A Theory of Capital-Driven Cycles in Insurance

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Abstract

This paper shows asymmetric information restricts capital flows to insurers following catastrophes, resulting in an insurance cycle. Insurers hold capital to provide insurance. Indemnities increase in capital, but the premium to indemnity ratio decreases in capital. Capital is restricted after a catastrophe occurs because the market does not know which insurers have been affected by the catastrophe. This paper concludes that the insurance cycle is capital-driven and a consequence of asymmetric information.

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1 Introduction

The motivation for this paper is the insurance underwriting cycle; there are periods when insurance is expensive, underwriting is profitable, and coverage may be somewhat limited, yet other times when insurance is cheap, underwriting is less profitable, and coverage is more readily available. Gron (1994) documents this pattern, and argues that capital drives this cycle.[1] As shown in Section 2, Gron's result is consistent with a relatively simple model, provided that capital is exogenous. However, when capital levels are endogenous, insurance underwriting returns should be driven by the cost of capital.

Various other papers (e.g., Grace and Hotchkiss (1995), Chen, Wong, and Lee (1999), and Leng and Venezian (2003)) consider whether the insurance underwriting cycle is meaningfully linked to the overall performance of the economy. Grace and Hotchkiss conclude that the effects of shocks to various general economic variables have little effect on the underwriting profitability of the property-liability insurance industry. Harrington, Niehaus, and Yu (2013) further note that evidence provided by these studies needs to be interpreted with caution, not only because of limited sample sizes but also because of possible conditional heteroscedasticity in the various models.

The question which we address here is whether there are better and simpler explanations as to why the insurance cycle exists. In this paper, we show how asymmetric information restricts the market for insurance. Insurance companies know more about their losses than the market, leading to a breakdown of the provision of capital to insurance companies. Because this adversely affects the pricing and availability of insurance, it harms social welfare.

We model asymmetric information in Section 3 with the following structure on the insured risk. There is a risk that a catastrophe (an increase in the probability of loss for some customers) will occur. When a catastrophe occurs, an insurer knows its exposure to the catastrophe. If a catastrophe does not occur, insurers will be exposed only to their normal

[1] See also Cagle and Harrington (1995), Cummins and Danzon (1997), Doherty and Garven (1995), Niehaus and Terry (1993), and Winter (1994).

risks. The market knows whether a catastrophe has occurred, but does not know which insurers are affected. When a catastrophe occurs, capital is restricted from flowing into insurers, limiting their ability to underwrite insurance. This creates the insurance cycle – insurance will be more expensive after losses, and cheaper after profits.

Property-casualty insurance is important in the modern economy: over $612 billion were spent on property-casualty insurance in the United States in 2016.[2] This includes automobile and homeowners insurance, and various other lines of business. Not only are these important risks to insure, but there are also many occasions when insureds are required to insure these risks. For example, drivers are usually required to have automobile insurance, and homeowners are often required to insure their home if they have a mortgage. This paper will show why the insurance cycle affects property-casualty insurance, but not insurance products that indemnify mortality and morbidity risks such as life insurance, annuities, and health insurance. Specifically, losses in property-casualty insurance are catastrophe driven, whereas losses in life insurance, annuity, and health insurance markets are not.

The model finds the following empirical implications. As agency problems worsen at insurers, the insurance cycle becomes more pronounced. The insurance cycle is more pronounced for lines of business that are more catastrophe driven. Finally, we find that the insurance cycle is more pronounced following poor financial performance.

This paper also provides a novel motivation for insurance regulation: because agency problems at insurance companies impact the provision of insurance to the market, shareholders may not have sufficient motivation to exercising costly governance. Therefore, it may improve welfare for a regulator to enforce corporate governance regulation upon insurers.

This paper models accounting numbers from insurers as cheap talk. Leading up to bankruptcy, the reported values of liabilities are flat, and then right before bankruptcy,

[2] See Table 2, page 3 of the NAIC 2016 Property/Casualty & Title Industry Report. The $612 billion dollar figure cited here corresponds to total U.S. property-casualty insurance industry premiums collected in 2016. However, the industry spent $74.2 billion on reinsurance; thus, premiums (net of reinsurance) came to $537.92 billion during 2016.

they shoot up (Plantin and Rochet (2009)). This suggests that they were underreported all along, because insurance companies know more about their losses than the market. Insurance companies are required to keep loss reserves, but they may have an incentive to manipulate these reserves and underreport their losses.

This paper shows that the high-cost part of the insurance cycle can be thought of as a liquidity crunch. Conceptually, this paper is similar to Acharya and Viswanathan (2011) and He and Krishnamurthy (2013). In these papers, when an asset goes down in value, it impacts the portfolios of those invested in it. This leads to a sale of the assets, which leads to a further decrease in value. In Acharya and Viswanathan (2011), the sale occurs because the investment managers' portfolios are levered, and some are liquidated in a fire sale. In He and Krishnamurthy (2013), the investment manager faces an agency problem, which restricts the amount of outside investment in the portfolio. When the asset loses money, this creates a shock to the investment manager's wealth, which lowers the amount that be invested in the asset. Our paper gives another channel that can worsen a liquidity crunch – asymmetric information. If the insiders know more about the value of their losses than the outside world, this will make the liquidity crunch even worse.

The paper is structured as follows. Section 2 presents a competitive model of insurance where each insurer holds capital to pay losses if there is a catastrophe. Section 3 presents a dynamic version of this model: each insurer knows the state of current policies when they underwrite new policies, but the market does not. Because the insurer knows more about the state of their policies than the market, capital flows are restricted into insurers, limiting insurance provision. Section 4 concludes.[3]

[3] All proofs for lemmas, theorems and corollaries that appear in this paper are available at http://bit.ly/cyclesappendix.

2 Model of the Insurance Cycle

Insureds have income w and utility function $u(\cdot)$ ($u' > 0$, $u'' < 0$), but face risk of loss. The loss occurs with probability π and results in loss of wealth of X. This risk is partially catastrophe driven. A catastrophe affects an insured with probability θ. When an insured is affected by a catastrophe, the probability of a loss is π_H, while the probability of a loss is π_L without a catastrophe, where $\pi_H > \pi_L$. For example, if the relevant risk is a fire, there is a small probablity that the house will burn down on its own (π_L), but when a forest fire occurs in the vicinity of the house, the probability of a loss increases (to π_H). Thus, the unconditional probability of loss is $\pi = \theta\pi_H + (1 - \theta)\,\pi_L$.

Each insurer is risk-neutral and has capital K, which it can allocate between underwriting insurance and investing in the market, at rate ρ. Insurers hold sufficient capital to pay losses when a catastrophe occurs.[4] There are many insurers and many insureds per insurer (formally, each insurer is a point $x \in [0, 1]$ and each insured is a point $(x, y) \in [0, 1]^2$).

An insurance contract states the premium, P, paid by the insured, and the indemnity, L, paid to the insured if a loss occurs. When covered by this contract, the insured has utility

$$U\,(L, P) = \pi u\,(w - P - X + L) + (1 - \pi)\,u\,(w - P)$$

For tractability, we assume u is CARA (results are qualitatively similar without this assumption). Insurers can invest in the market for gross return $\rho > 1$.[5] Each insurer underwrites insurance for m insureds to maximize expected profit.[6] Each insurer's profit, however, depends on if the insurer is affected by the catastrophe. If the insurer is unaffected by a catastrophe, operating profits is $O_L = m\,[P - \pi_L L]$. However, if the insurer is affected by the catastrophe,

[4] This assumption is justified if there is a large personal loss from failing to pay policyholders, for example, future exclusion from the market. Alternatively, if insurers follow a value-at-risk model, behavior would be the same so long as θ is larger than required confidence level of the value-at-risk model.

[5] Capital backing insurance is assumed to earn a lower return than long-term capital investment. Formally, the return paid to liquid assets is normalized to 1, and the return to long-term capital investment is $\rho > 1$.

[6] To simplify exposition, we assume in the body of the paper that insurers offer the same contract. This is shown to be optimal in Theorem 1 because insureds have concave utility, resulting in a unique optimal contract between insurers and insured.

the probability of loss will be higher, $\pi_H > \pi_L$, so operating profit is $O_H = m\left[P - \pi_H L\right]$. To be able to pay policyholders, it must be that $I + O_L \geq 0$ and $I + O_H \geq 0$. Because $O_H < O_L$, this constraint binds in a catastrophe, so $I \geq -O_H$. Because the value of each insurer is operating profits plus investment income, each insurer maximizes

$$\Pi = m\left[P - \pi L\right] + I + (K - I)\rho$$

subject to the constraints that $0 \leq I \leq K$, $m \geq 0$, and I is big enough to cover losses if the insurer is affected by the catastrophe, $I \geq -O_H$, or equivalently,

$$I \geq m\left(\pi_H L - P\right).$$

We will solve the model recursively. First, we will solve the optimal contract between insurers and insured, given capital K. Next, we will consider the optimal choice of K.

Equilibrium: Given capital K, the market for insurance is in equilibrium if:

- Insurers optimally underwrite insurance: m, P, L, and I maximize Π.
- Insureds select the best insurance policy available (also considering self-insurance).
- The number of insurance policies must be feasible, so $0 \leq \int_0^1 m_x dx \leq 1$.

Lemma 1 *If any insured buys insurance, all insureds will buy insurance in equilibrium.*

Insureds are identical and risk-averse, while insurers are risk-neutral, so all insureds buy the same insurance policy.[7] Because insurance is provided in a competitive market, insurers charge lower premiums than what a monopolist insurer would charge. Theorem 1 shows how much insureds will pay for a given level of insurance.

[7] Rothschild and Stiglitz (1976) show an instability in the market for insurance. In their model, insurers do not know the type of the insured, but each insured knows whether they are high risk or low risk. Their main result is that the only possible equilibrium is the separating equilibrium. As a part of this separating equilibrium, low-risk insureds may choose not to buy insurance. This conflicts with Theorem 1 because all insureds in our model are the same – the agency problem is at the insurance company.

Theorem 1 *Given market conditions, insurers write insurance with indemnity chosen to maximize their premium-to-indemnity ratio. For indemnity L, the equilibrium premium is $P = L\pi_P$, where $\pi_P \in (\pi, \pi_H)$. π_P is strictly decreasing in L. The market for insurance strictly improves welfare for insureds.*

Theorem 1 gives the premium for any level of indemnity. Symmetry implies that $m = 1$ for all insurers so $I = \pi_H L - P(L)$. Define the gross return on providing insurance as $R(I)$, so that we can express insurers' profit as $\Pi = R(I) * I + (K - I)\rho$, where $R(I) = (1-\theta)(\pi_H - \pi_L)\dfrac{L}{I}$. Because insurers choose how much capital to invest in underwriting insurance, writing insurance must provide a larger return than their outside option, ρ. Thus, it must be the case that $R(I) \geq \rho$ (if this holds strictly, $I = K$). This gives us the conditions for an equilibrium:

1. $P = L\pi_P$
2. $\pi_P = \dfrac{\pi u'(w - X + L - P)}{\pi u'(w - X + L - P) + (1-\pi) u'(w - P)}$
3. $I = (\pi_H - \pi_P) L$
4. $R(I) \geq \rho$, $K \geq I$, and one holds with equality.

This implies that financially constrained insurers will not provide full insurance. If the competitive market provides full insurance, it must be fairly priced (by Theorem 1, when $L = X$, $P(X) = \pi X$) and insurers average zero operating profit, which fails to return to capital backing insurance. This leads to Corollary 1.

Corollary 1 *The market never provides full insurance coverage. That is, $L < X$.*

Up to this point, we have shown that, in equilibrium, premiums increase in indemnities, but the premium to indemnity ratio decreases in the indemnity. Theorem 2 derives the equilibrium for a given level of capital.

Theorem 2 *There is a unique symmetric equilibrium in the market for insurance. Given a level of I, insurers underwrite indemnity $L(I)$, the unique solution to*

$$(\pi_H - \pi_P) L = I,$$

charging premium $P = L\pi_P$, where

$$\pi_P = \frac{\pi}{\pi + (1-\pi) e^{A(L(I)-X)}},$$

earning gross return of

$$R(I) = \frac{\pi_H - \pi}{\pi_H - \pi_P}.$$

Finally, $L(I)$ is increasing in I, yet $R(I)$ is decreasing in I. If $R(K) \geq \rho$, then $I = K$. If $R(K) < \rho$, then I satisfies $R(I) = \rho$.

The intuition behind Theorem 2 is that capital provides the supply of insurance. For small levels of capital, such that $R(K) > \rho$, the market for insurance is constrained: insurers use all their capital to write insurance. However, if $R(K) \leq \rho$, insurers will not increase their underwriting when they gain access to more capital. Thus, not all insurance capital is used to underwrite insurance, so that underwriting insurance earns return ρ.

The model captures the intuition that premiums and returns to insurance are decreasing in insurance capital. If capital varies exogenously, an insurance cycle would result. When capital is scarce, indemnities are low, but premiums are expensive (relative to indemnities). When capital is plentiful, indemnities are generous, but the premiums are modest (closer to actuarially fair). Capital of insurers is not exogenous, because insurers can raise capital, however. The cost of capital to the insurer is $\gamma > \rho$, because investors require a risk premium.

Theorem 3 *The insurer raises capital $K^* = (1-\theta)(\pi_H - \pi_L)\dfrac{L^*}{\gamma}$, and the equilibrium pre-*

mium to indemnity ratio is

$$\frac{P\left(L^{*}\right)}{L^{*}}=\pi_{H}-(1-\theta)\left(\pi_{H}-\pi_{L}\right)\frac{1}{\gamma}.$$

Insurers earn only their cost of capital, yet the market provides incomplete insurance coverage (formally, $L^{*}<X$).

Theorem 3 produces several implications about insurance pricing. Insurance will be more expensive when the cost of capital is larger, and premiums are more sensitive to the cost of capital in more catastrophe-driven lines of insurance (lines with higher $\pi_H-\pi_L$). This depends crucially on the assumption that insurers can raise capital efficiently. Section 3 shows how asymmetric information restricts the flow of capital, producing insurance cycles.

Corollary 2 *Insureds are better off when insurers have more capital, or equivalently, when the cost of capital is lower for insurers.*

3 The Insurance Cycle

This section develops an endogenous capital-driven insurance cycle. Each insurer knows more about its existing losses than the market. If a catastrophe occurs, the insurer knows its exposure, but the market does not. For example, the market can see that a severe earthquake has struck a certain area in California, but the market does not know which insurer is exposed to those losses. This asymmetric information restricts financing, resulting in an insurance cycle.

There are two generations of insureds. Each insured has CARA utility and risk of loss X with probability π. The first generation of insureds is insured at time 0, and their losses will be paid out at time 2. However, the insurer learns the state of the policies at time 1. Also, at time 1, the second generation buy insurance, and their losses will be paid out at time 3.

This overlap is necessary so that insurers (and only insurers) know the state of their early policies when underwriting late policies.[8]

We assume the following decomposition of catastrophe risk. In the first period, a publically-observable catastrophe occurs with probability ϕ. If a catastrophe strikes, an insurance company is affected with probability λ, and it is unaffected with probability $(1-\lambda)$. If an insurance company is affected, then the probability of loss for their insureds is π_H, while the probability of loss at unaffected companies is π_L. If a catastrophe does not occur, all insureds have a probability of loss of π_L. Thus, $\theta = \phi\lambda$.

As in Section 2, underwriting and investment decisions can be summarized by how much capital is devote to underwriting insurance in each state of the world. Define I_0 as the capital an insurer devotes to underwriting insurance for the first generation of insureds. Similarly, define I_{nc} as the capital devoted to underwriting the second generation provided that there is no catastrophe, $I_{c,u}$ as the capital devoted to underwriting the second generation provided that there is a catastrophe, but that the insurer is unaffected, and $I_{c,a}$ as the capital that an insurer devotes to underwriting insurance when there is a catastrophe that affects the insurer. As in Section 2, indemnity levels $\{L_0, L_{nc}, L_c\}$ and premiums $\{P(L_0), P(L_{nc}), P(L_c)\}$ are functions of capital, $\{I_0, I_{nc}, I_{c,u}, I_{c,a}\}$.

Capital structure of insurers plays a pivotal role in the analysis. We assume that insurers have equity E, but raise new funds with debt contracts.[9] The insurer issues debt D_0 at time 0 with face F_2 for repayment at time 2. However, the insurer has the option to rollover this debt by repaying $C_2 \leq F_2$ at time 2, so the insurer will need to pay $\gamma(F_2 - C_2)$ at time 3. Also, if the insurer issues more debt d_s for $s \in \{c, nc\}$ at time 1, they will have to repay f_s at time 3, but this debt is junior to debt issued at $t = 0$.[10] For simplicity, wealso assume that

[8]Similar results hold for more than two generations.

[9]Equity is less information sensitive than debt. Unaffected insurers prefer issuing debt to equity, because is has a smaller cross-subsidy to affected insurers. Though affected insurers would prefer pooling with equity, issuing equity would reveal them to be bad quality. Use of debt at $t = 0$ could be justified by assuming a small probability that an insurer is poor quality.

[10]This structure is justified if the agent can divert cash flows across time. The prepayment option could be restated as assuming the firm can buy back its bonds and the cost of capital is constant.

they have a similar prepayment option for the late debt, so if they make an early payment of c_s, the remaining payment required on the debt is $f_2 - \frac{1}{\gamma} c_s$.[11]

Assumption 2: Insureds are sufficiently risk-averse so that insurers provide insurance. Formally, $R(0) > \max\left\{\frac{\gamma^2}{1-\lambda}, \gamma^2\left[\frac{1}{\phi}\left(\frac{\gamma}{\rho} - 1\right) + 1\right], \frac{\gamma}{\rho}\gamma^2\right\}$.

Because a catastrophe harms insurers' ability to raise capital, it is a liquidity shock. In equilibrium, there are two ways that insurers can address catastrophe risk: they can use precautionary savings or they can borrow, but pay a premium for funds. Assumption 2 guarantees that insurers find it profitable to underwrite insurance. If Assumption 2 fails, the market for insurance may disappear following a catastrophe, which would be an extreme form of the insurance cycle.

To provide debt to the firm, lenders must be paid back sufficiently to cover their cost of capital. For early creditors to be willing to provide capital, discounted expected repayment is at least as large as the capital that they provide. For late creditors, the discounted expected repayment also must be at least as large as the capital that they provide, given that their claim is junior to the early creditors. The insurer will optimally choose their borrowing, savings, and underwriting decisions. Thus, wewill express the cost of raising debt d_s at $t = 1$ as $\kappa_s(d_s)$ for $s \in \{c, nc\}$. Note that κ_c is the expected cost to the unaffected insurer. Similarly, define $\kappa_0(D_0)$ as the cost of raising D_0 at $t = 0$.

Because there is no credible signal of the state of an insurer's policies, any message would be perceived as cheap talk, so affected insurers will mimic the unaffected insurers, resulting in a pooling equilibrium. Thus, $I_{c,u} = I_{c,a}$.

Given the state $s \in \{0, nc, c\}$, insurers provide an indemnity L_s and charge premium $P(L_s)$, where $P(\cdot)$ is from Theorem 1. By Theorem 2, insurers earn return $R_s = \frac{\pi_H - \pi}{\pi_H - \pi_P}$ from writing insurance.

There are two things that the insurer can do at time 0: he can underwrite insurance, or

[11] For clarity, we denote the debt issued at $t = 0$ with capital letters and debt issued at $t = 1$ with lower case letters.

he can save to underwrite insurance later:

$$I_0 + S_0 \leq E + D_0, \tag{1}$$

where S_0 is the insurer's savings at $t = 0$. Similarly, underwriting decisions at $t = 1$ must be feasible as well:

$$I_c + S_c \leq \rho S_0 + d_c \tag{2}$$

and

$$I_{nc} + S_{nc} \leq \rho S_0 + d_{nc}, \tag{3}$$

where S_c and S_{nc} are the savings decisions at $t = 1$ given a catastrophe and no catastrophe, respectively. Each insurer maximizes its expected $t = 3$ value, so each insurer's objective is

$$\Pi = \gamma \Pi_0 + \phi \Pi_c + (1 - \phi) \Pi_{nc}, \tag{4}$$

where Π_0 is the expected profit from underwriting insurance at $t = 0$:

$$\Pi_0 = R_0 I_0 - \kappa_0 (D_0), \tag{5}$$

Π_c is the expected profit at $t = 1$ if a catastrophe strikes:

$$\Pi_c = R_c I_c - \kappa_c (d_c) + \rho^2 S_c \tag{6}$$

and Π_{nc} is the expected profit at $t = 2$ if a catastrophe does not strike:

$$\Pi_{nc} = R_{nc} I_{nc} - \kappa_{nc} (d_{nc}) + \rho^2 S_{nc}. \tag{7}$$

Theorem 4 establishes the existence of the insurance cycle.

Theorem 4 *An endogenous debt overhang problem limits insurers' access to credit following* *a catastrophe, limiting provision of insurance (provision of insurance remains constant in the absence of a catastrophe). Formally, $R_c \geq R_{nc} \geq R_0$ and $R_c > R_0$. If the insurer is allowed to pay a dividend at $t = 0$, $R_c > R_{nc} = R_0$ for all $E > 0$.*

Theorem 4 shows that the return to writing insurance increases following a catastrophe. By Theorem 3, the premium to indemnity ratio increases but indemnities decrease. This occurs even though the catastrophe is noninformative of future losses, because risk is assumed to be independent over time.

Corollary 3 *The value of insurers' debt increases in the absence of a catastrophe. Following a catastrophe, the value of the equity decreases at affected insurers, but increases at unaffected insurers.*

Because capital acts as the supply of insurance, a catastrophe creates a supply shock to insurance, resulting in a lower quantity (indemnity) and higher price (premium to indemnity ratio). By Theorem 2, we can express the premium to indemnity ratio in a state $s \in \{0, c, nc\}$ as

$$\frac{P(L_s)}{L_s} = \pi_H - \frac{(1 - \phi\lambda)(\pi_H - \pi_L)}{R_s}$$

Thus, we can express the impact of the insurance cycle as

$$\begin{aligned} C &= \frac{P(L_c)}{L_c} - \frac{P(L_0)}{L_0} \\ &= (1 - \phi\lambda)(\pi_H - \pi_L)\left[\frac{1}{R_0} - \frac{1}{R_c}\right]. \end{aligned} \tag{8}$$

Thus, we can see how changes in parameters affect C, so we have the impact of fundamentals on the cycle.

Corollary 4 *Insurance is more expensive after a catastrophe strikes than in the absence of a catastrophe. Formally, $C > 0$.*

We see here that insurance, measured by premium to indemnity ratio, gets more expensive following a catastrophe. For tractability, we will focus on two types of equilibria: the savings equilibrium, and the inefficient borrowing equilibrium. Further, we will assume that insurers can pay a dividend at $t = 0$, so that $R_0 = \gamma^2$ (alternatively, we could assume that E is not too large ex ante). As shown in Theorem 4, in the savings equilibrium, $R_{nc} = \gamma^2$ and $R_c = \gamma^2 \left(\frac{1}{\phi} \left(\frac{\gamma}{\rho} - 1 \right) + 1 \right)$, while in the inefficient borrowing equilibrium, $R_{nc} = \gamma^2$ and either $R_c = \frac{\gamma^2}{1 - \phi\lambda^2}$ or $R_c = \frac{\gamma^2}{1 - \lambda}$. We refer to the type of equilibrium by the source of the marginal dollar of funding.[12] These are descriptions of the unique equilibrium on different regions in the parameter space, not multiple equilibria. By restricting attention to these two areas (because R_0, R_c, and R_{nc} do not depend on π_H and π_L), we are able to derive another implication.

Corollary 5 *Lines of insurance that are more catastrophe driven (higher $\pi_H - \pi_L$) are more expensive and have harsher cycles.*

A risk is more catastrophe driven if it is more correlated with the catastrophe (this is captured by an increase in π_H and decrease in π_L so that π remains constant). As shown in Corollary 5, more catastrophe driven risks are more expensive insurance and exhibit harsher cycles. This can explain why we do not see an insurance cycle in lines of insurance where there is no catastrophic element to it, such as life insurance, health insurance and annuities. Further, this explains why certain lines of insurance appear to be particularly expensive – the prices must leave enough profit to pay insurers a sufficient return on capital backing policies.

3.1 Comparative Statics in Savings Equilibrium

This section provides comparative statics for the case when the marginal dollar of funding for insurers comes from savings, a scenario referred to as the saving equilibrium. In the

[12] It should be noted that insurers may raise funds via the debt market ex post in the savings equilibrium, but the marginal dollar of funding comes from savings.

saving equilibrium, $R_c = \gamma^2 \left(\frac{1}{\phi} \left(\frac{\gamma}{\rho} - 1 \right) + 1 \right)$ and $R_0 = \gamma^2$. Thus,

$$C = (1 - \phi\lambda)(\pi_H - \pi_L) \frac{\gamma - \rho}{\gamma^2 [\gamma - (1 - \phi)\rho]}.$$

Corollary 6 *The insurance cycle becomes more pronounced and the insured are worse off when ρ is lower.*

There are a number of factors that could harm ρ, the effective return earned by insurance companies on their investments. First, corporate taxes would lower the effective return of capital held within the firm. Thus, the model predicts that increased corporate income taxes would worsen the insurance cycle, because it harms the ability of insurance companies to keep precautionary savings for catastrophes.

Corollary 6 shows a distinct result for regulation of insurers. If capital held by insurance companies is subject to free cash flow problems (for example, if managers are tempted to consume excessive perks when there is abundant capital), this will lower the effective return on investment at insurance companies, ρ. Corollary 6 shows that in the presence of such agency problems, insureds are worse off. Due to competition, there are no economic profits in equilibrium, suggesting that insurers may lack incentive to perform governance, because much of the benefit of governance goes to the consumer. This suggests a role for insurance regulation. The usual motivation for regulation is protecting unsophisticated policyholders,[13] so it may appear that lines of insurance with only sophisticated policyholders should not be regulated. Corollary 6 suggests otherwise, but this needs to be formalized in a richer model that incorporates governance.

Corollary 7 *Increasing the cost of capital (γ and ρ) dampens the insurance cycle, but harms insureds.*

[13] The traditional argument for insurance regulation is that insurers would otherwise write contracts that exploit policyholders, because the policyholders misunderstand the contract. Plantin and Rochet (2009) argue that regulation is necessary to protect policyholders, not only in bankruptcy, but also in preventing financial distress. They argue policyholders will not represent themselves due to the free-rider problem.

When the cost of capital is higher, the insurance cycle is less volatile. Holding $\gamma - \rho$ constant[14], a simultaneous increase in both γ and ρ will dampen the effects of the insurance cycle. That is, this change will produce a decrease in C. However, this change causes insurance to be more expensive in both states of the world, so insureds are harmed, even though the cycle is smaller.

Corollary 8 *When the risk premium increases (increasing γ but not ρ), the insurance cycle is harsher iff ϕ is large enough. For a fixed ϕ, the severity of the insurance cycle in inverted U-Shaped in the risk premium.*

When the risk premium increases, the insurance cycle will become more severe for risks that occur often enough, but the insurance cycle will be dampened for the very unlikely events. However, because the cutoff for ϕ is increasing in γ, for a fixed ϕ and ρ, the severity of the insurance cycle is inverted U-Shaped in γ.

Corollary 9 *As the catastrophe becomes more likely (ϕ) or more widespread (λ), the cycle will be dampened. However, holding the total risk of catastrophe ($\phi\lambda$) constant, if the catastrophe becomes less likely and more widespread, the insurance cycle will be more pronounced.*

As the catastrophic event becomes more likely, the insurer devotes more capital to it, and thus the cycle diminishes. More interesting is the result that if the catastrophe becomes less likely but more widespread, the cycle becomes more pronounced. Insurers can only profit from the catastrophe if they are not hit, so as a catastrophe becomes more widespread, it becomes less profitable to save capital to back insurance. This results is a decrease in welfare, because the same insurance is provided in the absence of a catastrophe, but less is provided when a catastrophe occurs.

Corollary 10 *Insurance cycles will be harsher during financial crises.*

[14] The proof of Corollary 7 shows the result also holds if $\frac{\rho}{\gamma}$ is constant.

Insurance cycles will be more pronounced in bad times than during good times. We proxy for this by examining what happens to premiums when insurers observe a low realization of ρ. In the absence of a catastrophe, there will be no effect on prices, because insurers have access to capital. However, when a catastrophe occurs, and there is low realized ρ, we will see a shock to capital backing insurance and thus an increase in premiums. Therefore, for a small change in ρ, $\frac{1}{L_{nc}} P\left(L_{nc}\right) = \frac{1}{L^*} P\left(L^*\right)$ and is thus unchanged, while $\frac{1}{L_c} P\left(L_c\right)$ increases.

3.2 Comparative Statics in Inefficient Borrowing Equilibrium

This section provides comparative statics for the case when the marginal dollar of funding for insurers comes from borrowing following a catastrophe, a scenario referred to as the borrowing equilibrium. Because there is a debt overhang problem, unaffected insurers must pay a premium for funds. If insurers are moderately constrained, even affected insurers, which have measure λ, will be able to repay late debt if they are not affected again, which happens with probability $\phi\lambda$. Thus, lenders are repaid with probability $1 - \phi\lambda^2$, so the cost of capital to unaffected insurers is $R_c = \frac{\gamma^2}{1 - \phi\lambda^2}$ (because unaffected lenders always repay). If insurers are very constrained, affected insurers never repay, so the cost of capital to unaffected insurers is $R_c = \frac{\gamma^2}{1 - \lambda}$. Because insurance is provided efficiently in the absence of a catastrophe, $R_0 = R_{nc} = \gamma^2$, we know the severity of the insurance cycle.

Corollary 11 *The cycle is less severe when the cost of capital is higher.*

Corollary 11 shows the analogous result to Corollary 7: when the cost of capital is higher, the insurance cycle is less severe. Because the cost of capital is higher, consumers are worse off.

Corollary 12 *If insurers are moderately constrained, the severity of the cycle is inverted U-Shaped in the probability of a catastrophe, ϕ and the severity of the catastrophe, λ.*

Insurance is more expensive when there is more catastrophe risk, both in normal times and following catastrophes. For small levels of catastrophe risk, the impact on premiums in normal times is small enough that increased exposure to catastrophe risk results in a larger cycle. When catastrophe risk becomes sufficiently prevalent, however, insurance when in normal times becomes expensive enough that the difference starts to decrease.

Corollary 13 *If insurers are very constrained, the severity of the cycle is decreasing in the probability of the catastrophe, ϕ, and inverted U-Shaped in the severity of the catastrophe, λ.*

When insurers are very constrained, increasing the probability of the catastrophe decreases the severity of the cycle. The severity of the catastrophe has a similar intuition as in Corollary 12. Similar intuition leads us to the following corollary.

Corollary 14 *For a given level of catastrophe risk, $\phi\lambda$, more widespread catastrophes (higher λ, lower ϕ) are associated with more severe cycles.*

4 Conclusion

In this paper, we model a perfectly competitive market for insurance where insurers hold capital to pay operating losses in any state of the world. Insurance provided to insureds, and thus their utility, is increasing in the amount of capital that insurers have.

This paper is a dynamic model, in which insurers raise capital to back insurance. If a catastrophe strikes, the market will not know the impact that this catastrophe had on a given insurance company, limiting the insurer's ability to access capital. This will cause a decrease in the provision of insurance, and thus a drop in welfare to the following generation of insureds.

We find several results with this paper. First, as agency and tax costs increase for insurers, the insurance cycle will become more pronounced. Also, as a risk becomes more catastrophe driven, or as scope of a catastrophe increases, the insurance cycle becomes more pronounced. Finally, insurance cycles will be more pronounced if a catastrophe occur during a financial crisis. This holds because when a catastrophe occurs, the insurer will be unable to raise capital in the market, and the returns of their existing capital will be lower because of the financial crisis. This will result in an even lower provision of insurance than the normal catastrophe.

This paper also has another interesting result: in a perfectly-competitive market for insurance where insurers hold capital to back insurance, there will never be full insurance. This holds because the insurer must earn a sufficient return on their capital, but when the market for insurance is perfectly competitive and provides full insurance, insurance will be fairly priced. Because fairly priced insurance by definition breaks even, this cannot be an equilibrium. Therefore, our model can help explain why we tend to see incomplete insurance coverage provided in the market. The model further predicts that insurance provision will be closer to efficient in certain lines of insurance, such as life, than others, like property-casualty, because the provision of insurance is decreasing in how catastrophe driven a line of insurance is.

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