Quantitative Finance and Economics

QFE, 3(1): 145–164.
DOI: 10.3934/QFE.2019.1.145
Received: 08 November 2018
Accepted: 29 March 2019
Published: 04 April 2019

http://www.aimspress.com/journal/QFE

Research article

Was the U.S. life insurance industry in danger of systemic risk by using derivative hedging prior to the 2008 financial crisis?

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Abstract: This paper is an historical study—with implications for the present—of the extent to which the life insurance industry contributed to systemic risk prior to the 2008 financial crisis by using derivatives to hedge product and asset risks. First, we present evidence that the life insurance industry insufficiently appreciated the risks of variable annuities with guaranteed benefits (VAGB) in the run-up to the 2008 crisis. With USD 1.6 trillion in contracts under guarantees, VAGB had become a vast and lucrative part of life insurer activities. But the guarantees expose insurers to market risk. Our analysis suggests that those risks were insufficiently hedged. Second, we assess the cumulative magnitude of all derivative risks (including VAGB risks) and find that they probably do not rise to level of a systemic threat. As part of our analysis, we introduce a new methodology for assessing the diversification of life insurers, both individually and as an industry, with respect to their counterparties (banks) in derivative hedging. We find that the life insurance industry was relatively diversified. Our contribution is three-fold: First, we demonstrate the possibility of endemic misperception of risk within a financial sector. Second, we provide a new quantitative tool to assess the potential for the contagion of risk to spread from guarantors (banks) of life insurer derivative hedges to the life insurance sector by failure of the guarantors to perform. The 2008 crisis period provides a unique laboratory to test this and other theories of risk behavior. Third, we add to the discussion of Systemically Important Financial Institutions (SIFIs).

Keywords: systemic risk; derivative hedging; variable annuities with guaranteed benefits (VAGB); diversification

JEL codes: C18, C23, G21, G22, G32, C51

1. Introduction

This paper is an historical study—with implications for the present—of the extent to which the life insurance industry contributed to systemic risk prior to the 2008 financial crisis by using derivatives to hedge product and asset risks. Although the financial crisis is now a decade past, the crisis provides in many ways a worst-case scenario for testing the potential of life insurers for generating systemic risk. Since the crisis, safeguards have been added to the US and global financial systems that are designed to mitigate the impacts of future crises. If the role of life insurers was only nominal in the great 2008 crisis, then the role of life insurers in similar future crises is unlikely to be substantial. On the other hand, if life insurers contributed materially to systemic risk in 2008, then it is important to identify the manner and magnitude of that contribution in order to judge the adequacy of counter measures that have been adopted.

As part of the reaction to the 2008 crisis, a new category of financial institutions has been recognized: SIFI's—Systemically Important Financial Institutions. Negative financial developments within a SIFI putatively have the potential to spill over into and negatively impact the financial system as a whole. Since the 2008 crisis, a number of large banks have been recognized as SIFI's. Subsequently, some large life insurers made the list. Increased regulatory scrutiny and capital requirements are imposed on SIFI's.[1] During the crisis, the main insurer problem that drew notice lay with the Financial Products division of AIG, which had obligations for credit default swaps. Certainly, some life insurers hold vast portfolios of assets that rival those of large banks. International financial regulators (the Financial Stability Board (FSB)), with the assistance of the International Association of Insurance Supervisors (IAIS), recognized that life insurers also sell products (life policies, annuities) that bear some similarities to bank products (term deposits, CD's). So there are the parallel questions of whether life insurers and reinsurers as a sector threatened the stability of the financial system and whether individual insurers were important enough to do so.

Both banks and insurers have tools to mitigate the risks of their activities. In this paper, we focus on one of these tools as employed by life insurers: derivative hedging. Prior to the 2008 financial crisis, did life insurers use derivatives to manage their risks appropriately? More importantly, if there were some risks that may not have been managed appropriately, was substantial

[1] The Financial Stability Board (FSB) started identifying global systemically important banks (G-SIBs) in 2011 with an initial list of 29 banks, followed by annual updates. The FSB started to identify global systemically important insurers (G-SIIs) in 2013 with an initial list of 9 insurers. For identified G-SIBs and G-SIIs, higher capital buffer and supervision are expected. Source: http://www.fsb.org/work-of-the-fsb/policy-development/systematically-important-financial-institutions-sifis/global-systemically-important-financial-institutions-g-sifis/

systemic risk created? In this paper, we examine these questions with regard to life insurers' use of derivatives to manage the risks of variable annuities with guaranteed benefits (VAGB)—extremely popular and lucrative new products in the pre-crisis period. Our answers to these questions, after appropriate qualifications, are Yes to the first, and No to the second. In this paper, we present evidence that prior to the 2008 financial crisis, life insurers did not fully appreciate the risks of variable annuities with guaranteed benefits (VAGB) and insufficiently hedged the risks. However, although those risks were significant, as we shall see, the collective level of life insurers' exposure to the even larger class of all derivative hedging risks, including those of VAGB, probably did not rise to the level of a systemic threat.

VAGBs are modified variable annuities. In the early 1990's, life insurers began adding extra-cost benefit guarantees to their regular variable annuity products. These guarantees protect the purchasing annuitants against downturns in financial markets, but they simultaneously expose insurers to corresponding market risks. [2] The VAGB market is likely the largest novel source of risk for life insurers. It grew strongly prior to the financial crisis of 2008. At the end of 2007, the total value of VAGB purchaser accounts covered by guarantees was about USD 1.6 trillion.[3] Life insurers earn lucrative fees for providing guarantees to VAGB contracts. In the years that preceded the financial crisis, these fees were earned without apparent cost. However, the financial crisis that began in 2007, and reached an inescapable inflection point in September, 2008 with the bankruptcy of Lehmann Brothers, exposed life insurers to the possibility of having to make good on their guarantees as results fell below the guaranteed levels. VAGB benefit guarantees now necessitate that life insurers carry additional reserves on their balance sheets to ensure contractual guarantees to annuitants. Insurers also often try to hedge VAGB risks through the use of derivatives. Insurers use derivatives to hedge not just VAGB risks, but also various financial risks, in general—especially interest rate risk, market risk, credit risk, and foreign exchange rate risk.[4] By the end of 2007, 161 life insurers were active in derivative transactions (from Schedule DB of the National Association of Insurance Commissioners (NAIC) annual reports). This number includes most of the largest life insurers. The effectiveness with which life insurers handled the complexity of their product risk and utilized the available risk management tools is in question. In particular, we question life insurers' management of VAGB risks, which has been little studied.

We therefore begin with a baseline study of life insurers' management of VAGB risks. We focus our attention on using data prior to the 2008 financial crisis so as to immunize our results from the confounding effects of the financial crisis, subsequent regulatory changes (e.g., by the NAIC) imposed on insurers related to derivative usage, and the Dodd Frank Act changes with respect to

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[2] There are four major sub-types of variable annuities with guaranteed benefits products: Variable Annuities with Guaranteed Death Benefit (GMDB), Variable Annuities with Guaranteed Income Benefit (GMIB), Variable Annuities with Guaranteed Accumulation Benefit (GMAB), and Variable Annuities with Guaranteed Withdrawal Benefit (GMWB).

[3] According to life insurers' annual filings in 2007, the sum of total VAGB related account value amounted to USD 1,602,355,514,102.

[4] Cummins et al. (2001) analyzed incentives for derivative use by U.S. life insurers and property-liability insurers.

derivative usage by insurers. We examine the important issue of whether insurers behaved as though derivative hedging may be a substitute for capital accumulation in mitigation of their VAGB risks.

Then we expand the scope of our investigation. More generally, we consider the possible exposure of the life insurance industry to systemic risk that may arise out of the industry's interrelationships with counterparties in all derivative hedging contracts, not just for VAGB. We introduce a methodology that assesses the degree of diversification of insurer derivative activity among counterparties (which are banks, mainly). The methodology is based upon a matrix of empirical exposures that link insurers with counterparties. Analysis of the linkages reveals the potential for counterparty default to spread systemic risk to insurers collectively or individually.

The major reason for life insurers to hold derivative contracts is to hedge their asset risk and product risk. Standardized derivative contracts may be traded on exchanges; idiosyncratic contracts may be traded over-the-counter (OTC). However, hedging engenders additional risks such as basis risk (with exchange-traded derivatives) and counterparty credit risk (with OTC derivatives). The reliability and solvency of the counterparty may not be taken for granted, and is pertinent to this paper.

As was made abundantly clear during the financial crisis, counterparty credit risk cannot be ignored. This potential credit risk can affect insurers issuing VAGB contracts that are attempting to hedge their financial risk with derivatives, thus making them sensitive to systemic risk spread by counterparties. In our analysis of the NAIC Schedule DB forms for 2007, we found that insurance companies' participating derivative counterparties were concentrated among a relatively few large investment bank partners, some of whom have been identified as having systemic risk potential (Goldman Sacks, J P Morgan, Lehman Brothers [then still functioning], etc.) The use of derivatives to hedge risks is only as effective as the counterparties' ability to perform. Systemic risk could spread, like contagion, across the web of entities linked in derivative transactions. In the case of a default (such as Lehman Brothers on September 15, 2008 with over $600 billion in assets), insurers are forced to bring this unanticipated risk back onto their own books. Under risk based capital requirements, insurers may have to raise more capital, exactly at a time when raising capital may be difficult or expensive.

Our analysis of the NAIC Schedule DB forms has also shown that many large insurers use derivative instruments for investment and other purposes unrelated to hedging of underwriting risk. This furthers their vulnerability to systemic counterparty and economic risk.

Finally, since our data analysis has shown that active derivative-utilizing insurers tend to be very large in capitalization, the downfall of such an insurer can itself have systemic implications. Administrators of the insurer receivership will scramble to find other insurers to assume the existing books of business of the insolvent insurer. In addition, the guarantee funds of the various states may make financial assessments on all other insurers in the state to cover the insolvent insurer's liabilities (including liabilities associated with VAGB contract holders). This could in turn jeopardize the solvency of other insurers. Moreover, many large insurers themselves also have reinsurance departments, further intensifying the systemic potential for the breadth of impact of a potential insolvency. Thus, our preliminary data analysis has shown that derivative usage has the potential both to make the insurer susceptible to systemic risks, and possibly to create systemic risk potential. With this in mind, we propose to investigate the following research questions relative to systemic risk and insurers' derivative usage.

2. Research questions

Our study addresses the following two major issues: First, how did life insurers manage VAGB product risk in the context of their capital structure decision prior to 2008? In particular, did life insurers substitute derivative hedging for capital accumulation in order to help offset product risk?

The literature on capital and risk in the U.S. life insurance industry found that life insurers are in a risk-limiting mode (Baranoff and Sager, 2002, 2003; Baranoff et al., 2007). Life insurers generally tend to balance an increase in one type of risk by a reduction of another type of risk. Since VAGB contracts are more susceptible to market risks (interest, investment returns, etc.), for which active derivative options are available, either over the counter (OTC) or on exchanges, we expect to see more derivative hedging when the insurer has substantial VAGB risk in place. However, the relationship between these two risk management tools, capital and derivative hedging, is an open question to be tested.

The second question to address is whether or not, prior to the 2008 crisis, involvement with counterparties in over-the-counter derivative contracts exposed major life insurers to systemic risk due to concentrated exposure with respect to a selected few systemically important investment counterparties? If so, how serious could this concentrated exposure situation have been?

In the second phase of our study, we expand the scope of our analysis to embrace the risk of all derivative use, not just those for VAGB. This second phase builds upon the empirical relationships we find in investigating the first research question, since, as discussed above, systemic risk impacts life insurers directly through their derivative holdings. Moreover, the interplay of derivative holdings with other risk management tools and risk metrics makes the situation complex.

3. Review of literature

Systemic risk in the insurance industry has been drawing attention since the financial crisis of 2008. In a study on American International Group (AIG), the insurer thought to have played the most significant role in the crisis, Baranoff (2013) finds that AIG's problems were caused by non-insurance activities. For the insurance sector, Harrington (2009) contends that "the insurance sector as a whole was largely and perhaps remarkably on the periphery of the crisis." Harrington (2013) further proposes that insurance activities pose low systemic risk.

However, with the advance of econometric methods on measuring systemic risk, researchers find more significant interconnectedness among financial firms than previously perceived (Acharya et al., 2010; Billio et al., 2012). The insurance literature connects reinsurance business and insurer-bank activities to other financial institutions. For the US property-casualty insurance industry, Park and Xie (2014) conclude that the likelihood of systemic risk caused by reinsurance transactions is small. Kessler (2013) argues that the reinsurance business model lacks the elements that make a financial institution systemically important. Cummins and Weiss (2014) agree that the core activities of U.S. insurers do not pose systemic risk. But they conclude that both life and property-casualty insurers are vulnerable to reinsurance crises. More importantly, they point out that "noncore activities such as financial guarantees and derivatives trading may cause systemic risk." Indeed, using Granger causality test, Chen et al. (2014) examine interconnectedness between banks and insurers and conclude that banks create significant systemic risk for insurers but not vice versa.

Insurer-bank interconnectedness has been increasing as banks usually serve as counterparties of insurers' derivative activities. In fact, researchers have studied the use of derivatives to hedge life insurer financial risks (Hoyt, 1989; Colquitt and Hoyt, 1997; Cummins et al., 2001). With the surge in popularity of variable annuities with guaranteed benefits (VAGBs) products right before the financial crisis, dynamic hedging has become an integral part of these products (Geneva Association, 2011). Baranoff et al. (2016) propose a measure to quantify financial risk resulting from various guarantees and find that life insurers may even reduce capital as guarantee risk increases. The finding suggests that the negative financial impact to insurers can be exacerbated in the event that counterparty banks default.

To protect the financial stability of the insurance industry from systemic risk, regulators have been actively seeking improvement of insurance regulation. The literature on current methodology focuses on two strands of studies (Bisias et al., 2012). The first strand proposes methods for identification or designation of Global Systemically Important Financial Institutions (G-SIFIs).[5] The banking industry pioneered in developing measures on the interconnectedness among firms and to what extent a firm contributes to systemic risk of the industry. Commonly used methods include ΔCoVaR (Adrian and Brunnermeier, 2016), marginal expected shortfall (MES) (Acharya et al., 2012), and the Granger causality network (Billio et al., 2012). Using monthly stock return data, Billio et al. (2012) applied principal components analysis to examine connectedness of hedge funds, banks, broker/dealers, and insurance companies. Recent proposed methods refine examination of the industry network (Härdle et al., 2016; Pourkhanali et al., 2016; Chen et al., 2019).

The second strand of literature applies these systemic risk measures to assess financial vulnerability of the financial services institutions including banking and insurance industries with respect to systemic risk (Bernal et al., 2014; Bierth et al., 2015; Rauch et al., 2015; Black et al., 2016). Most systemic risk measures use publicly available data such as equity and bond information of public firms and credit default swap premiums. As noted in Eling and Pankoke (2016), "to a certain extent, all systemic risk measures rely on co-movements of stock market returns." As public data suffers from limitation on availability for the entire industry, researchers have started to analyze regulatory data (Gouriéroux et al., 2012; Glasserman and Young, 2015). Moreover, using different systemic risk measures and data, the literature has not come up with conclusive results on identification of SIFIs and vulnerability of financial institutions to systemic risk. In fact, Benoit et al. (2013) compare commonly used systemic risk measures and find no advantages over traditional market risk measures.

[5] The Financial Stability Board (FSB) defines SIFIs thusly: "Systemically important financial institutions (SIFIs) are financial institutions whose distress or disorderly failure, because of their size, complexity and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity." The FSB has defined global systemically important banks (G-SIBs) since 2011and started to identify G-SIBs. In consultation with the International Association of Insurance Supervisors (IAIS) and national authorities, the FSB began identifying global systemically important insurers (G-SIIs) in 2013. http://www.fsb.org/work-of-the-fsb/policy-development/systematically-important-financial-institutions-sifis/global-systemically-important-financial-institutions-g-sifis/

Our method adds to the literature as an immediate regulatory tool. Instead of assessing financial vulnerability of an insurer to systemic risk as a whole, we identify the additional financial risk exposure introduced by derivative hedging activities, in which the systemic risk spreads contagiously from the counterparties to the insurers. Using life insurers' regulatory annual filings to the NAIC, our method assesses for each insurer the size and concentration exposure to counterparties of derivative activities, which can be monitored by regulators.

4. Data

We use NAIC life insurers' annual statement filings for 2006 and 2007 for our empirical study. We choose this period for the primary reason that it is before the financial crisis that exploded with the Lehmann Brothers insolvency of September, 2008. If the impact of systemic risk from derivative interconnectivity with other insurers or financial institutions is to be found, it is more likely to be found prior to the 2008 crisis than after, since the adoption of crisis-mitigation strategies in the aftermath would blunt such effects. For life insurers' derivatives transactions, Schedule DB on the annual statement provides extensive detail on each specific derivative contract, including whether it is used for hedging, investment, or other purposes, as well as identification of the counterparty. Omitting some anomalous and outlier observations (such as firms with capital ratios greater than 1 or smaller than 0), we have 1,592 firm-years of data for 2006–2007.

5. Research methodology

For the portion of the current study dealing with VAGB and derivative use, we present a capital structure regression model that incorporates derivative use and VAGB product risk along with asset risk and other product risks following the business strategy hypothesis developed in Baranoff et al. (2007). [See Table 2 and "Findings", below.] The literature on capital structure is vast. The field was originally developed to explain how firms choose between debt and equity when raising funds, but has been adapted to incorporate other objectives, such as how risks affect capital decisions. Baranoff et al. (2013) provide a good review of the capital and risk interconnections for life insurers. In brief, most studies find that firms act in a risk-limiting manner—if they assume more risk in one area, they reduce risk in other areas, ceteris paribus. Only in exceptional circumstances is the acquisition of risk in one area associated with an increase of risk in others, ceteris paribus. One common such situation is hypothesized to derive from the existence of guarantee funds, which encourage troubled firms to "go for broke." The inclusion of appropriate controls, such as size and business focus, is important. The literature generally regards the accumulation of capital as a risk reduction strategy, ceteris paribus, as it provides a buffer against financial risk.

With regard to the second research question, the potential impact of systemic risk, we now present a methodology for investigating this question. The premise for the methodology is the observation that concentration of the insurance industry's derivative activities among a few counterparties could create systemic risk. Conversely, diversification of the insurance industry's hedging activities among many counterparties could mitigate the potential for systemic risk.

Empirical databases that support analysis of the extent of concentration/diversification therefore should contain measures of the involvement of any given insurer with any given counterparty. We find such measures in Schedule DB of the NAIC annual statements.

Suppose we have m insurers and n counterparties, and let a_{ij}= the exposure of insurer j to the possibility of default by counterparty i on derivatives owned by insurer j for which counterparty i is obligated to perform. There are various measures of "exposure" that could be utilized. The methodology does not require, and is not tied to, a particular exposure measure. Different insights could be gained by performing the analysis multiple times with multiple measures.

As a first cut at a measure, a_{ij}could be the notional amount of derivatives that insurer j holds for which counterparty i must perform. This definition of a_{ij} has some disadvantages—e.g., it does not take into account the total amount of the counterparty's derivative activity, nor does it take into account how much the counterparty has in available resources to meet its obligations.

A better definition might take a_{ij} to be the ratio of the notional amount of derivatives that insurer j holds for which counterparty i must perform to the total notional amount of derivatives issued to all insurers for which counterparty i must perform. This definition also has disadvantages. For example, although it takes into account the total amount of the counterparty's derivative activity, it does not account for the ability of counterparty i to perform.

A still better definition might take a_{ij} to be the ratio of the notional amount of derivatives that insurer j holds for which counterparty i must perform to the total resources of counterparty i that are available to perform for all derivatives insured to all insurers.

For illustrative purposes in this paper, we shall take a_{ij} to be the insurer's own calculated "potential exposure" to counterparty i as reported to the NAIC in Schedule DB of the insurer's annual report. This potential exposure is a "statistically derived measure of the potential increase in derivative instrument credit risk exposure … resulting from future fluctuations in the underlying interest upon which derivative instruments are based." (Weekly Special Report of the NAIC's Capital Markets Bureau, http://www.naic.org/capital_markets_archive/110610.htm, p.3) It is typically a small fraction (often approximately 0.5%) of the notional amount of derivatives.

Consider the nxm matrix $A = [a_{ij}]$. Since most insurer counterparties are banks, we shall henceforth refer to banks instead of counterparties. Then column j of A represents the exposure of insurer j to the risk of derivative default by the members of the banking industry.

Further, consider the mxm matrix $A'A$, where A' denotes the transpose of A. The jth diagonal element of $A'A$ is $a_{1j}^2 + a_{2j}^2 + \cdots + a_{nj}^2$. This element is a Herfindahl-like measure for insurer j of its diversification (or concentration) of derivative hedging default risk among the n member institutions of the banking industry. For a given total of derivative default risk for insurer j (i.e., given $a_{1j} + a_{2j} + \cdots + a_{nj}$= constant), the diagonal element is minimized when the derivative default risks are evenly spread among banks – i.e., when $a_{1j} = a_{2j} = \cdots = a_{nj}$ (maximal diversification). The diagonal element is maximized when the derivative default risk is all concentrated in a single bank—i.e., when all but one of $a_{1j}, a_{2j}, \ldots a_{nj}$ are zero.

Now consider the sum of the diagonal elements, i.e., the trace, $tr(A'A)$. This is the sum of the Herfindahl-like derivative default risk diversification measures over all insurers. Therefore, the trace could be interpreted as the insurance industry's exposure to the risk of derivative hedging default. This default risk arises from two sources: the probability of default by counterparties (banks) and the extent to which the insurers have concentrated the risk. The first source is exogenous to insurers; the second is endogenous. The combination can be interpreted as a measure of exposure of the insurance industry to the systemic risk of banking industry default on derivatives.

Analysis of the matrix A therefore can illuminate some of the ways by which the banking industry may be a source of systemic risk for insurers. We anticipate that further analysis of the matrix A could illuminate additional aspects of this relationship. We mention two additional possibilities:

(1) Cluster analysis. For insurers j and k, their off-diagonal element in $A'A$ is

$$a_{1j}a_{1k} + a_{2j}a_{2k} + \cdots + a_{nj}a_{nk} \tag{1}$$

This is essentially the correlation between the two insurers' exposures to derivative default risk across the banking industry. That is, it assesses the extent of correspondence between the patterns of diversification of derivative default risk between the two insurers. The presence of many large positive off-diagonal terms, especially if they are linked in a chain from one insurer to another, suggests the ability of a bank default to affect many insurers. Cluster analysis could be employed, using $A'A$ as a similarity matrix, to identify groups of insurers with similar—hence linked—diversification patterns. The result could be a tree of relationships among insurers, showing how bank-triggered derivative defaults could spread among insurers.

(2) Factor analysis. The matrix A' could be viewed as m observations (the insurers) on n variables (the banks). A factor analysis of A' would attempt to explain the columns of A (the banks) in terms of latent factors (estimated as linear combinations of banks). If successful, the factor analysis would identify a few linear combinations of banks that would explain most of the variability in the patterns of insurer default exposure within banks. Those few linear combinations would be examined for interpretability in terms of the variables (banks) that load high on them. To enhance the identification of factor-participating banks, various rotations of the factor pattern could be employed. It would be illuminating if, for example, the first factor involved mostly large investment banks and the second factor emphasized medium commercial banks. Likewise, the matrix A could be viewed as n observations (the banks) on m variables (the insurers) and a factor analysis of A performed. That is, both Q- and R-form factor analysis might prove insightful.

Just as matrix A can reflect the potential exposure of insurers to systemic risk from banks, we can similarly assess the potential exposure of banks to systemic risk from insurers by utilizing a corresponding matrix B. Let b_{ij}= the exposure of bank i to the possibility of needing to perform on the derivatives owned by insurer j for which bank i bears a performance obligation. With matrix $A = [a_{ij}]$, we contemplated the possibility of a variety of metrics for a_{ij}. Likewise, with matrix $B = [b_{ij}]$, various metrics could be used for b_{ij}. Perhaps we could even use b_{ij}=a_{ij}. However, we will likely prefer asymmetric metrics for the two industries' exposures to each other.

Consider the nxm matrix $B = [b_{ij}]$. Row i of B represents the exposure of bank i to the risk of needing to perform on the derivative obligations owned by the members of the insurance industry. Further, consider the nxn matrix $'$. The ith diagonal element of BB' is $b_{i1}^2 + b_{i2}^2 + \cdots + b_{im}^2$. This element is a Herfindahl-like measure for bank i of its diversification (or concentration) of derivative performance exposure among the member insurers of the insurance industry.

Now consider the sum of the diagonal elements, i.e., the trace, $tr(BB')$. This is the sum of the Herfindahl-like derivative performance exposure measures over all banks. Therefore, $tr(BB')$could be interpreted as the banking industry's exposure to the risk of performance on derivative hedging. This performance risk arises from two sources: the derivative owners (insurers) and the extent that the banks have concentrated the risk. The first source is exogenous to banks; the second is endogenous. The combination can be interpreted as a measure of exposure of the banking industry to the systemic risk of the insurance industry's derivative hedging performance requirements.

We have observed that it may make sense to choose B = A for some appropriate metric of derivative interrelationship. Then $tr(BB') = tr(A'A)$. But mathematically, it is true that $tr(AA')$ $= tr(A'A)$. This says that the insurance industry's collective measure of exposure to the risk of derivative hedging default $tr(A'A)$is the same as the banking industry's exposure to the systemic risk of the insurance industry's derivative hedging performance requirements $tr(A'A)$ In this case, the diagonal elements of $A'A$ show how that common exposure is apportioned among the m insurers, and the diagonal elements of AA' show how it is apportioned among the n banks.

For the purposes of this paper, we shall concentrate on the exposure of insurers to banks as a source of systemic risk and analyze A. We shall not pursue B here.

6. **Findings**

For our first research question—the risk-taking behavior and relationships between risk management tools—we ran a capital structure regression model for 2006–2007. The response variable is life insurers' capital ratio (CAP) and the explanatory variables are specified in Table 1. We use generalized estimating equations (GEE) to estimate the model, where both the firm effect and the year effect are taken into account. We also specify an option in the GEE model to adjust for possible autocorrelation in the residuals. The estimation results are given in Table 2.

The results in Table 2 support the general finding that use of derivatives and involvement with VAGB are associated with lower capital levels. We may distinguish four cases, depending upon whether a life insurer uses derivatives or not and is involved with VAGB or not. The case of life insurers not using derivatives and not being involved with VAGB products provides a baseline. The other three cases may be derived from Table 2 as deviations from the baseline. Life insurers that do not use derivatives but are involved with VAGB have capital ratios that, ceteris paribus, average −0.0806 in relation to the baseline, or 0.0806 below insurers that are involved with neither. Life insurers that do use derivatives but are not involved with VAGB products have capital ratios that average 0.0373 below insurers that are involved with neither. Life insurers that both use derivatives and are involved with VAGB average −0.0806 −0.0373 + 0.0558 = −0.0621 in relation to the baseline, or 0.0621 below insurers that are involved with neither. Consistent with these findings is the view that life insurers, in the period before the financial crisis, considered use of derivatives to be a partial substitute for capital in hedging risks. Furthermore, given a level of derivative hedging and control variables, holding VAGB is associated with a reduction in capital, as though VAGB per se were risk mitigating.

Table 1. Variable definitions.

Variable Name	Definition
CAP	Capital/Assets
Atotal	Total assets
Wtotal	Total writings (face value of insurance in force)
TotPrem	Total premiums (all lines)
Size	Log(Atotal*Wtotal*TotPrem)/3
OAR	Asset risk (stdev of monthly returns)
Phealth	Health writings/Total writings
RBCratio	Risk Based Capital = 100*Market capital/(2*Authorized capital)
RetOnCap	Income/Market capital
Ngroup	Indicator for member of group (1 = Yes, 0 = No)
VAGB_Dummy	Indicator for VAGB products (1 = Yes, 0 = No)
Derivative_Dummy	Indicator for Derivatives (1 = Yes, 0 = No)

Table 2. U.S. life insurers capital structure GEE analysis 2006–2007.

Parameter	Estimates	S.E.	Z-Statistic	P-Value
Intercept	0.5149	0.0616	8.36	< 0.0001
Size	−0.0341	0.0023	−14.78	< 0.0001
Log (OAR)	0.0340	0.0049	7.01	< 0.0001
Phealth	0.1604	0.0158	10.15	< 0.0001
Log (RBCratio)	0.0838	0.0050	16.78	< 0.0001
RetOnCap	0.0418	0.0132	3.17	0.0015
Ngroup	0.0433	0.0134	3.23	0.0012
VAGB_Dummy	−0.0806	0.0211	−3.82	0.0001
Derivative_Dummy	−0.0373	0.0161	−2.32	0.0205
VAGB*Derivative Interaction	0.0558	0.0250	2.23	0.0260
Scale	0.1753	.	.	.
R^2 = 0.5928				

Note: 1,592 observations used.

Before proceeding to analyze the exposure of insurers to counterparty default, we first present some data to profile the life insurance industry. These data provide context in which to judge the importance of the issues.

As the following tables show, most life insurers were not involved with derivatives during this time period. However, the life insurers that were involved with derivatives held most of the capital and assets of the industry. Derivative-involved life insurers are the heavyweights of the life insurance industry.

Table 3a. US life insurance industry 2005–2007.

Year	Number of Life Insurers	Total Assets of Life Insurance Industry (USD)	Total Invested Assets of Life Insurance Industry (USD)	Total Capital of Life Insurance Industry (USD)
2005	941	4,435,217,600,000	2,846,430,800,000	343,634,559,571
2006	905	4,777,937,400,000	2,929,461,300,000	361,722,847,510
2007	853	5,047,136,000,000	3,011,010,100,000	382,002,786,677

Table 3b. Life insurers active in derivatives 2005–2007.

Year	Number of Insurers Active in Derivatives at Year End	Total Assets of Insurers Using Derivatives (USD)	Total Invested Assets of Insurers Using Derivatives (USD)	Total Capital of Insurers Using Derivatives (USD)
2005	148	3,718,651,700,000	2,353,158,000,000	246,727,594,862
2006	153	4,045,112,800,000	2,434,719,000,000	263,482,862,262
2007	148	4,299,883,100,000	2,494,447,800,000	278,654,985,104

Table 3c. Insurers active in derivatives as percentage of corresponding life insurance industry totals.

Year	% of Insurers	Total Assets	Total Invested Assets	Capital
2005	15.73%	83.84%	82.67%	71.80%
2006	16.91%	84.66%	83.11%	72.84%
2007	17.35%	85.19%	82.84%	72.95%

One measure of the significance of life insurer derivative activity is the notional amount of their derivatives. The notional amount is a measure of the value of underlying assets covered by the derivative contracts. As the next table shows, the notional amounts are substantial for life insurers. Life insurers also report to the NAIC their own calculated estimate of "potential exposure" to each counterparty with which they have derivative contracts (on Schedule DB of their annual statements). Typically, these estimates of potential exposures are about 0.5% of the notional amounts.

Table 4. Notational and potential exposure amounts of life insurers' derivative activities.

Year	Number of Insurers Active in Derivatives at Year End	Total Notional Amount of Derivatives of Life Insurers Active in Derivatives (USD)	Potential Exposures to Counterparties of Life Insurers Active in Derivatives (USD) *
2005	148	596,347,402,662	3,198,943,337
2006	153	763,967,960,637	4,274,924,092
2007	148	919,831,932,582	5,517,884,687

Note: * "Potential exposure" is estimated and self-reported by the insurer. It is supposed to be "a statistically derived measure of the potential increase in derivative instrument credit risk exposure, for derivative instruments which generally do not have an initial cost paid consideration received, resulting from future fluctuations in the underlying interests upon which derivative instruments are based."[6]

We have constructed the matrix *A* of linkages between insurers and counterparties and populated it with the values a_{ij} = the "potential exposure" of insurer *j* to counterparty *i*, collected from Schedule DB for 2007.

Since there are hundreds of insurers and hundreds of counterparties, we have restricted the analysis for this demonstration to the top 20 life insurers by total notional amount of derivative activity and to the top 20 counterparties by total potential exposure. Thus the matrix A has 20 rows (counterparties) and 20 columns (insurers).

The following table shows a portion of the matrix A for selected counterparties and insurers. For example, Hartford estimated in 2007 that it had a "potential exposure" of USD 14,115,708 for its derivative activities with Deutsche Bank. The complete matrix is too cumbersome to show, even if restricted to 20 rows x 20 columns, so we have selected a few entities for concreteness of presentation.

Table 5. Potential exposure of selected insurers with selected counterparties, 2007 (USD).

		Insurers			
		Hartford Life & Ann Ins Co	Metropolitan Life Ins Co	New York Life Ins & Ann Corp	Prudential Ins Co of America
Counterparties	Deutsche Bank	14,115,708	60,071,133	437,640	4,771,718
	Goldman Sachs	435,434	53,647,235	-	-
	HSBC	3,158,519	16,294,425	-	-
	JP Morgan	1,242,807	51,366,559	495,621	523,855
	Lehman Brothers	10,145,944	17,462,882	1,407,304	-
	Merrill Lynch	4,862,340	84,290,803	-	4,970,749

[6] Weekly Special Report of the NAIC's Capital Markets Bureau, http://www.naic.org/capital_markets_archive/110610.htm, p.3.

The row totals (Table 6) of matrix A show the total potential exposures that the 20 insurers with largest total notional amount collectively had with each of the counterparties. For example, the 20 insurers estimated that their potential exposure to Morgan Stanley, by virtue of their derivative activities with that firm, totaled USD 716,697,578 in the aggregate. Morgan Stanley accounted for 16% of the total potential exposure of these 20 life insurers.

Table 6. Life insurer potential exposure, by counterparty, 2007 (USD).

Counterparty	Top 20 Insurers' Total Potential Exposure to Counterparty	Percent of Total
AIG	120,380,491	2.7%
Barclays	346,924,372	7.8%
Bear Stearns	101,054,565	2.3%
BNP	149,122,486	3.3%
Bank of America	222,144,625	5.0%
CITI	105,697,815	2.4%
Credit Suisse	233,417,888	5.2%
Deutsche Bank	468,838,081	10.5%
Goldman Sachs	319,400,246	7.1%
HSBC	70,433,692	1.6%
JP Morgan	455,050,996	10.2%
Lehman Brothers	372,824,426	8.3%
Merrill Lynch	271,458,711	6.1%
Morgan Stanley	716,697,578	16.0%
Royal Bank of Canada	21,959,563	0.5%
Royal Bank of Scotland	118,282,521	2.6%
Salomon Brothers	37,647,961	0.8%
SunTrust	9,540,354	0.2%
UBS	202,164,167	4.5%
Wachovia	132,538,774	3.0%
TOTAL	4,475,579,312	100.0%

The column sums of matrix *A* (Table 7) show the total potential exposures that each insurer has with these 20 counterparties in the aggregate. For example, Metropolitan Life had a total of USD 699,546,300 in potential exposure to the 20 bank counterparties. Metropolitan Life accounted for 15.6% of total potential exposure to counterparties.

Table 7. Life insurer potential exposure, by life insurer, 2007 (USD).

Insurer	Total Potential Insurer Exposure to Top 20 Counterparties	Percent of Total
Allstate Life Ins Co	149,753,466	3.3%
Principal Life Ins Co	250,902,496	5.6%
Jackson Natl Life Ins Co	103,817,373	2.3%
John Hancock Life Ins Co	365,089,161	8.2%
Massachusetts Mutual Life Ins Co	538,174,821	12.0%
Metropolitan Life Ins Co	699,546,300	15.6%
Monumental Life Ins Co	169,354,788	3.8%
Pacific Life Ins Co	190,652,527	4.3%
Sun America Life Ins Co	173,073,460	3.9%
Genworth Life Ins Co	429,162,352	9.6%
Hartford Life & Ann Ins Co	344,113,083	7.7%
Sun Life Assur Co of Canada US	125,564,975	2.8%
ING USA Ann & LIfe Ins Co	268,381,761	6.0%
Transamerica Life Ins Co	153,333,322	3.4%
Metlife Ins Co of CT	152,568,395	3.4%
Hartford Life Ins Co	347,668,267	7.8%
AXA Equitable Life Ins Co	0	0.0%
Allianz Life Ins Co of N Amer	0	0.0%
New York Life Ins & Ann Corp	4,156,443	0.1%
Prudential Ins Co of America	10,266,322	0.2%
TOTAL	USD 4,475,579,312	100.0%

Calculation of the diagonal elements of the matrix $A'A$ yields the Herfindahl-like concentration measures for each of the 20 insurers. $tr(A'A)$ is the sum of these 20 concentration measures. $tr(A'A)$ is an index of concentration for the industry as a whole. Since the diagonal elements are very large numbers, it may be more meaningful to compare them with the minimum and maximum values that each could be. The minimum concentration for insurer *j* would result from spreading the total exposure for insurer *j* equally among its counterparties. For example, Allstate's minimum Herfindahl-like concentration measure could be attained by dividing its total potential exposure of USD 149,753,466 into 20 equal portions among the 20 counterparties. The maximum concentration would result from concentrating all of the total potential exposure in one counterparty.

Table 8 shows the ratios of each insurer's actual diagonal element (concentration) to its minimum possible diagonal element and to its maximum possible diagonal element:

Table 8. Ratio of actual Herfindahl concentration to minimum and maximum possible, 2007.

Insurer	Actual ÷ Minimum	Actual ÷ Maximum
Allstate Life Ins Co	231%	12%
Principal Life Ins Co	207%	10%
Jackson Natl Life Ins Co	214%	11%
John Hancock Life Ins Co	311%	16%
Massachusetts Mutual Life Ins Co	196%	10%
Metropolitan Life Ins Co	166%	8%
Monumental Life Ins Co	182%	9%
Pacific Life Ins Co	227%	11%
Sun America Life Ins Co	309%	15%
Genworth Life Ins Co	232%	12%
Hartford Life & Ann Ins Co	1530%	77%
Sun Life Assur Co of Canada US	321%	16%
ING USA Ann & Life Ins Co	203%	10%
Transamerica Life Ins Co	196%	10%
Metlife Ins Co of CT	193%	10%
Hartford Life Ins Co	509%	25%
AXA Equitable Life Ins Co	N/A	N/A
Allianz Life Ins Co of N America	N/A	N/A
New York Life Ins & Ann Corp	382%	19%
Prudential Ins Co of America	906%	45%
Industry	323%	16%

The tables illustrates that the life industry is heterogeneous in the degree of its concentration. Metropolitan Life's actual exposure concentration among counterparties is only 8% of the maximum it could be and is only 166% of the minimum it could be. Both figures are industry minima and about half the industry aggregate amounts. So although Metropolitan Life accounts for a substantial part of industry exposure, it diversifies much more than the industry does. On the other hand, Hartford has a larger than average share of the exposure, but is the most highly concentrated insurer, with an actual exposure close to the maximum and more than 15 times the minimum.

7. Contributions and implications

The financial crisis of 2008 was perhaps the greatest threat to the global financial and economic system in the last century, except for the Great Depression. Since the crisis, regulatory reforms have been adopted with one view in mind: to prevent a recurrence. The period of the financial crisis therefore provides a laboratory that is no longer available for testing theories of causation and prevention. Changed circumstances mean that we cannot re-run the tape of history using current data to test if our tools would have worked. The crisis period provides the most challenging circumstances since the 1930's. Historical studies of the crisis period can inform our judgment on whether we have the correct theories and have adopted appropriate preventative tools. Important among these theories about the crisis is the notion that misperception of risk can grow endemically within a financial sector (e.g., lending institutions that supported real estate), spread contagiously to other sectors, and precipitate a crisis by the failure of an important systemically interlocked entity (e.g., Lehman Brothers).

Our contribution is three-fold and is focused on the role of the life insurance sector in the crisis. First, we provide quantitative evidence that suggests the possibility of endemic misperception of risk within a financial sector. In the run-up to the 2008 crisis, fees on life insurer sales of variable annuities with guaranteed benefits became a huge part of life insurer income. Our first analysis using an econometric model shows that involvement in VAGB, after controlling for other risks and relevant insurer characteristics, was associated with decreases in capital, even in the face of hedging by derivatives. This suggests that life insurers insufficiently hedged VAGB risks, for after modest hedging, involvement in VAGB was associated with reductions in capital—just as though VAGB, on a *net* basis, was risk reducing. Fees for VAGB were earned in return for life insurers' guarantees to policyholders to make them whole in case of market reversals. Prior to the crisis, such fees were booked without having to perform on the guarantees. It became easy throughout the sector to downplay the risks, especially when competitors were booking still more income by taking still larger risks, with apparent impunity. It is sometimes said that history does not repeat itself, but it does rhyme. One can interpret this saying as a warning that future crises may not arise in the same way as the 2008 crisis. VAGB risks may be adequately hedged now–but other risks may be endemically misjudged.

Second, we provide a new quantitative tool to assess the potential for the contagion of risk to spread from guarantors (banks) of life insurer derivative hedges to the life insurance sector by failure of the guarantors to perform. We form an nxm matrix $\mathbf{A}$, where entry a_{ij} represents a measure of the exposure of insurer j to the possibility of default by bank i on the derivative obligations owed by the bank to the insurer. Then the diagonal elements of $\mathbf{A'A}$ summarize the exposures of the individual insurers to potential default by the banks. Moreover, $tr(\mathbf{A'A})$ measures the susceptibility of the life insurance sector as a whole to contagion from the banking sector. These exposures are a Herfindahl-like measure of diversification/concentration of derivative hedging among counterparty banks. Using 2007 data reported to the NAIC for the most significant life insurers and banks, we evaluated $tr(\mathbf{A'A})$ and found it to be relatively small in comparison with the volume of obligations. This finding is for all involvement with derivative hedging, and therefore applies *a fortiori* to the smaller category of derivative hedging of VAGB risks.

Moreover, the life insurance sector was relatively diversified. The actual estimated exposure to derivative risk was about \$4.5 billion. In itself, this magnitude of sector exposure seems manageable. But in addition, the risk was well diversified. Maximum diversification would result if each insurer's portion of this total were divided equally among the banks; minimum diversification would result from concentrating each insurer's portion in one bank. If all insurers were minimally diversified, the sector diversification score $tr(\mathbf{A'A})$ would have been 6.2 times as large as it actually was; at maximum diversification, the sector diversification score would have been about 0.31 times actual. The diversification was much closer to maximum than minimum.

Third, we are able to add to the discussion of SIFI's. Following theories of the crisis, regulators have tried to identify financial institutions with the size and interlocking relationships sufficient to threaten the financial system if they were to be destabilized and default on their obligations. Initial attention was focused on banks. Subsequently, some life insurers were identified. Most insurers that are involved with derivatives are purchasers rather than writers.[7] So life insurers' most likely contribution to a crisis would be as recipients of risk contagion spread from another sector. This could impair the obligation of insurers to pay claims, including annuities. Our analysis can identify insurers most likely to be recipients of contagion spread from banks. For 2007, we found that the maximum exposure to banks through derivatives for an individual insurer was about $700 million, with the total exposure about $4.5 billion. These are figures that should be manageable, given the capital and assets of the insurers. This suggests that life insurers may not have been pressing candidates for SIFI status prior to the 2008 crisis on account of their derivative connections with banks. If that was the case, then the extension of SIFI status to life insurers probably would not have helped prevent or mitigate the 2008 crisis, and, by extension, would unlikely prevent or mitigate a similar crisis now when more safeguards are in place.

Acknowledgments

This manuscript benefited from the valuable comments of three anonymous reviewers.

Conflict of interest

The author declares no conflict of interest in this paper.

References

Acharya VV, Brownlees C, Engle R, et al. (2010) Measuring Systemic Risk, *In Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance*, New York: John Wiley & Sons, 87–120.

Acharya VV, Engle R, Richardson M (2012) Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks. *Am Econ Rev* 102: 59–64.

Adrian T, Brunnermeier MK (2016) CoVaR. *Am Econ Rev* 106: 1705–1741.

Baranoff EG, Sager TW (2002) The Relations among Asset Risk, Product Risk, and Capital in the Life Insurance Industry. *J Bank Financ* 26: 1181–1197.

Baranoff EG, Sager TW (2003) The Interrelationship among Organizational and Distribution Forms and Capital and Asset Risk Structures in the Life Insurance Industry. *J Risk Insur* 70: 375–400.

Baranoff EG, Sager TW, Papadopoulos S (2007) Capital and Risk Revisited: A Structural Equation Model Approach for Life Insurers. *J Risk Insur* 74: 653–681.

Baranoff EG (2013) An Analysis of the AIG Case–Understanding Systemic Risk and its Relation to Insurance. *J Insur Regul* 31: 243.

Baranoff EG, Sager TW, Shi B (2013) Capital and Risk Interrelationships in the Life and Health Insurance Industries: Theories and Applications. *Handb Insur*, 889–915.

Baranoff EG, Sager TW, Shi B (2016) The Risk of Variable Annuity Guarantees and Life Insurer Capital. *Asia-Pac J Risk Insur* 10: 155–192.

[7] An exception in the 2008 crisis was AIG, which had substantial involvement in writing credit default swaps.

Benoit SG, Hurlin CC, Pérignon C (2013) A Theoretical and Empirical Comparison of Systemic Risk Measures. Working Paper, University of Orléans, Orléans, France.

Bernal O, Gnabo JY, Guilmin G (2014) Assessing the Contribution of Banks, Insurance and Other Financial Services to Systemic Risk. *J Bank Financ* 47: 270–287.

Bierth C, Irresberger F, Weiß GN (2015) Systemic Risk of Insurers Around the Globe. *J Bank Financ* 55: 232–245.

Billio M, Getmansky M, Lo AW, et al. (2012) Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors. *J Financ Econ* 104: 535–559.

Bisias D, Flood M, Lo AW (2012) A Survey of Systemic Risk Analytics. Working Paper, MIT Operations Research Center.

Black L, Correa R, Huang X, et al. (2016) The Systemic Risk of European Banks During the Financial and Sovereign Debt Crises. *J Bank Financ* 63: 107–125.

Chen CY, Härdle WK, Okhrin Y (2019) Tail Event Driven Network of SIFIs. *J Econom* 208: 282–298.

Chen H, Cummins JD, Viswanathan KS (2014) Systemic Risk and the Interconnectedness between Banks and Insurers: An Econometric Analysis. *J Risk Insur* 81: 623–652.

Colquitt LL, Hoyt RE (1997) Determinants of Corporate Hedging Behavior: Evidence from the Life Insurance Industry. *J Risk Insur* 64: 649–671.

Cummins JD, Phillip RD, Smith SD (2001) Derivatives and Corporate Risk Management Participation and Volume Decisions in the Insurance Industry. *J Risk Insur* 68: 51–90.

Cummins JD, Weiss MA (2014) Systemic Risk and the U.S. Insurance Sector. *J Risk Insur* 81: 489–527.

Eling M, Pankoke DA (2016) Systemic Risk in the Insurance Sector: A Review and Directions for Future Research. *Risk Manag Insur Rev* 19: 249–284.

Geneva Association (2011) Variable Annuities with Guarantees and Use of Hedging. Available from: http://www.genevaassociation.org/PDF/Insurance_And_Finance/GA2011–I&FSC10.pdf.

Glasserman P, Young HP (2015) How Likely is Contagion in Financial Networks? *J Bank Financ* 50: 383–399.

Gouriéroux C, Héam JC, Monfort A (2012) Bilateral Exposures and Systemic Solvency Risk. *Can J Econ* 45: 1273–1309.

Härdle WK, Wanga W, Yu L (2016) TENET: Tail-Event driven NETwork risk. *J Econ* 192: 499–513.

Harrington SE (2009) The Financial Crisis, Systemic Risk, and the Future of Insurance Regulation. *J Risk Insur* 76: 785–819.

Harrington SE (2013) The Dodd-Frank Act, Solvency II, and U.S. Insurance Regulation. *J Financ Perspect* 1: 1–12.

Hoyt RE (1989) Use of Financial Futures by Life Insurers. *J Risk Insur* 56: 740–748.

Kessler D (2013) Why Re (insurance) Is Not Systemic. *J Risk Insur* 81: 477–488.

Park SC, Xie X (2014) Reinsurance and Systemic Risk: The Impact of Reinsurer Downgrading on Property-Casualty Insurers. *J Risk Insur* 81: 587–622.

Pourkhanali A, Kim J, Tafakori L, et al. (2016) Measuring Systemic Risk Using Vine-Copula. *Econom Model* 53: 63–74.

Rauch J, Weiss MA, Wende S (2015) Default Risk and Contagion in the US Financial Sector: An Empirical Analysis of the Commercial and Investment Banking, and Insurance Sectors. Working Paper, University of Cologne, Cologne.

Weekly Special Report of the NAIC's Capital Markets Bureau (2010) Available from: http://www.naic.org/capital_markets_archive/110610.htm.