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ABSTRACT

Liabilities ceded by life insurers to shadow reinsurers (i.e., less regulated and unrated off-balance-sheet entities) 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. Our adjustment for shadow insurance reduces risk-based capital by 53 percentage points (or 3 rating notches) and increases default probabilities by a factor of 3.5. We develop a structural model of the life insurance industry and estimate the impact of current policy proposals to limit or eliminate shadow insurance. In the counterfactual without shadow insurance, the average company using shadow insurance would raise prices by 10 to 21 percent, and annual life insurance underwritten would fall by 7 to 16 percent for the industry.

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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 insurer liabilities are safe (and boring) because they are more predictable, have a longer maturity, and are less vulnerable to runs. Hence, 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.

We show that developments in the life insurance industry over the last decade shatter this traditional view. As a consequence of changes in regulation, life insurers are using reinsurance to move liabilities from operating companies that sell policies to affiliated reinsurers that are less regulated and unrated. These "shadow reinsurers" are captives or special purpose vehicles in states (e.g., South Carolina and Vermont) or offshore domiciles (e.g., Bermuda and Barbados) with more favorable capital regulation or tax laws. In contrast to traditional reinsurance with unaffiliated (i.e., third-party) reinsurers, these transactions do not transfer risk because the liabilities stay within the holding company.

Using new data on life and annuity reinsurance agreements, we map out the financial plumbing of U.S. life insurer liabilities, paying particular attention to the shadow insurance sector. We find that liabilities ceded to shadow reinsurers grew rapidly 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 percent 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 significantly from 2 cents in 2002.

A view shared by some industry players, some state regulators, and perhaps rating agencies is that shadow insurance makes the industry more efficient without significantly increasing risk, by reducing the impact of onerous capital requirements and taxes. However, we cannot rule out an alternative hypothesis that shadow insurance increases risk because the financial statements necessary for accurate risk assessments are not publicly available. In particular, we do not know the amount of equity in shadow reinsurers, the fragility of their funding arrangements, or the risk profile of their assets and liabilities. Therefore, we attempt to quantify the potential risk of shadow insurance 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. This implies an expected loss of $14.4 billion for the industry, which is 26 percent of the total capacity of state guaranty funds. Although far from conclusive because of limited available data, our findings highlight the importance of more transparency on shadow insurance.

By reducing the cost of financial and regulatory frictions, shadow insurance lowers the marginal cost of issuing policies for life insurers. To estimate the impact of shadow insurance on equilibrium in the retail market, we develop a structural model of the life insurance industry. Demand is determined by the random coefficients logit model, in which product differentiation is along both observable and unobservable company characteristics. Supply is determined by imperfectly competitive operating companies that sell policies and cede reinsurance to affiliated reinsurers for the purposes of capital management. We estimate the structural model under an identifying assumption that shadow insurance lowers prices, but it does not affect demand directly.

The New York State Department of Financial Services has called for a national moratorium on further approval of shadow insurance (Lawsky (2013)). Furthermore, the Financial Stability Oversight Council has designated some life insurers as "systemically important" and placed them under Federal Reserve supervision, which could limit shadow insurance through new reporting and capital requirements (Federal Insurance Office (2013)). We use the structural model to estimate the impact of these policy proposals to limit or eliminate shadow insurance. Our estimate of the counterfactual depends on whether ratings and risk-based capital already reflect shadow insurance. Under the hypothesis that they do, the average company using shadow insurance would raise prices by 10 percent, and annual life insurance underwritten would fall by $6.8 billion for the industry, which is 7 percent of the current market size. Under an alternative hypothesis that they do not, the average company using shadow insurance would raise prices by 21 percent, and annual life insurance underwritten would fall by $14.9 billion for the industry, which is 16 percent of the current market size.

The fundamental motive for shadow insurance is the same agency problems that lead to higher leverage, higher dividend rates, and increased risk taking in regulated financial institutions. For example, the presence of state guaranty funds lowers the marginal cost of issuing policies from the perspective of life insurers (Lee, Mayers, and Smith (1997)). Shareholders may prefer higher leverage and dividend rates because portfolio decisions outside the insurance industry (e.g., in mutual funds) are not subject to capital regulation. Our focus is not on why life insurers have high leverage but rather on how they achieve higher leverage through reinsurance and how that affects risk and equilibrium in the retail market.

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 a variety of reasons, including risk transfer as well as capital and tax management (Mayers and Smith (1990), Adiel (1996)). Froot (2001) finds evidence for limited transfer of catastrophe event risk, which highlights the importance of capital market frictions in the supply side of reinsurance markets. 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 holding company, 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 in 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.[1] Our work complements this literature by showing that a set of capital regulation and accounting rules, which is specific to the liability side, has a profound impact on reinsurance activity and pricing behavior in the retail market.

The remainder of the paper is organized as follows. Section 2 discusses the changes in life insurance regulation and captive laws that preceded shadow insurance. Section 3 describes the data on life and annuity reinsurance. Section 4 documents the rapid growth of shadow insurance over the last decade. In Section 5, we attempt to quantify the potential risk of shadow insurance and its impact on expected loss for the industry. In Section 6, we develop a model of optimal insurance pricing and reinsurance. In Section 7, we estimate the structural model and the counterfactual without shadow insurance. Section 8 concludes with broader implications of our findings.

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, straining their capital positions. 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 discuss these developments and related institutional background, to the extent that they are relevant to this paper.

[1] See Ellul, Jotikasthira, Lundblad, and Wang (2012), Merrill, Nadauld, Stulz, and Sherlund (2012), Becker and Opp (2013), and Becker and Ivashina (2015).

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 a reinsurer that reports under GAAP, thereby reducing overall reserves. In practice, however, unaffiliated reinsurance can be expensive because of the limited supply of capital for this purpose.

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. 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 usually have several advantages over traditional reinsurers. First, captives allow life insurers to keep the underwriting profits within the holding company. Second, captives can hold less capital because they report under GAAP or are not subject to risk-based capital regulation. Third, their financial statements are confidential to the public, rating agencies, and even regulators outside their state of domicile. Finally, captives have a more flexible financial structure that allows them to fund reinsurance transactions through letters of credit or securitization. In Appendix A, we provide balance sheet examples that illustrate these advantages 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 captive. 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. Combined with the fact that securitization is rare in practice (Stern, Rosenblatt, Nadell, and Andruschak (2007)), captives do not transfer risk outside the holding company and exist solely for the purpose of capital and tax management. Hence, 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 (2003–2013a)). 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 1.1 (Reinsurance Assumed), 3.1 (Reinsurance Ceded), and 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 that faces the same reporting and capital requirements as an operating company. 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, which are a subset of affiliated reinsurers that are unauthorized and do not have an A.M. Best rating. 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 describes the characteristics of the life insurers in our sample, by whether they were using shadow insurance. We refer the reader to Appendix B for a description of the company characteristics. 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, 78 companies used shadow insurance, whereas 443 companies did not. However, the life insurers using shadow insurance captured 48 percent of the market share for both life insurance and annuities. Furthermore, the average liabilities of life insurers using shadow insurance were 317 percent 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

In this section, we document the rapid growth of shadow insurance over the last decade, as a consequence of the changes in life insurance regulation and captive laws (see Section 2). We start with a case study of the MetLife group, which is the largest insurance group in the U.S. 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. Quite strikingly, the liabilities disappear from the balance sheets of operating companies that sell policies and end up in less regulated and nontransparent 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. Hence, 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 rapidly 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 rapidly from \$36 billion in 2002 to \$375 billion in 2012. This trend is consistent with the changes in life insurance regulation and captive laws. In contrast, affiliated annuity reinsurance is nearly constant until 2007, then grew rapidly from \$91 billion in 2007 to \$197 billion in 2012. This growth cannot be explained by Regulation (A)XXX, which does not apply to annuities. However, it is consistent with the hypothesis that life insurers faced capital constraints during the financial crisis and therefore used affiliated reinsurance to boost their capital positions (Koijen and Yogo (2015)).

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 rapidly from virtually none in 2002 to 19 percent 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 percent in 2002 to 46 percent in 2012. In contrast, the share of unaffiliated reinsurance ceded to these offshore domiciles shrank slightly over the same period.

4.4. Reinsurance with Unrated and Unauthorized Reinsurers

Figure 4 decomposes life and annuity reinsurance ceded by A.M. Best rating of the reinsurer, separately for affiliated and unaffiliated reinsurance. The share of affiliated reinsurance ceded to unrated reinsurers grew rapidly from 21 percent in 2002 to 76 percent in 2012. In contrast, the share of unaffiliated reinsurance ceded to unrated reinsurers shrank 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 rapidly from 19 percent in 2002 to 70 percent in 2012. In contrast, the share of unaffiliated reinsurance ceded to unauthorized reinsurers is nearly constant over the same period.

4.5. Growth of Shadow Insurance

Figure 6 reports total reinsurance ceded by U.S. life insurers to shadow reinsurers. Shadow insurance grew rapidly 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. This growth represents a significant buildup of leverage in a less regulated and nontransparent part of the insurance industry.

Figure 7 documents the rapid growth of shadow insurance from the perspective of retail customers that buy policies. As we discussed in Section 3, the life insurers using shadow insurance capture 48 percent 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 significantly from 2 cents in 2002.

5. Potential Risk of Shadow Insurance and Its Impact on Expected Loss

In this section, we first show that ratings are unrelated to shadow insurance, which is consistent with the hypothesis that rating agencies perceive the risk of shadow insurance to be small. However, we cannot rule out an alternative hypothesis that ratings do not adequately reflect the risk of shadow insurance. Therefore, we attempt to quantify the potential risk of shadow insurance based on publicly available data and plausible assumptions. Finally, we estimate the potential impact of shadow insurance on expected loss for the industry.

5.1. 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 this section, we empirically investigate the magnitude of adjustment for shadow insurance, which reveals the perceived importance of risk. We refer the reader to Appendix B for a description of the company characteristics that we use in our analysis, including a cardinal version of A.M. Best rating based on risk-based capital guidelines.

In column (1) of Table IV, we estimate the relation between A.M. Best rating and a dummy for shadow insurance by ordinary least squares. Our simplest specification controls for only year and A.M. Best financial size category, whose coefficients are not reported for brevity. The coefficient on shadow insurance is economically small and statistically insignificant.[2] Ratings are only 0.03 standard deviations higher for life insurers that use shadow insurance.

Our preferred specification in column (2) of Table IV adds the conventional determinants of ratings according to A.M. Best Company (2011). Although we do not know the proprietary model used by A.M. Best Company, our regression recovers a high R^2 of 62 percent. The most important determinant of ratings is company size, captured by log liabilities and A.M. Best financial size category. Ratings increase by 0.17 standard deviations per one standard deviation increase in log liabilities. Risk-based capital is also an important determinant of ratings. Ratings increase by 0.13 standard deviations per one standard deviation increase in risk-based capital. Importantly, ratings remain unrelated to shadow insurance with a statistically insignificant coefficient of zero. Column (3) shows that our results are not sensitive to nonlinearities, by adding squared characteristics to the regression.

A possible reason for the absence of a negative relation between ratings and shadow insurance is omitted variables bias. A.M. Best Company could have soft information that

[2] We have examined the share of gross life and annuity reserves ceded to shadow reinsurers as an alternative measure of shadow insurance with similar results.

is positively related to both ratings and the use of shadow insurance. We address this concern by instrumental variables, where the instrument for shadow insurance is the market share for term life insurance interacted with a dummy for stock company in 1999. The motivation for the instrument is that Regulation XXX had a stronger effect 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 company characteristics in our specification, because Regulation XXX applies only to new policies issued after 2000 and does not apply retroactively to existing liabilities. Appendix B contains details about the construction of the instrument and further motivation for why it is plausibly exogenous.

In column (4) of Table IV, we estimate our preferred specification for the relation between A.M. Best rating and company characteristics by instrumental variables.[3] The coefficient on shadow insurance is positive and statistically insignificant. Therefore, omitted variables do not appear to explain the absence of a negative relation between ratings and shadow insurance.

Another possible reason for the absence of a negative relation between ratings and shadow insurance is that the other variables in our regression already absorb the risk of shadow insurance. In particular, A.M. Best Company (2013b) claims to adjust risk-based capital for shadow insurance. In column (5) of Table IV, we investigate this possibility by estimating the relation between risk-based capital and company characteristics 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.

If we take the ratings at face value, the following hypothesis is consistent with the evidence in Table IV.

HYPOTHESIS 1: *Shadow insurance does not significantly increase the risk of life insurers. Ratings and risk-based capital correctly reflect the absence of risk.*

Under Hypothesis 1, shadow insurance makes the industry more efficient by reducing the impact of onerous capital requirements and taxes, such as Regulation (A)XXX. However, the evidence in Table IV is also consistent with the following alternative.

[3] In the first stage regression that is not reported, the instrument is a highly relevant predictor of shadow insurance with a coefficient of 0.05 and a standard error of 0.01.

Hypothesis 2: *Shadow insurance increases the risk of life insurers. Ratings and risk-based capital do not adequately reflect the presence of risk.*

We cannot rule out Hypothesis 2 because the financial statements of shadow reinsurers are not publicly available. In particular, we do not know the amount of equity in shadow reinsurers, the fragility of their funding arrangements, or the risk profile of their assets and liabilities. The fact that accurate risk assessments are difficult calls for more transparency on shadow insurance.

5.2. Potential Risk of Shadow Insurance

Whether Hypothesis 2 is true matters only insofar as the potential risk is economically large. In this section, we attempt to quantify the potential risk of shadow insurance based on publicly available data and plausible assumptions.

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 assume the following under Hypothesis 2.

Assumption 1: *Shadow reinsurers do not hold equity (i.e., $\widehat{E} = 0$). The risk profile of reinsurance ceded is identical to assets and liabilities that remain on balance sheet, so the risk charge on $\widehat{L}$ is κ.*

The assumption on shadow reinsurers' equity is plausible for two reasons. First, shadow reinsurers are not required to hold excess capital because they are not subject to risk-based capital regulation. For example, captives in Vermont are required to hold only $250,000 in equity and are allowed to count letters of credit as admitted assets (Captives and Special Purpose Vehicle Use Subgroup (2013)). Second, Lawsky (2013) finds widespread use of fragile sources of funding, such as conditional letters of credit (guaranteed by the parent company) and naked parental guarantees, based on regulatory data that are not publicly available. These fragile sources of funding erode the effective equity in shadow reinsurers.[4]

[4]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)).

The assumption on the risk profile of reinsurance ceded is a natural starting point, in the absence of evidence that it is safer than assets and liabilities that remain on balance sheet.

We now ask how the operating company's balance sheet would change if shadow insurance were moved back on balance sheet. Assumption 1 yields simple adjustments to risk-based capital and leverage based on publicly available data.

PROPOSITION 1: *Under Assumption 1, the adjusted risk-based capital is*

$$\frac{E+\widehat{E}}{\kappa L+\kappa\widehat{L}}=\frac{RBC\times L}{L+\widehat{L}}, \tag{1}$$

and the adjusted leverage is

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

Table V reports both reported and adjusted risk-based capital for the average company using shadow insurance. Our adjustment reduces risk-based capital from 208 to 155 percent, or by 53 percentage points, in 2012. According to equation (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 adjusted and reported risk-based capital has increased over time as shadow insurance $\widehat{L}$ has grown relative to liabilities L that remain on balance sheet.

To better understand the magnitude of the adjustment to risk-based capital, we apply an analogous adjustment to the cardinal version of A.M. Best rating based on risk-based capital guidelines (see Appendix B). That is, we adjust the rating as Rating $\times\, L/(L+\widehat{L})$, following equation (1). Table V shows that the rating drops by 3 notches from A to B+ for the average company using shadow insurance in 2012. We next merge both reported and adjusted ratings to the term structure of default probabilities, which we calibrate in Appendix C. The adjusted ratings imply a 10-year cumulative default probability of 3.0 percent in 2012, which is 3.5 times higher than that implied by the reported ratings.

5.3. Potential Impact of Shadow Insurance on Expected Loss

Let $\Pr(m|\text{Rating})$ be the marginal default probability between years $m-1$ and m, conditional on A.M. Best rating. Let θ be the loss ratio conditional on default, which we calibrate to be 0.25 (see Appendix C). Let $R(m)$ be the zero-coupon Treasury yield at maturity m (Gürkaynak, Sack, and Wright (2007)). For each company and year, we estimate the present value of expected loss as

$$\sum_{m=1}^{15} \frac{\Pr(m|\text{Rating})\theta L}{R(m)^m}. \tag{3}$$

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

Table VI shows that 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 into perspective, we estimate the total capacity of state guaranty funds in the last column of Table VI. All states cap annual guaranty association assessments, typically at 2 percent 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 percent in 2002 to 26 percent in 2012.

6. A Model of Insurance Pricing and Reinsurance

As we discussed in Section 1, regulators recognize the potential risk of shadow insurance and are considering policy reform to limit or eliminate it. To understand how such policy reform would affect equilibrium in the retail market, we develop a model of the supply side of insurance markets. In our model, a holding company consists of an operating company that sells policies to retail customers and an affiliated reinsurer (i.e., captive or special purpose vehicle) that faces looser capital regulation. The holding company uses affiliated reinsurance to move capital between the two companies to reduce the overall cost of financial and regulatory frictions. In doing so, affiliated reinsurance lowers the operating company's marginal cost of issuing policies and increases the equilibrium supply in the retail market.

Our model has some elements that are familiar from existing models of reinsurance in the property and casualty literature. For example, Froot and O'Connell (2008) model the demand for unaffiliated reinsurance (with risk transfer) when insurance companies face capital market frictions and imperfect competition. In addition to these familiar elements, we add affiliated reinsurance (without risk transfer) as a powerful tool for capital management, which has become the predominant form of reinsurance for life insurers over the last decade.

For concreteness, we tailor the model to the life insurance market, which is the focus of our structural estimation in Section 7. However, the key insights from our model would carry over to the annuity market. For simplicity, we do not model taxes explicitly because it is difficult to do so realistically, and the tax benefits of reinsurance may not be separately identified from a reduced cost of financial and regulatory frictions. Although U.S. tax laws disallow reinsurance for the primary purpose of reducing tax liabilities, it can be an important side benefit as we discussed in Section 2.

6.1. Holding Company's Maximization Problem

The holding company consists of an operating company and an affiliated reinsurer. 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 π. Let $R_{L,t}$ be the discount rate on liabilities in period t. Then the actuarial value is $V_t = \pi/R_{L,t}$ 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 controls 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, facing a downward-sloping demand curve. 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 operating company can also cede reinsurance to an unaffiliated reinsurer outside the holding company. Let $D_t \geq 0$ be the quantity of unaffiliated reinsurance ceded in period t at an exogenous premium $P_{D,t}$.

The holding company's profit in period t is

$$Y_t = \sum_{s=0}^{\infty} \delta^s [(P_{t-s} - V_t)Q_{t-s} - (P_{D,t-s} - V_t)D_{t-s}], \tag{4}$$

where $\delta = (1-\pi)\lambda$. This equation says that total profit is the profit from the sale of policies minus the cost of unaffiliated reinsurance, summed across all policies 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. Note that affiliated reinsurance does not appear in equation

(4) because it nets out of the holding company's profit (in the absence of tax effects).

6.1.1. *Balance Sheet Dynamics*

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

$$L_t = \sum_{s=0}^{\infty} \delta^s V_t (Q_{t-s} - B_{t-s} - D_{t-s}) = \frac{\delta V_t}{V_{t-1}} L_{t-1} + V_t (Q_t - B_t - D_t). \tag{5}$$

This equation says that liabilities are the sum of policies net of 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

$$A_t = R_{A,t} A_{t-1} + L_t - \frac{\delta V_t}{V_{t-1}} L_{t-1} + Y_t. \tag{6}$$

This equation can be derived from the flow of funds identity, which says that the change in assets is equal to the change in liabilities plus profit.[5]

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

$$K_t = A_t - (1 + \rho) L_t, \tag{7}$$

where a higher ρ implies tighter capital regulation. Our formulation of statutory capital has two interpretations, both of which lead to equation (7). First, operating companies must hold additional reserves under Regulation (A)XXX (see Section 2). 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 function of the affiliated reinsurer is to assume reinsurance from the operating company. The affiliated reinsurer's liabilities at the end of period t are

$$\widehat{L}_t = \sum_{s=0}^{\infty} \delta^s V_t B_{t-s} = \frac{\delta V_t}{V_{t-1}} \widehat{L}_{t-1} + V_t B_t. \tag{8}$$

[5] We could modify equation (6) to include other sources of funding, such as direct capital injections from the parent company. However, these other sources are more expensive and less preferred to affiliated reinsurance by revealed preference.

Its assets at the end of period t are

$$\widehat{A}_t = R_{A,t}\widehat{A}_{t-1} + \widehat{L}_t - \frac{\delta V_t}{V_{t-1}}\widehat{L}_{t-1}. \tag{9}$$

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

$$\widehat{K}_t = \widehat{A}_t - (1+\widehat{\rho})\widehat{L}_t. \tag{10}$$

6.1.2. Financial and Regulatory Frictions

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)). In addition, increased use of shadow insurance could draw regulatory scrutiny or intervention (Lawsky (2013)). We model these financial and regulatory frictions through a cost function:

$$C_t = C\left(\frac{K_t}{L_{t-1}}, \frac{\widehat{K}_t}{\widehat{L}_{t-1}}\right). \tag{11}$$

We assume that this function is strictly decreasing and convex. That is, low statutory capital relative to lagged liabilities, in either the operating company or the affiliated reinsurer, draws regulatory scrutiny or intervention.

The holding company maximizes firm value, or the present value of profits minus the cost of financial and regulatory frictions:

$$J_t = Y_t - C_t + \mathbb{E}_t[M_{t+1}J_{t+1}], \tag{12}$$

where M_{t+1} is the stochastic discount factor. The choice variables are the price P_t, affiliated reinsurance B_t, and unaffiliated reinsurance D_t.

6.2. *Optimal Insurance Pricing and Reinsurance*

We now describe the holding company's optimal choice of insurance price and reinsurance. To simplify notation, we first define the operating company's *shadow cost of capital* as

$$c_t = -\frac{\partial Y_t}{\partial P_t}\left(\frac{\partial K_t}{\partial P_t}\right)^{-1} = -\frac{\partial C_t}{\partial K_t} + \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial K_t}\right]. \tag{13}$$

The shadow cost of capital is the marginal reduction in profit that the holding company is willing to accept to increase the operating company's statutory capital by a dollar. Alternatively, it quantifies the importance of financial and regulatory frictions, in either the present or the future. Similarly, we define the affiliated reinsurer's shadow cost of capital as

$$\widehat{c}_t = -\frac{\partial C_t}{\partial \widehat{K}_t} + \mathbb{E}_t\left[M_{t+1}\frac{\partial J_{t+1}}{\partial \widehat{K}_t}\right]. \tag{14}$$

Proposition 2: *The optimal price is*

$$P_t = \left(1 - \frac{1}{\epsilon_t}\right)^{-1}\Phi_t, \tag{15}$$

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

$$\Phi_t = \frac{(1+(1+\rho)c_t)V_t}{1+c_t} \tag{16}$$

is the marginal cost of issuing policies. Furthermore, $\partial\Phi_t/\partial B_t < 0$.

We prove Proposition 2 in Appendix D. The first term in equation (15) is familiar from the Bertrand pricing formula. The optimal price is decreasing in the elasticity of demand. The second term is marginal cost that arises from financial and regulatory frictions. Marginal cost increases with the shadow cost of capital and tighter capital regulation (i.e., higher ρ). Affiliated reinsurance reduces the operating company's shadow cost of capital and thereby lowers the marginal cost of issuing policies.

Proposition 3: *If affiliated insurance is at an interior optimum, it satisfies*

$$c_t\rho = \widehat{c}_t\widehat{\rho}. \tag{17}$$

Optimal unaffiliated reinsurance is positive only if

$$P_{D,t} < \frac{(1+(1+\rho)c_t)V_t}{1+c_t} \tag{18}$$

at $D_t = 0$.

We prove Proposition 3 in Appendix D. Equation (17) 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 (17) holds with $c_t < \widehat{c}_t$ after affiliated reinsurance.

Inequality (18) says that the operating company cedes reinsurance to an unaffiliated reinsurer only if the marginal cost is less than the marginal benefit. The marginal benefit of unaffiliated reinsurance can be higher than that of affiliated reinsurance because of risk transfer and underwriting assistance.

7. Impact of Shadow Insurance on the Retail Market

To bring the model of the life insurance industry to the data, we first introduce additional parametric assumptions about the demand function and marginal cost. We then estimate the structural model under an identifying assumption that shadow insurance lowers prices, but it does not affect demand directly. Finally, we use the structural model to estimate the counterfactual without shadow insurance.

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. We focus on 10-year guaranteed level term life insurance for males aged 30 as representative of the life insurance market. Appendix B contains further details about the data on life insurance prices.

7.1. Empirical Specification

Operating companies compete in the life insurance market by setting prices. Demand is determined by the random coefficients logit model, which can be derived from a discrete choice problem (Berry, Levinsohn, and Pakes (1995)). 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

$$q_{n,t}(\alpha,\beta) = \frac{\exp\{\alpha P_{n,t} + \beta' \mathbf{x}_{n,t} + \xi_{n,t}\}}{1 + \sum_{m=1}^{N} \exp\{\alpha P_{m,t} + \beta' \mathbf{x}_{m,t} + \xi_{m,t}\}}, \tag{19}$$

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

$$\overline{q}_{n,t} = \frac{Q_{n,t}}{S_t + \sum_{m=1}^{N} Q_{m,t}} = \int q_{n,t}(\alpha,\beta) dF(\alpha,\beta). \tag{20}$$

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

$$\epsilon_{n,t} = -\frac{\partial \log(\overline{q}_{n,t})}{\partial \log(P_{n,t})} = -\frac{P_{n,t}}{\overline{q}_{n,t}} \int \alpha q_{n,t}(\alpha,\beta)(1 - q_{n,t}(\alpha,\beta)) dF(\alpha,\beta). \tag{21}$$

Each company prices insurance according to equation (15). 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 one if company n uses shadow insurance in year t. 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 the marginal cost of company n in year t as

$$\Phi_{n,t} = \left(1 - \frac{1}{\epsilon_{n,t}}\right) P_{n,t} = \exp\{\phi \mathrm{SI}_{n,t} + \psi' \mathbf{y}_{n,t} + \nu_{n,t}\}, \tag{22}$$

where the structural error $\nu_{n,t}$ represents an unobservable cost shock. Shadow insurance lowers marginal cost according to Proposition 2, so we anticipate that $\phi < 0$.

7.2. Identifying Assumption

Since price is endogenous to demand, we make the following identifying assumption.

Assumption 2: *The structural error in demand* (20) *satisfies*

$$\mathbb{E}[\xi_{n,t}|\mathrm{SI}_{n,t}, \mathbf{x}_{n,t}] = 0. \tag{23}$$

The structural error in marginal cost (22) *satisfies*

$$\mathbb{E}[\nu_{n,t}|\mathrm{SI}_{n,t}, \mathbf{y}_{n,t}] = 0. \tag{24}$$

Equation (23) says that shadow insurance is uncorrelated with demand, conditional on observable characteristics. For example, retail customers purchase life insurance based on company size and A.M. Best rating, but they do not know which life insurers use shadow insurance. 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), Robinson and Son (2013), this paper, and related media coverage). An alternative justification for the exclusion restriction, which we find less plausible, is that retail customers do not care about shadow insurance because they expect the state guaranty associations to ultimately pay off their claims.

Equation (24) says that shadow insurance is uncorrelated with the cost shock, conditional on observable characteristics. This assumption is valid only under the null that $\mathbf{y}_{n,t}$ contains all determinants of marginal cost that are also related to shadow insurance. Under the alternative that our specification omits an important determinant, the coefficient on shadow insurance is subject to an omitted variables bias. We address this concern in one of the robustness checks below.

We estimate demand (20) and marginal cost (22) jointly based on Assumption 2. Since we essentially follow Berry et al. (1995), we only describe details about the estimation that are specific to our implementation. The company characteristics in our specification of $\mathbf{x}_{n,t}$ are A.M. Best rating and the conventional determinants of ratings (see Section 5): log liabilities, risk-based capital, leverage, current liquidity, return on equity, and a dummy for stock company. Given the mean and standard deviation of (α, β), we invert equation (20) 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.

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 (22) 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 heteroskedasticity and correlation between the structural errors for demand and marginal cost.

7.3. Structural Estimates of the Life Insurance Market

The first two columns of Table VII report the estimated parameters for the random coefficients logit model of demand (20). Our preferred specification limits the random coefficients to log liabilities, 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. Demand is positively related to both company size and A.M. Best rating. That is, the mean coefficient on log liabilities is 2.71, and the mean coefficient on A.M. Best rating is 0.13. 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.

The third column of Table VII reports the estimated coefficients for marginal cost (22). Shadow insurance lowers marginal cost by 13 percent with a standard error of 3 percent. Other important determinants of marginal cost are A.M. Best rating and leverage. Marginal cost decreases by 7 percent per one standard deviation increase in A.M. Best rating. Similarly, marginal cost decreases by 4 percent per one standard deviation increase in leverage.

7.3.1. Robustness Checks

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.

As we discussed above, our identifying assumption for marginal cost could be subject to an omitted variables bias. To address this concern, we replace shadow insurance in moment restriction (24) with the market share for term life insurance interacted with a dummy for stock company in 1999 (see Appendix B). The market share in 1999 is plausibly exogenous to marginal cost after 2002, conditional on company characteristics in our specification, because Regulation XXX applies only to new policies issued after 2000 and does not apply retroactively to existing liabilities. Table E.1 in Appendix E shows that the structural estimates with alternative instruments are similar to those in Table VII. In particular, the estimated coefficient on shadow insurance is −0.44 with a standard error of 0.18. Although the coefficient is less precisely estimated than in Table VII, we can still reject the null that shadow insurance has no effect on marginal cost.

7.4. Retail Market without Shadow Insurance

We estimate two counterfactuals based on the estimated structural model in Table VII, corresponding to Hypotheses 1 and 2. For Hypothesis 1, we first set $\mathrm{SI}_{n,t} = 0$ in equation (22) 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 (20) and supply (22).

Under Hypothesis 1, Table VIII shows that marginal cost would increase by 13.3 percent for the average company using shadow insurance in 2012. In response to higher marginal cost, the average company would raise prices by 10.4 percent. The quantity of annual life insurance underwritten 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 percent of its current size of \$91.5 billion in 2012.

The second counterfactual in Table VIII is based on Hypothesis 2, in which ratings and risk-based capital do not adequately reflect shadow insurance. We first adjust the ratings, risk-based capital, and leverage for shadow insurance based on Proposition 1. We then plug in the adjusted ratings, risk-based capital, and leverage in equation (20). We then set $\mathrm{SI}_{n,t} = 0$ and plug in the adjusted ratings, risk-based capital, and leverage in equation (22). Finally, we solve for the new price vector that satisfies the equilibrium conditions for demand (20) and supply (22).

The adjustments to ratings, risk-based capital, and leverage ultimately imply much larger effects under Hypothesis 2 compared with Hypothesis 1. Table VIII shows that marginal cost would increase by 27.1 percent for the average company using shadow insurance in 2012. In response to higher marginal cost, the average company would raise prices by 21.3 percent. The industry as a whole would shrink by \$14.9 billion, which is 16 percent of the current market size.

8. Conclusion

The current size of the U.S. shadow insurance sector is \$364 billion, or 25 cents of every dollar insured by the life insurers using shadow insurance. Depending on additional activity abroad, the U.S. activity could just be the tip of an iceberg. Even documenting the size of the European shadow insurance sector turns out to be a daunting task because of limited public disclosure and inconsistent reporting requirements. This problem can be addressed with a global standard for complete and transparent financial statements.

We do not know whether the current level of capital, as a consequence of the capital requirements offset by shadow insurance, is socially optimal. However, the counterfactuals in this paper are valuable for making progress on an important aspect of this difficult question. If the capital requirements were too conservative after the changes in life insurance regulation (see Section 2), shadow insurance makes the industry more efficient without significantly increasing risk. Under Hypothesis 1, shadow insurance enables the average company to lower prices by 10 percent, leading to a \$6.8 billion increase in annual life insurance underwritten for the industry. If the capital requirements were appropriate after the changes in life insurance regulation but before the captive laws, shadow insurance makes the industry too large at the cost of the state guaranty funds. Under Hypothesis 2, shadow insurance enables the average company to lower prices by 21 percent, leading to a \$14.9 billion increase in annual life insurance underwritten for the industry. However, shadow insurance increases expected loss by \$9.5 billion for the industry.

To fully answer the question of optimal regulation, we must first understand the broader consequences of failure in the insurance industry, which is an important research agenda that is beyond the scope of this paper. First, the financial crisis has shown that even relatively small shocks could amplify because of the interconnectedness of financial institutions and the endogeneity of asset prices. Banks fund reinsurance transactions through letters of credit, so systemic drawdowns of these credit lines could put the banking sector at risk. Second, life insurers are the most important institutional investors of corporate bonds, so their problems could spill over into real investment and economic activity. Finally, the insurance industry diversifies the most important sources of idiosyncratic risk in the economy, so shocks to supply or confidence in the industry could have large welfare consequences (Einav, Finkelstein, and Schrimpf (2010), Koijen, Van Nieuwerburgh, and Yogo (2015)).

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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. Shadow reinsurers are a subset of affiliated reinsurers that are unauthorized and do not have an A.M. Best rating. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

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

This is a list of the U.S. operating companies of the MetLife group and their affiliated reinsurers in 2012, whose net reinsurance ceded is greater than $0.1 billion in absolute value. 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.

Table IV
Relation between Ratings and Shadow Insurance

	A.M. Best rating				Risk-based
	OLS			IV	capital
Variable	(1)	(2)	(3)	(4)	(5)
Shadow insurance	0.03	0.00	0.02	0.25	-0.02
	(0.06)	(0.06)	(0.06)	(0.34)	(0.05)
Log liabilities		0.17	0.18	0.13	0.15
		(0.04)	(0.04)	(0.06)	(0.05)
Risk-based capital		0.13	0.34	0.15	
		(0.02)	(0.05)	(0.02)	
Leverage		-0.01	-0.02	0.01	-0.46
		(0.03)	(0.04)	(0.03)	(0.06)
Current liquidity		0.08	0.16	0.06	0.18
		(0.02)	(0.06)	(0.02)	(0.04)
Return on equity		0.03	0.02	0.03	0.01
		(0.02)	(0.02)	(0.02)	(0.02)
Stock company		0.05	0.06	0.02	0.12
		(0.06)	(0.06)	(0.07)	(0.06)
Squared:					
Log liabilities			0.02		
			(0.02)		
Risk-based capital			-0.10		
			(0.02)		
Leverage			-0.05		
			(0.02)		
Current liquidity			0.00		
			(0.01)		
Return on equity			0.00		
			(0.00)		
R^2	0.60	0.62	0.64	0.63	0.33
Observations	6,641	6,641	6,641	6,351	6,641

Columns (1) to (3) estimate the relation between A.M. Best rating and company characteristics by ordinary least squares (OLS). Column (4) estimates the same relation by instrumental variables (IV), where the instrument for shadow insurance is the market share for term life insurance interacted with a dummy for stock company in 1999 (see Appendix B). Column (5) 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 heteroskedasticity and correlation within insurance group. The sample consists of U.S. life insurers from 2002 to 2012.

Table V

Risk Measures Adjusted for Shadow Insurance

	Risk-based capital (%)			Rating		10-year default probability (%)		
Year	Reported	Adjusted	Difference	Reported	Adjusted	Reported	Adjusted	Ratio
2002	160	150	-10	A+	A	0.7	1.3	1.8
2003	170	156	-14	A+	A	0.7	1.3	2.0
2004	168	146	-22	A	A−	0.8	1.6	2.0
2005	197	166	-31	A	A−	0.9	1.8	2.0
2006	190	164	-25	A+	A−	0.7	1.5	2.3
2007	199	171	-28	A	B++	1.0	2.2	2.3
2008	199	174	-25	A	B++	0.8	2.1	2.6
2009	227	182	-45	A	B++	0.9	2.5	2.8
2010	250	197	-53	A	B+	0.9	2.8	3.1
2011	238	194	-44	A	B+	1.0	2.8	2.9
2012	208	155	-53	A	B+	0.9	3.0	3.5

Average risk-based capital, A.M. Best rating, and 10-year cumulative default probability are reported for U.S. life insurers using shadow insurance. The adjustment for shadow insurance is based on Assumption 1.

Table VI
Expected Loss Adjusted for Shadow Insurance

Year	Expected loss (billion $)			Guaranty funds
	Reported	Adjusted	Difference	(billion $)
2002	2.8	2.9	0.1	40.6
2003	2.6	2.9	0.3	38.0
2004	2.8	4.3	1.5	35.9
2005	2.8	4.2	1.4	33.4
2006	2.7	4.2	1.5	36.3
2007	3.1	6.6	3.5	38.7
2008	4.2	9.7	5.5	50.7
2009	3.7	11.5	7.7	47.6
2010	4.0	12.2	8.2	46.2
2011	4.7	13.5	8.8	49.2
2012	4.9	14.4	9.5	56.4

The reported expected loss is based on equation (3) aggregated across U.S. life insurers. The adjustment for shadow insurance is based on Assumption 1. The total capacity of state guaranty funds is the maximum annual assessment aggregated across all states, projected to remain constant over the next 10 years (Gallanis (2009)).

Table VII
Structural Estimates of the Life Insurance Market

	Demand		
Variable	Mean	Standard deviation	Marginal cost
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 (20) and marginal cost (22) 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 heteroskedasticity-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.

Table VIII
Retail Market without Shadow Insurance

	Hypothesis	
	1	2
Percent change in:		
Marginal cost	13.3	27.1
Price	10.4	21.3
Change in quantity (billion $):		
Companies using shadow insurance	-7.2	-15.8
Other companies	0.4	0.9
Total	-6.8	-14.9

The counterfactual without shadow insurance is based on the estimated structural model in Table VII. The changes in marginal cost of issuing policies and price are for the average company using shadow insurance in 2012. The change in quantity of annual life insurance underwritten is in units of gross life reserves.

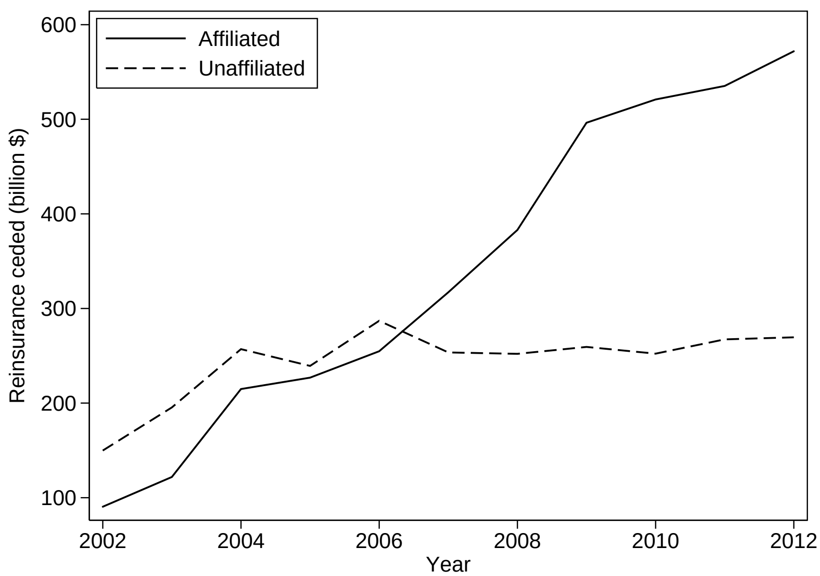

FIGURE 1. Reinsurance ceded to affiliated and unaffiliated reinsurers. Life and annuity reinsurance ceded by U.S. life insurers to affiliated and unaffiliated reinsurers is reported. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

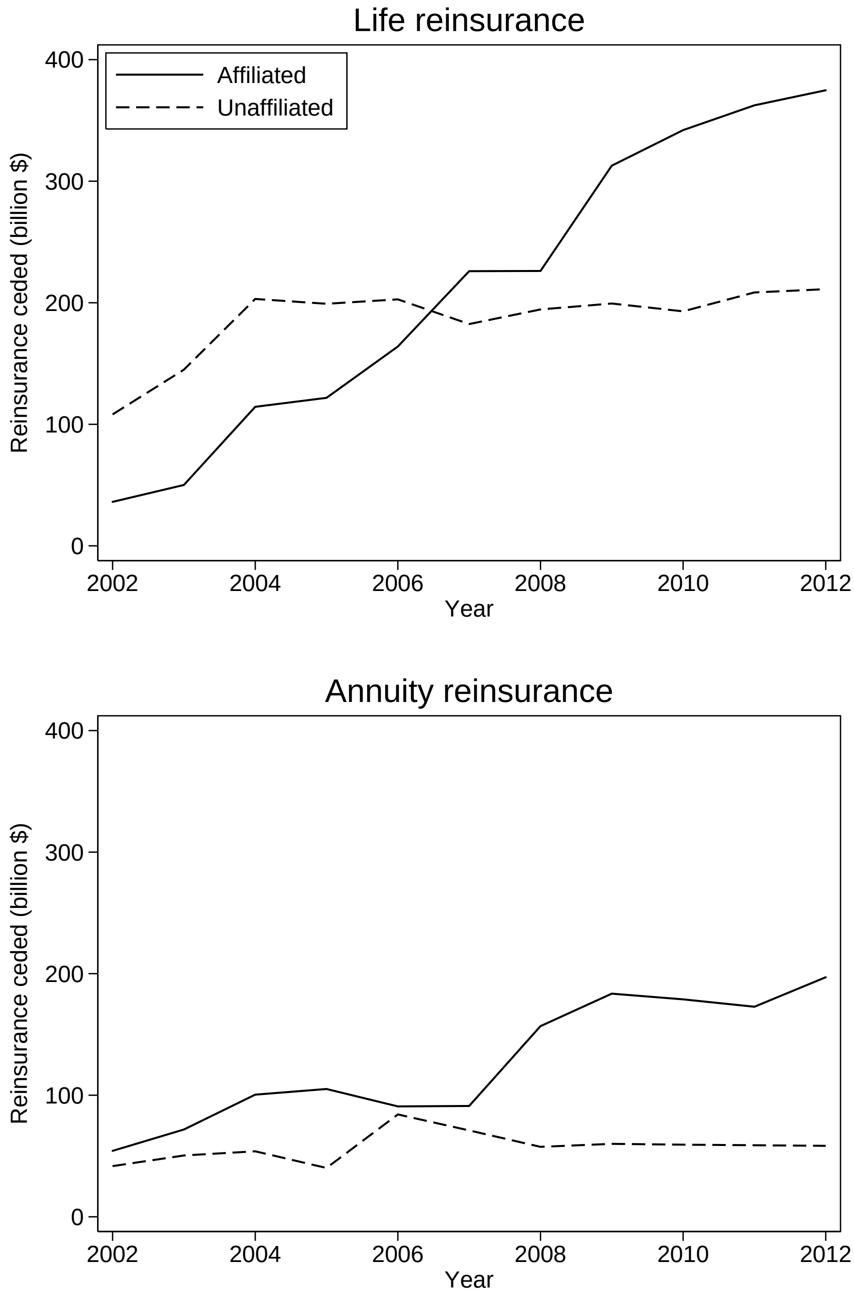

FIGURE 2. Life versus annuity reinsurance ceded to affiliated and unaffiliated reinsurers. Reinsurance ceded by U.S. life insurers to affiliated and unaffiliated reinsurers is reported, separately for life and annuity reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance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

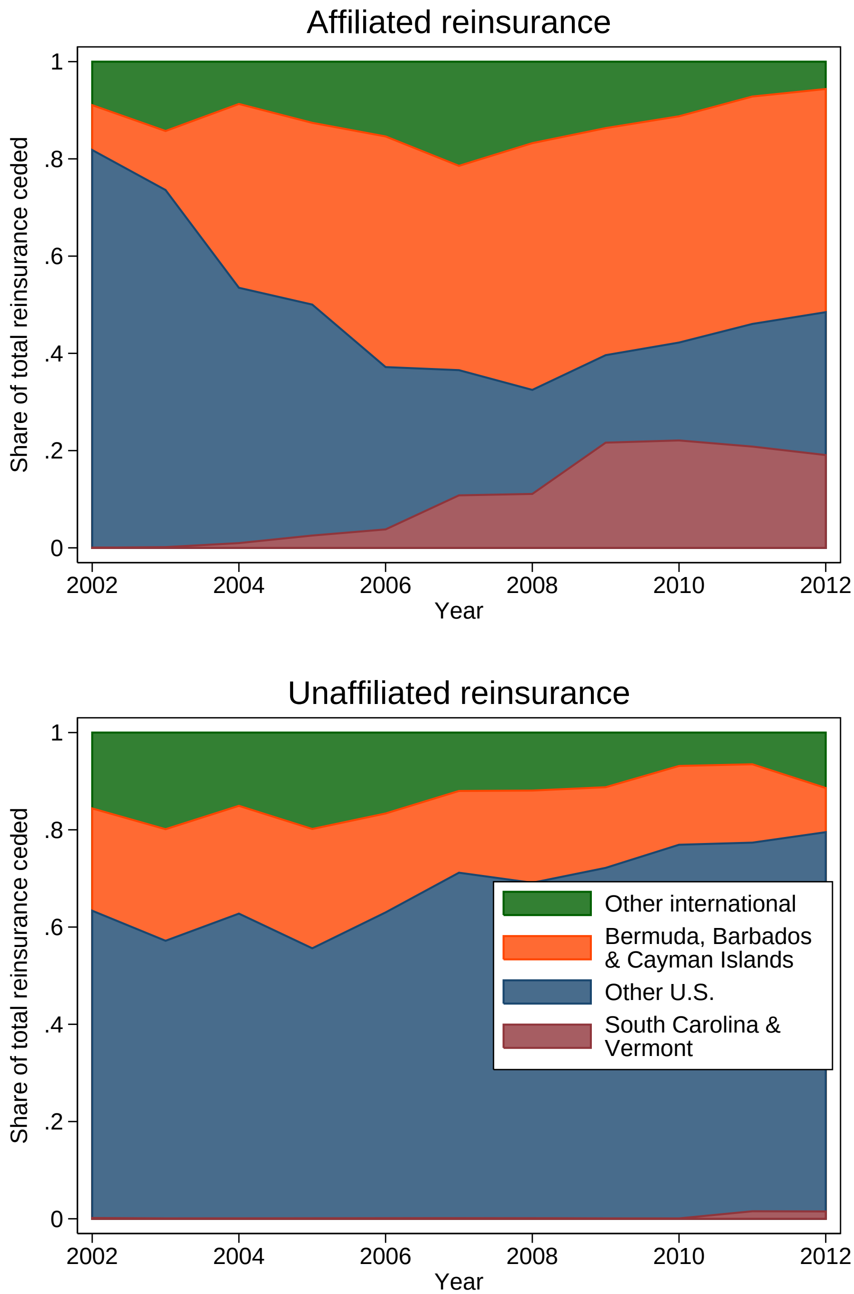

FIGURE 3. Reinsurance ceded by the reinsurer's domicile. Life and annuity reinsurance ceded by U.S. life insurers is decomposed by the reinsurer's domicile, separately for affiliated and unaffiliated reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

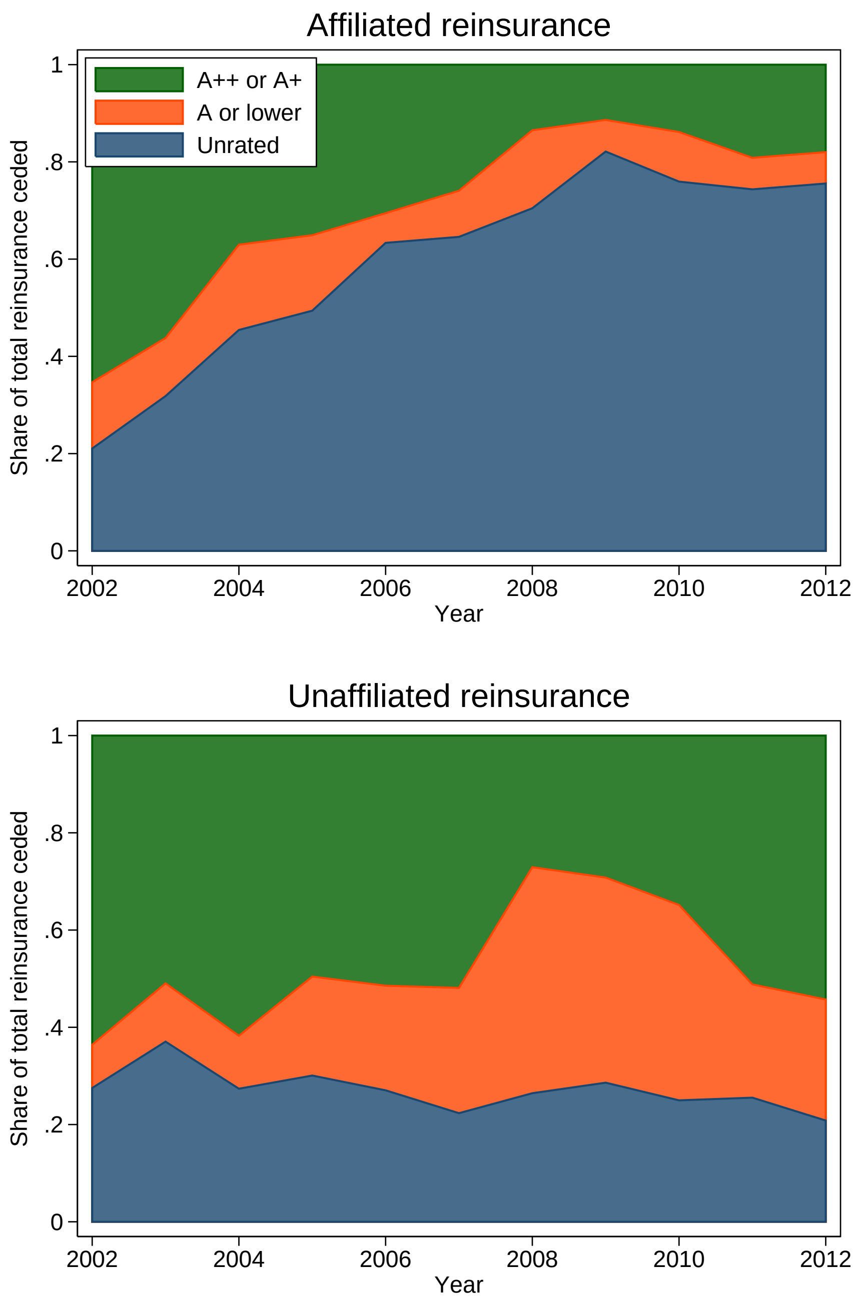

FIGURE 4. Reinsurance ceded by rating of reinsurer. Life and annuity reinsurance ceded by U.S. life insurers is decomposed by A.M. Best rating of the reinsurer, separately for affiliated and unaffiliated reinsurance. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve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

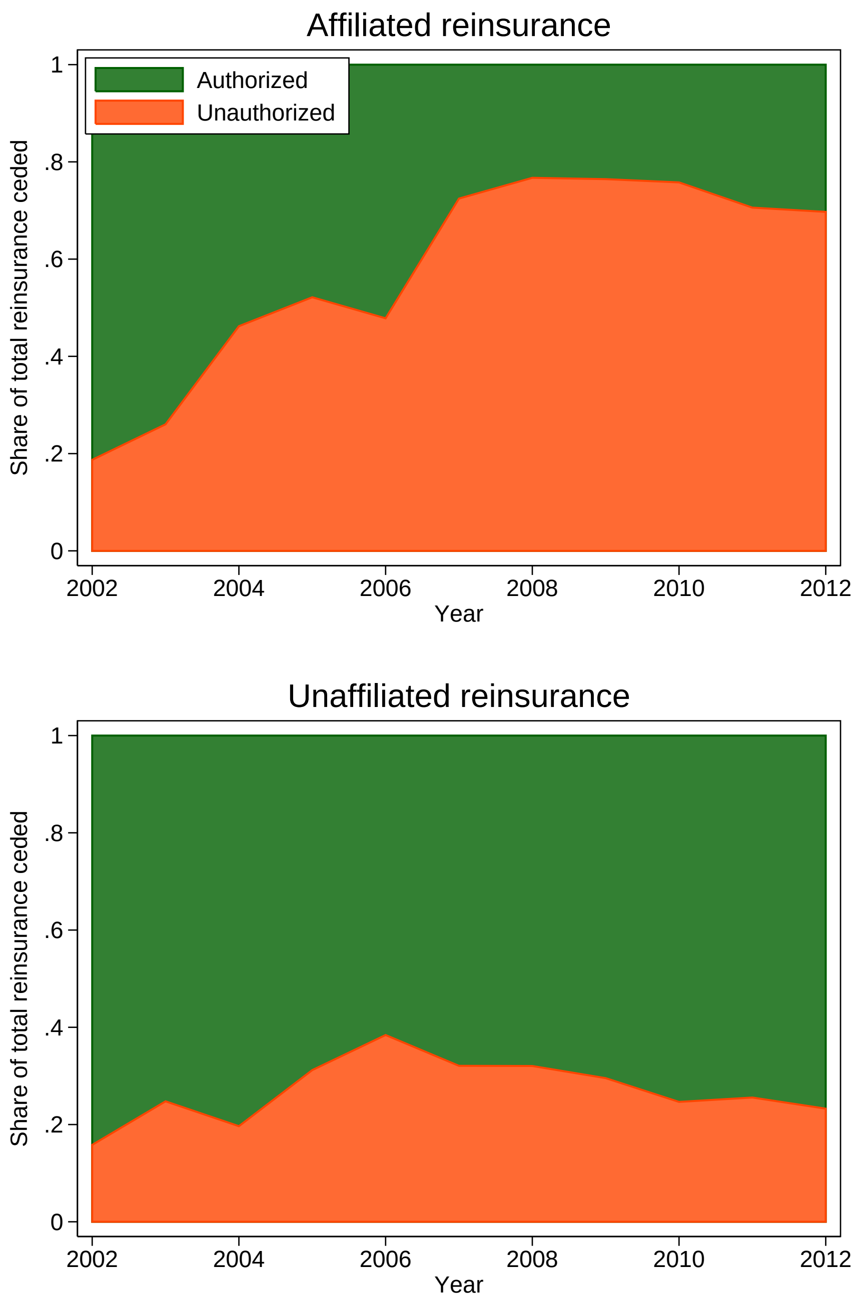

FIGURE 5. Reinsurance ceded to unauthorized reinsurers. Life and annuity reinsurance ceded by U.S. life insurers is decomposed by whether the reinsurer is authorized in the ceding company's domicile, separately for affiliated and unaffiliated reinsurance. Reinsurance ceded is the sum of reserve credit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

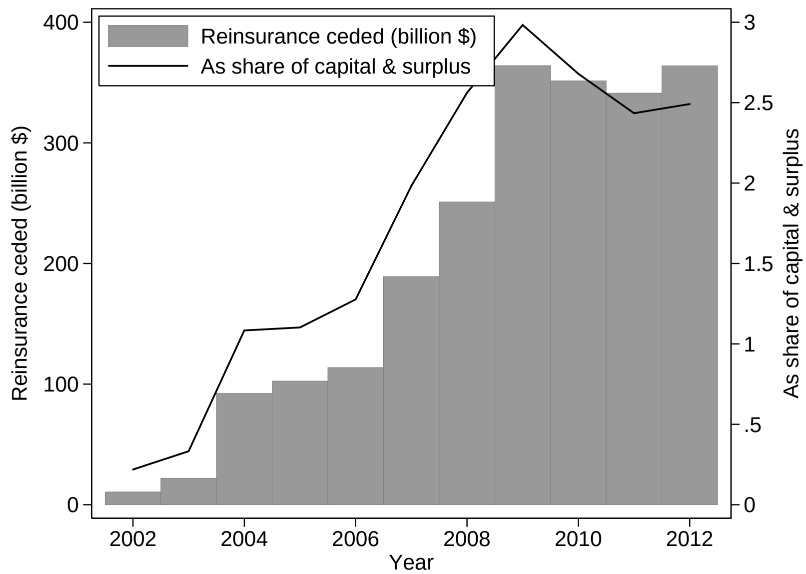

FIGURE 6. Reinsurance ceded to shadow reinsurers. Life and annuity reinsurance ceded by U.S. life insurers to shadow reinsurers is reported in total dollars and as a share of the capital and surplus of the ceding companies. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance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

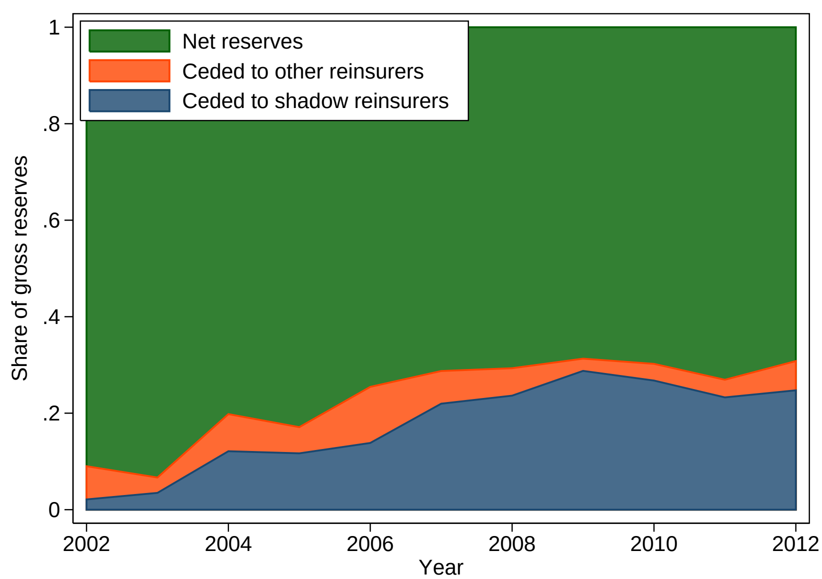

FIGURE 7. Decomposition of gross reserves for life insurers using shadow insurance. Gross life and annuity reserves for U.S. life insurers using shadow insurance are decomposed into reinsurance ceded versus net reserves held. Reinsurance ceded is the sum of reserve credit taken and modified coinsurance reserve ceded.

Appendix A. Stylized Examples of Captive Reinsurance

We illustrate the balance sheet mechanics of how an operating company can free up 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.[6] The latter two types are different from coinsurance in that the ceding company retains control of the assets, so the captive does not need to establish a trust fund. However, the examples show that all three types 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 to retail customers 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.[7]

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.

[6]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.

[7]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)

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)

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 holding company. 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)

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)

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 holding company. 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)

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

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

A		L	
Bonds	$10		
		Equity	$10

⟹

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

⟹

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

Captive
(in domicile with looser capital regulation)

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

A		L	
		Equity	$0

⟹

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 holding company. The operating company must hold a statutory reserve of $110, while the captive can hold a GAAP reserve of $90.

Appendix B. Data Description

B.1. Company Characteristics

We construct the following company characteristics based on the NAIC annual financial statements (A.M. Best Company (2003–2013b)). 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: Logarithm of as reported total liabilities, except in Tables VII and E.1, where it is the logarithm of gross life reserves.
- 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 percent) 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. Our adjustment for shadow insurance assumes that the denominator is proportional to aggregate reserve for life contracts less modco reserve.
- 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 in the current and prior year.
- A.M. Best financial size category: A measure of company size (coded from one to fifteen) based on the adjusted policyholders' surplus for the insurance group.

B.2. Instrument for Shadow Insurance

To construct the instrument for shadow insurance, we first calculate the market share for term life insurance in 1999 as the face amount of term life insurance in force divided by its sum across all companies. We then interact the market share with a dummy for stock company in 1999.

We cannot test whether the instrument for shadow insurance is a direct determinant of ratings. However, we can see whether it is an important determinant of ratings in 1999, prior to the changes in life insurance regulation that preceded shadow insurance. In Table B.1, we estimate the relation between A.M. Best rating and company characteristics in 1999 by ordinary least squares. The coefficient on the instrument is economically small. Ratings increase by 0.02 standard deviations per one standard deviation increase in the instrument. Although this result does not prove that the instrument is exogenous, we find comfort in knowing that it is not an obvious determinant of ratings in 1999.

Table B.1
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 rating 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 heteroskedasticity and correlation within insurance group. The sample consists of U.S. life insurers in 1999.

B.3. 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 in the paper, but we have also examined 20-year policies and older age groups. 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 financial statements with life insurance premiums 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 yield at maturity m. We define the actuarial value of 10-year term life insurance at age n per dollar of death benefit as

$$V(n) = \left(1 + \sum_{m=1}^{9} \frac{\prod_{l=0}^{m-1} \pi_{n+l}}{R(m)^m}\right)^{-1} \left(\sum_{m=1}^{10} \frac{\prod_{l=0}^{m-2} \pi_{n+l}(1 - \pi_{n+m-1})}{R(m)^m}\right). \tag{25}$$

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.

Appendix C. Default Probabilities and Loss Conditional on Default

C.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 percent 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 A.M. Best rating. 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.[8] 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 probability of default conditional on impairment:

$$\Pr(m|\text{Rating}) = \omega(m|\text{Rating}) \times 0.22. \quad (26)$$

We use an analogous formula for the cumulative default probability. Our estimates are

[8] 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.

consistent but possibly 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, as we discussed above.

C.2. Loss 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.

Appendix D. Proofs

Proof of Proposition 2: Using equations (5) and (8), we can rewrite profit (4) recursively as

$$Y_t = \delta \left[Y_{t-1} + \left(1 - \frac{V_t}{V_{t-1}} \right) \left(L_{t-1} + \widehat{L}_{t-1} \right) \right] + (P_t - V_t) Q_t - (P_{D,t} - V_t) D_t. \tag{27}$$

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

$$\begin{aligned} K_t = & R_{A,t} K_{t-1} + (1+\rho) \left(R_{A,t} - \frac{\delta V_t}{V_{t-1}} \right) L_{t-1} + \delta \left[Y_{t-1} + \left(1 - \frac{V_t}{V_{t-1}} \right) \left(L_{t-1} + \widehat{L}_{t-1} \right) \right] \\ & + (P_t - (1+\rho) V_t) Q_t + \rho V_t B_t - (P_{D,t} - (1+\rho) V_t) D_t. \end{aligned} \tag{28}$$

Substituting equations (8) and (9) in equation (10), we have

$$\widehat{K}_t = R_{A,t} \widehat{K}_{t-1} + (1+\widehat{\rho}) \left(R_{A,t} - \frac{\delta V_t}{V_{t-1}} \right) \widehat{L}_{t-1} - \widehat{\rho} V_t B_t. \tag{29}$$

Therefore, the state variables in period t are Y_{t-1}, L_{t-1}, $\widehat{L}_{t-1}$, K_{t-1}, and $\widehat{K}_{t-1}$.

The first-order condition for price is

$$\frac{\partial J_t}{\partial P_t} = \frac{\partial Y_t}{\partial P_t} + c_t \frac{\partial K_t}{\partial P_t} = Q_t + (P_t - V_t) \frac{\partial Q_t}{\partial P_t} + c_t \left[Q_t + (P_t - (1+\rho) V_t) \frac{\partial Q_t}{\partial P_t} \right] = 0, \tag{30}$$

which implies equation (15). The partial derivative of marginal cost with respect to affiliated reinsurance is

$$\frac{\partial \Phi_t}{\partial B_t} = \left(\frac{\rho V_t}{1 + c_t} \right)^2 \frac{\partial c_t}{\partial K_t}. \tag{31}$$

Note that

$$\frac{\partial c_t}{\partial K_t} = -\frac{\partial^2 C_t}{\partial K_t^2} + \mathbb{E}_t \left[M_{t+1} \frac{\partial^2 J_{t+1}}{\partial K_t^2} \right] < 0 \tag{32}$$

since $\partial^2 C_t / \partial K_t^2 > 0$ by assumption and $\partial^2 J_{t+1} / \partial K_t^2 < 0$ by Stokey, Lucas, and Prescott (1989, Theorem 9.8). *Q.E.D.*

Proof of Proposition 3: The first-order condition for affiliated reinsurance is

$$\frac{\partial J_t}{\partial B_t} = c_t \frac{\partial K_t}{\partial B_t} + \widehat{c}_t \frac{\partial \widehat{K}_t}{\partial B_t} = (c_t \rho - \widehat{c}_t \widehat{\rho}) V_t = 0, \tag{33}$$

which implies equation (17). Optimal unaffiliated reinsurance is positive only if

$$\frac{\partial J_t}{\partial D_t} = \frac{\partial Y_t}{\partial D_t} + c_t \frac{\partial K_t}{\partial D_t} = -(P_{D,t} - V_t) - c_t(P_{D,t} - (1+\rho)V_t) > 0 \tag{34}$$

at $D_t = 0$, which is equivalent to inequality (18). *Q.E.D.*

Appendix E. Additional Results

Table E.1
Structural Estimates of the Life Insurance Market with Alternative Instruments

	Demand		
Variable	Mean	Standard deviation	Marginal cost
Price	-1.31		
	(0.53)		
Shadow insurance			-0.44
			(0.18)
Log liabilities	2.74	0.26	0.07
	(0.05)	(0.10)	(0.03)
A.M. Best rating	0.09	0.20	-0.06
	(0.09)	(0.39)	(0.03)
Risk-based capital	-0.06		0.00
	(0.08)		(0.02)
Leverage	0.16	0.31	-0.01
	(0.10)	(0.17)	(0.02)
Current liquidity	0.10		0.02
	(0.06)		(0.02)
Return on equity	-0.20		0.04
	(0.03)		(0.02)
Stock company	0.08		0.11
	(0.10)		(0.07)
Observations	1,684		

The estimation in Table VII is repeated with alternative instruments for marginal cost. The instruments for marginal cost are the market share for term life insurance interacted with a dummy for stock company in 1999 (see Appendix B), company characteristics, and year dummies.