	1.5972	1.6055	.7504	-.0802	3.5043
CATDIS05	3,055	.0308	0	.1851	0	.8599
CATDIS06	3,055	.0269	0	.1803	0	.9942
CAT05	3,055	.0178	0	.0934	0	.5481
CAT06	3,055	.0142	0	.0835	0	.4514
Asset	3,055	12.5854	12.5025	1.7693	9.0384	17.1647
Best Rating	3,055	10.7496	11.00	1.4742	6.00	13.00
Combined ratio change	3,055	-.1631	-1.00	56.2576	-99.00	118.00
BCAR change	3,055	1.6531	4.10	70.5274	-192.10	174.90
RBC change	3,055	69.4884	4.0451	786.2898	-874.0027	1954.64

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Table 5. Ratings Model Regression Results

Table 5 shows the regression results of the rating model. The ordered probit regression model is adapted as an estimation method where the dependent variable is the numerical conversion of the A.M. Best rating. The numerical conversion for the Best rating is presented in Appendix I. The sample includes all Property Casualty insurers with A.M. Best ratings in the U.S. during 2001-2008.

Variables	Whole Sample		2001-2005		2006-2008	
Investment Yield	.0436		.0450		.0370	
	[.0060]	***	[.0070]	***	[.0123]	***
Combined Ratio	-.0004		-.0004		-.0008	
	[.0002]	***	[.0002]	**	[.0003]	***
Premium/Surplus	-.0021		-.0021		-.0026	
	[.0002]	***	[.0002]	***	[.0003]	***
Net Premium Growth	.0005		.0006		.0000	
	[.0000]	***	[.0001]	***	[.0002]	
Reinsurance Recoverable/Surplus	-.0023		-.0023		-.0026	
	[.0001]	***	[.0001]	***	[.0002]	***
Reserve/Surplus	-.0030		-.0031		-.0029	
	[.0002]	***	[.0002]	***	[.0003]	***
Junk Bonds/Asset	-.0101		-.0108		-.0119	
	[.0018]	***	[.0020]	***	[.0045]	***
BCAR	.0010		.0009		0.0011	
	[.0000]	***	[.000]	***	[.0001]	***
Log[Asset]	.3721		.3921		.3611	
	[.0070]	***	[.0089]	***	[.0123]	***
Public Dummy	.5836		.5675		.6243	
	[.0236]	***	[.0290]	***	[.0401]	***
Single Dummy	-.2818		-.2252		-.3760	
	[.0314]	***	[.0392]	***	[.0529]	***
Firm Age	.0010		.0011		.0007	
	[.0003]	***	[.0003]	***	[.0004]	*
PCAT	-.3712		-.1859		-.7197	
	[.0707]	***	[.0873]	***	[.1180]	***
Likelihood Ratio[LR]	5,551.3		3,738.1		1,900.7	
Estrella pseudo-R2	0.4221		0.4289		0.4095	
McFadden's LRI	0.1405		0.1421		0.1451	
Number of Obs	10,910		7,118		3,792	

*** - significant at the 1 percent level; ** - significant at the 5 percent level; *-significant at the 10 percent level

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Table 6. The Estimated Latent Rating Score from the Ordered Probit Regression

Table 6 displays summary statistics of the estimated latent rating score from the ordered probit regression by the actual assigned A.M. Best rating.

Rating	Num	Mean	Median	STD	Min	p1	p25	p75	p99	Max
A++	927	5.334	5.358	0.850	2.670	3.606	4.688	5.853	7.525	8.192
A+	3152	4.931	4.893	0.730	1.381	3.169	4.453	5.412	6.766	7.308
A	5741	4.552	4.516	0.626	1.258	3.092	4.136	4.932	6.197	7.319
A-	4175	4.177	4.130	0.615	2.168	3.035	3.720	4.567	5.795	6.746
B++	1523	3.809	3.755	0.575	2.172	2.618	3.432	4.158	5.411	5.888
B+	1017	3.522	3.412	0.657	2.073	2.290	3.060	3.868	5.415	6.308
B	547	3.406	3.428	0.654	0.279	1.376	3.041	3.786	4.898	5.157
B-	249	3.031	2.975	0.779	-0.697	-0.045	2.639	3.482	4.791	5.431
C++	119	2.981	2.834	0.754	1.038	1.038	2.513	3.451	4.635	4.635
C+	41	2.422	2.531	0.832	-0.646	-0.646	2.293	2.775	3.813	3.813
C	21	2.039	2.148	0.980	-0.581	-0.581	1.403	2.855	3.061	3.061
C-	22	2.044	1.973	0.845	0.815	0.815	1.473	2.590	3.349	3.349

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Table 7. Capital Changes after the Rating Standard Change

Table 7 displays robust fixed effect regression results where the dependent variable equals the change of surplus as a proportion of net admitted assets from year t to t+1. The sample includes Property Casualty insurance companies with Hurricane-risk prone lines of business, which are defined as direct premiums written for homeowners, farm owners, auto physical damage, commercial multiperil [non-liability], or inland marine in AL, FL, MS, SC, or TX. Panel A reports the regression results by line and by A.M. Best rating. We define an insurer as a commercial insurer if the direct premiums written in commercial lines of business are more than 50% of the insurer's total premiums written. Panel B presents the coefficient estimates of CATDIS05 and CATDIS06 from the six by line and rating sub-sample regressions. The full regression results are available upon request.

Panel A.

	By A.M. Best Rating in year t					
Variables	All PC Insurers		Commercial Insurers		Personal Insurers	
Intercept	-.6237	***	-.5472	***	-.8271	***
	[.045]		[.047]		[.104]	
DISTANCE	.0199	***	.0182	***	.0279	***
	[.002]		[.002]		[.004]	
CATDIS05	-.0296	***	.0005		-.0305	***
	[.007]		[.022]		[.008]	
CATDIS06	-.0162		-.0018		-.0204	*
	[.010]		[.029]		[.011]	
CAT05	.0626	***	.0382		.0265	
	[.015]		[.047]		[.018]	
CAT06	.0359		.0062		.0255	
	[.022]		[.067]		[.025]	
Log[Asset]	.0514	***	.0426	***	.0758	***
	[.003]		[.004]		[.009]	
Δ Combined Ratio	-.0005	***	-.0003	***	-.0007	***
	[.000]		[.000]		[.000]	
Δ RBC	-.0000		-.0000		.0000	
	[.000]		[.000]		[.000]	
Pseudo R-Square	0.715		0.619		0.745	
F-value	9.461		5.745		9.042	
Number of Obs.	3,055		2,482		562	

Panel B.

		N	R-Square	CATDIS05	CATDIS06
Commercial	A and above	1,594	0.728	0.0248	-0.0453
	A-	610	0.783	0.0684	0.1605***
	B++ and below	278	0.707	-0.0087	0.0962
Personal	A and above	342	0.715	-0.0018	-0.0345**
	A-	122	0.903	-0.0211	0.0176
	B++ and below	109	0.728	-0.1359***	-0.0500

*** - significant at the 1 percent level; ** - significant at the 5 percent level; *-significant at the 10 percent level

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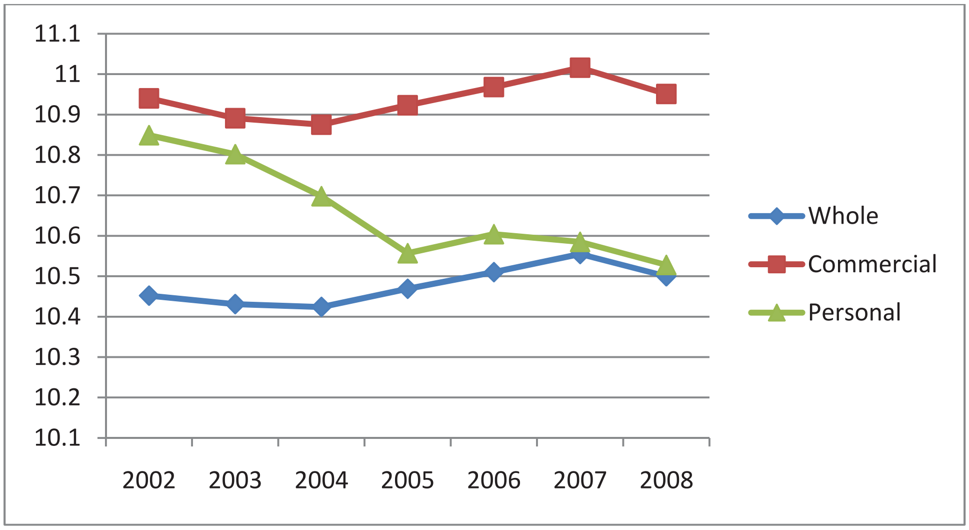

Figure 1. Rating Change: 2002-2008

Note: “Rating” is a numerical conversion of the A.M. Best rating. The conversion table is in Appendix I. “Whole” is the average rating of entire PC insurers in the U.S. “Commercial” is the average rating of Hurricane risk-exposed commercial line PC insurers, and “Personal” is the average rating of Hurricane risk-exposed personal line PC insurers.

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Appendix I. Rating conversion table

A.M. Best Rating	Numeric Conversion
A++	13
A+	12
A	11
A-	10
B++	9
B+	8
B	7
B-	6
C++	5
C+	4
C	3
C-	2
D	1
E,F,Ex	0