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Shadow Insurance*

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Abstract

Life insurers use reinsurance to move liabilities from regulated and rated companies that sell policies to shadow reinsurers, which are less regulated and unrated off-balance-sheet entities within the same insurance group. U.S. life insurance and annuity liabilities ceded to shadow reinsurers grew from $11 billion in 2002 to $364 billion in 2012. Life insurers using shadow insurance, which capture half of the market share, ceded 25 cents of every dollar insured to shadow reinsurers in 2012, up from 2 cents in 2002. By relaxing capital requirements, shadow insurance could reduce the marginal cost of issuing policies and thereby improve retail market efficiency. However, shadow insurance could also reduce risk-based capital and increase expected loss for the industry. We model and quantify these effects based on publicly available data and plausible assumptions.

Keywords: Capital regulation, demand estimation, life insurance industry, regulatory arbitrage, reinsurance

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1. Introduction

Life insurance and annuity liabilities of U.S. life insurers were $4,068 billion in 2012, which is substantial even when compared with $6,979 billion in savings deposits at U.S. depository institutions (Board of Governors of the Federal Reserve System (2013)). However, little research exists on life insurer liabilities, especially in comparison with the large banking literature. The reason, perhaps, is the traditional view that life insurance and annuity liabilities are safe because they are more predictable, have a longer maturity, and are less vulnerable to runs. Thus, the conventional wisdom is that all of the interesting action is on the asset side of the balance sheet, where life insurers take on some investment risk.

Developments in the life insurance industry over the last decade challenge this traditional view. As a consequence of changes in regulation (see Section 2), life insurers are using reinsurance to move liabilities from operating companies (i.e., regulated and rated companies that sell policies) to less regulated and unrated off-balance-sheet entities within the same insurance group. These "shadow reinsurers" are captives or special purpose vehicles in states (e.g., South Carolina and Vermont) or offshore domiciles (e.g., Bermuda, Barbados, and Cayman Islands) with more favorable capital regulation or tax laws. In contrast to traditional reinsurance with unaffiliated reinsurers, these transactions do not transfer risk because the liabilities stay within the same insurance group.

Using U.S. data on reinsurance agreements (see Section 3), we document new facts about life insurance and annuity liabilities in Section 4, with a special emphasis on the shadow insurance sector. We find that liabilities ceded to shadow reinsurers grew significantly from $11 billion in 2002 to $364 billion in 2012. This activity now exceeds total unaffiliated reinsurance in the life insurance industry, which was $270 billion in 2012. Life insurers using shadow insurance tend to be larger and capture 48% of the market share for both life insurance and annuities. These companies ceded 25 cents of every dollar insured to shadow reinsurers in 2012, up from 2 cents in 2002.

By relaxing capital requirements, shadow insurance could reduce the marginal cost of issuing policies and thereby improve retail market efficiency. However, shadow insurance could also reduce risk-based capital because it allows life insurers to issue more policies for a given amount of equity. We develop a simple model in Section 5 to illustrate these effects. In our model, a holding company consists of an operating company that sells policies and an affiliated reinsurer whose only role is to assume reinsurance from the operating company. The key friction is that required capital in the two companies is regulated, and the operating company faces tighter capital regulation than the affiliated reinsurer.[1] Affiliated reinsurance

[1]We take as given that life insurers are regulated, which breaks the Modigliani and Miller (1958) theorem. The deeper economic frictions that justify regulation include informational frictions and agency problems,

allows the holding company to reallocate liabilities between the two companies to reduce the overall cost of regulatory frictions.

The model predicts that affiliated reinsurance reduces the operating company's marginal cost of issuing policies and increases the equilibrium supply in the retail market. To quantify this effect, we estimate a differentiated product demand system for the life insurance market, assuming oligopolistic price setting (Berry, Levinsohn, and Pakes (1995)). Our identifying assumption is that shadow insurance reduces the operating company's marginal cost, but it does not affect demand directly. Our structural estimates imply that shadow insurance reduces life insurance prices by 10% for the average company and increases annual life insurance issued by $6.8 billion for the industry, which is 7% of the current market size.

If rating agencies and retail customers already have full knowledge of shadow insurance, life insurers and regulators should be indifferent to disclosing the financial statements of captives, or they may even prefer full disclosure to avoid any chance of misinterpretation. Yet, the financial statements of captives are not publicly available, except for those recently released by the Iowa Insurance Division (2014). This leaves open the possibility that shadow insurance reduces risk-based capital and increases expected loss for the industry. In Section 6, we discuss the evidence from Lawsky (2013) and the financial statements of Iowa captives, which suggest that captives have significantly less equity than operating companies. We also quantify the potential risk of shadow insurance by adjusting measures of risk based on publicly available data and plausible assumptions. Our adjustment reduces risk-based capital by 53 percentage points (or 3 rating notches) and increases the 10-year cumulative default probability by a factor of 3.5 for the average company using shadow insurance.

Our work on life and annuity reinsurance is related to the literature on property and casualty reinsurance. This literature finds that property and casualty reinsurance is used for various reasons, including risk transfer as well as capital and tax management (Mayers and Smith (1990), Adiel (1996)). For life insurers, risk transfer has always been a less important motive because of the more predictable nature of their business, which explains why there is relatively little unaffiliated reinsurance. All of the growth in life and annuity reinsurance over the last decade is within the same insurance group, which points to capital and tax management as the primary motive for this activity.

Our work is also related to the literature on financial and regulatory frictions on the supply side of insurance markets. In particular, some recent papers show that capital regulation and accounting rules, when they interact with financial frictions, affect investment behavior on the asset side of the balance sheet (Merrill, Nadauld, Stulz, and Sherlund (2012), Becker and Opp (2013), Becker and Ivashina (2015), Ellul, Jotikasthira, Lundblad, and Wang

such as moral hazard in the presence of state guaranty funds (Lee, Mayers, and Smith (1997)).

(2015)). Our work complements this literature by showing that a set of capital regulation and accounting rules on the liability side has a profound impact on reinsurance activity and pricing behavior in the retail market (Koijen and Yogo (2015)).

2. Changes in Regulation That Preceded Shadow Insurance

The four basic motives of life and annuity reinsurance are risk transfer, underwriting assistance, capital management, and tax management (Tiller and Tiller (2009, Chapter 1)). Over the last decade, the latter two motives have become increasingly important relative to the former two because of two related developments. On the one hand, changes in regulation after 2000 forced life insurers to hold more capital against life insurance liabilities. On the other hand, new state laws after 2002 allowed life insurers to establish captives to circumvent the new capital requirements. In this section, we summarize these developments and related institutional background that is relevant to this paper.

2.1. Changes in Life Insurance Regulation

In January 2000, the National Association of Insurance Commissioners (NAIC) adopted Model Regulation 830, commonly referred to as Regulation XXX. This was followed by Actuarial Guideline 38 in January 2003, commonly referred to as Regulation AXXX. These changes in regulation forced life insurers to hold much higher statutory reserves on newly issued term life insurance and universal life insurance with secondary guarantees.

These changes in regulation are a matter of statutory accounting principles and do not apply to generally accepted accounting principles (GAAP). The reserve requirements under GAAP are much lower and closer to actuarial value. Therefore, an operating company that reports under statutory accounting principles can cede reinsurance to either an affiliated or an unaffiliated reinsurer that reports under GAAP to reduce overall reserves. In practice, unaffiliated reinsurance can be expensive because of capital market frictions and market power (Gron (1994), Froot (2001)).

2.2. New Captive Laws

South Carolina introduced new laws in 2002 that allow life insurers to establish captives, whose primary function is to assume reinsurance from affiliated companies for the purpose of reducing overall reserves. States compete for captive business in order to increase employment and tax revenue (Cole and McCullough (2008)). Furthermore, the captive's state of domicile does not directly bear risk because the liabilities go back to the operating company (and ultimately the guaranty associations of states in which the policies were sold) when a captive fails. A captive structure that has proven especially successful is the special purpose financial captive, which is a type of special purpose vehicle that was introduced by South Carolina in 2004 and by Vermont in 2007. Twenty-six states have now adopted a version of the captive laws, eight of which have defined special purpose financial captives (Captives and Special Purpose Vehicle Use Subgroup (2013)).

Captives differ from traditional reinsurers in several important ways. First, captive reinsurance can be less expensive than unaffiliated reinsurance, especially after the fixed costs of entry have been paid. Second, captives can operate with less equity because they report under GAAP and are not subject to risk-based capital regulation. For example, captives in Vermont are required to have only $250,000 in equity and are allowed to count letters of credit as admitted assets (Captives and Special Purpose Vehicle Use Subgroup (2013)). Third, captives have a more flexible financial structure that allows them to fund reinsurance transactions through letters of credit or securitization. Finally, their financial statements are confidential to the public, rating agencies, and even regulators outside their state of domicile. Appendix A contains balance sheet examples that highlight these aspects of captive reinsurance.

U.S. tax laws disallow reinsurance for the primary purpose of reducing tax liabilities. However, it can be an important side benefit of captive reinsurance that motivates where a life insurer establishes its captives. Life insurance premiums are taxable at the state level, and the tax rates on premiums vary across states (Cole and McCullough (2008)). In addition, profits are taxable at the federal level, so an operating company can reduce overall tax liabilities by ceding reinsurance to an offshore captive. Bermuda, Barbados, and the Cayman Islands are important captive domiciles for this purpose.

Operating companies are ultimately responsible for all liabilities that they issue, even those that they cede to reinsurers. Moreover, captives typically do not transfer risk to outside investors through securitization (Stern, Rosenblatt, Nadell, and Andruschak (2007)). These facts together imply that captives do not transfer risk outside the insurance group and exist solely for the purpose of capital and tax management. Thus, captives have a function similar to asset-backed commercial paper conduits with explicit guarantees from the sponsoring bank (Acharya, Schnabl, and Suarez (2013)), prior to the recent regulatory reform of shadow banking (Adrian and Ashcraft (2012)).

3. Data on Life and Annuity Reinsurance

3.1. Data Construction

We construct our sample of life and annuity reinsurance agreements for U.S. life insurers from the Schedule S filings for fiscal years 2002 to 2012 (A.M. Best Company (2003–2013)). These financial statements are reported annually to the NAIC according to statutory accounting principles, which are conveniently organized along with ratings information by A.M. Best Company. The relevant parts of Schedule S for our analysis are Part 1.1 (Reinsurance Assumed), Part 3.1 (Reinsurance Ceded), and Part 4 (Reinsurance Ceded to Unauthorized Companies).

The data contain all reinsurance agreements (both ceded and assumed) at each fiscal year-end for any operating company or authorized reinsurer. An authorized reinsurer is subject to the same reporting and capital requirements as an operating company in its state of domicile, whereas an unauthorized reinsurer is not. In particular, the data contain reinsurance ceded by an operating company to an unauthorized reinsurer, such as a domestic captive or a foreign reinsurer. However, we do not observe reinsurance ceded by unauthorized reinsurers that do not report to the NAIC.

For each reinsurance agreement, we observe the identity of the reinsurer, the type of reinsurance, the effective date, reserve credit taken (or reserves held), and modified coinsurance reserve. The sum of reserve credit taken and modified coinsurance reserve is essentially the dollar amount of reinsurance ceded (see Appendix A). We know the identity of the reinsurer up to its name, domicile, whether it is affiliated with the ceding company, whether it is authorized in the ceding company's domicile, and whether it is rated by A.M. Best Company. We define *shadow reinsurers* as affiliated and unauthorized reinsurers without an A.M. Best rating. Our definition is stricter than "captives" because some captives are actually authorized.

3.2. Summary Statistics

Table I reports summary statistics for our sample of life and annuity reinsurance agreements, by whether they were ceded to unaffiliated or affiliated reinsurers. The table also reports the same statistics for shadow reinsurers. Although there are fewer affiliated than unaffiliated reinsurance agreements, the typical amount ceded is significantly higher for affiliated than unaffiliated reinsurance. For example, 456 unaffiliated reinsurance agreements originated in 2009. In comparison, only 120 affiliated reinsurance agreements originated in 2009, 67 of which were ceded to shadow reinsurers. Average unaffiliated reinsurance ceded was $37 million in 2009, which is much lower than $1,199 million for affiliated reinsurance and $2,003 million for shadow insurance. The average shadow insurance agreement grew from $60 million in 2002 to $502 million in 2012.

Table II summarizes the characteristics of the life insurers in our sample, by whether they were using shadow insurance.[2] Although most life insurers do not use shadow insurance, the ones that do tend to be larger, by either market share or total liabilities. In 2012,

[2]See Appendix B for a description of the data on company characteristics.

78 companies used shadow insurance, whereas 443 companies did not. However, the life insurers using shadow insurance captured 48% of the market share for both life insurance and annuities. Furthermore, the average liabilities of life insurers using shadow insurance were 317% higher than those of the other companies. The life insurers using shadow insurance are mostly stock instead of mutual companies. They also tend to have lower risk-based capital, higher leverage, assets with lower liquidity, and higher profitability.

4. New Facts about Shadow Insurance

We now document the rapid growth of shadow insurance over the last decade, as a consequence of changes in regulation summarized in Section 2. We start with a case study of the MetLife group, which is the largest insurance group in the United States by total assets. We then show that the rapid growth of affiliated reinsurance, especially with unrated and unauthorized reinsurers, stands in sharp contrast to the behavior of unaffiliated reinsurance over the same period.

4.1. A Case Study of the MetLife Group

Table III lists the U.S. operating companies of the MetLife group and their affiliated reinsurers in 2012. The operating companies all have an A.M. Best rating of A+ and cede reinsurance to the rest of the group. The reinsurers are all unrated and assume reinsurance from the rest of the group. The reinsurers are also unauthorized, except for MetLife Reinsurance of Delaware and MetLife Reinsurance of Charleston since 2009. The liabilities consistently disappear from the balance sheets of operating companies that sell policies and end up in less regulated and unrated reinsurers.

Net reinsurance ceded by Metropolitan Life Insurance (the flagship operating company in New York) was $39.1 billion, which was nearly three times their capital and surplus. In the same year, net reinsurance assumed by Missouri Reinsurance (a captive in Barbados) was $28.4 billion. The sum of net reinsurance ceded across all companies in Table III, which is total reinsurance ceded outside the MetLife group, was $5.7 billion. Thus, most of the reinsurance activity is within the MetLife group, rather than with unaffiliated reinsurers.

4.2. Growth of Affiliated Reinsurance

Figure 1 reports total reinsurance ceded by U.S. life insurers to affiliated and unaffiliated reinsurers. Affiliated reinsurance grew from $90 billion in 2002 to $572 billion in 2012. In contrast, unaffiliated reinsurance peaked at $287 billion in 2006 and is nearly constant thereafter. Affiliated reinsurance has exceeded unaffiliated reinsurance since 2007.

Figure 2 breaks down Figure 1 into life versus annuity reinsurance. Affiliated life reinsurance grew from $36 billion in 2002 to $375 billion in 2012. This trend coincides with the changes in life insurance regulation and new captive laws. In contrast, affiliated annuity reinsurance was nearly constant until 2007, then grew from $91 billion in 2007 to $197 billion in 2012. This growth is curious because Regulation (A)XXX does not apply to annuities, and its timing coincides with the financial crisis.

The use of affiliated annuity reinsurance during the financial crisis could be explained by a motive to smooth reserves, including that which arises from capital constraints (Koijen and Yogo (2015)). Under Actuarial Guideline 43, the reserve value of variable annuity liabilities under statutory accounting principles increases relative to that under GAAP after a period of high volatility (Credit Suisse (2012)). Therefore, a life insurer could smooth overall reserves by moving liabilities from an operating company that reports under statutory accounting principles to an affiliated reinsurer that reports under GAAP.

4.3. Geographic Concentration of Reinsurance

Figure 3 decomposes life and annuity reinsurance ceded by the reinsurer's domicile, separately for affiliated and unaffiliated reinsurance. The geography of affiliated reinsurance is characterized by increasing concentration, which is not present in unaffiliated reinsurance. As we discussed in Section 2, South Carolina and Vermont are the most important domiciles for domestic captives because of their capital regulation. The share of affiliated reinsurance ceded to these two states grew from virtually none in 2002 to 19% in 2012. In contrast, the share of unaffiliated reinsurance ceded to these two states remained low throughout the same period. Bermuda, Barbados, and the Cayman Islands are the most important domiciles for offshore captives because of their capital regulation and tax laws. The share of affiliated reinsurance ceded to these offshore domiciles grew from 9% in 2002 to 46% in 2012. In contrast, the share of unaffiliated reinsurance ceded to these offshore domiciles fell slightly over the same period.

4.4. Reinsurance with Unrated and Unauthorized Reinsurers

Figure 4 decomposes life and annuity reinsurance ceded by the A.M. Best rating of the reinsurer, separately for affiliated and unaffiliated reinsurance. The share of affiliated reinsurance ceded to unrated reinsurers grew from 21% in 2002 to 76% in 2012. In contrast, the share of unaffiliated reinsurance ceded to unrated reinsurers fell slightly over the same period.

Figure 5 decomposes life and annuity reinsurance ceded by whether the reinsurer is authorized in the ceding company's domicile, separately for affiliated and unaffiliated reinsurance. The share of affiliated reinsurance ceded to unauthorized reinsurers grew from 19% in 2002 to 70% in 2012. In contrast, the share of unaffiliated reinsurance ceded to unauthorized reinsurers is nearly constant over the same period and is 23% in 2012.

4.5. *Growth of Shadow Insurance*

Figure 6 reports total reinsurance ceded by U.S. life insurers to shadow reinsurers. Shadow insurance grew significantly from \$11 billion in 2002 to \$364 billion in 2012. In particular, growth accelerated during the financial crisis from 2006 to 2009. As a share of the capital and surplus of the ceding companies, shadow insurance grew from 0.22 in 2002 to 2.49 in 2012. As a share of gross life and annuity reserves for companies using shadow insurance, shadow insurance grew from 2 cents of every dollar insured in 2002 to 25 cents in 2012. This represents a significant accumulation of liabilities in a less regulated and nontransparent part of the insurance industry.

5. A Model of Insurance Pricing and Reinsurance

We now develop a simple model that illustrates the impact of shadow insurance on the retail market and risk-based capital. We make several simplifying assumptions to highlight the key economic mechanisms. First, we tailor the model to the life insurance market to match our empirical application, but the key economic insights would carry over to the annuity market. Second, we do not model equity issuance under the assumption that it is a more expensive way to raise statutory capital than affiliated reinsurance (Myers and Majluf (1984)), consistent with the evidence in Section 4. For a similar reason, we leave out unaffiliated reinsurance, which we modeled in an earlier version of this paper (Koijen and Yogo (2013)). Finally, we do not model taxes because it is difficult to do so realistically, and the tax benefits of reinsurance are not separately identified from a reduced cost of regulatory frictions based on publicly available data.

5.1. *A Holding Company's Maximization Problem*

A holding company consists of an operating company and an affiliated reinsurer (i.e., a captive or a special purpose vehicle). In period t, the operating company offers long-term life insurance at a per-period premium of P_t per unit. As long as the policyholder pays P_t in each period $t+s$ for $s \geq 0$, the operating company promises to pay a dollar if the insured dies in period $t+s+1$, which occurs with probability $1-\pi$. Let R_L be a constant gross discount rate on liabilities in period t. Then the actuarial value is $V = (1-\pi)/R_L$ per unit, which is the present value of the death benefit in period $t+1$. A share $1-\lambda$ of policies sold in period t are lapsed in each period $t+s$ for $s \geq 1$. Alternatively, λ determines the effective maturity of life insurance. For example, one-period coverage is a special case when $\lambda = 0$, and lifetime coverage is a special case when $\lambda = 1$.

The operating company optimally prices insurance in an oligopolistic market, where we assume the existence of a Nash equilibrium in prices. The operating company faces a demand function that is continuous, continuously differentiable, and strictly decreasing in its own price. Let Q_t be the quantity of policies sold in period t. After the sale of policies, the operating company can cede reinsurance to the affiliated reinsurer. Let $B_t \geq 0$ be the quantity of affiliated reinsurance ceded in period t.

The holding company's profit in period t is

$$Y_t = \sum_{s=0}^{\infty} \delta^s (P_{t-s} - V) Q_{t-s}, \tag{1}$$

where $\delta = \pi\lambda$. Total profit is the sum of profits across all policies sold that remain in effect. Only a share δ of policies sold in period $t-1$ remain in effect in period t because of attrition through death and lapsation. Affiliated reinsurance does not affect total profit under the maintained assumption of no tax effects.

5.1.1. Balance Sheet Dynamics

We now describe how the sale of policies and affiliated reinsurance affect the balance sheet. The operating company's liabilities at the end of period t are

$$L_t = \sum_{s=0}^{\infty} \delta^s V (Q_{t-s} - B_{t-s}) = \delta L_{t-1} + V(Q_t - B_t). \tag{2}$$

Liabilities are the sum of policies net of affiliated reinsurance that remain in effect, evaluated at actuarial value. Let $R_{A,t}$ be the return on assets in period t. The operating company's assets at the end of period t are

$$A_t = R_{A,t} A_{t-1} + V(Q_t - B_t) + Y_t. \tag{3}$$

This equation follows from the flow of funds identity, which says that the change in assets is the change in liabilities plus total profit.

We define the operating company's statutory capital at the end of period t as

$$K_t = A_t - (1 + \rho) L_t, \tag{4}$$

where a higher $\rho > 0$ implies tighter capital regulation. Our formulation of statutory capital has two interpretations, both of which lead to equation (4). First, as we discussed in Section 2, operating companies must hold additional reserves under Regulation (A)XXX. Under this interpretation, $1 + \rho$ is the ratio of statutory reserve to actuarial value. Second, operating companies that face risk-based capital regulation must hold additional capital to buffer shocks to their liabilities. Under this interpretation, ρ is the risk charge on liabilities.

The only role of the affiliated reinsurer is to assume reinsurance from the operating company. The affiliated reinsurer's liabilities at the end of period t are

$$\widehat{L}_t = \sum_{s=0}^{\infty} \delta^s VB_{t-s} = \delta \widehat{L}_{t-1} + VB_t. \tag{5}$$

Its assets at the end of period t are

$$\widehat{A}_t = R_{A,t} \widehat{A}_{t-1} + VB_t. \tag{6}$$

We assume that the affiliated reinsurer faces looser capital regulation than the operating company, which is captured by $\widehat{\rho} \in (0, \rho)$. We define the affiliated reinsurer's statutory capital at the end of period t as

$$\widehat{K}_t = \widehat{A}_t - (1 + \widehat{\rho}) \widehat{L}_t. \tag{7}$$

We define the holding company's excess capital at the end of period t as

$$W_t = A_t + \widehat{A}_t - (1 + \rho) \left(L_t + \widehat{L}_t \right). \tag{8}$$

Excess capital corresponds to the operating company's statutory capital if its balance sheet were consolidated with that of the affiliated reinsurer. Alternatively, if we interpret ρ as the risk charge on liabilities, this equation corresponds to risk-based capital in differences instead of as a ratio (i.e., $(A_t - L_t + \widehat{A}_t - \widehat{L}_t)/(\rho(L_t + \widehat{L}_t))$).

5.1.2. Objective Function

The Insurance Holding Company System Regulatory Act protects the interests of existing policyholders and the state guaranty funds by restricting the movement of capital within a holding company, including through affiliated reinsurance (National Association of Insurance Commissioners (2011, Appendix A-440)). Furthermore, increased use of shadow insurance could draw regulatory scrutiny or intervention (Lawsky (2013)). We model these regulatory frictions through a cost function:

$$C_t = C \left(\frac{K_t}{L_{t-1}}, \frac{\widehat{K}_t}{\widehat{L}_{t-1}} \right).$$

We assume that this cost function is continuous, twice continuously differentiable, strictly decreasing, and strictly convex. The cost function is decreasing because higher statutory capital, relative to balance sheet size as captured by lagged liabilities, reduces the likelihood of regulatory scrutiny or intervention. The cost function is convex because these benefits of higher statutory capital have diminishing returns.

In each period t, the holding company chooses the insurance price P_t and affiliated reinsurance B_t to maximize firm value. The holding company has limited liability and operates as long as excess capital relative to balance sheet size exceeds a constant default boundary: $W_t/(L_{t-1} + \widehat{L}_{t-1}) \geq \tau$. We assume the absence of arbitrage, which implies the existence of a stochastic discount factor M_{t+1} that is strictly positive but not necessarily unique (Cochrane (2001, Chapter 4)). Thus, firm value is the present value of profits minus the cost of regulatory frictions:

$$
\begin{aligned}
J_t =& Y_t - C_t + \mathbb{E}_t[M_{t+1} J_{t+1}] \\
=& Y_t - C_t + \Pr_t\left(\frac{W_{t+1}}{L_t + \widehat{L}_t} \geq \tau\right) \mathbb{E}_t\left[M_{t+1} J_{t+1} \middle| \frac{W_{t+1}}{L_t + \widehat{L}_t} \geq \tau\right],
\end{aligned} \tag{9}
$$

where the second line follows from the normalization that firm value conditional on default is zero.

5.2. *Optimal Insurance Pricing and Reinsurance*

To simplify notation, we first define the operating company's *shadow cost of capital* as[3]

$$
c_t = -\frac{\partial C_t}{\partial K_t} + \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial K_t}\right].
$$

The shadow cost of capital quantifies the importance of regulatory frictions in either the present or the future. Similarly, we define the affiliated reinsurer's shadow cost of capital as

$$
\widehat{c}_t = -\frac{\partial C_t}{\partial \widehat{K}_t} + \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial \widehat{K}_t}\right].
$$

The following proposition characterizes the optimal insurance price and affiliated reinsurance.

PROPOSITION 1: *The optimal insurance price is*

$$
P_t = \left(1 - \frac{1}{\epsilon_t}\right)^{-1} \Phi_t, \tag{10}
$$

[3]Our assumptions on the cost function imply that the value function is differentiable (Stokey, Lucas, and Prescott (1989, Theorem 4.11)), and the partial derivative with respect to statutory capital can be passed inside the conditional expectation by Leibniz's rule.

where $\epsilon_t = -\partial \log(Q_t)/\partial \log(P_t)$ *is the elasticity of demand and*

$$\Phi_t = \frac{(1 + (1 + \rho)c_t)V}{1 + c_t}$$

is the marginal cost of issuing policies. If affiliated reinsurance is at an interior optimum, it satisfies

$$c_t \rho = \widehat{c}_t \widehat{\rho}. \tag{11}$$

We prove Proposition 1 in Appendix C. The first term in equation (10) is familiar from the Bertrand pricing formula. The optimal insurance price is decreasing in the elasticity of demand. The second term is marginal cost that arises from regulatory frictions. Marginal cost increases with the shadow cost of capital and tighter capital regulation (i.e., higher ρ).

Equation (11) says that the holding company equates the shadow cost of capital across the two companies, appropriately weighted by the tightness of capital regulation. For example, suppose that the two companies have the same shadow cost of capital prior to affiliated reinsurance. Then the operating company cedes reinsurance to the affiliated reinsurer that faces looser capital regulation (i.e., $\widehat{\rho} < \rho$). The operating company's statutory capital rises relative to the affiliated reinsurer's, so that equation (11) holds with $c_t < \widehat{c}_t$ after affiliated reinsurance.

COROLLARY 1: *Affiliated reinsurance reduces the marginal cost of issuing policies (i.e.,* $\partial \Phi_t / \partial B_t < 0$*). Furthermore, affiliated reinsurance reduces excess capital if* $\partial P_t / \partial B_t < 0$.

We prove Corollary 1 in Appendix C. Affiliated reinsurance reduces the operating company's shadow cost of capital and thereby reduces the marginal cost of issuing policies. A lower marginal cost implies a lower price through equation (10), provided that the demand elasticity does not decrease to more than offset the lower marginal cost. Thus, affiliated reinsurance could reduce the insurance price and increase the quantity of policies issued.

If affiliated reinsurance reduces the insurance price, it also reduces excess capital according to Corollary 1. The reason is that the marginal increase in equity from the additional business is less than the marginal increase in capital required to support the additional liabilities. Thus, affiliated reinsurance could reduce risk-based capital and increase the probability of default. In practice, we cannot accurately assess these effects because the balance sheets of captives are not publicly available, which means that we do not directly observe excess capital (8) or the probability of default (9).

5.3. *Impact of Shadow Insurance on the Retail Market*

In Appendix D, we quantify the impact of shadow insurance on the retail market by estimating a differentiated product demand system for the life insurance market, together with the optimal pricing equation. Demand is determined by the random coefficients logit model (Berry et al. (1995)), where product differentiation is along company characteristics. We specify marginal cost as an exponential-linear function of shadow insurance and company characteristics. We then estimate the structural model under an identifying assumption that shadow insurance reduces marginal cost, but it does not affect demand directly. Finally, we use the structural model to estimate counterfactual insurance prices and market size in the absence of shadow insurance.

We summarize our conservative estimates under the assumption that ratings and risk-based capital already reflect the risk of shadow insurance. In Koijen and Yogo (2013), we also reported larger effects under an alternative assumption that ratings and risk-based capital do not adequately reflect the risk of shadow insurance. Marginal cost would increase by 13.3% for the average company using shadow insurance in 2012. In response to higher marginal cost, the average company would raise prices by 10.4%. The quantity of life insurance issued annually would fall by $7.2 billion for the operating companies using shadow insurance, while the other companies would gain $0.4 billion because of substitution effects. Higher prices mean that some potential customers would stay out of the life insurance market. The industry as a whole would shrink by $6.8 billion, which is 7% of its current size of $91.5 billion in 2012.

6. Potential Risk of Shadow Insurance

We now discuss the possibility that shadow insurance reduces risk-based capital and increases expected loss for the industry. As we discussed in Section 2, captives are not subject to Regulation (A)XXX or risk-based capital regulation. Therefore, captives would have to voluntarily hold as much capital as the operating companies in order for shadow insurance to not affect risk at the holding company level. Two pieces of evidence suggest that this is not always the case.

First, Lawsky (2013) has examined non-public financial statements of captives that assume reinsurance from operating companies in New York and found widespread use of fragile sources of funding, such as conditional letters of credit (guaranteed by the parent company) and naked parental guarantees. These fragile sources of funding erode the effective equity in captives. Moody's Investors Service shares a similar view that "because many companies' captives are capitalized at lower levels compared to flagship companies, the use of captives tends to weaken capital adequacy" (Robinson and Son (2013, p. 3)).

Second, the Iowa Insurance Division (2014) recently released financial statements for eight captives in their domicile for 2013 and 2014. These financial statements report how much equity these captives have when evaluated under the statutory accounting principles that apply to operating companies. Six of the eight captives have significantly negative equity under statutory accounting. When aggregated over the eight captives, total equity under statutory accounting is −$2.7 billion in 2014.

We do not have sufficient data to accurately assess the potential risk of shadow insurance. Based on publicly available data, we can only explore what plausible assumptions imply for risk. In Appendix E, we quantify the potential risk of shadow insurance by adjusting measures of risk based on two assumptions. First, we assume that captives do not have equity under statutory accounting, consistent with the two pieces of evidence. Second, we assume that the risk profile of reinsurance ceded is identical to assets and liabilities that remain on the balance sheet, which is a natural starting point. Under these assumptions, our adjustment reduces risk-based capital by 53 percentage points (or 3 rating notches) and increases the 10-year cumulative default probability by a factor of 3.5 for the average company using shadow insurance. This implies an expected loss of $14.4 billion for the industry, which is 26% of the total capacity of state guaranty funds.

7. Conclusion

We have documented new facts about reinsurance for U.S. life insurers. All of the growth in life and annuity reinsurance over the last decade is explained by affiliated reinsurance within the same insurance group, rather than unaffiliated reinsurance across groups. This growth in affiliated reinsurance accelerated during the financial crisis, especially for annuity reinsurance. Affiliated reinsurance is geographically concentrated in states (e.g., South Carolina and Vermont) and offshore domiciles (e.g., Bermuda, Barbados, and Cayman Islands) with more favorable capital regulation or tax laws. Shadow insurance is the part of affiliated reinsurance that is with less regulated and unrated reinsurers. The U.S. shadow insurance sector grew significantly from $11 billion in 2002 to $364 billion in 2012. Life insurers using shadow insurance ceded 25 cents of every dollar insured to shadow reinsurers in 2012, up from 2 cents in 2002.

Based on publicly available data, we do not know the amount of equity in captives, the fragility of their funding arrangements, or the risk profile of their assets and liabilities. Therefore, we cannot conclusively tell whether shadow insurance simply offsets inefficient capital requirements and taxes, or whether it increases expected loss for the industry. In the interest of more transparency, state regulators could release the financial statements of captives, following the lead of the Iowa Insurance Division. More broadly, financial disclosure should not be limited to the United States because insurance is a global business. In particular, we do not know the size of the European shadow insurance sector because of limited disclosure and inconsistent reporting requirements across countries.

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Table I
Summary Statistics for Reinsurance Agreements

	Number of reinsurance agreements ceded to			Mean reinsurance ceded (million $)		
Year	Unaffiliated	Affiliated	Shadow	Unaffiliated	Affiliated	Shadow
2002	1,493	157	53	26	77	60
2003	960	119	70	26	116	59
2004	753	149	89	101	528	502
2005	824	182	110	28	211	163
2006	681	146	85	54	227	231
2007	599	114	65	39	345	451
2008	566	132	88	25	613	717
2009	456	120	67	37	1,199	2,003
2010	410	116	56	10	509	776
2011	310	110	49	56	626	640
2012	328	120	45	89	392	502

Summary statistics for life and annuity reinsurance agreements are reported, by origination year and whether they were ceded to unaffiliated or affiliated reinsurers. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded. Shadow reinsurers are a subset of affiliated reinsurers that are unauthorized and do not have an A.M. Best rating.

Table II
Characteristics of Life Insurers Using Shadow Insurance

	Using shadow insurance	
Statistic	No	Yes
Number of companies	443	78
Market share (%):		
Life insurance	52	48
Annuities	52	48
Stock company (%)	91	99
Mean:		
Log liabilities	0.00	3.17
A.M. Best rating	A−	A
Risk-based capital (%)	307	208
Leverage (%)	72	89
Current liquidity (%)	158	80
Return on equity (%)	7	18

Summary statistics for U.S. life insurers in 2012 are reported, by whether they were using shadow insurance. The market shares are based on gross reserves held for life insurance and annuities, respectively.

Table III

Affiliated Reinsurance within the MetLife Group

Company	Domicile	A.M. Best rating	Net reinsurance ceded (billion $)
Metropolitan Life Insurance	New York	A+	39.1
MetLife Investors USA Insurance	Delaware	A+	13.3
General American Life Insurance	Missouri	A+	3.9
MetLife Insurance of Connecticut	Connecticut	A+	3.6
MetLife Investors Insurance	Missouri	A+	2.6
First MetLife Investors Insurance	New York	A+	1.6
New England Life Insurance	Massachusetts	A+	1.0
Metropolitan Tower Life Insurance	Delaware	A+	0.8
MetLife Reinsurance of Delaware	Delaware		-0.4
MetLife Reinsurance of South Carolina	South Carolina		-3.1
Exeter Reassurance	Bermuda		-5.6
MetLife Reinsurance of Vermont	Vermont		-9.9
MetLife Reinsurance of Charleston	South Carolina		-12.9
Missouri Reinsurance	Barbados		-28.4
Total for the MetLife group			5.7

The U.S. operating companies of the MetLife group and their affiliated reinsurers, whose net reinsurance ceded is greater than $0.1 billion in absolute value in 2012, are listed. Net reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded minus the sum of reserves held and modified coinsurance reserve assumed.

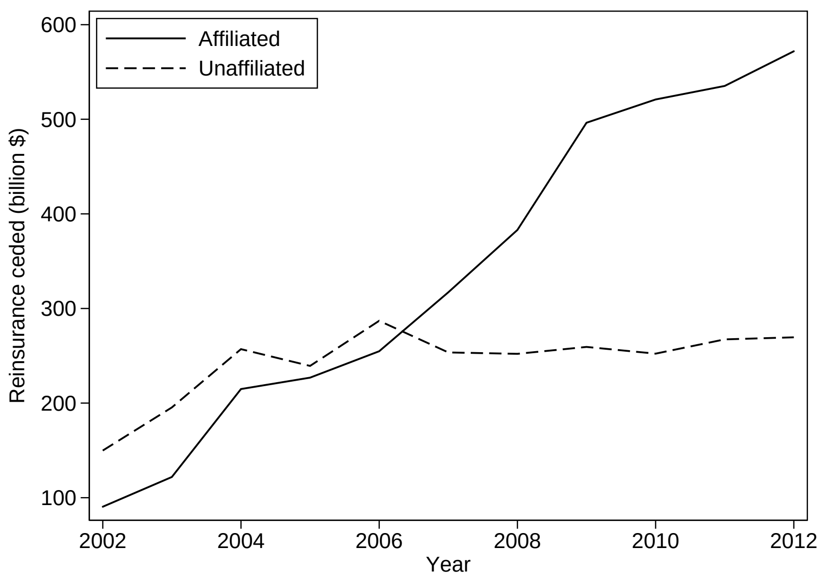

FIGURE 1. Reinsurance ceded to affiliated and unaffiliated reinsurers. Life and annuity reinsurance ceded by U.S. life insurers to affiliated and unaffiliated reinsurers is reported. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

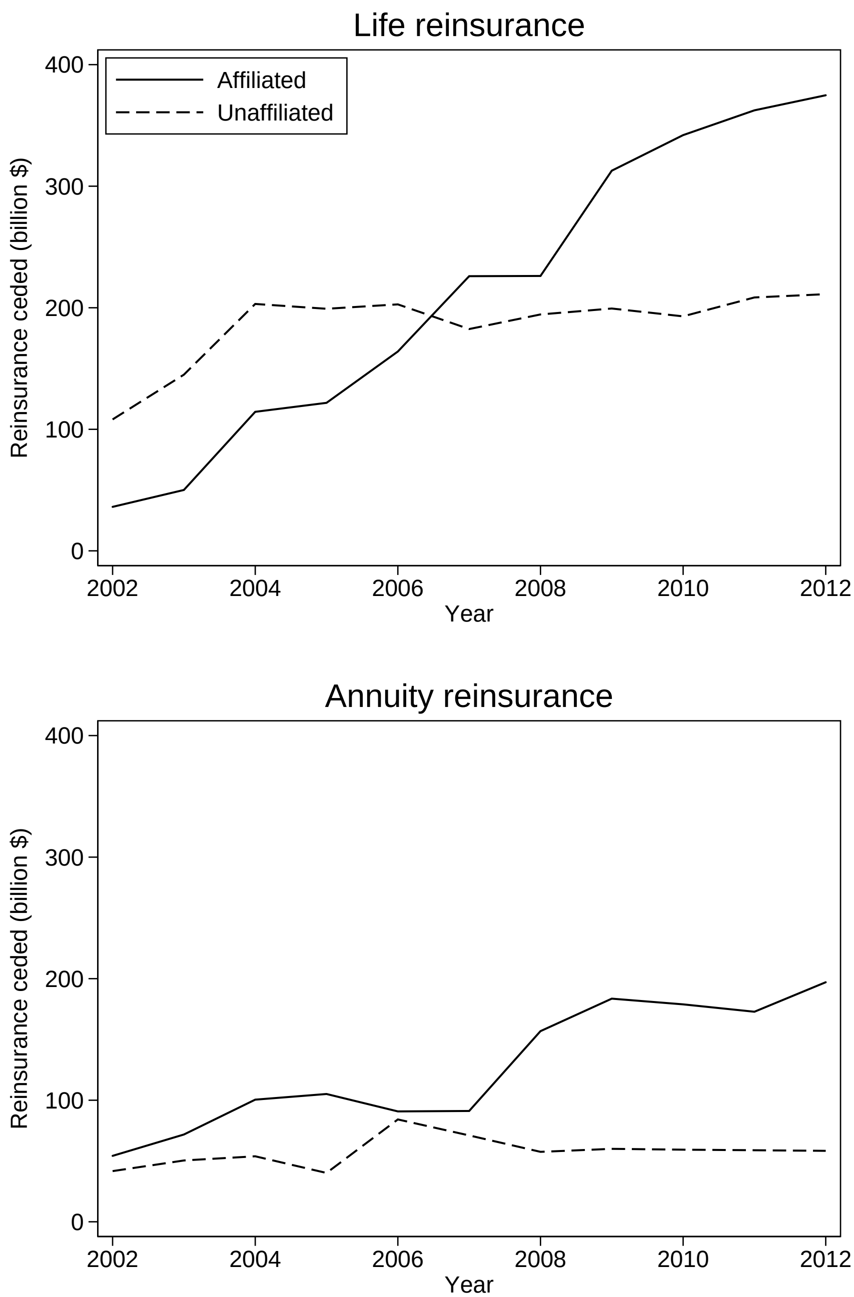

FIGURE 2. Life versus annuity reinsurance ceded to affiliated and unaffiliated reinsurers. Reinsurance ceded by U.S. life insurers to affiliated and unaffiliated reinsurers is reported, separately for life and annuity reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

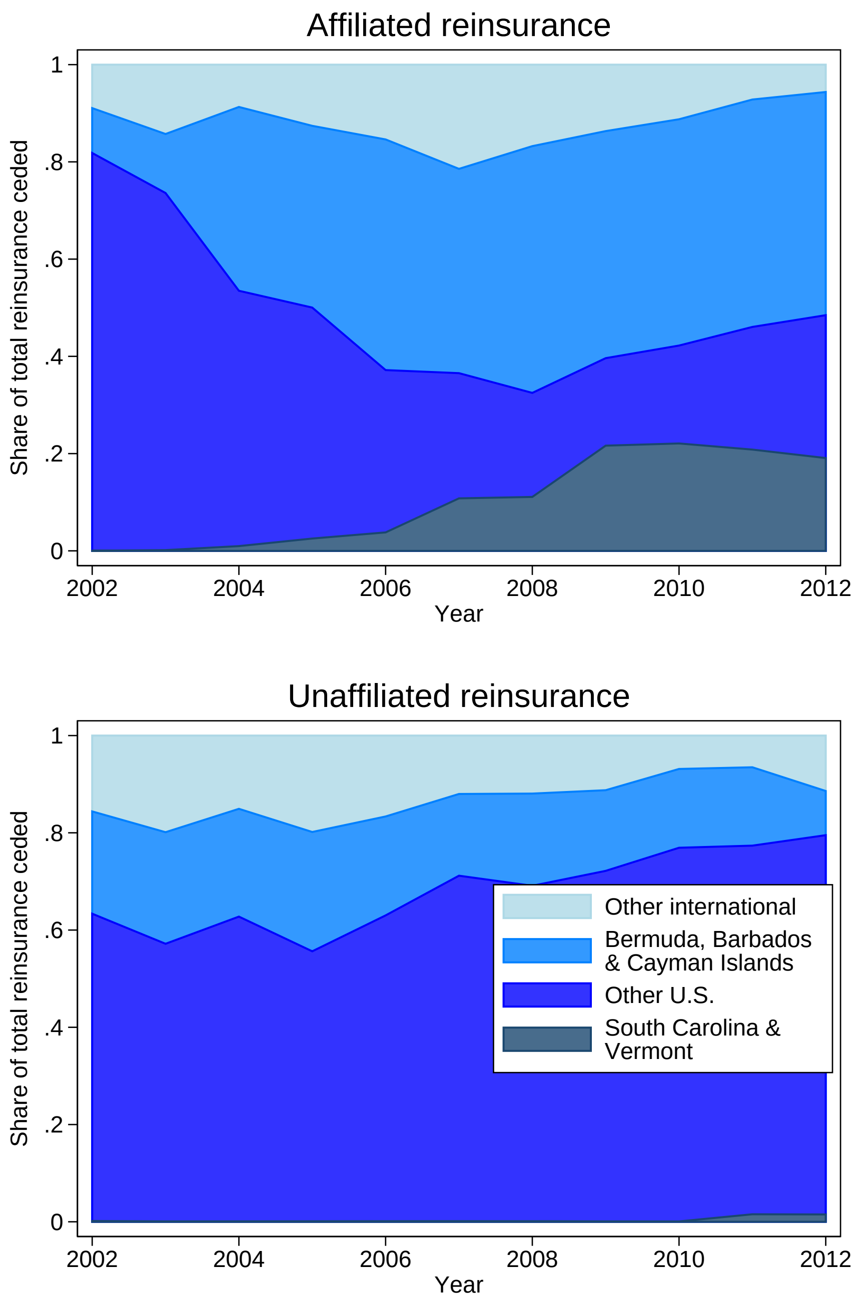

FIGURE 3. Reinsurance ceded by the reinsurer's domicile. Life and annuity reinsurance ceded by U.S. life insurers is decomposed by the reinsurer's domicile, separately for affiliated and unaffiliated reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

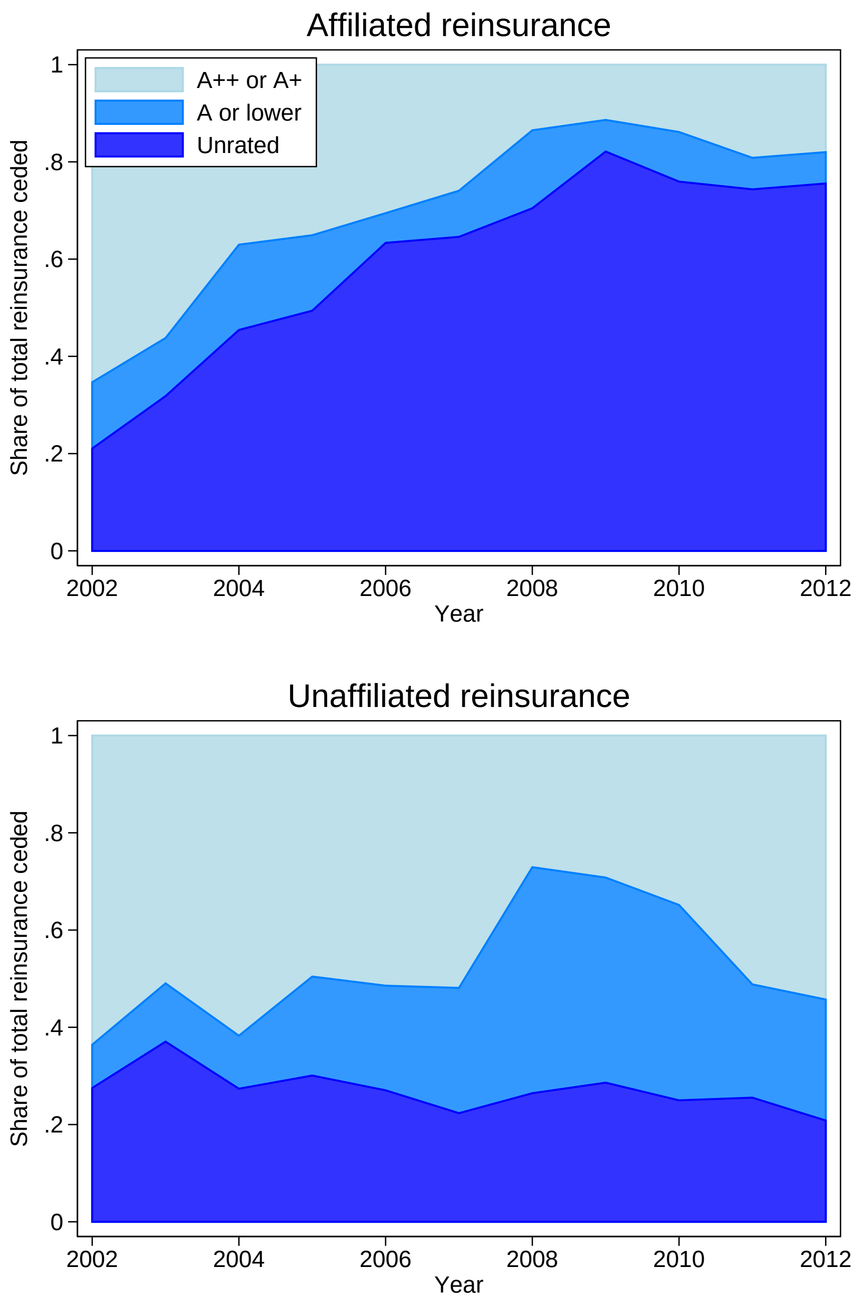

FIGURE 4. Reinsurance ceded by rating of reinsurer. Life and annuity reinsurance ceded by U.S. life insurers is decomposed by the A.M. Best rating of the reinsurer, separately for affiliated and unaffiliated reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

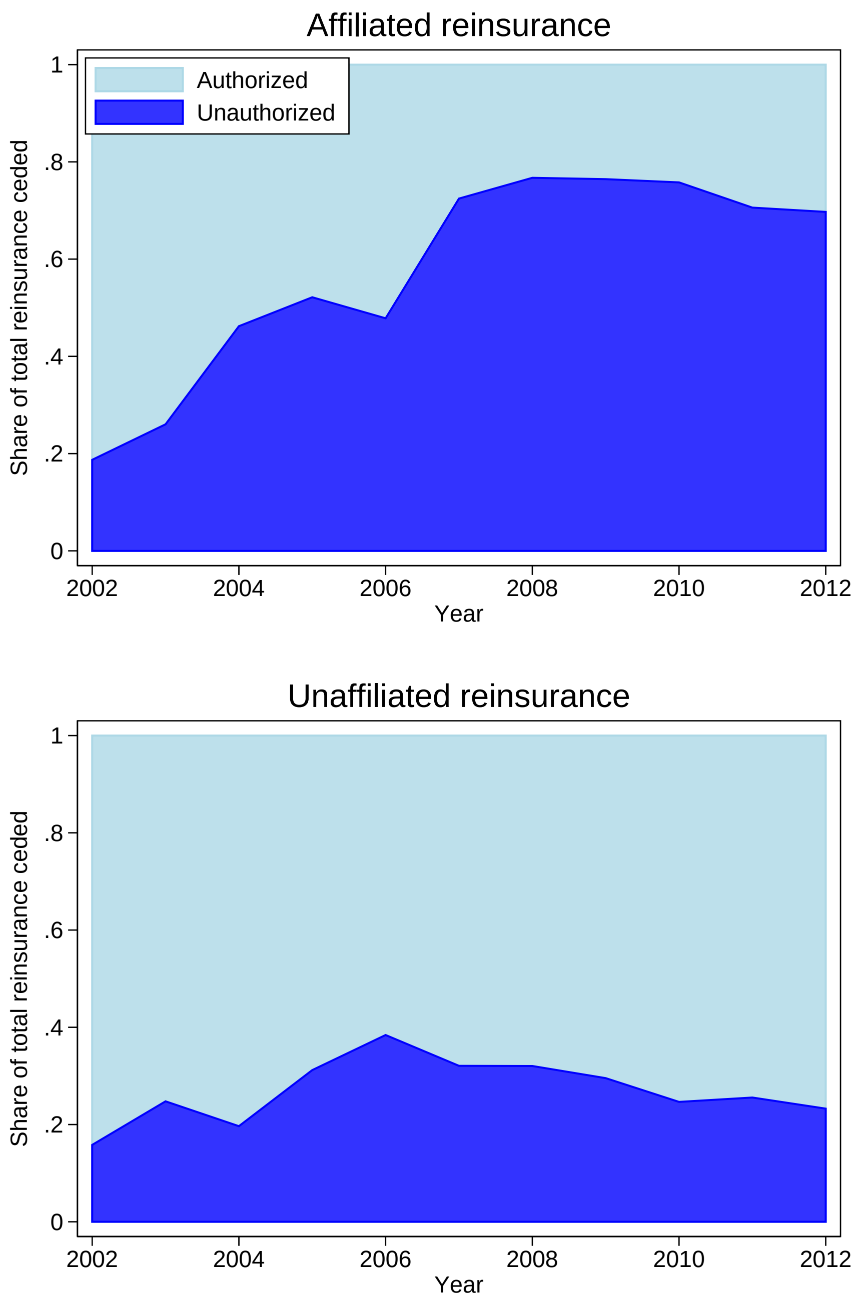

Figure 5. Reinsurance ceded to unauthorized reinsurers. Life and annuity reinsurance ceded by U.S. life insurers is decomposed by whether the reinsurer is authorized in the ceding company's domicile, separately for affiliated and unaffiliated reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

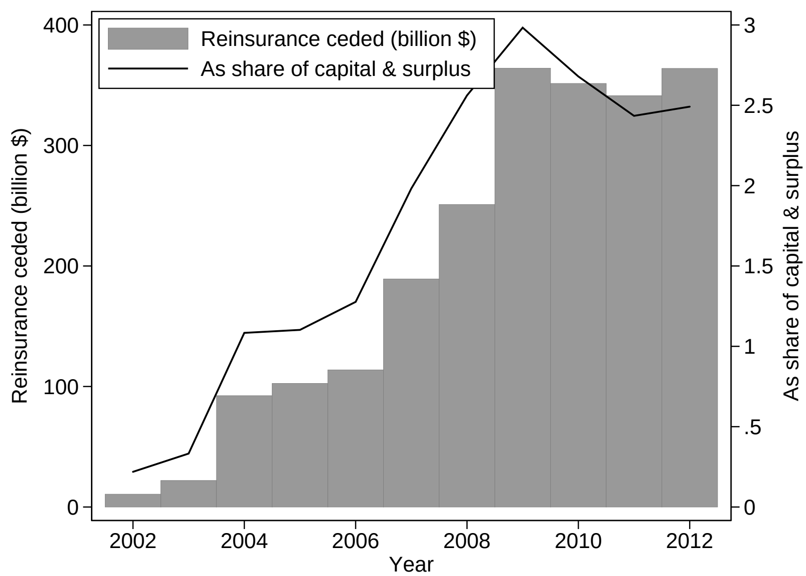

Figure 6. Reinsurance ceded to shadow reinsurers. Life and annuity reinsurance ceded by U.S. life insurers to shadow reinsurers is reported in total dollars and as a share of the capital and surplus of the ceding companies. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

Appendix A. Stylized Examples of Captive Reinsurance

We illustrate the balance sheet mechanics of how an operating company can increase statutory capital by ceding reinsurance to an unauthorized captive. We offer three examples to illustrate the three main types of reinsurance: coinsurance, coinsurance with funds withheld, and modified coinsurance.[4] The latter two types differ from coinsurance in that the ceding company retains control of the assets, so the captive does not need to establish a trust fund. The examples show that the three types of reinsurance can achieve the same economic outcomes. We refer the reader to Loring and Higgins (1997) and Tiller and Tiller (2009, Chapters 4–5) for further details.

A.1. Coinsurance

In Figure A.1, the operating company starts with $10 in bonds and no liabilities, so its equity is $10. For simplicity, the captive is initially a shell company with no assets. In the first step, the operating company sells term life insurance for $100. The operating company must record a statutory reserve of $110, which is higher than the GAAP reserve of $90 because of Regulation XXX. Consequently, its equity is reduced to $0.

In the second step, the operating company cedes all liabilities to the captive, paying a reinsurance premium of $100. Reserve credit on reinsurance ceded to an unauthorized reinsurer requires collateral through a trust fund established in or an unconditional letter of credit from a qualified U.S. financial institution (National Association of Insurance Commissioners (2011, Appendix A-785)). Therefore, the captive establishes a trust fund with $90 in bonds and secures a letter of credit up to $20 to fund the difference between statutory and GAAP reserves. For simplicity, our example ignores a small fee that the captive would pay to secure the letter of credit. On the liability side, the captive records a GAAP reserve of only $90 because it is not subject to Regulation XXX.[5]

As a consequence of captive reinsurance, the operating company's balance sheet is restored to its original position with $10 in equity. The captive ends up with an additional $10 in cash that it can use for various purposes, including a commission to the operating company or a dividend to the parent company.

[4]The types of life reinsurance in the data are coinsurance, modified coinsurance, combination coinsurance, yearly renewable term, and accidental death benefit. The types of annuity reinsurance are coinsurance, modified coinsurance, combination coinsurance, and guaranteed minimum death benefit.

[5]Our example assumes that the operating company's domicile does not require mirror reserving, and the captive's domicile does not count a letter of credit as an admitted asset. If we flip both of these assumptions, the economics of this example remains the same. The captive records the letter of credit as a $20 asset and holds a statutory reserve of $110, so its equity remains $10.

A.2. Coinsurance with Funds Withheld

The first step in Figure A.2 is the same as in Figure A.1. In the second step, the operating company cedes all liabilities to the captive, paying a reinsurance premium of $10. The operating company withholds $90 in the transaction, investing it in bonds. The withheld assets are recorded as a “funds held” liability for the operating company and as a “funds deposited” asset for the captive. The captive secures a letter of credit up to $20 to fund the difference between statutory and GAAP reserves. On the liability side, the captive records a GAAP reserve of only $90 because it is not subject to Regulation XXX.

A.3. Modified Coinsurance

The first step in Figure A.3 is the same as in Figure A.1. In the second step, the operating company cedes all liabilities to the captive, paying a reinsurance premium of $10. The operating company withholds $90 in the transaction, investing it in bonds. The withheld assets are recorded as a “modco reserve” liability for the operating company and as a “modco deposit” asset for the captive. The captive secures a letter of credit up to $20 to fund the difference between statutory and GAAP reserves. On the liability side, the captive records a GAAP reserve of only $90 because it is not subject to Regulation XXX.

Operating company
(in domicile with tighter capital regulation)

Initial balance sheet:

A		L	
Bonds	$10		
		Equity	$10

⟹ *1. Sells insurance for $100 (with statutory reserve of $110 and GAAP reserve of $90).*

A		L	
Bonds	$10		
Premium	$100	Reserve	$110
		Equity	$0

⟹ *2. Cedes reinsurance.*

A		L	
Bonds	$10		
		Equity	$10

Captive
(in domicile with looser capital regulation)

Initial balance sheet:

A		L	
		Equity	$0

⟹ *2. Assumes reinsurance. Establishes trust with $90 in bonds. Secures letter of credit up to $20.*

A		L	
Trust: Bonds	$90	Reserve	$90
Letter of credit			
Cash	$10		
		Equity	$10

FIGURE A.1. An example of captive reinsurance: Coinsurance. This example illustrates how coinsurance affects the balance sheets of an operating company and an unauthorized captive, both of which are part of the same insurance group. The operating company must hold a statutory reserve of $110, while the captive can hold a GAAP reserve of $90.

Operating company
(in domicile with tighter capital regulation)

Initial:

A		L	
Bonds	\$10		
		Equity	\$10

⟹ *1. Sells insurance for \$100 (with statutory reserve of \$110 and GAAP reserve of \$90).*

A		L	
Bonds	\$10		
Premium	\$100	Reserve	\$110
		Equity	\$0

⟹ *2. Cedes reinsurance, paying \$10 premium. Invests \$90 in bonds.*

A		L	
Bonds	\$100	Funds withheld	\$90
		Equity	\$10

Captive
(in domicile with looser capital regulation)

Initial:

A		L	
		Equity	\$0

⟹ *2. Assumes reinsurance. Secures letter of credit up to \$20.*

A		L	
Funds deposited	\$90	Reserve	\$90
Letter of credit			
Cash	\$10		
		Equity	\$10

Figure A.2. An example of captive reinsurance: Coinsurance with funds withheld. This example illustrates how coinsurance with funds withheld affects the balance sheets of an operating company and an unauthorized captive, both of which are part of the same insurance group. The operating company must hold a statutory reserve of \$110, while the captive can hold a GAAP reserve of \$90.

Operating company
(in domicile with tighter capital regulation)

Initial balance sheet:

A		L	
Bonds	$10		
		Equity	$10

⟹ *1. Sells insurance for $100 (with statutory reserve of $110 and GAAP reserve of $90).*

A		L	
Bonds	$10		
Premium	$100	Reserve	$110
		Equity	$0

⟹ *2. Cedes reinsurance, paying $10 premium. Invests $90 in bonds.*

A		L	
Bonds	$100	Modco reserve	$90
		Equity	$10

Captive
(in domicile with looser capital regulation)

Initial balance sheet:

A		L	
		Equity	$0

⟹ *2. Assumes reinsurance. Secures letter of credit up to $20.*

A		L	
Modco deposit	$90	Reserve	$90
Letter of credit			
Cash	$10		
		Equity	$10

FIGURE A.3. An example of captive reinsurance: Modified coinsurance. This example illustrates how modified coinsurance affects the balance sheets of an operating company and an unauthorized captive, both of which are part of the same insurance group. The operating company must hold a statutory reserve of $110, while the captive can hold a GAAP reserve of $90.

Appendix B. Data on Company Characteristics

We construct the following company characteristics based on the NAIC annual financial statements (A.M. Best Company (1999–2013)). The relevant parts for our construction are Liabilities, Surplus and Other Funds; Exhibit 5 (Aggregate Reserve for Life Contracts); Exhibit of Life Insurance; and Schedule S Part 6 (Restatement of Balance Sheet to Identify Net Credit for Ceded Reinsurance).

- Log liabilities: The logarithm of as reported total liabilities.
- Leverage: The ratio of as reported total liabilities to as reported total assets.

A.M. Best Company (2011) constructs the following company characteristics as part of the rating process.

- A.M. Best rating: We convert the A.M. Best financial strength rating (coded from A++ to D) to a cardinal measure (coded from 175 to 0%) based on risk-based capital guidelines (A.M. Best Company (2011, p. 24)).
- Risk-based capital: A.M. Best capital adequacy ratio, which is the ratio of adjusted capital and surplus to required capital.
- Current liquidity: A measure of balance sheet liquidity, defined as the ratio of current assets (i.e., unencumbered cash and unaffiliated investments) to total liabilities.
- Return on equity: A measure of profitability, defined as the ratio of net operating gain after taxes to the average capital and surplus over the current and prior year.
- A.M. Best financial size category: A measure of company size (coded from 1 to 15) based on the adjusted policyholders' surplus for the insurance group.

Appendix C. Proofs

Proof of Proposition 1: We first rewrite total profit and statutory capital in period t as functions of the state variables: Y_{t-1}, L_{t-1}, $\widehat{L}_{t-1}$, K_{t-1}, and $\widehat{K}_{t-1}$. Using equations (2) and (5), we rewrite equation (1) recursively as

$$Y_t = \delta Y_{t-1} + (P_t - V)Q_t.$$

Substituting equations (2) and (3) in equation (4), we have

$$K_t = R_{A,t}K_{t-1} + (1+\rho)(R_{A,t} - \delta)L_{t-1} + \delta Y_{t-1} + (P_t - (1+\rho)V)Q_t + \rho V B_t.$$

Substituting equations (5) and (6) in equation (7), we have

$$\widehat{K}_t = R_{A,t}\widehat{K}_{t-1} + (1+\widehat{\rho})(R_{A,t} - \delta)\widehat{L}_{t-1} - \widehat{\rho} V B_t.$$

The first-order condition for the insurance price is

$$\begin{aligned}\frac{\partial J_t}{\partial P_t} =& \frac{\partial Y_t}{\partial P_t} + c_t \frac{\partial K_t}{\partial P_t} \\ =& Q_t + (P_t - V)\frac{\partial Q_t}{\partial P_t} + c_t \left(Q_t + (P_t - (1+\rho)V)\frac{\partial Q_t}{\partial P_t} \right) = 0,\end{aligned}$$

which implies equation (10). The first-order condition for affiliated reinsurance is

$$\begin{aligned}\frac{\partial J_t}{\partial B_t} =& c_t \frac{\partial K_t}{\partial B_t} + \widehat{c}_t \frac{\partial \widehat{K}_t}{\partial B_t} \\ =& (c_t \rho - \widehat{c}_t \widehat{\rho}) V = 0,\end{aligned}$$

which implies equation (11). *Q.E.D.*

Proof of Corollary 1: The partial derivative of marginal cost with respect to affiliated reinsurance is

$$\frac{\partial \Phi_t}{\partial B_t} = \left(\frac{\rho V}{1 + c_t} \right)^2 \frac{\partial c_t}{\partial K_t}.$$

The sign of this partial derivative is determined by

$$\frac{\partial c_t}{\partial K_t} = -\frac{\partial^2 C_t}{\partial K_t^2} + \mathbb{E}_t \left[M_{t+1} \frac{\partial^2 J_{t+1}}{\partial K_t^2} \right] < 0,$$

which follows from the assumption $\partial^2 C_t / \partial K_t^2 > 0$ and $\partial^2 J_{t+1} / \partial K_t^2 < 0$ by Stokey et al. (1989, Theorem 4.8).

We rewrite excess capital in period t as

$$W_t = K_t + \widehat{K}_t - (\rho - \widehat{\rho})\widehat{L}_t.$$

The partial derivative of excess capital with respect to affiliated reinsurance is

$$\begin{aligned}\frac{\partial W_t}{\partial B_t} =& \frac{\partial K_t}{\partial B_t} + \frac{\partial \widehat{K}_t}{\partial B_t} - (\rho - \widehat{\rho})\frac{\partial \widehat{L}_t}{\partial B_t} \\ =& \frac{\partial P_t}{\partial B_t}\left(Q_t + (P_t - (1+\rho)V)\frac{\partial Q_t}{\partial P_t}\right) \\ =& \frac{\partial P_t}{\partial B_t} Q_t \epsilon_t \left(\frac{1}{\epsilon_t} - 1 + \frac{(1+\rho)V}{P_t}\right).\end{aligned}$$

The expression inside the parentheses is positive since

$$\frac{P_t}{V}\left(1 - \frac{1}{\epsilon_t}\right) < 1 + \rho \Leftrightarrow \frac{1 + (1+\rho)c_t}{1 + c_t} < 1 + \rho \Leftrightarrow \rho > 0.$$

Appendix D. A Structural Model of the Life Insurance Market

We develop a structural model to test the prediction that shadow insurance reduces the marginal cost of issuing policies and increases the equilibrium supply in the retail market. We estimate the structural model on the life insurance market, rather than the annuity market, for two reasons. First, as we discussed in Section 4, life insurance accounts for a larger share of affiliated reinsurance than annuities because of Regulation (A)XXX. Second, variable annuities account for most of the annuity market, and data on their rider fees are not readily available.

D.1. Data on Life Insurance Prices

Our sample of life insurance premiums is from Compulife Software (2002–2012), which is a computer-based quotation system for insurance agents. We focus on 10-year guaranteed level term life insurance for males aged 30 as representative of the life insurance market. However, we have also examined 20-year policies and older age groups for robustness. We pull quotes for all states at the end of June in each year from 2002 to 2012, for the regular health category and a face amount of \$1 million. We merge the life insurance premiums with the company characteristics in Appendix B by company name. Whenever the premium is not available for an operating company, we assign the average premium for its insurance group.

Our measure of price is the premium divided by actuarial value. Let π_n be the one-year survival probability at age n, and let $R(m)$ be the zero-coupon Treasury (gross) yield at maturity m. We define the actuarial value of 10-year term life insurance at age n per dollar of death benefit as

$$V(n) = \left(1 + \sum_{m=1}^{9} \frac{\prod_{l=0}^{m-1} \pi_{n+l}}{R(m)^m}\right)^{-1} \left(\sum_{m=1}^{10} \frac{\prod_{l=0}^{m-2} \pi_{n+l}(1 - \pi_{n+m-1})}{R(m)^m}\right).$$

We use the appropriate mortality table from the American Society of Actuaries: the 2001 Valuation Basic Table before January 2008 and the 2008 Valuation Basic Table after January 2008. These mortality tables are derived from the actual mortality experience of insured pools, so they account for potential adverse selection. We smooth the transition between the two vintages of the mortality tables by geometric averaging.

D.2. Empirical Specification

Operating companies optimally price insurance in an oligopolistic market. Demand is determined by the random coefficients logit model, which can be derived from a discrete choice problem. Since all companies sell the same type of policy, product differentiation is along company characteristics that capture reputation in the retail market. Life insurance is a type of intermediated savings, so the natural alternative is all saving vehicles that are intermediated by financial institutions other than insurance companies. Therefore, we specify the "outside good" as total annual saving by U.S. households in savings deposits, money market funds, and mutual funds (Board of Governors of the Federal Reserve System (2013, Table F.100)).

Let $P_{n,t}$ be the price of insurance sold by company n in year t. Let $\mathbf{x}_{n,t}$ be a vector of observable characteristics of company n in year t, which are determinants of demand. The probability that retail customers with preference parameters (α, β) buy insurance from company n in year t is

$$q_{n,t}(\alpha, \beta) = \frac{\exp\{\alpha P_{n,t} + \beta' \mathbf{x}_{n,t} + \xi_{n,t}\}}{1 + \sum_{m=1}^{N} \exp\{\alpha P_{m,t} + \beta' \mathbf{x}_{m,t} + \xi_{m,t}\}},$$

where N is the total number of operating companies. The structural error $\xi_{n,t}$ captures company characteristics that are unobservable to the econometrician.

Let S_t be the demand for the outside good in year t, and let $Q_{n,t}$ be the demand for insurance sold by company n in year t. Let $F(\alpha, \beta)$ denote the distribution of preference parameters, which is multivariate normal with a diagonal covariance matrix. The market share for company n in year t is

$$\overline{q}_{n,t} = \frac{Q_{n,t}}{S_t + \sum_{m=1}^{N} Q_{m,t}} = \int q_{n,t}(\alpha, \beta) dF(\alpha, \beta). \tag{D.1}$$

The demand elasticity for insurance sold by company n in year t is

$$\epsilon_{n,t} = -\frac{\partial \log(\overline{q}_{n,t})}{\partial \log(P_{n,t})} = -\frac{P_{n,t}}{\overline{q}_{n,t}} \int \alpha q_{n,t}(\alpha,\beta)(1 - q_{n,t}(\alpha,\beta)) dF(\alpha,\beta).$$

Equation (10) is the optimal pricing equation for each company in Nash equilibrium. Marginal cost varies across operating companies because of differences in the shadow cost of capital. Let $\mathrm{SI}_{n,t}$ be a dummy that is 1 if company n uses shadow insurance in year t.[6] Let $\mathbf{y}_{n,t}$ be a vector of observable characteristics of company n in year t, which are determinants of marginal cost. We parameterize marginal cost for company n in year t as

$$\Phi_{n,t} = \left(1 - \frac{1}{\epsilon_{n,t}}\right) P_{n,t} = \exp\{\phi \mathrm{SI}_{n,t} + \psi' \mathbf{y}_{n,t} + \nu_{n,t}\}, \tag{D.2}$$

where the structural error $\nu_{n,t}$ represents an unobservable cost shock. Shadow insurance reduces marginal cost according to Proposition 1, so we expect that $\phi < 0$.

D.3. Identifying Assumption

Because insurance prices are endogenous to demand, we make the following identifying assumption.

ASSUMPTION 1: *The structural error in demand* (D.1) *satisfies*

$$\mathbb{E}[\xi_{n,t} | \mathrm{SI}_{n,t}, \mathbf{x}_{n,t}] = 0. \tag{D.3}$$

The structural error in marginal cost (D.2) *satisfies*

$$\mathbb{E}[\nu_{n,t} | \mathrm{SI}_{n,t}, \mathbf{y}_{n,t}] = 0. \tag{D.4}$$

We estimate demand (D.1) and marginal cost (D.2) jointly under Assumption 1. Equation (D.3) says that shadow insurance is uncorrelated with demand, conditional on observable characteristics. A motivation for this identifying assumption is that retail customers only care about shadow insurance insofar as it reduces prices under the hypothesis that it does not increase risk. Another motivation is that retail customers do not bother gathering information about shadow insurance beyond what is already reflected in the A.M. Best

[6]The dummy for shadow insurance is 1 if gross life and annuity reserves ceded to shadow reinsurers is positive. We have also considered the share of gross life and annuity reserves ceded to shadow reinsurers, which is a continuous measure between 0 and 1. Because there are relatively few companies that use shadow insurance (see Table II), there is little cross-sectional variation in the intensive margin that is useful for identification. Therefore, we report the results based on the dummy for shadow insurance to make clear that our identification is coming from the extensive margin of whether the life insurer uses shadow insurance.

rating. This exclusion restriction is plausible because the negative attention from regulators and rating agencies came after 2012 (e.g., A.M. Best Company (2013b), Lawsky (2013), Koijen and Yogo (2013), Robinson and Son (2013), and related media coverage).

The company characteristics in our specification of $\mathbf{x}_{n,t}$ are the A.M. Best rating and the conventional determinants of ratings described in Appendix B: log liabilities, risk-based capital, leverage, current liquidity, return on equity, and a dummy for stock company. Thus, the marginal effect of the A.M. Best rating can be interpreted as soft information used in the rating process that is not captured by these other variables. Given the mean and standard deviation of (α, β), we invert equation (D.1) to recover the structural errors $\xi_{n,t}$, approximating the integral through simulation. We then construct the moments for demand by interacting the structural error with a vector of instruments, which consists of shadow insurance, company characteristics, and squared characteristics.

Equation (D.4) says that shadow insurance is uncorrelated with the cost shock, conditional on observable characteristics. The implicit assumption is that $\mathbf{y}_{n,t}$ contains all determinants of marginal cost that are also related to shadow insurance. The company characteristics in our specification of $\mathbf{y}_{n,t}$ are the same as those in $\mathbf{x}_{n,t}$, plus year dummies. Given (ϕ, ψ), we invert equation (D.2) to recover the structural errors $\nu_{n,t}$. We then construct the moments for marginal cost by interacting the structural error with a vector of instruments, which consists of shadow insurance, company characteristics, and year dummies.

We stack the moments for demand and marginal cost and estimate the system by two-step generalized method of moments. The weighting matrix in the first step is block diagonal in demand and marginal cost, where each block is the inverse of the quadratic matrix of the instruments. The optimal weighting matrix in the second step is robust to heteroscedasticity and correlation between the structural errors for demand and marginal cost.

D.4. Structural Estimates of the Life Insurance Market

Columns (1) and (2) of Table D.I report the estimated mean and standard deviation of the random coefficients in demand (D.1). Our preferred specification limits the random coefficients to log liabilities, the A.M. Best rating, and leverage. The mean coefficient on price is -1.33 with a standard error of 0.50. This implies a demand elasticity of 2.18 for the average company in 2012. The mean coefficient on log liabilities is 2.71, and the mean coefficient on the A.M. Best rating is 0.13. That is, demand is positively related to both company size and the A.M. Best rating. The standard deviation of the random coefficient on log liabilities is 0.24 and statistically significant. Similarly, the standard deviation of the random coefficient on leverage is 0.33 and statistically significant.

Column (3) of Table D.I reports the estimated coefficients for marginal cost (D.2).

Shadow insurance reduces marginal cost by 13% with a standard error of 3%. Other important determinants of marginal cost are the A.M. Best rating and leverage. Marginal cost decreases by 7% per one standard deviation increase in the A.M. Best rating. Similarly, marginal cost decreases by 4% per one standard deviation increase in leverage.

We have attempted to estimate a richer model in which price and risk-based capital also have random coefficients. However, the standard deviations of the random coefficients on price and risk-based capital converge to zero, and large standard errors reveal that the richer model is poorly identified. Similarly, we were not able to identify a richer model in which the covariance matrix for the random coefficients is not diagonal. The identification problem arises from the fact that the variation in aggregate market shares can only identify a limited covariance structure for the random coefficients.

D.5. Retail Market in the Absence of Shadow Insurance

The structural estimates in Table D.I allow us to estimate counterfactual insurance prices and market size in the absence of shadow insurance. We first set $\mathrm{SI}_{n,t} = 0$ in equation (D.2) to estimate the counterfactual marginal cost for each company in the absence of shadow insurance. We then solve for the new price vector that satisfies the equilibrium conditions for demand (D.1) and supply (D.2). We summarize our findings in Section 5.

Table D.I
Structural Estimates of the Life Insurance Market

	Demand		
Variable	Mean (1)	Standard deviation (2)	Marginal cost (3)
Price	-1.33		
	(0.50)		
Shadow insurance			-0.13
			(0.03)
Log liabilities	2.71	0.24	0.02
	(0.05)	(0.11)	(0.01)
A.M. Best rating	0.13	0.12	-0.07
	(0.08)	(0.58)	(0.03)
Risk-based capital	-0.07		0.01
	(0.07)		(0.02)
Leverage	0.11	0.33	-0.04
	(0.09)	(0.15)	(0.02)
Current liquidity	0.09		0.00
	(0.06)		(0.01)
Return on equity	-0.21		0.04
	(0.03)		(0.02)
Stock company	0.07		0.01
	(0.10)		(0.03)
Observations	1,711		

The random coefficients logit model of demand (D.1) and marginal cost (D.2) are estimated jointly by generalized method of moments. The specification for marginal cost includes year dummies, whose coefficients are not reported for brevity. The instruments for demand are shadow insurance, company characteristics, and squared characteristics. The instruments for marginal cost are shadow insurance, company characteristics, and year dummies. The coefficients are standardized, and heteroscedasticity-robust standard errors are reported in parentheses. The sample consists of U.S. life insurers from 2002 to 2012, which are matched to term life insurance prices from Compulife Software.

Appendix E. Potential Impact of Shadow Insurance on Risk and Expected Loss

We first show that ratings are unrelated to shadow insurance. This finding is consistent with the hypothesis that ratings correctly reflect the absence of risk in shadow insurance. However, this finding is also consistent with an alternative hypothesis that ratings do not adequately reflect the presence of risk, which is a potential concern given the evidence in Section 6. Therefore, we quantify the potential risk of shadow insurance under the alternative hypothesis based on publicly available data and plausible assumptions.

E.1. Relation between Ratings and Shadow Insurance

According to A.M. Best Company (2013b), ratings and risk-based capital fully reflect the risk of shadow insurance. In Table E.I, we empirically investigate the relation between ratings and shadow insurance, which reveals the perceived magnitude of risk. Appendix B describes how we convert the A.M. Best rating to a cardinal measure and also describes the conventional determinants of ratings that we use as regressors. We standardize ratings and all regressors that are not dummy variables, so that the coefficients have a straightforward interpretation.

In column (1) of Table E.I, we estimate the relation between ratings and a dummy for shadow insurance by ordinary least squares.[7] Our simplest specification controls for only year and A.M. Best financial size category, whose coefficients are not reported for brevity. A coefficient of 0.03 on shadow insurance has the wrong sign if we expect shadow insurance to increase risk. However, the coefficient is economically small and statistically insignificant, as ratings are only 0.03 standard deviations higher for life insurers that use shadow insurance. In column (2), we show that the coefficient on shadow insurance is robust to controlling for the conventional determinants of ratings. In Koijen and Yogo (2013), we also showed that the results are robust to controlling for nonlinearities through squared characteristics.

Because we do not know the proprietary model used by A.M. Best Company, omitted variables could explain the absence of a negative relation between ratings and shadow insurance. For example, A.M. Best Company could have soft information that is positively related to both ratings and the use of shadow insurance. We could address this concern through instrumental variables, but the challenge is that many known characteristics that correlate with shadow insurance (see Section 3) are also direct determinants of ratings.

Our instrument is the market share for term life insurance in 1999, interacted with a dummy for stock company in 1999. For each company, we calculate its market share as the face amount of term life insurance in force divided by the sum across all companies.

[7] See footnote 6 for why we use a dummy instead of a continuous measure for shadow insurance.

The motivation for the instrument is that Regulation XXX had a stronger impact on life insurers with more presence in the term life insurance market. The interaction accounts for the fact that among those companies affected by Regulation XXX, the stock companies have a stronger incentive to take advantage of the captives laws after 2002 (Mayers and Smith (1981)). The market share in 1999 is plausibly exogenous to ratings after 2002, conditional on the conventional determinants of ratings, because Regulation XXX applies only to new policies issued after 2000 and does not apply retroactively to existing liabilities.

We cannot test whether the instrument is exogenous to ratings. However, we can verify that the instrument is not an obvious direct determinant of ratings in 1999, prior to changes in regulation that preceded shadow insurance. In Table E.II, we estimate the relation between ratings and company characteristics in 1999 by ordinary least squares. The coefficient on the instrument is economically small and statistically insignificant. Ratings increase by only 0.02 standard deviations per one standard deviation increase in the instrument. If the instrument were a direct determinant of ratings, we would have expected the coefficient to be economically large and statistically significant.

In column (3) of Table E.I, we estimate the relation between ratings and shadow insurance by instrumental variables.[8] The coefficient on shadow insurance again has the wrong sign, as ratings are 0.25 standard deviations higher for life insurers that use shadow insurance. However, the coefficient is statistically insignificant with a standard error of 0.34. Interestingly, the coefficients on the conventional determinants have the expected signs with higher ratings awarded to life insurers that are larger and have higher risk-based capital, more liquid assets, and higher profitability. Overall, the evidence in Table E.I does not suggest an economically meaningful negative relation between ratings and shadow insurance.

In addition to ratings, A.M. Best Company (2013b) claims to adjust risk-based capital for shadow insurance. In column (4) of Table E.I, we investigate the relation between risk-based capital and shadow insurance by ordinary least squares. Risk-based capital is negatively related to shadow insurance, but the coefficient is economically small and statistically insignificant. Risk-based capital is only 0.02 standard deviations lower for life insurers that use shadow insurance.

E.2. Potential Impact of Shadow Insurance on Risk

The evidence in Table E.I is consistent with the hypothesis that ratings and risk-based capital correctly reflect the absence of risk in shadow insurance. However, this evidence is also consistent with an alternative hypothesis that ratings and risk-based capital do not adequately reflect the presence of risk. We now quantify the potential risk of shadow insurance

[8] In a first-stage regression that is not reported, the instrument is a highly relevant predictor of shadow insurance with an F-statistic of 21 (Stock and Yogo (2005)).

under the alternative hypothesis based on publicly available data and plausible assumptions. The fact that accurate risk assessments are difficult highlights the importance of more transparency.

We start with accounting identities and a simple rating framework for an operating company that cedes reinsurance to a shadow reinsurer. Let A and L be the operating company's assets and liabilities, so its equity is $E = A - L$. We define leverage as L/A and risk-based capital as $\text{RBC} = E/(\kappa L)$, where the risk charge $\kappa > 0$ summarizes the risk profile of assets and liabilities. Let $\widehat{A}$ and $\widehat{L}$ be the shadow reinsurer's assets and liabilities, so its equity is $\widehat{E} = \widehat{A} - \widehat{L}$. Liabilities $\widehat{L}$ are observable based on reinsurance ceded by the operating company to the shadow reinsurer. However, we do not observe $\widehat{E}$ (equivalently $\widehat{A}$) or the risk profile of $\widehat{A}$ or $\widehat{L}$. Therefore, we make the following assumption based on the evidence in Section 6.

ASSUMPTION 2: *Shadow reinsurers do not have equity (i.e., $\widehat{E} = 0$). The risk profile of reinsurance ceded is identical to assets and liabilities that remain on the balance sheet, so the risk charge on $\widehat{L}$ is κ.*

We now ask how the operating company's balance sheet would change if shadow insurance were moved back on balance sheet. Assumption 2 yields simple adjustments to risk-based capital and leverage based on publicly available data.

PROPOSITION 2: *Under Assumption 2, the adjusted risk-based capital is*

$$\frac{E + \widehat{E}}{\kappa\left(L + \widehat{L}\right)} = \frac{RBC \times L}{L + \widehat{L}}. \tag{E.1}$$

The adjusted leverage is

$$\frac{L + \widehat{L}}{A + \widehat{A}} = \frac{L + \widehat{L}}{A + \widehat{L}}. \tag{E.2}$$

Our adjustment reduces risk-based capital from 208% to 155%, or by 53 percentage points, for the average company using shadow insurance in 2012. According to equation (E.1), risk-based capital falls because equity does not change, but the capital required to support the additional liabilities (i.e., the denominator of the ratio) rises. The difference between reported and adjusted risk-based capital has increased from 10 percentage points in 2002 to 53 percentage points in 2012, as shadow insurance $\widehat{L}$ has grown relative to liabilities L that remain on balance sheet.

We ultimately do not know how ratings would be adjusted for shadow insurance because they are based on a proprietary model and soft information that are not publicly available. However, we could get a sense of the potential magnitude by assuming that ratings are a direct function of risk-based capital. Under this assumption, we first convert the A.M. Best rating to the equivalent risk-based capital based on the guideline table in A.M. Best Company (2011, p. 24). For example, a rating of A is equivalent to risk-based capital of 145%. We then apply equation (E.1) to obtain the adjusted risk-based capital, which implies an adjusted rating by the same guideline table. We find that the rating drops by 3 notches from A to B+ for the average company using shadow insurance in 2012.

In Appendix F, we estimate the term structure of default probabilities by A.M. Best rating. These estimates imply default probabilities for each company, corresponding to the reported rating versus the adjusted rating. The adjusted ratings imply a 10-year cumulative default probability of 3.0% for the average company using shadow insurance in 2012, which is 3.5 times higher than that implied by the reported ratings.

E.3. Potential Impact of Shadow Insurance on Expected Loss

We can use the A.M. Best rating to estimate expected loss because it reflects a life insurer's claims-paying ability without support from the state guaranty associations. Let $\Pr(m|\text{Rating})$ be the marginal default probability between years $m-1$ and m, conditional on the rating. Let θ be the loss ratio conditional on default, which we estimate to be 0.25 (see Appendix F). Let $R(m)$ be the zero-coupon Treasury (gross) yield at maturity m (Gürkaynak, Sack, and Wright (2007)). For each company, we estimate the present value of expected loss as

$$\sum_{m=1}^{15} \frac{\Pr(m|\text{Rating})\theta L}{R(m)^m}.$$

To estimate the expected loss adjusted for shadow insurance, we modify this formula by using the adjusted rating instead and replacing L with $L + \widehat{L}$.

The expected loss based on reported ratings and liabilities is \$4.9 billion for the industry in 2012. The expected loss increases to \$14.4 billion when ratings and liabilities are adjusted for shadow insurance. The difference between adjusted and reported expected loss grew from \$0.1 billion in 2002 to \$9.5 billion in 2012. Since state guaranty associations ultimately pay off all liabilities by assessing the surviving companies, this expected loss represents an externality to the life insurers not using shadow insurance. State taxpayers also bear a share of the cost because guaranty association assessments are tax deductible.

To put these estimates of expected loss into perspective, we estimate the total capacity of state guaranty funds. All states cap annual guaranty association assessments, typically at 2% of recent life insurance and annuity premiums. Following Gallanis (2009), we estimate the total capacity of state guaranty funds as the maximum annual assessment aggregated across all states, projected to remain constant over the next 10 years. As a share of the total capacity of state guaranty funds, the expected loss for the industry grew from 7% in 2002 to 26% in 2012.

Table E.I
Relation between Ratings and Shadow Insurance

	A.M. Best rating			Risk-based
	OLS		IV	capital
Variable	(1)	(2)	(3)	(4)
Shadow insurance	0.03	0.00	0.25	-0.02
	(0.06)	(0.06)	(0.34)	(0.05)
Log liabilities		0.17	0.13	0.15
		(0.04)	(0.06)	(0.05)
Risk-based capital		0.13	0.15	
		(0.02)	(0.02)	
Leverage		-0.01	0.01	-0.46
		(0.03)	(0.03)	(0.06)
Current liquidity		0.08	0.06	0.18
		(0.02)	(0.02)	(0.04)
Return on equity		0.03	0.03	0.01
		(0.02)	(0.02)	(0.02)
Stock company		0.05	0.02	0.12
		(0.06)	(0.07)	(0.06)
R^2	0.60	0.62	0.63	0.33
Observations	6,641	6,641	6,351	6,641

Columns (1) and (2) estimate the relation between A.M. Best ratings and company characteristics by ordinary least squares (OLS). Column (3) estimates the same relation by instrumental variables (IV), where the instrument for shadow insurance is the market share for term life insurance in 1999, interacted with a dummy for stock company in 1999 (see Appendix B). Column (4) estimates the relation between risk-based capital and company characteristics by OLS. All specifications include dummies for year and A.M. Best financial size category, whose coefficients are not reported for brevity. The coefficients are standardized, and the standard errors in parentheses are robust to heteroscedasticity and correlation within insurance group. The sample consists of U.S. life insurers from 2002 to 2012.

Table E.II
Relation between Ratings and Company Characteristics in 1999

Variable	Coefficient
Instrument for SI	0.02
	(0.02)
Log liabilities	0.20
	(0.06)
Risk-based capital	0.09
	(0.03)
Leverage	0.00
	(0.05)
Current liquidity	0.06
	(0.03)
Return on equity	-0.04
	(0.03)
Stock company	0.18
	(0.06)
R^2	0.68
Observations	826

The relation between A.M. Best ratings and company characteristics is estimated by ordinary least squares. The specification includes dummies for A.M. Best financial size, whose coefficients are not reported for brevity. The coefficients are standardized, and the standard errors in parentheses are robust to heteroscedasticity and correlation within insurance group. The sample consists of U.S. life insurers in 1999.

Appendix F. Default Probabilities and Loss Conditional on Default

We describe the term structure of default probabilities and the loss ratio conditional on default, which we use to estimate expected loss in Appendix E.

F.1. Term Structure of Default Probabilities

We use the term structure of impairment rates from A.M. Best Company (2013a). A.M. Best Company designates an insurer as financially impaired upon the first regulatory action that restricts its activity (i.e., liquidation, supervision, rehabilitation, receivership, conservatorship, a cease-and-desist order, suspension, license revocation, or administrative order). They estimate the impairment rates by pooled method of moments, using the universe of A.M. Best rated companies from 1977 to 2012. Their sample covers 5,097 companies that account for 98% of the U.S. insurance industry by premium volume. A.M. Best Company (2013a, Exhibit 2) reports the cumulative impairment rates from one to fifteen years by rating category. We calculate the marginal impairment rate between years $m-1$ and m as the first difference of the cumulative impairment rates, which we denote as $\omega(m|\text{Rating})$.

A.M. Best Company's impairment rates have three drawbacks for our application. First, their sample includes property and casualty insurers, and they do not have separate estimates just for life insurers. Second, their estimates are subject to survivorship bias because insurers are dropped from the sample when their ratings are withdrawn.[9] Third, we do not know the precision of their estimates because standard errors are not reported. Unfortunately, we could not obtain the data necessary to replicate their study. Although we have a complete list of impairments (A.M. Best Company (2013c, pp. 20–34)), we do not have the universe of A.M. Best rated companies from 1977 to 2012.

An impaired insurer could subsequently default on policyholder claims. A default occurs when a state regulator liquidates an insolvent insurer, and guaranty associations provide coverage to the policyholders in their state. To estimate the probability of default conditional on impairment, we merge the list of life insurer insolvencies from 1991 to 2012 (Peterson (2013)) with the list of life insurer impairments (A.M. Best Company (2013c, pp. 20–34)). Since there are 325 impairments of which 71 led to insolvency, we estimate the probability of default conditional on impairment to be 0.22.

We estimate the marginal default probability as the marginal impairment rate times the

[9]Ratings can be withdrawn for various reasons including voluntary liquidations, mergers and acquisitions, company request, lack of proper financial information for evaluation, and substantial changes that make the rating process inapplicable.

probability of default conditional on impairment:

$$\Pr(m|\text{Rating}) = \omega(m|\text{Rating}) \times 0.22.$$

We use an analogous formula for the cumulative default probability. Our estimates are consistent but potentially biased because of sampling correlation between the impairment rate and the probability of default conditional on impairment. We cannot quantify the magnitude of the bias because we do not know the precision of the impairment rates.

F.2. Loss Ratio Conditional on Default

For each life insurer insolvency from 1991 to 2012, we have the associated costs and total liabilities from Peterson (2013). The associated costs are the sum of funds necessary for reinsurance assumed, claims paid by the guaranty associations, and expenses incurred by the guaranty associations, less assets recovered. We estimate the loss ratio as the sum of associated costs divided by the sum of total liabilities aggregated across all insolvencies, which is 0.25.