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Research Report

Emergence of Systemically Important Insurers

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The Emergence of Systemically Important Insurers

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Abstract

The increasingly intertwined banking and insurance sectors have lead to calls for stronger regulatory oversight of the insurance industry as potentially systemically risky. Ultimately systemic risk impacts the real economy, and this paper measures the risk via interconnectedness of the banking, insurance and real economy firms in the US for 500 firms from 2003-2011. Systemic risk in the banking sector peaked with the top of the housing cycle in 2006, while in the insurance sector it continued to rise until September 2008. The rescue of AIG and announcement of TARP dramatically decreased this interconnectedness risk. The results clearly demonstrate that whilst banking firms are the most consistently systemically risky in the economy, insurance firms are a readilly identifiable group displaying substantial systemic risk via interconnectedneess with the financial sector and the real economy.

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1 Introduction

Systemic financial events are problematic because of their potential impact on the real economy. In the turmoil of the period of 2007-2011 regulatory authorities and governments intervened to stave off collapse in many firms or industries where this was deemed to be of significant interest to the total economy, and this included important insurance companies, such as AIG. Since 2008 some jurisdictions have also decided to bring regulatory authority for insurance and banking activities under a common regulator (such as the Prudential Regulatory Authority at the Bank of England), while others retain separate regulators for both, usually under an umbrella organisation (such as the European System of Financial Supervisors which includes the European Banking Authority and the European Insurance and Occupational Pensions Authority). The notable exception is the US where the Dodd-Frank act allows the Federal Reserve to oversight non-bank financial companies only once they have been designated as 'too big too fail'. On June 4, 2013 three institutions were nominated for this category – AIG, Prudential and General Electric; that is two insurance companies and the financial activities of a large manufacturing conglomerate.

Given the policy response, the empirical literature on measuring the potential systemic risk generated from the insurance sector is surprisingly small. Billio et al. (2012), Archarya et al. (2011), Brownlees and Engle (2011), and Chen et al. (2013) include insurance and banking firms, the Vol-lab project at Stern provides updated systemic risk rankings for insurance companies as well as banks, analysed in Acharya and Richardson (2014), Billio et al. (2013) include banking, insurance and sovereign sectors, and our companion paper Dungey et al. (2013) includes insurance, banking and non-financial sectors and the chapters of Biggs and Richardson (2014a) specifically analyse the insurance sector; see particularly Cummins and Weiss (2014a), Harrington (2014), Paulson et al. (2014). The related literature on contagion effects considers a wider range of sectors, including for example Boyson et al. (2010), Bekaert et al. (2010) and Longstaff (2010), but does not usually directly address measurement of systemic risk. Darolles et al. (2012) is an exception, specifically pointing out that systemic risk and contagion are identifiably different features, and that mixing them will result in empirically confusing outcomes.

This paper addresses the separable measurement of systemic risk in the insurance sector of the US economy, incorporating the linkages between insurance and banking sectors, as well as linkages with firms of the real economy. Our approach relies firstly on understanding systemic risk as interconnections in a system of time varying risk shocks, consistent with the proposals of Schwarcz and Schwarcz (2014), and secondly on exploiting the technology

of interconnectedness algorithms, such as typified by Google search engines. In this way we produce not only an overall dynamic index of systemic risk for the financial sector, but also specifically for the insurance sector, the banking sector, and for each of the individual firms in our sample of 502 S&P500 stocks over the period 2003-2011 – thus with the important limitation that our sample is limited to listed companies of considerable capital value.[1] The risk shocks to each company are modeled with daily realized volatilities calculated from high frequency market trading data, and augmented by firm characteristics of leverage, liquidity and size.

Our results make four important contributions. First, we show that the profile of our systemic risk measure for insurance is quite different to that for the banking sector during the lead-up to the 2008-2009 financial crisis in the US, complementary to the analysis provided in Acharya and Richardson (2014). Second, the different profile for insurance companies reflects analysis of their balance sheets and investment behaviour during the sample period, and indeed our third finding concerns the intertwining of the insurance and banking sectors as partly contributing to the nature of these systemic risk profiles. Finally, we contribute to the debate on whether insurers are indeed as systemically risky as the banking sector.

Turning first to the profile of systemic risk in the two sectors. In the insurance sector, systemic risk fell from the beginning of the sample until May 2006 and then continued to increase until 2008. It was only the rescue of AIG that severed the link between increasing systemic risk in the insurance sector to the rest of the economy. There is particularly apparent a mirroring between rising systemic risk in insurance and falling systemic risk for banking in the period from late 2006 to September 2008. The banking sector systemic risk index rose prior to the end of 2006. The peak of the index is closely correlated with that of the US housing cycle with the subsequent reduction in systemic risk consistent with falling growth of exposure to the mortgage market after this point. Notably, the ABX market for mortgage backed securities began to decline in early 2007, considerably before what is now commonly considered the peak of the crisis in September 2008; see Dungey et al. (2013).

Our second finding is that these patterns are completely consistent with existing analysis of the balance sheets and investment behaviour of insurance companies. While the literature consistently shows that the core insurance products provide little evidence of increased risk, many insurers have moved into a much wider range of financial services, including more systemically risky areas of CDS and securitised loans; Cummins and Weiss

[1]Thus we exclude several large firms such as State Farm, Nationwide and regionally important firms such as Farmers and many smaller firms in every industry.

(2014b), Baluch et al. (2011), Cummins and Weiss (2014a), Paulson et al. (2014). In fact a contributing factor to the crisis may well have been the concurrent conditions of rising house prices, increased availability of mortgage refinancing opportunities and the low interest rate environment; Khandani et al. (2013). Changes to regulatory laws governing insurers in 2000 increased their capital requirements and may have induced them into regulatory arbitrage activities in the shadow insurance sector, with rapid growth in off-balance sheet reinsurance activities in the next decade; Koijen and Yogo (2013).

Our third finding supports the increased intertwining of the insurance and banking sectors. Billio et al. (2012) find that while there is little evidence of interconnectedness between insurers, banking, hedge funds and brokers in the 1990s, this changed dramatically in the 21st century. The wider product range taken by insurers in the 21st century, particularly after the repeal of the Glass-Stegall Act in 1999, may have led to a perceived increase in diversification and reduced risk profile by investors, and hence be responsible for the declining riskiness for insurers in the early part of our results; Biggs and Richardson (2014b).

During the period of decline in the housing market post-2006, while banks were reducing their exposure to this sector, the exposure of the insurance sector through their CDO commitments increased. For companies such as AIG this lead to calls on collateral; Harrington (2009). Harrington (2009) also records that AIG ceased to write CDO products in 2005 in response to the slower housing market. The mortgages supporting the ABX market show evidence of declining quality at this time, Demyanyk and Van Hemert (2011), although Dungey et al. (2013) find that the contribution of these vintage of issuance effects are relatively small compared with other potential explanators (including credit rating and common financial market conditions). The increased use of credit risk transfer products such as CDOs and swap committments in the banking sector contributes to higher systemic risk, despite falls in the apparent risk for individual institutions, Nijskens and Wagner (2011), and there is no reason to suppose that this effect would not also occur in the insurance sector, Schwarcz and Schwarcz (2014). In fact, in this paper the increasing interconnectedness both within and between the banking and insurance sectors provides evidence of this effect.[2]

Finally, we consider the question of whether insurance companies are as systemically

[2]The methodology of Nijskens and Wagner (2011) essentially rests on changes in the beta estimates of the common factors between banking sector participants, where this emerges from higher correlations; see also Billio et al. (2012). Further, Harrington (2009) reports that the majority of the bailout assistance paid to AIG was subsequently transferred to the banking sector, see also Acharya and Richardson (2014).

important as banking institutions in the financial system. Insurance sector commentators have consistently commented that applying banking style regulation to insurance companies is unwarranted, and warned that even the most systemically important insurers may be significantly less systemic than a mid-ranking bank. We address this question directly, and find that while the top cluster of most systemically risky financial firms in the economy are indeed banks, they are closely followed by a cluster of systemically risky insurance companies - who outrank many other financial institutions in terms of their systemic risk.

The different evolution of systemic risk in the insurance and banking sectors, and the results from both interconnectedness and marginal expected capital shortfall measures of systemic risk, strongly support the need to implement macroprudential oversight in the insurance sectors complementary to that in the banking sector. Despite the finding supported in the existing literature that insurance per se is not systemically risky as a core business, insurance companies are not constrained to this activity, and non-core activities are a potentially important source of systemic risk; Cummins and Weiss (2014b), Baluch et al. (2011), Biggs and Richardson (2014b), Harrington (2014); however, see also Acharya and Richardson (2014) who argue for the importance of insurancers as a potential source of systemic risk (p.156). The major source of the problems with AIG was the activities of its CDS and lending activities via its Financial Products subsidiary, but these rebounded clearly on the whole conglomerate, see also Schwarcz and Schwarcz (2014) for discussion. Activity in each sector contributes to overall financial systemic risk, and the intertwining of the risk transfer between them leads to differing profiles of how this risk emerged and behaved for the two sectors during the most recent crisis.

This paper proceeds by reviewing the newly developing regulatory environment, particularly the inclusion of insurance companies under macro-prudential regulatory structures in a number of important jurisdictions. The methodological approach taken to measuring systemic risk by interconnectedness is in Section 3. The data are described in Section 4. Section 5 presents the results for insurers and banks, and compares these with the marginal expected shortfall indices generated by Brownlees and Engle (2011).

2 Macroprudential Regulatory Environment

The regulatory environment in 2014 is almost unrecognisably different to that which prevailed prior to the crisis, in say 2006. The interim has seen the rise of macro-prudential regulatory policy, focussed on the stability of the financial system because of its effects on

the real economy. Micro-prudential regulation, based on individual firms and consumer protection retains an important role, but is being supplemented by this new agenda.

Practical implementation of macro-prudential regulation has thus far agreed on a number of common features. In most jurisdictions both deposit-taking institutions and insurance providers are now the subject of regulatory oversight. While banks were subject to regulatory policy prior to the crisis almost everywhere, this was not always true for non-bank deposit taking institutions – for example in New Zealand – and regulated non banks were not always overseen by the same authority as banks – for example in the UK. In Europe, pan-European authorities have been established to oversee the financial system in the Euro Area, rather than the panoply of national arrangements prior to the crisis.

While deposit-taking institution regulation has been the subject of international focus for a considerable period, due at least in part to the Basel Committee frameworks, macro-prudential regulatory oversight of insurance functions is newer. The experience of the crisis showed the critical role insurers can play in both propagating and amplifying crisis.

Although there is evidence that insurance companies can be viewed as the 'victims' of financial instability, rather than perpetrators (Cummins and Weiss, 2014a,b; Chen et al., 2013), the blurring between the product offerings of financial institutions and insurance companies, and their role in the credit risk transfer markets, are clearly important. Cummins and Weiss (2014b) find that while there is limited evidence that the core business of insurance is systemically important, non-core activities are potentially systemically risky – a conclusion which accords with the detailed analysis of the collapse of AIG in Harrington (2009) and the framework of the of Insurance Supervisors (2013).[3]

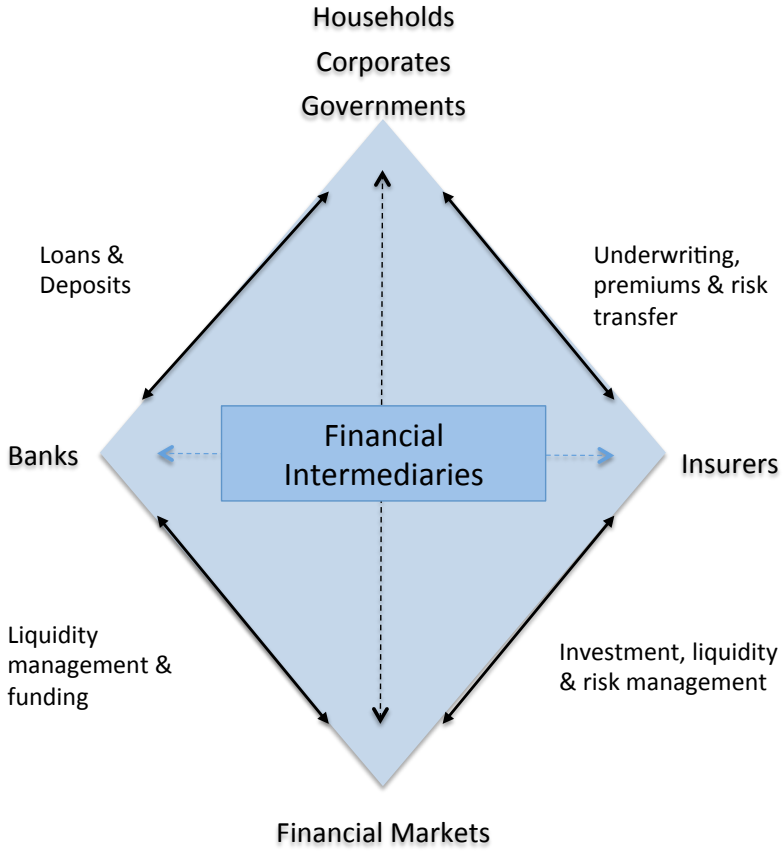
The proposal in this paper is to examine whether firms engaged in the insurance industry contribute to systemic risk, and builds on the results in Billio et al. (2012), Brownlees and Engle (2011), and Acharya and Richardson (2014). The majority view holds that traditional insurance is not systemic; see the chapters in Biggs and Richardson (2014a) but for a contrary view Acharya and Richardson (2014). It does not engage in leveraging for asset accumulation in combination with maturity transformation. Instead, it is funded by premiums paid up front that provide strong operating cash flow without the requirement for wholesale funding. Insurance policies are generally long term with controlled outflows that led to insurers acting as stabilizers to the financial system during the most recent financial crisis.

New regulators such as the UK's Prudential Regulatory Authority clearly state that al-

[3]Reinsurance functions do have the potential to be economically disruptive, but most authors suggest this is not on the same scale as banking sector disruptions; Baluch et al. (2011).

though they do not regard insurance companies as having the same systemic risk as banking institutions, they nevertheless do pose a potential systemic threat (Prudential Regulation Authority (2013)) a sentiment echoed by other regulators such as the Reserve Bank of New Zealand in taking on regulatory oversight of this sector. Some jurisdictions, such as Australia, were already co-regulating insurance and deposit-taking institutions under a common regulator – the Australian Prudential Regulatory Authority - but this tended to be the exception rather than the rule. Unsurprisingly increased regulatory attention to insurance industry activities has been unpopular with most incumbents; see for example Masters (2013),Schwarcz and Schwarcz (2014).

Figure 1: ROLES OF BANKING AND INSURANCE



The complexities of regulating a financial sector for systemic risk lie in the varying roles that these institutions play in the economy. Figure 1 illustrates the roles of banking and insurance in an economy as may be drawn from any undergraduate class in banking and finance. Banking transforms credit across time and actors, insurance transfers risk. On the edges of the diamond, there likely exists some clarity about the role institutions may play. However, this is increasingly not the usual structure of the financial sector. The

existing literature has identified systemic risk in insurance companies as emerging through their exposure to non-core business, particularly in CDS markets and securities lending through the actions of subsidiaries rather than the insurance functions themselves and in the presence of increasingly strong bilateral links between the insurance and banking sectors; see of Insurance Supervisors (2013), Koijen and Yogo (2013), Cummins and Weiss (2014b); Chen et al. (2013), Baluch et al. (2011). Most firms are involved in a variety of risk and credit transformation functions, including between financial firms, and insurance companies have substantial holdings of corporate bonds (Acharya and Richardson (2014)). In addition firms exhibit a degree of 'complexity' in the sense of Cummins and Weiss (2014a) in terms of organisational, geographical and product complexity which contribute to their systemic vulnerability. While text books may discuss financial sector firms whose activities are defined by the edges of our diamond, the reality is that firms, both insurers and deposit-takers, are now active to varying degrees in both credit and risk transformation, and thus sit at the centre of our diamond. Examples abound; Barclays offers insurance products as well as banking, ING offers deposit taking as well as insurance. Changes in financial markets over the last two decades have created greater homogeneity of the risks faced by firms competing in the financial sector – a potential threat to systemic risk identified well in advance in Eatwell (2004). This makes understanding and developing an optimal regulatory framework particularly difficult.

The driving force for insurance firms to encroach on traditional banking areas the need to diversify and seek higher return, as exemplified in results of a 2013 survey from StateStreet (2013). At the same time, banks facing higher regulatory and capital costs entailing the need for scarce liquid instruments such as government bonds, are withdrawing from traditional business lines and leaving this field to the less cash-constrained insurance sector.

While for pragmatic reasons most discussion centers on regulating sectors or firms, there have been some calls to regulate product lines; see comments in Masters (2013) for example. Each approach faces important risks in the form of regulatory arbitrage and moral hazard. These issues cannot be analyzed in isolation from the impact of the services that the financial sector supplies to the real economy. Macro-finance models of systemic risk generally focus on the credit creation function of the financial sector, leading to concentration on banking sector stability. Risk management functions such as insurance are not deemed to be non-substitutable in the same way as the payments and settlements system, and thus not a direct systemic risk; Cummins and Weiss (2014b),Cummins and

Weiss (2014a). However, when the companies which provide these functions are extending their activities into the edges of the credit creation sector, and offering products that quickly intertwine with the banking sector there is cause for concern; for example see Acharya and Richardson (2014).

Consequently, this paper specifically models the insurance and banking sectors interconnected with both themselves and the real economy. While some authors have previously considered both types of financial sector firms – Billio et al. (2012), Chen et al. (2013), Brownlees and Engle (2011), and Archarya et al. (2011) – most concentrate on the banking sector alone. Only in our companion paper Dungey et al. (2013) have the interconnections with the real economy been explicitly considered, and they are shown to make a substantial difference to measures of systemic risk.

3 Methodology

We use an enhanced and adapted version of the eigenvector centrality measures often used in network analysis, in particular PageRank of Google.

In a nutshell, we consider a network of financial and non-financial firms. Each company is endowed with a given shock in its risk. The firms are connected throughout the correlations between the shocks. A financial firm is systemically important if its shock is connected to many other financial and non-financial shocks, and if its strongest linkages are with other companies that are also systemically important.

Let N be the number of firms in the system. We denote by $S_{k\,t}$ the systemic importance, or centrality, of firm k at time t. It depends on the systemic importance of its peers:

$$S_{k\,t} = \sum_{j=1}^{N} S_{j\,t} c_{k\,j\,t}. \tag{1}$$

The time varying $c_{k\,j\,t}$ represents the transmission channel between companies k and j at time t. Its dynamics are given by the strength of the connections, which is captured by the correlations, denoted by ρ:

$$c_{k\,j\,t} = \frac{|\rho_{k\,j\,t}|}{\sum_{i \in \mathcal{S}_{j\,t}} |\rho_{i\,j\,t}|}. \tag{2}$$

The system of systemic importances can be written in matrix form as $\mathbf{S}_t = \mathbf{C}_t \cdot \mathbf{S}_t$, and its solution is the eigenvector associated with the largest eigenvalue of $\mathbf{C}_t$, which by construc-

tion is one.[4]

One of the features of the build-up of the financial crisis was the increase in system-wide risks, which is captured by the average systemic importance of the financial sector. Indeed, as the strength of the transmission channels increases, the network becomes more dense, which translates into an increase of the systemic importances. Let $\mathbf{S}_t^{Fin}$ be the subset of $\mathbf{S}_t$ that contains the N^{Fin} financial institutions. The systemic risk index of the financial sector, denoted GS_t^{Fin}, equals

$$GS_t^{Fin} = \frac{1}{GS_B^{Fin}} \sum_{k=1}^{N^{Fin}} \frac{S_{kt}^{Fin}}{N^{Fin}}. \tag{3}$$

The normalization GS_B^{Fin} makes GS_t^{Fin} relative to a particular benchmark. We choose September 15, 2008 as the day on which the Lehman Brothers bankruptcy was announced. Therefore if $GS_t^{Fin} = 1$ the systemic risk index of the financial sector at day t is as high as in September 15, 2008.

Since $\mathbf{S}_t^{Fin}$ is a subset of $\mathbf{S}_t$, we can choose another financial subset and easily construct systemic risk indexes for financial sub-sectors, such as insurance companies and deposit-taking institutions. Take, for instance, insurance companies and let $\mathbf{S}_t^{Ins}$ be the subset of $\mathbf{S}_t^{Fin}$ that contains these institutions. The insurers systemic risk index is the average of $\mathbf{S}_t^{Ins}$:

$$GS_t^{Ins} = \frac{1}{GS_B^{Fin}} \sum_{k=1}^{N^{Ins}} \frac{S_{kt}^{Ins}}{N^{Ins}}.$$

Note that the normalization is the same as in (3), so GS_t^{Ins} and GS_t^{Fin} are comparable.

Firm characteristics play an important role in ranking systemically important financial institutions: a large, leveraged and illiquid firm should be ranked high; in our application this specifically takes into account that insurance companies are an order of magnitude smaller than the largest banks, Cummins and Weiss (2014a). For firm k we denote them by $size_{kt}$, lvg_{kt} and liq_{kt} respectively, and are gathered into the vector $\mathbf{fc}_{kt} = (size_{kt}, lvg_{kt}, liq_{kt}^{-1})$. Then each company index gains systemic importance from these features:

$$\mathbf{S}_t = \alpha \mathbf{C}_t \cdot \mathbf{S}_t + \boldsymbol{\omega}' \mathbf{fc}_t,$$

where $\boldsymbol{\omega}$ is a vector of positive weights that regulates the contribution of the firm character-

[4]The transmission matrix $\mathbf{C}_t$ has zeros in the main diagonal, since a firm does not transmit risk to itself.

istics, and $\alpha < 1$ is a scaling that weights the relative contribution of the interconnections. The balance between the contributions of the connections and the firm contributions is therefore given by α and $\boldsymbol{\omega}$. The solution for the systemic risk importances at time t is:

$$\mathbf{S}_t = (\mathbf{I} - \alpha \mathbf{C}_t)^{-1} \boldsymbol{\omega}' \mathbf{fc}_t.$$

Finally, our ranking metric –the Systemic Risk (SR) ranking– is

$$SR_t = \text{rank}(\mathbf{S}_t).$$

The methodology we propose is straightforward and quick to calculate with no need for optimizations, and it takes into account linkages between the financial sector and the real economy while incorporating firm characteristics.

4 Data

Computing the shocks and the transmission matrix

The data for computing the shocks in risks consist of 5 minute observations on stocks between 9:30am and 4:00pm each trading day from the S&P500 index for the period January 2, 2003 to December 30, 2011 downloaded from the Thomson Reuters Tick History database provided by SIRCA. We retain stocks listed on the NYSE, NYSE (Aex) Consolidated and Nasdaq from the '0#.SPX' list available from the database, and adjust for changes in RIC codes through mergers and acquisitions, stock splits and trading halts. The 5 minute sampling frequency is chosen as representative of current benchmark practice in the literature in attempting to compromise between information and noise; see for example Lahaye et al. (2011) and Andersen et al. (2007).[5]

The dataset represents a draw of stocks from those listed on the S&P500 rather than a full record of all stocks traded in this index during 2003-2011. Some stocks also contain significant numbers of missing values in the dataset, and we drop a small number with insufficiently complete data. We force the inclusion of Lehman Bros, Fannie Mae and Freddie Mac, and for the latter two use data sourced from OTC and NYSE Arca trades after they were no longer traded on the exchange. The final sample contains 502 stocks

[5] Although there is some work on optimal sampling frequency for univariate series in Bandi and Russell (2006), this problem has not yet been addressed in a multi asset environment with stocks with differing liquidity and trading intensities.

over 2262 trading days.[6]

It may be argued that in the US there are large non-listed insurance companies, and hence not included in our system. The bulk of these companies have the legal form of mutuals; a number of them operate as reciprocals. State Farm, Liberty, and Nationwide are examples. The same applies to other large conglomerates with insurance business lines, such as Berkshire Hathaway (with two reinsurance subsidiaries: Berkshire Hathaway Reinsurance Group and General Re). Our methodology can still be used for non listed companies if, instead of the market price, the assets under management (AUM) are used for computing the volatilities. AUM have been used by, for instance, Billio et al. (2012). The drawback, however, is that AUM is only available, at best, at monthly frequency, as opposed to daily.

Risks are measured with annualized realized daily volatilities computed from 5 minute data for each stock as the sum of squared intradaily returns, with overnight returns excluded. Let r_{jti} be the intraday trade return of firm j on day t at 5-minutes time $i = 1, \ldots, N$. The annualized realized volatility, x_{jt}, is given by

$$x_{jt} = 100\sqrt{252}\sqrt{\sum_{i=1}^{N} r_{jti}^2}.$$

This measure of realized volatility will include price discontinuities, or jumps (see e.g. Barndorff-Nielsen and Shephard, 2004), which is an important component of tracking co-movements during periods of financial stress. Many applications wish to exclude jumps, for example in assessing underlying integrated volatility for derivative pricing. In the current context however jumps are a means by which news is incorporated into the markets, and cojumping is potentially a particularly important contributor to increased systemic risk; Dungey et al. (2009), Lahaye et al. (2011), Andersen et al. (2007).

To extract the volatility shocks we filter the realized volatilities with ARFIMA models. Andersen et al. (2001), Andersen et al. (2003) and Luciani and Veredas (2011) show that the ARFIMA models are an accurate representation of the long-memory stylized fact of realized volatility. The transmission matrix $\mathbf{C}_t$ is computed as in (2) and sample correlations are tested for the null hypothesis of zero. If the null cannot be rejected they are set to zero.

The characteristics of each firm are represented with firm size, leverage, and liquidity

[6]Data processing is documented in the web-appendix to our companion paper Dungey et al. (2013), including the complete list of included stocks. C+ codes are available on request to both replicate the data and make alternative selections.

data obtained from Thomson Reuters Datastream. Size is measured by market capitalization, and observed daily. Leverage is defined as the book value of assets minus the book value of equity plus the market value of equity. As it uses both market and book-based information, it is available daily. Liquidity is book-based and described by the sum of cash and short term investments divided by the book value of assets, and is available every quarter.[7] Since these variables differ in scale, they are standardized.

To compute the time variation in $\mathbf{C}_t$ we consider a rolling window of 400 days (roughly 1.5 years), compute the shocks, their correlations, and the firm characteristics. The network and firm characteristic contributions are calibrated as follows: we set $\alpha = 0.66$, $\omega_{size} = 0.4$, $\omega_{lvg} = 0.4$ and $\omega_{liq} = 0.2$. The choice of 0.66 for α is based on calibration (Google suggests 0.85 for solving the problem of dangling websites), while the choice of $\omega_{liq} = 0.2$ is to avoid large discontinuities as the balance sheet data are released every quarter. The choice of α and $\boldsymbol{\omega}$ do not affect calculations of the systemic risk indexes when $\alpha = 1$ and $\omega = 0$. Robustness to different choices for α and $\boldsymbol{\omega}$ for individual firm results are available in the web appendix.

5 Results

The data set contains 20 insurance companies and 18 deposit–taking institutions (all of whom were recipients of funding from TARP); see Table 1 for the classification. We do not concentrate on the separate indices for other financial firms in the data set due to the diversity of their interests, for example, dealer/brokers, real estate investment, health care investment, and funds management advice.

Figure 2 shows the systemic risk profiles for the total of all financial sector firms (grey line), the insurance companies (black line) and deposit–taking institutions (dashed line). The index for the entire financial sector shows a gradual increase from early 2007 to the crisis itself in September 2008. The index for the entire financial sectro rises up to the

[7]The methodology allows to choose different firm characteristics for different sectors, and even for different firms. Our choice is motivated in terms of general characteristics that under stress may prompt a fall out of a firm and cause a seizing up or breakdown of the connected peers, which may induce a systemic crisis. For example, one may argue that traditional insurers do not assume leverage to enhance expected investment returns as in banking. Insurers primarily target liability-driven investment, which, if well executed, should not entail systemic risks. Likewise, traditional insurers do not experience liquidity runs. Cash outflows are tied to the occurrence of insured events, such deaths or natural catastrophes, and claims are typically paid out over extended periods. These arguments however do not hold if the insurers embark in non-insurance business lines, such as investment in illiquid assets or shadow banking activities, as explained in previous section.

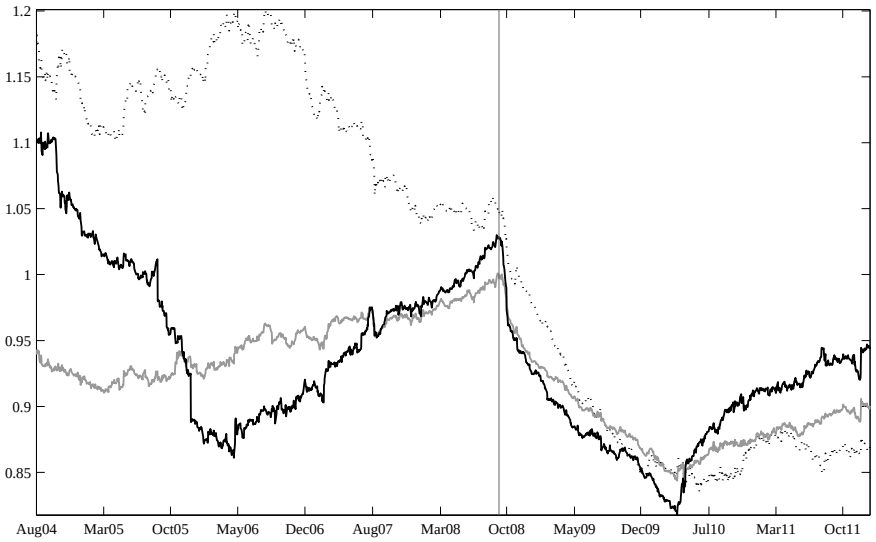
Table 1: Classification of Financial Stocks

Deposit	Insurance
Bank of America Corporation	ACE
BB&T Corporation	AFLAC Inc
The Bank of New York Mellon Corporation	American International Group Inc
Citigroup Inc	Assurant Inc
Comerica Incorporated	The Allstate Corporation
Huntington Bancshares Incorporated	The Chubb Corporation
JPMorgan Chase & Co	Cincinnati Financial Corp
KeyCorp	Genworth Financial Inc
M&T Bank Corporation	Hartford Financial Services Group Inc
Peoples United Financial Inc	Lincoln National Corp
PNC Financial Services Group Inc	Marsh & McLennan Companies Inc
Regions Financial Corp	MBIA Inc
Synovus Financial Corp	MetLife Inc
SunTrust Banks Inc	MGIC
State Street Corp	Principal Financial Group Inc
US Bancorp	Progressive Corp
Wells Fargo & Company	Prudential Financial Inc
Zions Bancorp	Torchmark Corp
	Unum Corporation
	XL Capital

Chapter 11 filing for Lehman and remains high until September 23, 2008 followng the bailout of AIG. The index began a sustained drop on the announced approval of TARP on October 3, 2008 until beginning to rise again from April 2010, consistent with concerns over Greek sovereign debt. Detailed analysis of the overall systemic risk index may be found in Dungey et al. (2013).

The systemic risk index for insurance companies fell from the beginning of the sample until mid-2006. During this first part of the sample insurance companies were engaged in expanding their financial activities additional to core insurance business; and this diversification may have contributed to the market assessment that these businesses were becoming less homogenous and hence as a sector less systemically risky – although as it turns out this was not in fact the case; see Eatwell (2004). Part of their drive towards more profitable lines of business was to maintain access to investor funding in an environment where banking was providing very high rates of return. The exposure of insurers to catastrophic risks, such as payouts for Hurricane Katrina evident in the strong drop in mid late 2005 on the figure, differentiates them from other industries (thus the drop), and provides incentives to seek other forms of income, despite their ability to rely on steady premium income rather than a deposit base as in banking. Their expansion, particularly via subsidiaries, into CDS and CDO products and securitized loans (and potentially the shadow insurance market),

Figure 2: Systemic risk indexes – financial subsectors



The grey line is the systemic risk index for the financial sector, the dashed line for deposit–taking institutions, and the black line for insurance firms.

in retrospect exposed them to substantial risk. While house prices were rising these risks were relatively contained, although concern had been expressed even prior to the stalling of the US housing market that many of these credit risk transfer products were underpriced; see for example Cummins and Weiss (2014a), Harrington (2009), Trichet (2009). Real estate related investments comprise approximately 25 percent of insurance company assets in 2012, Paulson et al. (2014).

The systemic risk index for insurance firms rose steadily from May 2006 until September 18, 2008; Acharya and Richardson (2014) show that a substantial rise in their SRISK expected shortfall measure of systemic risk for insurers also occurred in 2007. During this period, while the housing market stalled and then fell, and banking actively attempted to reduce its exposure to this sector, the products that many insurers were exposed to became increasingly problematic. The exposure of AIG, particularly via its Financial Products subsidiary, resulted in the need to post significant collateral against its CDS exposure; Harrington (2009). Reassessments of the quality of the underlying mortgages for the ABX market resulted in a dramatic revaluation of products in this segment; Longstaff (2010). Clearly the bailout of AIG in September 2008 was a turning point for the systemic risk of the insurance sector, indicating particularly that their entwinement with all aspects of the economy was critical in systemic stability.[8] In fact, the improvement in the insurance

[8]It is also possible that Hurricane Ike, which had significant insurance claims, acted to reduce the corre-

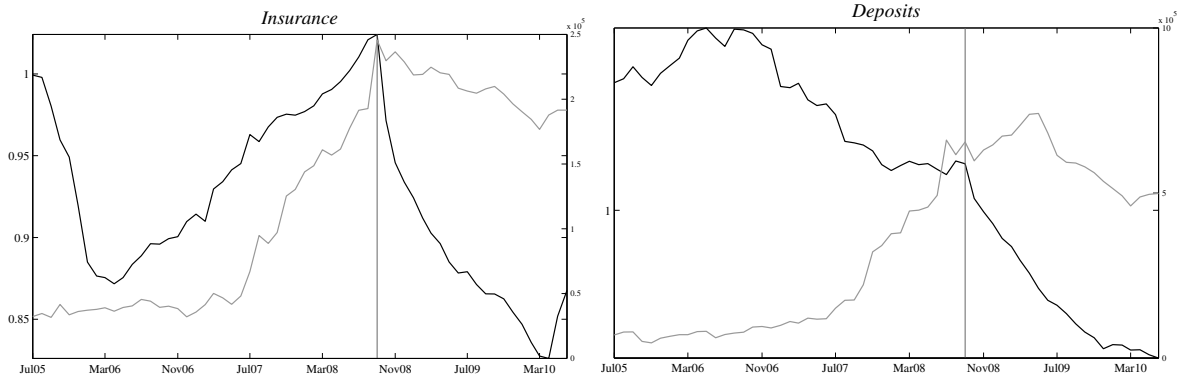
industry may have been critical for stabilising the banking sector in view of the growing empirical evidence that insurance sector shocks transmit significantly into the banking sector; Billio et al. (2012) and Chen et al. (2013). The systemic risk index continues to decline until early April 2010 (April 5) at the point of high market anxiety prior to the scheduled Greek bond sale on April 8 and shows only increasing systemic risk for the remainder of the sample. By December 2011 the insurance companies were more systemic that the financial sector as a whole and, in particular, than the deposit–taking institutions; a result consistent with the SRISK results of Acharya and Richardson (2014) reflecting improved banking capital compared with insurers. This reflects the continued exposure of insurers to the CDS sector - and particularly their exposure to the European banking system; Cummins and Weiss (2014b), Harrington (2009).

By way of contrast we consider also the systemic risk index for the depository institutions. This reached its maximum on August 22, 2006, and its rise up to that point is aligned with the rise in housing prices and the subsequent turning point in the US housing market in the second half of 2006 and into 2007. In fact, the values of the index are above 1, reflecting that during the build–up of the crisis, the deposit–taking institutions were considerably more systemically risky that the financial sector as a whole. Once banks were no longer further extending their credit to riskier housing loans their vulnerability began to decline –evidence of reduced activity in this area can be found in the complete lack of new tranches of the ABX index for mortgage backed securities after January 2007; see Dungey et al. (2013). This index declines almost continuously until December 2009, aligned with the problems emerging in Greece, and then remains around those levels until November 2010, when it again begins to kick up. These results are consistent with Poirson and Schmittmann (2013) who find a substantial increase in interbank spillovers associated with the European crisis - and that this increase is smaller than that associated with the earlier US crisis events of 2008.

There are interesting comparisons between our systemic risk measures and the $SRISK$ index of Brownlees and Engle (2011). The latter measures risk as potential capital shortfall in the system on a monthly basis, which is quite different from our measure of interconnectedness, although the two are interrelated through spillovers and balance sheet contagion; Kiyotaki and Moore (2002). To compare our results with those of Brownlees and Engle (2011) we construct a monthly average GS index from our daily series, as shown in Figure 3 (left plot for deposit–taking and right plot for insurance firms). Note that the Brownlees

lations between the insurance sector and the remainder of the economy at this time, although settlements for Ike were ultimately less than one fifth those paid for Katrina.

Figure 3: GS VERSUS $SRISK$



The black line is the interconnectedness systemic risk index of this paper, while the grey line is the $SRISK$ sub–sector index.

and Engle sample ends in June 2010.

A comparison of the GS and $SRISK$ indices for insurance companies shows that while during the period from early 2005 to September 2008 the systemic risk measured by interconnectedness (GS) was growing, the systemic risk measured by potential capital shortfall ($SRISK$) was growing much more dramatically. This result is attributable to the assessment of risk in the data. The Brownlees and Engle (2011) method uses historical tail event data to determine the extent of potential capital shortfall, and with the relatively compressed distribution of returns in the early part of the sample this risk was under-estimated in the lead up to 2008. In contrast, the interconnectedness measures used here rely on the relationships between the entire distribution of the market data, and any contemporaneous movements between stocks whether they are tail events or not, will be reflected. For this reason, the two measures are highly complementary. One gives information about the interconnected nature of the economy, and the other gives information about the capacity of the economy to absorb a financially traumatic shock. When both measures are rising the danger from a systemic event is high as it is likely to both spread widely and be highly disruptive to the capitalisation of the economy.

Both indices turn in September 2008. From then on, the GS index declines relatively rapidly, while the $SRISK$ index declines more slowly. That is, the capital shortfall measure of systemic risk built steeply prior to September 2008, but this problem was only slightly alleviated during the following period. On the other hand, the systemic risk due to the interconnectedness of the firms declined in a pronounced manner post September 2008, as there was less commonality in the exposure of this sector. The deposit-taking sector indices similarly show that post 2008 while systemic risk measured by interconnectedness fell, that

measured by capital shortfall did not. Thus, while systemic risk due to interconnectedness appears to be alleviated post October 2008, capital shortfall risk remains attenuated.

The importance of linkages with the real economy

Our framework is distinguished by taking into account the linkages between the financial sector and non-financial firms. Here we explore the influence of the linkages between the insurance sector and the real economy in understanding systemic risk in that sector. To do this we construct a financial (sub–)sector index, denoted $\widetilde{GS}_t^{Fin}$, which uses only the set of firms in the financial sector as the base for calculating the measures, i.e. the the systemic importance of firm k at time t as it is defined in (1) is replaced by $\tilde{S}_{kt} = \sum_{j=1}^{N^{Fin}} \tilde{S}_{jt} c_{kjt}$ which only contains information about the connections between financials. For comparison we construct a similar index for the deposit-taking firms. Figure 4 illustrates the results.[9]

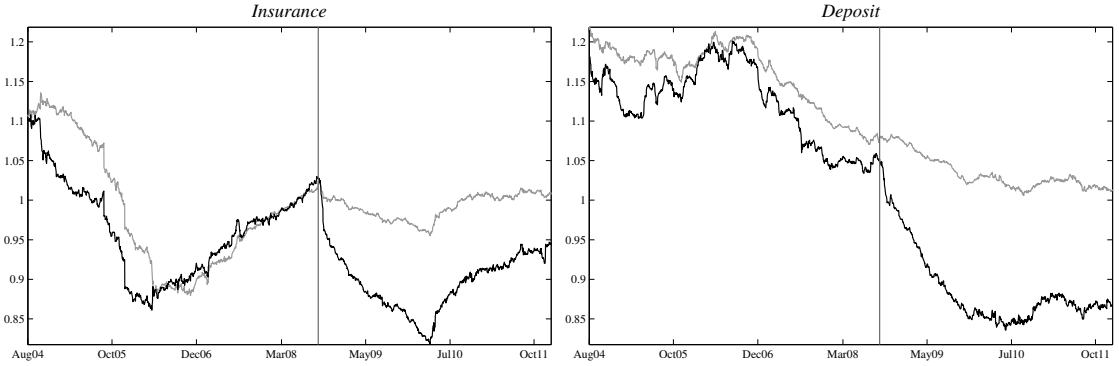
Consider the evidence for the insurance sector. Prior to September 2008, the run–up in systemic risk for the insurance sector measured either relative to the entire sample or to the financial sector alone is equivalent, suggesting that the links of the insurance sector with the real economy were not the driving force at this time. Post September 2008, a dramatic gap emerges. The interventions to rescue AIG are particularly evident –the GS_t^{Fin} index drops dramatically, although the $\widetilde{GS}_t^{Fin}$ index does not. This is particularly compelling evidence that the policy action changed the interconnectedness of risks between the insurance companies and the rest of the economy. While, as a result of credit shortages and declining economic conditions, firms in the real economy became considerably more risky, the insurance companies did not experience the same degree of increase in risk post the AIG rescue. Thus, the GS_t^{Fin} post–AIG for the insurance companies shows them as becoming relatively less risky compared with the rest of the economy, but the $\widetilde{GS}_t^{Fin}$ shows a relatively slower decline in their systemic risk profile. With the end of the US recession in mid-2009 and the beginning of the Greek crisis, the whole economy based index of risk for insurance companies moves towards the financial sector index, recognizing that relative to the rest of the economy, the insurance sector is relatively exposed to market risks in this period. This does not seem to be the case for the deposit–taking firms.

In the deposit–taking sector, the gap between the GS_t^{Fin} and $\widetilde{GS}_t^{Fin}$ indices begins to open from late 2006, coupling with the turning point in the indices which we have previously associated with the peak of the housing cycle. The slower rate of decline in

[9]Comparison of the sector indices is complicated by the normalization of the total GS index. However this does not arise when the sub–sectors are calculated.

the $\widetilde{GS}_t^{Fin}$ index represents that risk in the deposit–taking sector is declining relative to this sector as a whole (recall that these are the comparator companies in the $\widetilde{GS}_t^{Fin}$ index, and that risk in the insurance sector is known to be rising). As the index is relative it is also increased riskiness of other firms that will drive a relative improvement in a single sector systemic risk index. Post the collapse of Lehman Brothers the gap between the GS_t^{Fin} and $\widetilde{GS}_t^{Fin}$ index opens substantially, reflecting a disconnection of the systemic risk driven through these firms with the economy as a whole. This is plausibly linked to the success of the policy interventions around this time, which alleviated the risks associated with financial institutions collapsing through regulatory intervention in an environment where lack of credit was adversely affecting business conditions for the remainder of the economy.[10] Effectively the historical links between the financial sector and the real economy were dramatically reduced for the period post September 2008.

Figure 4: WITH AND WITHOUT REAL ECONOMY LINKAGES



The black line is GS_t^{Fin} while the grey line is $\widetilde{GS}_t^{Fin}$, i.e. the systemic risk index without incorporating the linkages of the financial firms with the rest of the economy. Left plot for deposit–taking institutions and right for insurance firms.

Relative Systemic Risk of Deposit Taking and Insurance Firms

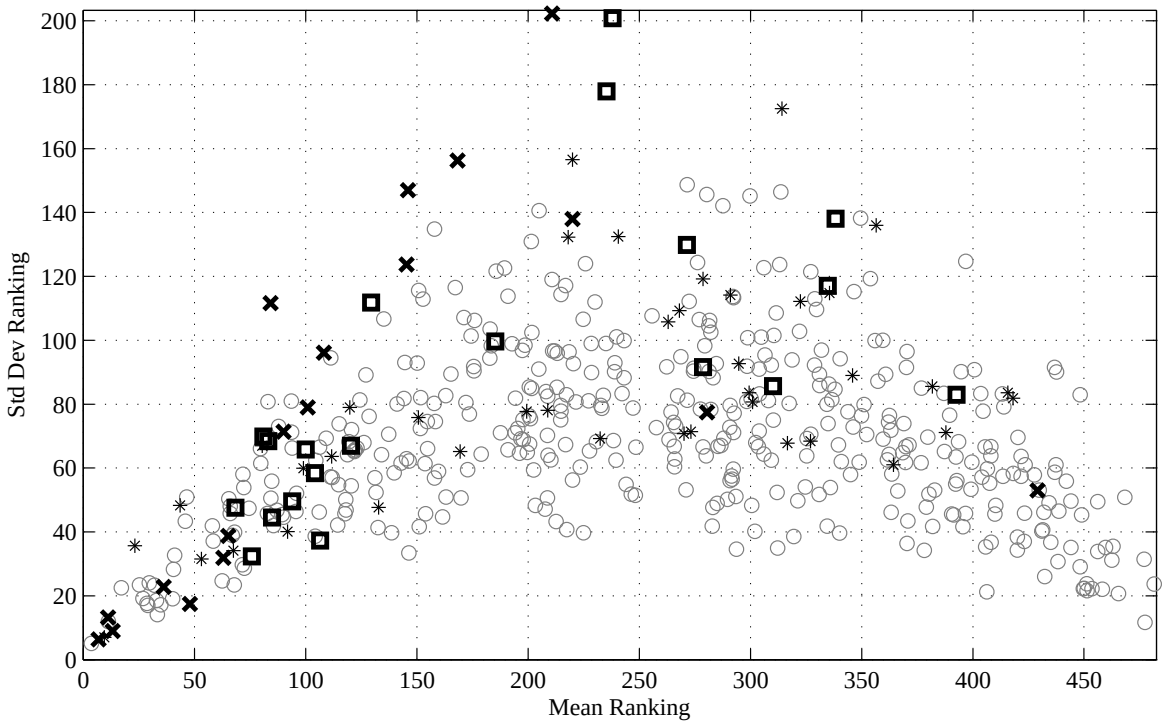
The spread of regulatory attention to insurers in the period since the rescue of AIG has prompted protest from the industry and reassurance from policy makers that insurers are recognised as less systemically risky than the banking sector (although Prudential has not beensuccessful in its legal attempts to remove itself from the list of those designated as 'too big to fail'). We provide empirical evidence around the validity of this statement using a

[10]Some evidence of this is available in the 35 percent rise in bankruptcy filings in US courts between June 2008 and June 2009 –sourced from US courts statistics available at http://www.uscourts.gov/Statistics/BankruptcyStatistics.aspx.

scatter plot of the average ranking of individual firms on the horizontal axis against the standard deviation of that ranking on the vertical axis in Figure 5. Its shape prompts us to name it the *boomerang curve*.

This boomerang curve has a useful and intuitive interpretation. Firms located near the origin are consistently highly systemic - they are consistently ranked amongst the most systemic firms through time. These firms are clearly of interest to macroprudential authorities. In contrast, firms at the other end of the boomerang are consistently amongst the least systemic firms, and are of little concern. The other group of interest involves firms located near the apex of the boomerang - those with a middling average rank, but high standard deviation. These firms have demonstrated the potential to be systemically important, despite their on average benign appearance.

Figure 5: Boomerang Curve



The squares represent insurance companies, the 'x' represent deposit-taking firms, while the asterisks represent other financial sector firms. Open circles represent non-financial firms.

The 'x' in Figure 5 show the location of the deposit-taking firms, while squares show the insurers. Other financial sector firms are given by asterisks and real economy firms by open circles. It is immediately apparent that not only are there a substantial number

of systemically important financial sectors near the origin, but that there is a distinct pattern in the location of banks and insurers that contributes immediately to the policy debate. Of the most systemically important financial firms, the deposit taking firms are nearest the origin - that is they are consistently the most systemic; in particular this group includes within the first 50 x 50 grid; JPMorgan Chase, Lehman Brothers, Bank of America, Wells Fargo, Goldman Sachs US Bancorp, Morgan Stanley and PNC Financial Services Group. Insurers comprise a broad second group - with Principal Financial, Loews, MetLife, Prudential and Allstate clustering together. This is entirely consistent with the existing rhetoric from both the discussion and empirical evidence of the academic literature, regulators and the industry that insurance is not as systemically important as banking.

A different pattern emerges near the apex of the boomerang. The firms nearest the apex (and their co-ordinates) are AIG (238,201), Synovus (211,202), Unum (235,178), that is two insurers – AIG and Unum – and a community bank. The AIG case has been subject to detailed analysis – Harrington (2009) provides an excellent review – particularly detailing the complex nature of this conglomerate of over 70 companies in 2006, their high exposure to the CDS market, mortgages, securities lending, and the extent to which their fate was interwoven with that of the banking sector. Harrington (2009) makes a convincing case that the rescue of this company was critically affected by considerations of their counterparty relationships. Many banking sector firms would have been seriously affected by failure of AIG – and this extended well beyond simple US counterparties, the EU banking system was highly vulnerable to any potential collapse in AIG.

The case of Unum is cloudier than most, as it is considerably complicated by a significant settlement package in May 2008 around allegations of artificially inflating stock prices during the early part of the decade. This couples with a number of significant settlements regarding bad faith practices in insurance payouts and company rebranding from UnumProvidential to Unum in 2007 to make this a particularly difficult firm to characterise.

The path of Synovus reflects their rapid decline from a record profit year in 2006, accompanied by ambitious geographical expansion plans to a group with a goodwill impairment of $480million in 2008, badly affected by decline in the housing market in its regional homeland in the South Eastern States and making financial losses every year from 2008 to 2011 (Synovus Annual Reports 2006-2012). Synovus had sufficiently impaired capital that it undertook a $968 million TARP contract with the US Treasury, and had a substantially longer period until repayment in July 2013 than most institutions.[11] As part of its return

[11]Extensions of TARP liabilities beyond December 2013 attract a higher rate of return to Treasury.

to profitability in 2012 it has undergone a dramatic restructure, consolidating its previous 30 banking charters into one organisation, but attempting to carefully retain its image as a community based bank.

A number of other institutions, such as Zions and Marsh and McLennan, are in this region in terms of ranking but with lower standard deviation – although this must be placed in context that the standard deviation remains considerably above that of the majority of real sector firms. The other institution clearly above the cluster, but slightly right of this group is Freddie Mac (314,172), who, along with Fannie Mae, were taken into conservatorship on September 6, 2008 before returning to government sponsored enterprise status - Fannie Mae on the other hand may be found to the right of the distribution at coordinates (416,84). The firms of no regulatory interest, that is those in the extreme right of the boomerang curve, are typically not from the financial sector, although one deposit taking institution, the People's United Financial is in the consistently least systematically important group.

The results support the industry and regulatory claims that insurance companies are less systemically important than the banking sector. However, as an industry group, the insurance companies are clustered immediately behind the banking sector in the systemic threat they pose to the economy. This comes about due to the strong interlinkages both within the financial sector, between banking and insurance, see also Schwarcz and Schwarcz (2014), but also through their strong links to the real economy – both through the insurance services they provide and their ventures into non-traditional products which form the shadow banking sector and thus an important part of credit creation for non-financial firms.

If macro-prudential regulation is designed to limit the disruptions to the real economy caused by withdrawal and contraction in credit markets then the growing presence of insurers in this market argues strongly for their inclusion in a regulatory framework which recognises the differential nature of their underlying customer base, whereby runs on insurance policies are unlikely although catastrophic events challenge capital periodically. The challenge will be to avoid regulatory arbitrage emerging in another sector of the economy to exploit the highly profitable business of the credit risk transfer services which are highly valued by the non-financial consumer and producer sectors of the economy.

6 Conclusions

The expansion of macroprudential regulatory practice to include insurance companies is well underway in the aftermath of the 2008-2009 crisis. While the US has retained its largely state-based approach to insurers, international regulatory practice is proceeding to establish rules and practices by which to identify potentially systematically important insurers; see of Insurance Supervisors (2013) for example, and many other nations are moving to joint regulatory national oversight of deposit-taking and insurance companies. While there is substantial evidence that traditional insurance products themselves are not likely to provoke systemically risky events, many insurers are now involved in product markets more typically associated with credit creation and banking functions, or in markets that intrinsically link them to the banking sector. Likewise many deposit taking institutions have diversified into insurance products. These two facets of the financial sector are strongly intertwined as companies look for profitable products and investment opportunities, and to some extent indulge in regulatory arbitrage.

This paper provides a measure of systemic risk for the insurance sector as represented by companies listed in the S&P500 involved in the insurance industry. To that end we miss non-listed companies or those with lower capital value. However, we compare this group with similar firms from the banking and real economy sectors. Specifically we measure systemic risk by interconnectedness, one of the major contributors to the identification of Globally Important Insurers from the of Insurance Supervisors (2013). We find an evolving pattern for systemic risk in the insurance sector using market based data which is consistent with balance sheet interpretations and the SRISK analysis of Acharya and Richardson (2014). During the period from 2003-2006 systemic risk in this sector was declining, representing the perceived diversification in the sector as insurance companies expanded their activities following the repeal of Glass-Stegal. During this time many took on credit-risk transfer products emerging from the banking sector and extended lines of credit, many of these products were in retrospect underpriced and some of which exposed them to the housing market. The turning point in the index mirrors the turning point in the systemic risk iin deposit taking institutions. After the peak in US housing prices banks reduced their growing credit to this sector, and price falls in housing impacted on the books of the insurance sector. The growing systemic importance through interconnectedness of the insurance sector for the real economy was cut with the rescue of AIG in September 2008, leading investors to separate the insurance products from the building woes in the real economy firms.

The question of whether insurance firms are truly of macroprudential regulatory concern is hotly debated by the industry. Traditional insurance products have a steady flow of income and ocassional large calls on capital with a catastrophic event such as Hurricane Katrina. Unlike the banking sector it is not subject to runs. However, when the product lines offered by the institutions in both sectors begin to blur so do the regulatory implications. Our evidence shows that the banking sector does play the most consistently systemically risky financial firms in the sample are deposit-taking institutions. However, there is a distinct cluster of insurance firms which follow this grouping, validating the claim that the insurance sector has a role to play in potentially transmitting systemic risk. It may well be that insurance products themselves are not vehicles for triggering crisis events, although see Acharya and Richardson (2014) for a contrasting view, however, the intertwining of this sector with the banking sector and their ventures into products supporting credit creation in the economy, mean these firms are an identifiable group where risk transfer to the real economy may potentially be reduced with regulatory action.

References

Acharya, V. V. and M. Richardson (2014). Is the insurance industry systemically risky? In J. H. Biggs and M. Richardson (Eds.), *Modernizing Insurance Regulation*, pp. 151–180. New Jersey: Wiley.

Andersen, T. G., T. Bollerslev, F. X. Diebold, and H. Ebens (2001). The distribution of realized stock return volatility. *Journal of Financial Economics 61*, 43–76.

Andersen, T. G., T. Bollerslev, F. X. Diebold, and P. Labys (2003). Modeling and forecasting realized volatility. *Econometrica 71*, 579–625.

Andersen, T. G., T. Bollerslev, F. X. Diebold, and C. Vega (2007). Real–time price discovery in global stock, bond and foreign exchange markets. *Journal of International Economics 73*, 251–277.

Archarya, V., L. Pederson, T. Phillipon, and M. Richardson (2011). Measuring systemic risk. Technical report, NYU Stern Working Paper.

Baluch, F., S. Mutenga, and C. Parsons (2011). Insurance, systemic risk and the financial crisis. *The Geneva Papers 36*, 126–163.

Bandi, F. and J. Russell (2006). Separating micro structure noise from volatility. *Journal of Financial Economics 79*, 655–692.

Barndorff-Nielsen, O. E. and N. Shephard (2004). Power and bipower variation with stochastic volatility and jumps. *Journal of Financial Econometrics 2*, 1–48.

Bekaert, G., M. Ehrmann, M. Fratzscher, and A. J. Mehl (2010). Global crises and equity market contagion. Technical report, NBER. Working paper 17121.

Biggs, J. H. and M. Richardson (2014a). *Modernizing Insurance Regulation*. New Jersey: Wiley.

Biggs, J. H. and M. Richardson (2014b). Modernizing insurance regulation: An overview. In J. H. Biggs and M. Richardson (Eds.), *Modernizing Insurance Regulation*, pp. 1–18. New Jersey: Wiley.

Billio, M., M. Getmansky, D. Gray, A. Lo, R. C. Merton, and L. Pelizzon (2013). Sovereign, bank and insurance credit spreads: Connectedness and system networks. Technical report. manuscript.

Billio, M., M. Getmansky, A. Lo, and L. Pelizzon (2012). Econometric measures for connectedness and systemic risk in the finance and insurance sectors. *Journal of Financial Economics 104*, 535–559.

Boyson, N. M., C. F. Stahel, and R. M. Stulz (2010). Hedge fund contagion and liquidity shocks. *The Journal of Finance 65*, 1789–1816.

Brownlees, C. and R. Engle (2011). Volatility, correlation and tails for systemic risk measurement. Technical report, NYU. manuscript.

Chen, H., J. D. Cummins, K. S. Viswanathan, and M. A. Wiess (2013). Systemic risk and the interconnectedness between banks and insurers: An econometric analysis. *The Journal of Risk and Insurance forthcoming*.

Cummins, J. D. and M. A. Weiss (2014a). Systemic risk and regulation of the U.S. insurance industry. In J. H. Biggs and M. Richardson (Eds.), *Modernizing Insurance Regulation*, pp. 85–136. New Jersey: Wiley.

Cummins, J. D. and M. A. Weiss (2014b). Systemic risk and the U.S. insurance sector. *The Journal of Risk and Insurance forthcoming*.

Darolles, S., P. Gagliardini, and C. Gourieroux (2012). Survival of hedge funds: Frailty vs contagion. Technical report, CREST. manuscript.

Demyanyk, Y. and O. Van Hemert (2011). Understanding the subprime mortgage crisis. *Review of Financial Studies 24*, 1848–1880.

Dungey, M., G. P. Dwyer, and T. Flavin (2013). Systematic and liquidity risk in sub-prime mortgage backed securities. *Open Economies Review 24*, 5–32.

Dungey, M., M. Luciani, and D. Veredas (2013). Googling SIFIs. Technical report, University of Tasmania. Working paper.

Dungey, M., M. MacKenzie, and V. Smith (2009). Empirical evidence of jumps in the term structure of the U.S. treasury market. *Journal of Empirical Finance 16*, 430–445.

Eatwell, J. (2004). International regulation, risk mangement and the creation of instability. Technical report, University of Cambridge. Lecture at the IMF: October 1, 2004.

Harrington, S. E. (2009). The financial crisis, systemic risk, and the future of insurance regulation. *The Journal of Risk and Insurance 76*, 785–819.

Harrington, S. E. (2014). Designation and supervision of insurance sifis. In J. H. Biggs and M. Richardson (Eds.), *Modernizing Insurance Regulation*, pp. 137–150. New Jersey: Wiley.

Khandani, A. E., A. W. Lo, and R. C. Merton (2013). Systemic risk and the refinancing ratchet effect. *Journal of Financial Economics 108*, 29–45.

Kiyotaki, N. and J. Moore (2002). Balance-sheet contagion. *The American Economic Review 92*, 46–50.

Koijen, R. S. and M. Yogo (2013). Shadow insurance. Technical report, London Business School. manuscript.

Lahaye, J., S. Laurent, and C. J. Neely (2011). Jumps, cojumps and macro announcements. *Journal of Applied Economics 26*, 839–921.

Longstaff, F. (2010). The subprime credit crisis and contagion in financial markets. *Journal of Financial Economics 97*, 436–450.

Luciani, M. and D. Veredas (2011). A model for vast panels of volatilities. Technical report, ECARES. Working paper 28.

Masters, B. (2013). Insurers claim unfair comparison with banks. *Financial Times*, 21 July 2013.

Nijskens, R. and W. Wagner (2011). Credit risk transfer activities and systemic risk: How banks became less risky individually but posed greater risks to the financial system at the same time. *Journal of Banking and Finance 35*, 2011.

of Insurance Supervisors, I. A. (2013). Globally systemic important insurers: Policy measures. Technical report.

Paulson, A., T. Plestis, R. Rosen, R. McMenamin, and Z. Mohey-Deen (2014). Assessing the vulnerability of the U.S. life insurance industry. In J. H. Biggs and M. Richardson (Eds.), *Modernizing Insurance Regulation*, pp. 61–84. New Jersey: Wiley.

Poirson, H. and J. Schmittmann (2013). Risk exposures and financial spillovers in tranquil and crisis times: Bank-level evidence. Technical report, IMF. Working Paper WP/13/142.

Prudential Regulation Authority (2013). The prudential regulation authority's approach to insurance supervision. Technical report, Prudential Regulation Authority.

Schwarcz, D. and S. L. Schwarcz (2014). Regulating systemic risk in insurance. *The University of Chicago Law Review 81*.

StateStreet (2013). Vision the insurance industry: Facing the future: Blueprint for growth. Technical report. Report on Survey conducted by the Economist Intelligence Unit.

Trichet, J.-C. (2009). Systemic risk. Technical report, Clare College, University of Cambridge. Clare Distinguished Lecture in Economics and Public Policy.