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Insurance activities and systemic risk

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Insurance Activities and Systemic Risk

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Abstract

This paper investigates systemic risk in the insurance industry. We first analyze the systemic contribution of the insurance industry vis-à-vis other industries by applying 3 measures, namely the linear Granger causality test, conditional value at risk and marginal expected shortfall, on 3 groups, namely banks, insurers and non-financial companies listed in Europe over the last 14 years. We then analyze the determinants of the systemic risk contribution within the insurance industry by using balance sheet level data in a broader sample. Our evidence suggests that *i)* the insurance industry shows a persistent systemic relevance over time and plays a subordinate role in causing systemic risk compared to banks, and that *ii)* within the industry, those insurers which engage more in non-insurance-related activities tend to pose more systemic risk. In addition, we are among the first to provide empirical evidence on the role of diversification as potential determinant of systemic risk in the insurance industry. Finally, we confirm that size is also a significant driver of systemic risk, whereas price-to-book ratio and leverage display counterintuitive results.

Keywords: Systemic Risk, Insurance Activities, Systemically Important Financial Institutions
JEL Classification: G01, G22, G28, G32

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1 Introduction

Following the 2007-2009 financial crisis and the 2010-2012 European sovereign debt crisis, the concept of systemic risk has become increasingly relevant.[1] After the collapse of Lehman Brothers in particular, the debate on systemic risk has been primarily focused on banks.[2] However, recent empirical evidence suggests that institutions not traditionally associated with systemic risk, such as insurance companies, also play a prominent role in posing systemic risk. In particular, some authors find that the insurance industry has become a non-negligible source of systemic risk (e.g. Billio et al. (2012) and Weiß and Mühlnickel (2014)). This is partially in contrast to other authors, who do not find evidence of systemic relevance for the industry as a whole (e.g. Harrington (2009), Bell and Keller (2009) and Geneva Association (2010)). Finally, other authors take a more granular perspective and argue that insurance companies might be systemically relevant, but that such risk stems from non-traditional (banking-related) activities (Baluch et al. (2011) and Cummins and Weiss (2014)) and that in general, the systemic relevance of the insurance industry as a whole is still subordinated with respect to the banking industry (Chen et al., 2014).

As the current literature does not provide a common understanding and clear evidence regarding the systemic relevance of the insurance industry and the activities connected thereto, we thus aim with this paper to fill this gap. In particular, we investigate *i)* the systemic relevance of the insurance industry vis-à-vis other industries and *ii)* the key drivers of systemic risk within the insurance industry.

To do so, we test 3 equity return-based measures of systemic risk, namely *1)* the indexes based on linear Granger causality tests proposed by Billio et al. (2012) (Granger test), *2)* the conditional value at risk proposed by Adrian and Brunnermeier (2011) (ΔCoVaR) and *3)* the dynamic marginal expected shortfall proposed by Brownlees and Engle (2012) (DMES), on 3 groups, namely banks, insurers and non-financial companies, all listed in Europe. We test the systemic relevance of each institution with respect to its own industry (*intra-industry*), with respect to *other industries* and with respect to the *total system*. Based on these estimations, we rank financial institutions according to their average systemic risk contribution over time and create an *industry composition index*. Finally, we investigate the drivers of systemic risk within

[1] Throughout this paper, we rely on the definition of systemic risk given by the Group of Ten (2001): *Systemic risk is the risk that an event will trigger a loss of economic value or confidence in a substantial segment of the financial system that is serious enough to have significant adverse effects on the real economy with high probability.*

[2] Lehman Brothers Holdings Inc. filed for Chapter 11 bankruptcy protection on September 15, 2008.

the insurance industry by focusing on the asset and liability composition of insurers' balance sheets.

Our evidence suggests that the insurance industry tends to persistently pose systemic risk over time and to play a subordinate role with respect to the banking industry, with some distinction in specific periods when the insurance industry becomes more systemic than the banking industry. Furthermore, we show that insurers with a relatively larger proportion of non-insurance-related activities tend to pose more systemic risk. In addition, we are among the first to provide evidence on the role of diversification of the asset portfolio with respect to systemic risk. We also find and confirm previous evidence that price-to-book and size do matter, whereas leverage seems to play an ambiguous role. Finally, our results are robust across different specifications and different samples.

The paper is organized as follows: section 2 provides a comprehensive literature review, section 3 describes the methodology and the data; section 4 describes the results and section 5 concludes the analysis.

2 Literature review

The literature on systemic risk has been steadily growing following the crises.[3] In particular, a wide range of new empirical methods for testing the systemic risk contribution of financial institutions has been proposed. Moreover, both academia and regulators have dedicated more attention to the role of non-banking financial institutions: among these institutions, insurance companies emerged as a potential source of systemic risk.[4]

Before the crises, there was substantial agreement among scholars in considering the insurance industry to be not systemically relevant. However, in the literature that emerged in the aftermath of the crises, although many studies still consider the insurance industry non-systemically relevant as a whole, some authors argued that the insurance industry might have become systemically relevant, particularly in a number of specific activities. Many agree in ranking non-core life insurance activities as the most systemically relevant, whereas core non-life insurance activities are considered the least systemically relevant. In addition, an ambiguous position is attributed to reinsurance activities.[5]

[3] By crises we mean both the 2007-2009 financial crisis and the 2010-2012 European sovereign crisis.

[4] A comprehensive review of the literature on systemic risk in the insurance industry is provided by Eling and Pankoke (2012).

[5] Studies by Swiss Re (2003) and by The Group of Thirty (2006) tend to exclude any systemic relevance for

Cummins and Weiss (2014) argue that according to primary indicators and contributing factors, such as leverage, interconnectedness and size of exposure to credit, market and liquidity risk, the most systemically relevant activities are non-core activities conducted mainly by life insurers. Moreover, Harrington (2009) concludes that systemic risk is potentially higher for life insurers due to the higher leverage, sensitivity to asset value decline and potential policyholder withdrawals during a financial crisis, whereas systemic relevance is relatively low in property and casualty (P&C) insurance due to low leverage ratios. Furthermore, by analyzing the takeover of AIG by the Federal Government in the United States, the author suggests that the AIG crisis was heavily influenced by the credit default swaps (CDS) written by AIG financial products and not by more traditional insurance products written by AIG's regulated insurance subsidiaries. The Geneva Association (2010) conducted an analysis on the role played by insurers during the 2008 crisis and argues that the substantial differences between banks and insurance companies, namely the long-term liability structure of insurers compared to banks and the strong cash flow granted by the inversion of the cycle, is sufficient to rule out systemically any implications of the insurance industry during the financial crises aside from the companies highly exposed towards non-core insurance activities. Bell and Keller (2009) analyze the relevant risk factors stemming from an insurance company and conclude that traditional insurers do not pose systemic risk and, as a consequence, are neither too big nor too interconnected to fail, and that insurers engaging in non-traditional activities, such as CDS, can pose substantial systemic risk. Baluch et al. (2011) provide further arguments for the lower relevance of P&C activities and the higher relevance of non-traditional life activities: the authors argue that the fundamental reason lies in the bank-like business type and the massive amount of interconnectedness needed to run these kinds of activities.

The concept of interconnection, as expressed, among others, in Baluch et al. (2011), represents the link between analyses focused on industry-specific characteristics and more general equity-based analyses in which prices reflect all the necessary information.[6] Equity-based measures aim to measure the effect of one institution on the system or vice versa and the level of interconnectedness of the system. These measures include the ΔCoVaR (Adrian and Brunnermeier (2011)), the MES and DMES (Acharya et al. (2010) and Brownlees and Engle (2012)), the Distressed Insurance Premium (DIP) (Huang et al. (2012)), Contingent Claims Analysis (CCA)

the reinsurance business. On the other hand, Cummins and Weiss (2014) claim that, despite historical evidence, both life and P&C insurers are exposed to reinsurance crises.

[6] A comprehensive review of the models applied to systemic risk is provided by Bisias et al. (2012).

(Gray and Jobst (2011)) and the linear and non-linear Granger causality test proposed by Billio et al. (2012). According to such measures, the insurance industry displays different degrees of systemic relevance. For instance, Acharya et al. (2010) argue that insurance companies are overall the least systemically relevant financial institutions. The authors provide estimations of the spillover effects through a measure of conditional capital shortfall, i.e. Systemic Expected Shortfall (SES) and MES for the U.S. financial industry during the 2007-2009 crisis. The contribution of Adrian and Brunnermeier (2011) extends the traditional value at risk concept to the entire financial system conditional on institutions being in distress. The authors apply the measure to a set of institutions, including banks and thrifts, investment banks, government sponsored enterprises and insurance companies, finding no distinction among the systemic relevance of different types of institutions. In contrast, Billio et al. (2012) apply the linear and non linear Granger causality test to a sample of banks, insurers, hedge funds and broker dealers operating in the U.S. in order to establish pairwise Granger causality among equity returns of financial institutions. Their evidence suggests that during the 2008 financial crisis, besides banks, insurance companies were a major source of systemic risk. This conclusion is partially in contrast to Chen et al. (2014): the authors agree that the linear Granger causality test attributes a systemic relevance to insurance companies comparable to the systemic relevance of banks. However, they argue that when applying a linear and non-linear Granger causality test to the same series corrected for heteroskedasticity, banks tend to cause more systemic risk and for longer periods of time then insurance companies. Weiß and Mühlnickel (2014) and Bierth et al. (2015) focus directly on the link between equity-based systemic risk measures and industry-specific fundamentals. Weiß and Mühlnickel (2014) estimate the systemic risk contribution based on ΔCoVaR and MES for a sample of U.S. insurers during the 2007-2008 crisis, inferring that insurers that were most exposed to systemic risk were on average larger, relied more heavily on non-policyholder liabilities and had higher ratios of investment income to net revenues. Bierth et al. (2015) analyze a much broader sample of insurers over a longer time horizon and find that the systemic risk contribution of the insurance sector is relatively small. However, they also argue that the contribution of insurers to systemic risk peaked during the 2007-2008 financial crisis and find that the interconnectedness of large insurers with the insurance industry is a significant driver of the insurers exposure to systemic risk. Finally, they argue that the contribution of insurers to systemic risk appears to be primarily driven by leverage, loss ratios and funding fragility.

Concluding, the existing literature provides a diversified and controversial picture of the systemic relevance of the insurance industry. In particular, there is a lack of empirical evidence on the link between industry-specific activities and their contribution to systemic risk measured by equity prices. On the one hand, some studies argue that due to its nature, the insurance industry does not pose systemic risk, and therefore measures based on equity values might be misled by spurious effects (e.g. increased risk aversion vis-à-vis the financial industry); on the other hand, some studies provide evidence on the role of the insurance industry in posing systemic risk and its growing importance in recent years. Yet, few studies attempt to analyze empirically the relative position of the insurance industry vis-à-vis other industries and the key drivers within the insurance industry. This contribution thus aims at bridging this gap by investigating the systemic risk contribution of the insurance industry relative to other industries and the key determinants on the balance sheet of insurers. Moreover, this is the first study that focuses on European insurers.

3 Methodology & Data

Our analysis consists of 2 steps:

i) we conduct an analysis of the systemic risk contribution of the insurance industry vis-à-vis other industries using equity-based measures of system risk (*industry analysis*);

ii) we then conduct an empirical analysis at balance sheet level of a broader sample of European insurers based on their systemic risk contribution (*analysis of fundamentals*).

3.1 Systemic Risk Measures and Rankings of Systemic Risk Contributions

For the industry analysis, we apply 3 widely used equity-based measures of systemic risk: *1)* **the Granger causality test** proposed by Billio et al. (2012), *2)* the **ΔCoVaR** proposed by Adrian and Brunnermeier (2011) and *3)* the **DMES** proposed by Brownlees and Engle (2012).[7] We identify 3 groups, namely banks, insurers and non-financials. In addition, for each systemic risk measure and for each group, we distinguish between 3 cases: the average contribution of the individual institution belonging to a single group *a)* within its group (*intra-industry*), *b)* towards the other 2 groups (*other industries*) and *c)* towards all 3 groups (*total system*).[8] We

[7] An extensive mathematical treatment of the 3 measures is provided in Appendix A.1.
[8] An extensive mathematical explanation of how the 3 cases are calculated is provided in Appendix A.1.

then calculate the average contribution of each industry by taking the median of the month (for the ΔCoVaR and the DMES, whereas the Granger causality test is calculated on a monthly basis) and the average through the institutions of the same industry. Finally, at each point in time, we rank the institutions of the total system from the *most* to the *least* systemically relevant according to each systemic risk measure. We then select the top 10 institutions at each point in time and calculate the relative weight of each industry within the top 10 over time, thereby creating an index. More formally, the group of selected institutions at each point in time is defined as

$$S_t^k = \{i_{1,t} > ... > i_{n,t} > ... > i_{10,t}\} \tag{1}$$

in which i_n represents an institution ranked from the most to the least systemic (with $n = 1 \rightarrow$ *most systemic*) according to the k measure, with k = Granger, ΔCoVaR, DMES. Then, the index for each systemic risk measure k is obtained as follows

$$I_t^k = \begin{cases} \frac{\sum_{n=1}^{10} \mathbb{1}_{i_{n,t}=Bank}}{10} \\ \frac{\sum_{n=1}^{10} \mathbb{1}_{i_{n,t}=Insurer}}{10} \\ \frac{\sum_{n=1}^{10} \mathbb{1}_{i_{n,t}=Non-Financial}}{10} \end{cases} \tag{2}$$

in which $\mathbb{1}$ is an indicator function that takes value 1 if the condition (e.g. if $i_n = Bank$) is met and 0 otherwise. Sums are then scaled between 0 and 1. Finally, we group all 3 indexes and form the total index, which is given by

$$I_t^{tot} = \begin{cases} \frac{\sum_k \sum_{n=1}^{10} \mathbb{1}_{i_{n,k,t}=Bank}}{3 \cdot 10} \\ \frac{\sum_k \sum_{n=1}^{10} \mathbb{1}_{i_{n,k,t}=Insurer}}{3 \cdot 10} \\ \frac{\sum_k \sum_{n=1}^{10} \mathbb{1}_{i_{n,k,t}=Non-Financial}}{3 \cdot 10} \end{cases} \tag{3}$$

It is worth remarking that the 3 systemic risk measures that we test in the analysis tend to represent different phenomena and therefore need to be correctly interpreted. The Granger causality test is a measure that allows us to quantify the degree of connectedness of an institution vis-à-vis a system of institutions. By creating a network of pairwise statistical relations, we can observe not only the degree of interdependence, but also the direction thereof. The measure is thus a good proxy for an analysis at an aggregate level (for example industry or other clusters), but its estimation could become cumbersome when the objective is to test the

individual interconnection with respect to a system of institutions as proxy for the market.[9] The ΔCoVaR measures the difference between the CoVaR conditional on the distress of an institution, i.e. the value-at-risk of the system conditional on an institution being in distress and the CoVaR conditional on the normal state of the institution. It is therefore able to capture the marginal contribution of a particular institution to the overall systemic risk. One of the main advantages of such a measure is its ability to capture the individual contribution of each institution to the system. Finally, the DMES measures, in a dynamic setting, the expected drop in equity value of an institution when the system is in distress. It is worth mentioning that this is not a direct measure of systemic risk, but is highly related to it. The contribution of Brownlees and Engle (2012) originates from the proposal of Acharya et al. (2010), in which the marginal expected shortfall of an institution coupled with its leverage, originate the systemic expected shortfall (SES), i.e. the expected capital shortage of an individual firm conditional on a substantial reduction in the capitalization of the system. The authors propose a similar measure called SRISK, which is based on a dynamic estimation of the MES and leverage ratios. A major advantage of such a contribution is its ability to capture time-varying effects, effects which are not observable following Acharya et al. (2010). However, both Brownlees and Engle (2012) and Acharya et al. (2010) estimate such systemic risk measures relying on the estimation of the marginal expected shortfall (MES) and of pre-determined leverage ratios: in order to avoid additional assumptions that might cast doubts on the reliability of the estimation,[10] we simply rely on the directly observable part of the measure, i.e. the DMES, which is sufficient to provide information on the individual fragility of the individual institution with respect to market tail events, which in turn have potential systemic implications.[11]

3.1.1 Data

The data set for the industry analysis consists of equity returns of 60 companies listed in Europe over a time window of 14 years, from January 1999 to December 2013, which becomes 17 years (i.e. from January 1996 to December 2013) for the Granger causality test due to the

[9] By market, we essentially mean a broad measure and proxy for the (real) economic activity such as a major stock index. Throughout the paper, we therefore interchangeably use the terms system and market as (almost) perfect substitutes.

[10] However, it is worth noting that Brownlees and Engle (2012) provide a series of robustness checks on the stability of the parametrization of the SRISK measure.

[11] Another major issue we face regarding the estimation of the SRISK is the frequency of the accounting data: since we focus on European insurers, we do not possess sufficiently long quarterly series of balance sheet data.

lag on the series.[12] For each group, we select the top 20 institutions in terms of capitalization from STOXX® Euro 600 Banks, STOXX® Euro 600 Insurance and STOXX® Europe 600 for banks, insurers and non-financials respectively.[13] Table 1 reports the list of the selected institutions, while table 2 reports the industry distribution of non-financial institutions. Data were collected both at daily and monthly frequencies. Table 3 reports the summary statistics of the 3 groups. To calculate the ΔCoVaR, we rely on a set of state variables as proposed in Adrian and Brunnermeier (2011), namely *i)* Market volatility (VIX for Europe), *ii)* Liquidity spread (3M Repo - 3M Bubill), *iii)* change in the short-term interest rate (3M Bubill), *iv)* the slope of the yield curve (10Y Bund - 3M Bubill), *v)* credit spread (BAA 5-7Y Corporate (Bank of America) - EURO Sovereign 5-7Y (Barclays)), *vi)* market returns (STOXX EURO 600 All shares). Table 4 reports the summary statistics for the state variables. Finally, tables 5, 6 and 7 report the summary statistics of monthly and daily returns for banks, insurers and non-financials respectively.

3.2 Systemic Risk Measures and Insurers' Fundamentals

For the analysis of fundamentals, we investigate the relation between asset and liability compositions and systemic risk measures. In particular, we focus on items on the balance sheet rather than on the income statement, i.e. measures of *stock* rather than *flow*. This is justified by the fact that the insurance industry is a liability-driven business which often entails a long-term horizon in which the ability to maintain outstanding financial promises might change over time.[14] The outstanding stocks, and therefore the underlying past and current capital allocation decisions, i.e. underwriting decisions and consequent asset allocation, thus have a profound impact on the dynamics of the value of the institution, especially when sudden changes in market conditions, such as the 2007-2009 financial crisis, occur.[15] Thus, it is worth dissecting the different components of the insurance balance sheet in order to understand where potential sources of systemic risk are. In addition, the analysis focuses on the business conducted at

[12] Data were downloaded from Datastream®.

[13] Within each group, companies are ranked according to the yearly average market capitalization over the 14-year time frame. We selected those companies which were continuously listed over the period.

[14] This is particularly true in the life and health business segment.

[15] In a public speech, the President of the European Central Bank (ECB) Mario Draghi emphasized this point and stated that "(...) *The models were built on flows, with little or no attention paid to stocks. But it was precisely from stocks that the irregularities and hence the crisis arose. Non linearities arise on a balance sheet when capital falls to zero and the agent goes into default* (...)" (Draghi, 2012). For a much broader perspective on stocks vs. flows, see for instance Borio and Disyatat (2011).

shareholders' risk, namely excluding items for which risk is borne by policyholders.[16] In this part of the analysis, we are thus able to test which features drive the contribution of insurers to systemic risk.

In order to test the relation between relevant balance sheet items and systemic relevance, we run OLS regressions with yearly fixed effects of the lagged individual insurer balance sheet characteristics on the individual systemic risk measure.[17] We specify a model that includes both asset and liability based indicators. This model allows on the one hand to separately analyze the systemic implications stemming from underwriting and investment decision[18] and on the other hand to avoid potential biases, such as omitted variables.

The baseline model for the i^{th} insurer is given by the following:

$$SR_t^i = \beta_0 + \beta_1 \cdot Price-to-book_{t-1}^i + \beta_2 \cdot Leverage_{t-1}^{i,A/L} + \beta_3 \cdot Size_{t-1}^{i,A/L} + \sum_j \beta_j \cdot X_{j,t-1}^i + \epsilon_t^i \quad (4)$$

in which *Price-to-book* is the market value to book value ratio, $Leverage^A$ is the ratio between tangible assets and tangible equity and $Leverage^L$ the ratio between liabilities and tangible equity, $Size^A$ is the logarithm of tangible assets and $Size^L$ is the logarithm of liabilities.[19] We specify both *Leverage* and *Size* in 2 different (but analogous) ways in order to avoid multicollinearity problems when regressing on the relevant balance sheet items and proxies.

X_j includes a set of balance sheet items and proxies for specific factors which may influence the systemic risk contribution of an insurance company. These include *Concentration*, *Investment Quality*, *Fixed Income Assets*, *Equity Assets*, *Cash*, *Insurance Activities*, *Total Debt* and *Separate Accounts*. More specifically, *Concentration* is the Herfindahl-Hirschman index (H-H) with respect to asset classes of the portfolio's holdings which broadly captures the degree of diversification of the portfolio[20]; *Investment Quality* is the amount of at least A-rated assets which proxies the quality of the asset allocation with respect to credit risk[21] and *Fixed Income Assets*, *Equity Assets* and *Cash* are the amount of fixed income, equity and cash assets classes

[16] This business is usually categorized as unit-linked or separate account business.

[17] We introduce the lag as to avoid endogeneity issues.

[18] It is worth noticing how underwriting decisions tend to shape investment decisions consistently with the typical liability-driven business approach of the insurance industry, but decisions on the asset allocation might be also influenced by other factors, such as the need to deliver investment performances, and not being limited to the replication of the liability portfolio.

[19] *Price-to-book*, *Leverage* and *Size* are usually identified as key drivers of systemic risk in financial institutions, see for instance Weiß and Mühlnickel (2014).

[20] The H-H index is a widely applied measure of concentration: it is computed as follows $\frac{\sum_i x_i^2}{(\sum_i x_i)^2}$. For its original applications, see Hirschman (1964).

[21] This typically includes fixed income assets as the rating mainly refers to credit risk.

respectively. Finally, *Insurance Activities* is the amount of insurance activities among total activities, *Total Debt* is the amount of debt which includes senior debt, i.e. mainly deposits for banking activities, and subordinated debt, *Separate Accounts* is the amount of business which is not at shareholder risk.[22]

3.2.1 Hypotheses and Expected Contributions

It is worth clarifying beforehand the expectations with respect to the marginal contribution of single factors on systemic risk. To this purpose, we formulate 2 ex-ante hypotheses: the first one is the following

H.1) The Systemic Risk contribution of insurers is mainly driven by the liability side, i.e. its capital structure.

In particular, we expect *Insurance Activities* as a proxy for traditional insurance business, to exert a negative contribution to systemic risk, i.e. $\frac{\partial SR}{\partial I.A.} < 0$; by contrast *Total Debt* is expected to positively contribute to systemic risk, i.e. $\frac{\partial SR}{\partial T.D.} > 0$: this could be loosely interpreted as proxy for banking activities, since deposits are classified as senior debt, but also more broadly as non-insurance activities. Finally, *Separate Accounts* (or unit-linked business) is expected to be insignificant as most of the risk connected to such business are transferred to policyholders.

An implication of such hypothesis is that the asset side tends to play a subordinated role in posing systemic risk in insurance, although its level of diversification and its credit quality might turn out to be relevant factors since underwriting decisions tend to be replicated in the asset side.[23] More formally, *Concentration* is a proxy for the degree of diversification of the asset portfolio. By a micro perspective, a higher degree of diversification could have a positive impact on the single institution in terms of risk diversification. However, by a macro perspective a higher degree of diversification could have a negative impact on the overall system due to the higher degree of interconnectedness among institutions. [24] Hence, as interconnectedness is a potential source of systemic risk (Billio et al., 2012), we formulate a second hypothesis:

H.2) A higher diversification of investments is associated with a higher contribution to systemic risk.

[22] Table 8 reports a detailed overview of the variables used throughout the analyses.

[23] In other words, (re)insurers focused on traditional insurance activities adopt asset and liability management strategies through which risks undertaken on the liability side are hedged (replicated) through the asset side.

[24] An extensive treatment of the argument is provided among others by Das and Uppal (2004), Wagner (2010), Ibragimov et al. (2011) and Raffestin (2014).

More specifically we expect *Concentration* to negatively contribute to the systemic relevance of an institution, i.e. $\frac{\partial SR}{\partial C.} < 0$. In addition, also *Fixed Income Assets*, *Equity Assets* and *Cash* might be significant contributors to systemic risk, in particular bonds might be expected to display a negative sign due to the generally lower degree of risk compared to equity, which in turn we expect to be a positive contributor and cash can be expected to display a negative sign as it could be loosely interpreted as a proxy for liquidity.

Finally, *Price-to-book*, $Leverage^{A/L}$ and $Size^{A/L}$ are in general positive contributor to systemic risk in financial institutions, although in the insurance context it might not always be the case.[25]

3.2.2 Data

For the analysis of fundamentals, we rely on a larger data set of insurers listed in Europe. We were able to collect both market data and balance sheet data for 61 European insurers from SNL Financials. Tables 9 and 10 report summary statistics for equity returns of the insurers and balance sheet variables. Table 11 displays the correlation matrix of balance sheet variables. Data for balance sheet variables is available from 2005 onwards, therefore the analysis of fundamentals can only cover the period between 2005 and 2013.

To test the relation between balance sheet composition and systemic risk contributions, we rely on 2 of the 3 measures that we estimated in the industry analysis, namely the ΔCoVaR and the DMES. This is due to the fact that while we can estimate these 2 measures using a representative index, this is no longer possible for the Granger causality test. In fact, for the purpose of the analysis, it is convenient to measure the marginal effect of each institution vis-à-vis the system, which can be proxied through a broad equity index.[26] Due to data availability, we use the FTSE All shares as proxy for the system.[27] For the analysis of fundamentals, we thus focus on the ΔCoVaR and the DMES. To match the yearly frequency of the balance sheet data, we estimate daily ΔCoVaR and DMES, then take the median of the month and average through the year.[28]

[25] See for instance Bierth et al. (2015).

[26] A similar approach is proposed in Bierth et al. (2015) and Brunnermeier et al. (2012).

[27] For the sake of consistency, we would have employed the Euro STOXX total market, but unfortunately the total return index is only available from 2002 onwards. Therefore, we use the FTSE All shares as a substitute and proxy for the European market as a whole.

[28] The systemic risk measures were re-estimated using the FTSE All shares as a system: not all of the 61 insurers were continuously listed between January 1999 and December 2013, therefore we calculated the measures with the available time series.

4 Empirical Results

4.1 Systemic Risk Measures and Rankings of Systemic Risk Contributions

4.1.1 The Granger causality test (Billio et al., 2012)

Figure 1 reports the evolution over time of the total number of causing (Granger-causal) significant connections over the total number of possible connections from a single institution belonging to each group towards its own industry (*intra-industry*). During the pre-crisis period, a generalized decrease in the connectivity level can be observed across the 3 groups: particularly in the period from 1999 to the end of 2004, the level of connectivity goes from roughly 20-25% to 10-15%; starting from 2005 onwards, the level of intra-industry connectivity among banks and insurers increases rapidly, spiking at 35-40% around the time of Lehman filing for bankruptcy and the subsequent AIG bailout. For non-financials, although the index signals an increase of the connectivity level, a Lehamn effect is much less visible. The filing for bankruptcy and the subsequent AIG bailout thus represent more of a shock to the financial industry than to the non-financial industry. The aftermath of Lehman in fact signals a clear increase in the connectivity level among banks: non-financials continue to display relatively lower levels of connectivity, whereas insurers tend to span halfway between banks and non-financials.

Figure 2 reports the evolution over time of the total number of Granger-causal significant connections over the total number of possible connections from each group towards *other industries*. The upper graph displays the average number of receiving (Granger-causal) connections for a single institution in each group from other industries. We can observe a clear pre- and post-Lehman trend which is consistent with the shock to the financial system as recorded in figure 1: before the filing for bankruptcy of Lehman, financial institutions tended to act as receivers more than non-financials; after Lehman the opposite occurs, with non-financials being net receivers. The lower graph displays the number of causing (Granger-causal) connections for each group from other industries. Clearly, the trend now follows opposite directions, with financial institutions becoming the net causer after Lehamn: in particular, banks from 2006 up to Lehman play a much stronger role compared to insurers, and the same tendency can be observed from 2009 to 2012. Once again, we can observe a subordinated role of insurers compared to banks as a cause of systemic risk, with a consequent role of net receiver played by non-financials.

Finally, figure 3 reports the evolution over time of the total number of causing and receiving

(Granger-causal) significant connections over the total number of possible connections from each group towards the *total system*. Once again, insurers tend to be subordinated compared to banks in causing as well as receiving systemic risk: even though a unique trend over time does not emerge, we can still observe how from 2007 through to 2013, insurers persistently pose less systemic risk compared to banks, with an increase in this difference from 2009 onwards.

In summary, the outcome provided by the Granger causality test provides a fairly clear picture over time of receivers and causers of systemic risk: non-financials behave as causers during tranquil periods and as net receivers during crises, whereas banks appear to be the most prominent causers of systemic risk in the aftermath of a crisis. In particular, among financial institutions, insurers display a more ambiguous behavior compared to banks and on average play a subordinated role compared to banks, especially during the 2007-2009 financial crisis and its aftermath. This is in line with existing findings for American insurance companies.[29]

4.1.2 ΔCoVaR (Adrian and Brunnermeier, 2011)

Figure 4 reports estimations of the average individual institutions' ΔCoVaR within its industry (*intra-industry*). The figure displays a strong differentiation between financial and non-financial institutions. Banks and insurers present the lowest values, with the 2 curves almost perfectly co-moving over the whole time window. Nevertheless, differences between banks and insurers do exist, especially in the aftermath of the crisis, where banks persistently tend to register lower values compared to insurers, with differences of up to 1 percentage point around the European sovereign crisis, i.e. between 2011 and 2012. Furthermore, a striking difference emerges when comparing non-financials with banks and insurers: with the Granger causality test, non-financials are consistently less interconnected within themselves and display persistently much higher values.[30]

Figure 5 reports results for the average individual institutions' ΔCoVaR towards *other industries*: pre-crises periods are clearly dominated by non-financials, whereas during and after the Lehman bankruptcy, banks and insurers become systemically more relevant, with non-financial companies still displaying a relatively higher contribution to systemic risk. It is clear that by changing the composition of the reference system towards which we estimate the measure, effects differ quite substantially: by considering the marginal effects of an institution towards other

[29] See, among others, Chen et al. (2014).

[30] Please note that we consider lower values to be a sign of higher systemic relevance, since the measure estimates market value losses.

industries, we can observe the spillover effects that one industry has onto other industries, and not surprisingly, non-financials had a higher influence on banks and insurers before the financial crisis occurred. This is mainly due to the exposure of the financial sector towards all other sectors rather than vice-versa.[31] This once again provides evidence on the financial nature of the crisis.

Finally, figure 6 reports the results of the average individual institutions' ΔCoVaR towards the *total system*. Here, it is worth noting that before the bankruptcy of Lehman, financials and non-financials display small differences in values, whereas after the crisis, the contribution to systemic risk of financial institutions increases dramatically, with banks once more dominating insurers in terms of marginal contribution. Even though the differences appear modest, we should stress the fact that the measure is estimated on daily returns and averaged through many institutions, therefore the average marginal contribution of banks after 2008 can be estimated as being roughly 20% higher compared to insurers, which makes it considerably higher.

In summary, ΔCoVaR provides a fairly clear indication of the behavior of financial and non-financial institutions, which is in line with the Granger causality test. Furthermore, if we consider the estimations of the *total system* to be more representative of the role of each group in posing systemic risk, insurers again tend to play a subordinated role compared to banks.

4.1.3 DMES (Brownlees and Engle, 2012)

Figure 7 reports the results for the average marginal contribution of the individual institution within its industry (*intra-industry*). The pattern of each group is comparable with the one obtained with the other 2 measures, and in particular with the ΔCoVaR. The 2 measures present the same peaks during the financial crises and report a higher level of systemic riskiness after the crises compared to the pre-crises period. Differences from the previous measures can be found in the spikes at the end of 2001 and 2003 reported by DMES: these spikes are mainly driven by the insurance industry and can be traced back to industry-specific events such as 9/11 and severe natural catastrophes occurring in Europe in 2003. Consistent with the design of the measure, these peaks are well captured by DMES due to its focus on tails of the distributions, i.e. severe events. In general, financial institutions report lower average DMES values than non-financial institutions, with some differences between banks and insurers depending on the period: in the aftermath of the crises, banks pose more risk than insurers.

[31] In the public debate, this is sometimes referred to as "Wall Street" vs "Main Street".

Figure 8 reports results for the average marginal contribution of the individual institution towards *other industries*: on the one hand, the measure indicates once more the distinction between financial and non-financial institutions, with the latter being overall less exposed to the financial sector; on the other hand, banks and insurers appear to be substantially equal in terms of contribution, with banks dominating in the aftermath of Lehman.

Finally, figure 9 reports the results for the average marginal contribution of the individual institution towards the *total system*. There is no significant difference from the results presented in both the Granger causality test and in the ΔCoVaR, which in turn confirms our results.

In summary, DMES confirms the outcome of the 2 other measures, attributing the higher systemic relevance to financial institutions, among which insurers prevail before Lehman and banks in its aftermath.

4.1.4 Systemically Important Financial Institutions (SIFIs)

We also report the average results towards the *total system* for those insurers labeled as SIFIs: this distinction is particularly relevant, since regulators indicated some common characteristics among these institutions which should make them more systemically relevant compared to the median insurer. It is thus worth analyzing their individual behavior vis-à-vis the *total system*. Figure 10 shows a higher average degree of causality compared to the full insurance group with significant peaks which can be observed during the Lehman bankruptcy. In general, we can observe that despite a higher causality compared to non-SIFIs, this sub-group of institutions still tends to play a minor role compared to banks in the aftermath of the Lehman crisis. Figure 11 reports a widespread increase of systemic contribution of SIFI insurers measured by ΔCoVaR in comparison to the full insurance sample and even compared to banks. The contribution towards the *total system* is the highest among the 3 groups throughout the period. Finally, figure 12 reports the result for the DMES: among the 3 measures, the DMES displays the smallest differences between SIFI insurers and non-SIFI insurers, with the period following the Lehman bankruptcy recording the systemic contribution of SIFIs as being significantly inferior to the contribution of banks.

4.1.5 Rankings

In order to provide a straightforward representation of the systemic relevance of the 3 groups according to the 3 measures, we display in figure 13 the 10 most systemically relevant institutions

grouped by industry at each point in time. The Granger causality test and the ΔCoVaR alternatively rank banks during crises and non-financials during tranquil periods as the most systemically relevant companies with a key distinction: banks are always present throughout the period, whereas non-financials disappear after the Lehman crisis. Insurers, despite always being present in the top 10 sub-group throughout the period, still play a subordinated role compared to banks. The DMES attributes a predominant role to insurance companies before the Lehman bankruptcy and to banks afterwards. The measure associates to non-financials an ancillary role only in tranquil periods. The systemic relevance of the 3 groups is finally summarized into a synthetic indicator that displays at each point in time the industry composition of the top 10 most systemic institutions according to the 3 measures.[32] The index clearly shows that non-financials dominate the index before Lehman, whereas banks dominate it thereafter. In contrast, insurers always tend to play a subordinated role both before and after the Legman bankruptcy.

In conclusion, we can summarize our findings as follows: *i)* the 3 measures make a clear distinction between financial and non-financial institutions; *ii)* among financial institutions, banks dominate insurers in terms of contribution to systemic risk in the aftermath of the financial crises, with insurers nevertheless displaying a persistent contribution to systemic risk over time; *iii)* there is no clear-cut evidence on higher systemic relevance of SIFI insurers; *iv)* trends in systemic risk contributions are time-dependent and tend to change rapidly, making the choice of the time span of analysis a crucial variable. Moreover, it is worth mentioning that the 3 measures were developed to capture different features of the systemic risk contribution of institutions, therefore inconsistencies over time should not be seen as lack of accuracy, but rather as emphasis on different factors that contribute to systemic risk.

In the next section, we analyze the determinants behind the systemic contribution of insurers: we attempt to shed further light on which activities within the insurance industry make some insurers more systemic than others. To do so and to overcome sample biases, particularly with respect to the choice of the time window to analyze, we collect a broader sample of data on European insurers over a longer period of time (than previously done in the literature).

[32] See equation (3).

4.2 Systemic Risk Measures and Insurers' Fundamentals

Table 12 reports the results of the panel regressions run on the ΔCoVaR and on the DMES.[33] The model described in equation (4), has 2 specifications: an asset oriented specification and a liability oriented specification, which differ for the definition of *Leverage* and *Size*. In addition, both specifications are tested on 3 different panels, namely *i) Full Sample*, *ii) Sample without Reinsurers* and *iii) Sample without Reinsurers and SIFIs*. We opt for 2 different specifications in order to avoid multicollinearity issues as some of the regressors present a relatively high level of correlation.[34] Finally, the 3 different panels aim to exclude potential biases induced by institutions with specific characteristics, such as reinsurers and SIFIs compared to the median insurer.

The results on the *Full Sample* of both the ΔCoVaR and the DMES suggest a statistically and economic significant positive contribution of *Size*, both if computed as total assets or total liabilities, although the magnitude of the coefficient is relatively moderate. By contrast, both *Price-to-book* and *Leverage* seem to be statistically significant when regressed on the ΔCoVaR, whereas they lose significance when regressed on the DMES. However the economic significance, both in terms of sign and magnitude suggest a controversial and minor effect on systemic risk, in line with the findings of Bierth et al. (2015). A potential interpretation could be that *Leverage* as measured among others in banking, does not properly fit insurers as measure of financial fragility, whereas *Price-to-book* could be a better indicator at a higher frequency, e.g. quarterly frequency, as it tends to reflect market sentiment in the relatively shorter term.

Striking results come from the effects of *Concentration*: in line with our second hypothesis ($H.2$) the degree of diversification of the asset allocation have a very strong statistically and economic significant negative impact on the systemic risk contribution of insurers, which implies that the more diversified a portfolio of assets is, the higher the propensity to pose systemic risk. Results remain strong under the 2 different specifications and the 2 different systemic risk measures. This is consistent with the theoretical argument outlaid among others by Das and Uppal (2004), Wagner (2010), Ibragimov et al. (2011) and Raffestin (2014), which has so far lacked empirical evidence. Also the *Investment Quality* of the asset portfolio seems to atter for the DMES, even though its statistical and economic significance appear rather small. In

[33] In order to ease the interpretation of coefficients, ΔCoVaR and DMES values are reported with inverted signs ad scaled by 100, e.g. a higher systemic relevance is associated with a higher (positive) value displayed by the 2 measures.

[34] Table 11 reports the correlations among regressors.

addition, the relative positions taken in major asset classes such as *Fixed Income Assets* and *Cash* appear to be statistically significant only for a sub-set of the specifications, although significance becomes weaker for the DMES, thereby highlighting potential biases in the sample. Also, the sign of the coefficients is always positive, thus making the economic interpretation difficult as both assets classes should (theoretically) be negatively linked to systemic risk. By contrast *Equity Assets* does not display statistical significance.

Insurance Activities display a strong economic and statistically significant coefficient across the 2 specifications and the 2 measures: as we per our conjecture ($H.1$), there exists a strong negative relation between the amount of insurance activities held in portfolio (with respect to all activities of the insurer) and the systemic risk contribution of the insurer. This evidence is consistent with the idea expressed in Cummins and Weiss (2014) that non-core activities are potentially more systemic than the traditional insurance activities, and in line with the evidence from U.S. insurers provided by Weiß and Mühlnickel (2014), in which non-policy holders' activities did cause systemic risk during the financial crisis.

Total Debt displays a statistically significant coefficient only for the DMES: the economic significance is robust and suggests that insurers with a capital structure more exposed to non policy holders' liabilities or more in general exposed to non-insurance (banking) activities, tend to pose more systemic risk. Finally, *Separate Accounts* appear to be weakly statistically significant in only one specification, i.e. asset oriented specification, of the ΔCoVaR and of the DMES, whereas they display statistically insignificant coefficients if specified with liability oriented variables.

Moving from the *Full Sample* to *Sample without Reinsurers* we note how for the ΔCoVaR, *Fixed Income Assets* becomes insignificant, whereas *Cash* remains unchanged. For the DMES we note how both *Concentration* and *Investment Quality* increase their significance, both economic and statistical. By contrast *Total Debt* loses some statistical significance, although its p value is still below 10%. *Price-to-book*, *Leverage* and *Size* remain mainly unchanged. Finally, moving to the reduced and potentially more robust sample, as it excludes potential biases both from reinsurers and SIFIs, we observe that the key drivers across the different specifications and for both measures are indeed *Concentration*, *Insurance Activities* and *Total Debt*. All other variables lose significance, except for few outliers. Such result strongly confirms that net of reinsurers and SIFIs, i.e. mostly big insurance groups, the key drivers of systemic risk in insurance are non-insurance activities and the level of diversification of its asset portfolio.

To summarize, we can conclude that *i) Insurance Activities* are a strongly economic and statistically significant factor for systemic risk in insurance, as well as *Total Debt*, which together strongly determine the capital structure of firms, *ii) Concentration*, i.e. diversification, if it can be considered optimal at single institution level, it may turn out to be deleterious at an aggregate (systemic) level. In addition we confirm that *Size* does matter, whereas *Leverage* appears to be a potentially misleading measure in insurance companies.

4.2.1 Robustness of Results

In addition to the robustness check that we conducted by testing the different specifications across 3 different panels we conduct a difference-in-differences (DiD) analysis to check for potential endogeneity issues.[35] Similar to Brunnermeier et al. (2012), we test the robustness of our findings around Lehman's filing for bankruptcy and subsequent AIG bailout.[36] Since Lehman's failure came as an exogenous shock, it represents a good candidate for a natural experiment.[37]

We adopt the following strategy for the DiD analysis: we run regressions using the same specifications as in equation (4) and we test single variables around the Lehman shock, i.e. systemic risk contribution in 2007 vs 2008, balance sheet items and proxies in 2006 vs 2007. In particular, we construct dummy variables for each of the relevant variable, i.e. *Concentration*, *Investment Quality*, *Fixed Income Assets*, *Equity Assets*, *Cash*, *Insurance Activities*, *Total Debt* and *Separate Accounts*.[38] The model is the following:

$$SR^i = \beta_0 + \beta_1 \cdot Price - to - book^i + \beta_2 \cdot Leverage^{i,A/L} + \beta_3 \cdot Size^{i,A/L} + \sum_{j \neq z} \beta_j \cdot X_j^i + \tag{5}$$

$$\delta_0 \cdot d.shock + \delta_1 \cdot d.X_z + \widehat{\delta} \cdot d.shock \cdot d.X_z + \epsilon^i \tag{6}$$

in which the $d.shock$ is a dummy variable which takes value 0 for 2007 and value 1 for 2008 (pre- and post-shock period) and the $d.X_z$ is a dummy that represents the control (or non-treated group) and the treatment group respectively. We specify 8 treatment groups, 1 for each relevant

[35] In the panel regressions we use a time lag between dependent and independent variables: theoretically such temporal mis-match should shelter our analysis from endogeneity or reverse causality issues.

[36] For further details on the applied DiD methodology, see, for instance, Meyer (1995) and Angrist and Krueger (1999). For a more didactic contribution, see Wooldridge (2010).

[37] AIG was bailed out by the U.S. Government a day after Lehman's bankruptcy filing.

[38] We neglect *Price-to-book*, *Leverage* and *Size* not because we neglect their importance, but because they have been substantially analyzed in previous work, see for instance Brunnermeier et al. (2012) for banks and (Bierth et al., 2015) for insurers.

variable: we divide the observations into 2 groups, above and below the median and assign value 0 and 1 depending on the expected sign of the variable. Table 13 provides an overview of the treatment variables.

Tables 14 - 17 report the results of the DiD around the Lehman bankruptcy and AIG bailout: the coefficient of interest is of course the interaction term $(\widehat{\delta})$ between the shock dummy and the control group. The striking result of such robustness check is that, *Insurance Activities*, *Total Debt* and *Separate Accounts* appear to be statistically and economically significant determinants of systemic risk, although not uniformly for the 2 measures: in fact, *Separate Accounts* are statistically insignificant for the ΔCoVaR. This confirms our hypothesis that the capital structure, i.e. the liability side, is the key driver of systemic risk in insurance. By contrast *Concentration* does not display significant coefficients: however, this shall not be taken as a rejection *in toto*, rather it deserves further investigation, since *Concentration* is just a proxy and by definition it is an imperfect measure and therefore, measurement errors might be a potential explanation for its insignificance.

5 Conclusion

In the present paper, we propose an analysis of the role of the insurance industry in posing systemic risk and the determinants therein. We divide the analysis into 2 parts: first, we conduct an aggregated industry analysis based on 3 measures of systemic risk on 3 different groups. By doing so, we aim to test the relative systemic risk contribution of the insurance industry vis-à-vis other industries. In the second part of the analysis, we investigate what are the potential determinants of systemic risk within the insurance industry by focusing on the asset and liability composition of insurers.

Our evidence suggests that financial institutions tend to cause more systemic risk than non-financial institutions; among financial institutions, banks pose more systemic risk than insurers, especially after the Lehman bankruptcy. Insurers do cause systemic risk, especially when they engage in non-insurance activities, e.g. banking activities. Furthermore, we find that systemic risk in the insurance industry is mainly driven by the liability side, i.e. the capital structure rather than the asset side: however, on the asset side we find that the level of diversification is also a strong determinant of systemic risk, although further investigation is needed. In addition, traditional variables associated with systemic risk in financial institutions, such as size is of

importance, whereas price-to-book and leverage seem to play a counterintuitive role. This is however in line with previous findings, which confirm for instance that leverage in insurance is fundamentally different compared to leverage in banking. Results are robust to a set of different specifications, different panels and different econometric methods. Finally, the choice of the time span should shelter the analysis from biases stemming from sample (time-dependency) selection.

In conclusion, we provide new evidence on the role of insurers in posing systemic risk, in particular on the role of insurance activities compared to non-insurance activities. Also, we are among the first to provide empirical evidence on the role of diversification in posing systemic risk, which should be further analyzed in future research. Moreover, we are the first to use a European set of companies and to use variables of *stock* rather than *flow*: the latter is particularly relevant to show how the stock of the outstanding business drives systemic risk contribution in the insurance industry.

Thus, our research has the potential to provide a significant contribution to shedding additional light on the debate on systemic risk in the insurance industry as well as insightful indications on how to assess the systemic relevance of insurance companies. This is particularly relevant in the light of the ongoing discussion on the role of SIFIs and on the specific regulations they might be subjected in the future. Furthermore, the present paper could serve as a basis for a theoretical treatment of the systemic risk contribution of the insurance industry, and thereby contribute to deepening the understanding of the underlying economic forces driving systemic risk.

A Appendix

A.1 Systemic Risk Measures

A.1.1 The Granger causality test (Billio et al., 2012)

We measure the systemic importance of an institution in terms of the total number of statistically significant pairwise connections based on linear Granger causality tests. This approach allows us to infer when equity price movements of an institution influence price movements of another institution over a given period of time. The Granger causality test measures the ability of 2 time series to forecast each other. We can write the system of equations as follows

$$y^i_{t+1} = \alpha^i y^i_t + \beta^{ij} y^j_t + \epsilon^i_{t+1} \tag{7}$$

$$y^j_{t+1} = \alpha^j y^j_t + \beta^{ji} y^i_t + \epsilon^j_{t+1} \tag{8}$$

in which coefficients α^i, β^{ij}, α^j, β^{ji} are estimated via linear regression and in which time series j is said to "Granger-cause" times series i if lagged values of j contain statistically significant information that helps in predicting i.

The *causality indicator* is defined as follow:

$$j \to i = \begin{cases} 1, & \text{if } j \text{ Granger causes } i \\ 0, & otherwise \\ 0, & \text{for } j \to j \end{cases} \tag{9}$$

Equation (9) allows us to calculate a series of indexes based on the total number of significant relations among institutions at a specific point in time.[39]The *Degree of Granger Causality* thus represents the fraction of statistically significant relationships over the total number of possible connections among the full sample,

$$DGC = \frac{1}{N(N-1)} \sum_{i=1}^{n} \sum_{j \neq i} (j \to i) \tag{10}$$

Moreover, we can differentiate between *causing* and *receiving* connections which are defined

[39]The level of significance K is set at 0.05.

as follows

$$Out : (j \to S)|_{DGC \geq K} = \frac{1}{N-1} \sum_{i \neq j} (j \to i)|_{DGC \geq K} \tag{11}$$

$$In : (S \to j)|_{DGC \geq K} = \frac{1}{N-1} \sum_{i \neq j} (i \to j)|_{DGC \geq K} \tag{12}$$

We then distinguish between 3 cases:

1) *intra-industry*:

$$(j \to ind^{-j})|_{DGC \geq K} = \frac{1}{(N-1)} \sum_{i \neq j} (j \to ind^{-j})|_{DGC \geq K} \tag{13}$$

$$(ind^{-j} \to j)|_{DGC \geq K} = \frac{1}{(N-1)} \sum_{j \neq i} (ind^{-j} \to j)|_{DGC \geq K} \tag{14}$$

2) *other industries*:

$$\left(j \to S^{-ind}\right)|_{DGC \geq K} = \frac{1}{2N} \sum_{i \neq j} (j \to S^{-ind})|_{DGC \geq K} \tag{15}$$

$$\left(S^{-ind} \to j\right)|_{DGC \geq K} = \frac{1}{2N} \sum_{i \neq j} (S^{-ind} \to j)|_{DGC \geq K} \tag{16}$$

3) *total system*:

$$(j \to S^{-j})|_{DGC \geq K} \frac{1}{3N-1} \sum_{i \neq j} (j \to S^{-j})|_{DGC \geq K} \tag{17}$$

$$(S^{-j} \to j)|_{DGC \geq K} \frac{1}{3N-1} \sum_{i \neq j} (S^{-j} \to j)|_{DGC \geq K}. \tag{18}$$

Each index represents the contribution of each individual institution. We then calculate industry averages by summing the total number of institutions' connections across each industry group.

A.1.2 ΔCoVaR (Adrian and Brunnermeier, 2011)

The measure extends the concept of *Value at Risk* (VaR) designed for individual institutions to the system as a whole. The CoVaR represent the VaR of a system conditional on institutions being in distress. The systemic contribution of an individual institution to the system is computed as the difference between the CoVaR of the institution in distress and the CoVaR in the median state, hence ΔCoVaR. Following Adrian and Brunnermeier (2011), we calculate

the ΔCoVaR using quantile regressions by setting the median state at the 50 percentile and the distress situation at the 95 percentile. We also include in the regressions a set of 6 state variables M_{t-1}, namely market volatility, liquidity spread, changes in the short-term interest rates, the slope of the yield curve, credit spreads and total equity returns, using 1 week lag.

Estimations are based on the following equations

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i \tag{19}$$

$$X_t^S = \alpha^{S|i} + \beta^{S|i} X_t^i + \gamma^{S|i} M_{t-1} + \varepsilon_t^{S|i} \tag{20}$$

where i represents the individual institution and S is the index representing the set of institutions under consideration. The predicted value from the regressions are then plugged into the following equation to obtain both the VaR of the individual institution and consequently the CoVaR

$$VaR_t^i(q) = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1} \tag{21}$$

$$CoVaR_t^i(q) = \hat{\alpha}^{S|i} + \hat{\beta}^{S|i} VaR_t^i(q) + \hat{\gamma}^{S|i} M_{t-1}. \tag{22}$$

Finally, the contribution of each institution to the system is calculated as follows:

$$\Delta CoVaR_t^i(q) = CoVaR_t^i(5\%) - CoVaR_t^i(50\%) = \hat{\beta}^{S|i}(VaR_t^i(5\%) - VaR_t^i(50\%)) \tag{23}$$

We then distinguish between 3 cases:

1) *intra-industry*:

$$X_t^S = \frac{\sum_{j \neq i} w_{t-1}^j \cdot r_t^j}{\sum_{j \neq i} w_{t-1}^j} \tag{24}$$

with *w=market capitalization, r= return, j= i's industry group*,

$$\Delta\overline{CoVaR}_t^{intra\text{-}industry|i} = \frac{1}{N} \sum_i^N \Phi^{-1}(0.5) \Delta CoVaR_{t \to t+h}^{intra\text{-}industry|i} \tag{25}$$

where $t \to t+h$ indicates 1 calendar month of daily ΔCoVaR.

2) *other industries*:

$$X_t^S = \frac{\sum_j w_{t-1}^j \cdot r_t^j}{\sum_j w_{t-1}^j} \tag{26}$$

with *w=market capitalization, r= return, j= excluding i's industry group,*

$$\Delta\overline{CoVaR}_t^{other\ industries|i} = \frac{1}{N}\sum_i^N \Phi^{-1}(0.5)\Delta CoVaR_{t\to t+h}^{other\ industries|i} \tag{27}$$

where $t \to t+h$ indicates 1 calendar month of daily ΔCoVaR.

3) *total system*:

$$X_t^S = \frac{\sum_{j\neq i} w_{t-1}^j \cdot r_t^j}{\sum_{j\neq i} w_{t-1}^j} \tag{28}$$

with *w=market capitalization, r= return, j= total system,*

$$\Delta\overline{CoVaR}_t^{total\ system|i} = \frac{1}{N}\sum_i^N \Phi^{-1}(0.5)\Delta CoVaR_{t\to t+h}^{total\ system|i} \tag{29}$$

where $t \to t+h$ indicates 1 calendar month of daily ΔCoVaR.

Where N represents the number of institutions for each of the 3 groups. In order to avoid correlation biases, i.e. under case 1) and 3), we always exclude institution i from the index representing the reference group.

A.1.3 DMES (Brownlees and Engle, 2012)

The measure is based on the expected loss conditional to a distressed situation (eg. returns being less than a certain quantile): Brownlees and Engle (2012) extend the measure proposed by (Acharya et al., 2010) by introducing a dynamic model characterized by time varying volatility and correlation as well a nonlinear tail dependence. The market model is defined as follows

$$r_{mt} = \sigma_{mt}\epsilon_{mt}$$

$$r_{it} = \sigma_{it}\rho_{it}\epsilon_{mt} + \sigma_{it}\sqrt{1-\rho_{it}^2}\xi_{it} \tag{30}$$

$$(\epsilon_{mt}, \xi_{it}) \sim F$$

where r_i is the market return of the i^{th} institution and σ_{it} is its conditional standard deviation, r_m is the market return of the system considered and σ_{mt} is its conditional standard deviation, ϵ and ξ are the shocks that drive the system and ρ_{it} is the conditional correlation between i and m. The one period ahead DMES can be expressed as follows

$$DMES^1_{it-1}(C) = \sigma_{it}\rho_{it}E_{t-1}(\epsilon_{mt}|\epsilon_{mt} < \frac{C}{\sigma_{mt}}) + \sigma_{it}\sqrt{1-\rho^2_{it}}E_{t-1}(\xi_{it}|\epsilon_{mt} < \frac{C}{\sigma_{mt}}) \tag{31}$$

where C is the conditioning systemic event which we assume to be equal to the 95^{th} percentile of the total period market return, i.e. $C = \Phi^{-1}(0.95)r_m$.[40] The conditional standard deviations and the conditional correlation are estimated by means of a TARCH and a DCC model respectively.[41] The tail expectations $E_{t-1}(\epsilon_{mt}|\epsilon_{mt} < \frac{C}{\sigma_{mt}})$ and $E_{t-1}(\xi_{it}|\epsilon_{mt} < \frac{C}{\sigma_{mt}})$ are calculated by means of a non-parametric kernel estimator and are given by the following equations

$$\hat{E}_h(\epsilon_{mt}|\epsilon_{mt} < k) = \frac{\sum_{i=1}^n \epsilon_{mt}K_h(\epsilon_{mt}-k)}{(n\hat{p}_h)} \tag{32}$$

$$\hat{E}_h(\xi_{it}|\epsilon_{mt} < k) = \frac{\sum_{i=1}^n \xi_{it}K_h(\epsilon_{mt}-k)}{(n\hat{p}_h)} \tag{33}$$

with

$$\hat{p}_h = \frac{\sum_{i=1}^n K_h(\epsilon_{mt}-k)}{n}$$

We then distinguish between 3 cases:

1) *intra-industry*:

$$r_{mt} = \frac{\sum_{j\neq i} w^j_{t-1}\cdot r^j_t}{\sum_{j\neq i} w^j_{t-1}} \tag{34}$$

with *w=market capitalization, r= return, j= i's industry group,*

$$\overline{DMES}^{intra\text{-}industry|i}_t = \frac{1}{N}\sum_i^N \Phi^{-1}(0.5)DMES^{intra\text{-}industry|i}_{t\to t+h} \tag{35}$$

where $t \to t+h$ indicates 1 calendar month of daily DMES.

[40] The choice over the $VaR_{0.95}$ of the market allows for a more direct comparison with the estimations of the ΔCoVaR.

[41] For further mathematical details, see Brownlees and Engle (2012).

2) *other industries*:

$$r_{mt} = \frac{\sum_j w_{t-1}^j \cdot r_t^j}{\sum_j w_{t-1}^j} \tag{36}$$

with *w=market capitalization*, *r= return*, *j= excluding i's industry group*,

$$\overline{DMES}_t^{other\ industries|i} = \frac{1}{N} \sum_i^N \Phi^{-1}(0.5) DMES_{t \to t+h}^{other\ industries|i} \tag{37}$$

where $t \to t+h$ indicates 1 calendar month of daily DMES.

3) *total system*:

$$r_{mt} = \frac{\sum_{j \neq i} w_{t-1}^j \cdot r_t^j}{\sum_{j \neq i} w_{t-1}^j} \tag{38}$$

with *w=market capitalization*, *r= return*, *j= total system*,

$$\overline{DMES}_t^{total\ system|i} = \frac{1}{N} \sum_i^N \Phi^{-1}(0.5) DMES_{t \to t+h}^{total\ system|i} \tag{39}$$

where $t \to t+h$ indicates 1 calendar month of daily DMES.

Where N represents the number of institutions for each of the 3 groups. In order to avoid correlation biases, i.e. under case 1) and 3), we always exclude institution i from the index representing the reference group.

B Tables

Table 1: Institutions: list of the institutions included in the 3 groups

Banks		
Name	**Ticker**	**Country**
HSBC	HSBA	UK
BANCO SANTANDER	E:SCH	ES
UBS	S:UBSN	CH
BNP PARIBAS	F:BNP	FR
LLOYDS BANKING GROUP	LLOY	UK
ROYAL BANK OF SCOTLAND	RBS	UK
BARCLAYS	BARC	UK
CREDIT SUISSE GROUP	S:CSGN	CH
BBV. ARGENTARIA	E:BBVA	ES
DEUTSCHE BANK	D:DBKX	DE
UNICREDIT	I:UCG	IT
SOCIETE GENERALE	F:SGE	FR
STANDARD CHARTERED	STAN	UK
INTESA SANPAOLO	I:ISP	IT
NORDEA BANK	W:NDA	SE
KBC	B:KB	BE
DANSKE BANK	DK:DAB	DK
COMMERZBANK	D:CBKX	DE
SVENSKA HANDBKN.	W:SVK	SE
SEB	W:SEA	SE
Insurers		
ALLIANZ	D:ALV	DE
PRUDENTIAL	PRU	UK
AXA	F:MIDI	FR
ZURICH INSURANCE GROUP	S:ZURN	CH
MUNICH RE	D:MUV2	DE
SWISS RE	S:SREN	CH
ING	H:ING	NL
ASSICURAZIONI GENERALI	I:G	IT
SAMPO	M:SAMA	FI
LEGAL & GENERAL	LGEN	UK
AVIVA	AV.	UK
AEGON	H:AGN	ND
MAPFRE	E:MAP	ES
HANNOVER RE	D:HNR1	DE
AGEAS	B:AGS	BE
RSA INSURANCE GROUP	RSA	UK
VIENNA INSURANCE GROUP	O:WNST	AT
SCOR SE	F:SCO	FR
SWISS LIFE	S:SLHN	CH
BALOISE	S:BALN	CH
Non-Financials		
BRITISH PETROLEUM	BP.	UK
VODAFONE	VOD	UK
NOVARTIS	S:NOVN	CH
NESTLE	S:NESN	CH
GLAXOSMITHKLINE	GSK	UK
ROYAL DUTCH SHELL	H:RDSA	UK
TOTAL	F:TAL	FR
ROCHE	S:ROG	CH
ENI	I:ENI	IT
TELEFONICA	E:TEF	ES
SANOFI	F:SQ@F	FR
NOKIA	M:NOK1	FI
SIEMENS	D:SIEX	DE
ASTRAZENECA	AZN	UK
L'OREAL	F:OR@F	FR
E ON	D:EONX	DE
BRITISH AMERICAN TOBACCO	BATS	UK
RIO TINTO	RIO	UK
LVMH	F:LVMH	FR
DIAGEO	DGE	UK

Table 2: Non-Financial institutions: list of the Non-Financial institutions included in the analysis classified according to GICI classification.

Name	**Sector**	**Industry Group**
BRITISH PETROLEUM	Energy	Energy
VODAFONE	Telecommunication	Telecommunication
NOVARTIS	Health Care	Pharmaceuticals & Biotechnology
NESTLE	Consumer Staples	Food & staples retailing
GLAXOSMITHKLINE	Health Care	Pharmaceuticals & Biotechnology
ROYAL DUTCH SHELL	Energy	Energy
TOTAL	Energy	Energy
ROCHE	Health Care	Pharmaceuticals & Biotechnology
ENI	Energy	Energy
TELEFONICA	Telecommunication	Telecommunication
SANOFI	Health Care	Pharmaceuticals & Biotechnology
NOKIA	Information technology	Technology hardware & Equipment
SIEMENS	Industrials	Capital Goods
ASTRAZENECA	Health Care	Pharmaceuticals & Biotechnology
L'OREAL	Consumer Staples	Households and Personal Products
E ON	Utilities	Utilities
BRITISH AMERICAN TOBACCO	Consumer Staples	House Beverage & Tobacco
RIO TINTO	Materials	Materials
LVMH	Consumer Staples	Households & Personal Products
DIAGEO	Consumer Staples	Food & staples retailing

Table 3: Total Return Indexes: descriptive statistics of the Total Return Indexes of the 60 institutions on the time period between January 1996 to December 2013. The upper part reports values at monthly frequency, whereas the lower part reports values at daily frequency.

Monthly Data	**#**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
Banks	**20**	4,319	0.0048	0.0119	0.1189	-1.2447	0.6602
Non-Financial	**20**	4,320	0.0086	0.0125	0.0808	-0.6628	0.5099
Insurers	**20**	4,304	0.0046	0.0117	0.1137	-2.0293	0.6745
Full Sample	**60**	12,943	0.0060	0.0121	0.1058	-2.0293	0.6745

Daily Data	**#**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
Banks	**20**	92,160	0.0002	0.0000	0.0256	-1.0957	0.5495
Non-Financial	**20**	92,160	0.0004	0.0000	0.0192	-0.4578	0.3226
Insurers	**20**	92,160	0.0002	0.0000	0.0245	-1.4949	0.3022
Full Sample	**60**	276,480	0.0003	0.0000	0.0232	-1.4949	0.5495

Table 4: State variables: descriptive statistics of daily data observed on the period between January 1999 to December 2013.

	Obs.	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
VIX	4,608	-0.0001	-0.0020	0.0614	-0.3506	0.4960
3M Repo-3M Bubill	4,608	-0.0167	-0.0091	0.6118	-2.0781	2.8463
3M Bubill	4,608	-0.0004	0.0000	0.1037	-1.3863	1.9459
10Y Bund - 3M Bubill	4,608	0.0145	0.0147	0.0076	-0.0022	0.0324
BAA 5-7Y Corp. - Euro Sov. 5-7Y	4,608	0.0118	0.0093	0.0075	-0.0080	0.0358
STOXX Euro 600 All shares	4,608	0.0002	0.0007	0.0124	-0.0793	0.0941

Table 5: Banks: log returns are observed both at *a)* monthly frequency and *b)* daily frequency. Observation period between January 1996 to December 2013.

***a)* Name**	**Ticker**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
HSBC	HSBA	216	0.0074	0.0086	0.0850	-0.3051	0.3178
BANCO SANTANDER	E:SCH	216	0.0075	0.0133	0.1051	-0.5183	0.3095
UBS	S:UBSN	216	0.0008	0.0047	0.1022	-0.4722	0.2654
BNP PARIBAS	F:BNP	216	0.0086	0.0092	0.1087	-0.4946	0.3052
LLOYDS BANKING GROUP	LLOY	215	-0.0001	0.0087	0.1375	-1.0936	0.5410
ROYAL BANK OF SCOTLAND	RBS	216	-0.0048	0.0104	0.1631	-1.2447	0.4344
BARCLAYS	BARC	216	0.0051	0.0196	0.1395	-0.8081	0.6393
CREDIT SUISSE	S:CSGN	216	0.0020	0.0140	0.1152	-0.6667	0.2333
BBV. ARGENTARIA	E:BBVA	216	0.0081	0.0155	0.1084	-0.5886	0.3150
DEUTSCHE BANK	D:DBKX	216	0.0023	0.0098	0.1206	-0.6229	0.4333
UNICREDIT	I:UCG	216	0.0023	0.0052	0.1215	-0.4667	0.3338
SOCIETE GENERALE	F:SGE	216	0.0060	0.0130	0.1342	-0.6053	0.2943
STANDARD CHARTERED	STAN	216	0.0075	0.0125	0.1104	-0.4134	0.4616
INTESA SANPAOLO	I:ISP	216	0.0060	0.0133	0.1214	-0.4655	0.6602
NORDEA BANK	W:NDA	216	0.0121	0.0173	0.0859	-0.2902	0.2820
KBC GROUP	B:KB	216	0.0048	0.0194	0.1530	-1.1424	0.6334
DANSKE BANK	DK:DAB	216	0.0080	0.0134	0.0987	-0.5550	0.4769
COMMERZBANK	D:CBKX	216	-0.0088	-0.0027	0.1465	-0.7785	0.5445
SVENSKA HANDBKN.	W:SVK	216	0.0122	0.0115	0.0703	-0.2447	0.2031
SEB	W:SEA	216	0.0089	0.0184	0.1037	-0.4589	0.3787

***b)* Name**	**Ticker**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
HSBC	HSBA	4,608	0.0004	0.0000	0.0187	-0.2080	0.1442
BANCO SANTANDER	E:SCH	4,608	0.0004	0.0000	0.0225	-0.1603	0.2088
UBS	S:UBSN	4,608	0.0000	0.0000	0.0236	-0.1889	0.2751
BNP PARIBAS	F:BNP	4,608	0.0004	0.0000	0.0253	-0.1893	0.1898
LLOYDS BANKING GROUP	LLOY	4,608	0.0000	0.0000	0.0300	-0.4148	0.4078
ROYAL BANK OF SCOTLAND	RBS	4,608	-0.0002	0.0000	0.0340	-1.0957	0.3050
BARCLAYS	BARC	4,608	0.0003	0.0000	0.0292	-0.2856	0.5495
CREDIT SUISSE	S:CSGN	4,608	0.0001	0.0000	0.0252	-0.1767	0.2461
BBV.ARGENTARIA	E:BBVA	4,608	0.0004	0.0000	0.0219	-0.1454	0.1991
DEUTSCHE BANK	D:DBKX	4,608	0.0001	0.0001	0.0252	-0.1753	0.2124
UNICREDIT	I:UCG	4,608	0.0001	0.0000	0.0264	-0.1896	0.1901
SOCIETE GENERALE	F:SGE	4,608	0.0003	0.0000	0.0272	-0.1771	0.2143
STANDARD CHARTERED	STAN	4,608	0.0004	0.0000	0.0252	-0.1795	0.2624
INTESA SANPAOLO	I:ISP	4,608	0.0003	0.0000	0.0265	-0.1846	0.1796
NORDEA BANK	W:NDA	4,608	0.0006	0.0000	0.0219	-0.1221	0.1492
KBC GROUP	B:KB	4,608	0.0002	0.0000	0.0301	-0.2866	0.4048
DANSKE BANK	DK:DAB	4,608	0.0004	0.0000	0.0201	-0.1719	0.1398
COMMERZBANK	D:CBKX	4,608	-0.0004	0.0000	0.0285	-0.2746	0.2048
SVENSKA HANDBKN.	W:SVK	4,608	0.0006	0.0000	0.0186	-0.1074	0.1329
SEB	W:SEA	4,608	0.0004	0.0000	0.0250	-0.2231	0.2322

Table 6: Insurers: log returns are observed both at *a)* monthly frequency and *b)* daily frequency. Observation period between January 1996 to December 2013.

***a)* Name**	**Ticker**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
ALLIANZ	D:ALV	216	0.0019	0.0119	0.1049	-0.4538	0.4230
PRUDENTIAL	PRU	216	0.0085	0.0214	0.1073	-0.5433	0.4310
AXA	F:MIDI	216	0.0055	0.0138	0.1214	-0.6390	0.3478
ZURICH INSURANCE GROUP	S:ZURN	216	0.0024	0.0115	0.1113	-0.7533	0.2935
MUNICH RE	D:MUV2	214	0.0057	0.0106	0.0884	-0.3837	0.3084
SWISS RE	S:SREN	216	0.0031	0.0158	0.1160	-0.8553	0.4279
ING GROEP	H:ING	216	0.0036	0.0118	0.1310	-0.7791	0.3262
ASSICURAZIONI GENERALI	I:G	216	0.0019	0.0080	0.0886	-0.4041	0.2532
SAMPO	M:SAMA	216	0.0183	0.0196	0.0892	-0.4501	0.2562
LEGAL & GENERAL	LGEN	216	0.0094	0.0187	0.1004	-0.5431	0.2776
AVIVA	AV.	216	0.0029	0.0098	0.1082	-0.5951	0.3514
AEGON	H:AGN	216	0.0018	0.0181	0.1319	-0.5931	0.6236
MAPFRE	E:MAP	216	0.0065	0.0096	0.0957	-0.4189	0.2777
HANNOVER RE	D:HNR1	202	0.0100	0.0140	0.0999	-0.6683	0.3550
AGEAS	B:AGS	216	-0.0022	0.0132	0.1844	-2.0293	0.6745
RSA INSURANCE GROUP	RSA	216	-0.0007	0.0077	0.1037	-0.5306	0.2485
VIENNA INSURANCE GROUP	O:WNST	216	0.0077	0.0008	0.0885	-0.6419	0.4381
SCOR SE	F:SCO	216	-0.0007	0.0131	0.1114	-0.6743	0.3231
SWISS LIFE	S:SLHN	216	-0.0005	0.0104	0.1456	-0.7104	0.6159
BÂLOISE	S:BALN	216	0.0070	0.0157	0.0967	-0.4777	0.2488

***b)* Name**	**Ticker**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
ALLIANZ	D:ALV	4,608	0.0000	0.0000	0.0227	-0.1568	0.1781
PRUDENTIAL	PRU	4,608	0.0004	0.0000	0.0262	-0.2231	0.2107
AXA	F:MIDI	4,608	0.0002	0.0005	0.0262	-0.2035	0.1978
ZURICH INSURANCE GROUP	S:ZURN	4,608	0.0001	0.0000	0.0229	-0.2257	0.1920
MUNICH RE	D:MUV2	4,608	0.0002	0.0000	0.0212	-0.1719	0.1653
SWISS RE	S:SREN	4,608	0.0002	0.0000	0.0230	-0.3292	0.1957
ING GROEP	H:ING	4,608	0.0002	0.0006	0.0297	-0.3213	0.2565
ASSICURAZIONI GENERALI	I:G	4,608	0.0000	0.0000	0.0182	-0.1612	0.1739
SAMPO	M:SAMA	4,608	0.0009	0.0000	0.0206	-0.1823	0.1367
LEGAL & GENERAL	LGEN	4,608	0.0005	0.0000	0.0252	-0.3408	0.2430
AVIVA	AV.	4,608	0.0002	0.0000	0.0259	-0.4060	0.2239
AEGON	H:AGN	4,608	0.0000	0.0000	0.0289	-0.2768	0.3022
MAPFRE	E:MAP	4,608	0.0003	0.0000	0.0222	-0.1508	0.1618
HANNOVER RE	D:HNR1	4,608	0.0005	0.0000	0.0218	-0.1989	0.1538
AGEAS	B:AGS	4,608	0.0001	0.0005	0.0353	-1.4949	0.2589
RSA INSURANCE GROUP	RSA	4,608	0.0000	0.0000	0.0238	-0.2426	0.1425
VIENNA INSURANCE GROUP	O:WNST	4,608	0.0004	0.0000	0.0179	-0.1974	0.1529
SCOR SE	F:SCO	4,608	0.0000	0.0000	0.0257	-0.3622	0.1907
SWISS LIFE	S:SLHN	4,608	0.0000	0.0000	0.0248	-0.2240	0.1877
BÂLOISE	S:BALN	4,608	0.0004	0.0000	0.0203	-0.1662	0.1891

Table 7: Non-Financials: log returns are observed both at *a)* monthly frequency and *b)* daily frequency. Observation period between January 1996 to December 2013.

***a)* Name**	**Ticker**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
BRITISH PETROLEUM	BP.	216	0.0058	0.0110	0.0742	-0.3714	0.1982
VODAFONE	VOD	216	0.0105	0.0176	0.0847	-0.2530	0.2669
NOVARTIS	S:NOVN	216	0.0070	0.0069	0.0609	-0.1707	0.2594
NESTLE	S:NESN	216	0.0094	0.0173	0.0523	-0.2074	0.1246
GLAXOSMITHKLINE	GSK	216	0.0058	0.0051	0.0627	-0.2058	0.2659
ROYAL DUTCH SHELL	H:RDSA	216	0.0067	0.0024	0.0697	-0.2999	0.2608
TOTAL	F:TAL	216	0.0094	0.0098	0.0680	-0.2370	0.2101
ROCHE	S:ROG	216	0.0064	0.0068	0.0644	-0.2654	0.1922
ENI	I:ENI	216	0.0091	0.0115	0.0672	-0.2365	0.2219
TELEFONICA	E:TEF	216	0.0093	0.0135	0.0884	-0.3293	0.3580
SANOFI	F:SQ@F	216	0.0110	0.0103	0.0686	-0.1901	0.1985
NOKIA	M:NOK1	216	0.0077	0.0155	0.1437	-0.4512	0.5099
SIEMENS	D:SIEX	216	0.0079	0.0181	0.1046	-0.3699	0.2960
ASTRAZENECA	AZN	216	0.0078	0.0100	0.0704	-0.2218	0.2523
L'OREAL	F:OR@F	216	0.0102	0.0133	0.0654	-0.2592	0.1606
E ON	D:EONX	216	0.0045	0.0161	0.0752	-0.3212	0.1880
BAT	BATS	216	0.0148	0.0174	0.0682	-0.2396	0.2173
RIO TINTO	RIO	216	0.0093	0.0189	0.1054	-0.4874	0.3274
LVMH	F:LVMH	216	0.0089	0.0151	0.1039	-0.6628	0.3172
DIAGEO	DGE	216	0.0096	0.0137	0.0618	-0.2476	0.1780

***a)* Name**	**Ticker**	**Obs.**	**Average**	**Median**	**St.Dev.**	**Min**	**Max**
BRITISH PETROLEUM	BP.	4,608	0.0003	0.0000	0.0173	-0.1404	0.1058
VODAFONE	VOD	4,608	0.0005	0.0000	0.0218	-0.1458	0.1371
NOVARTIS	S:NOVN	4,608	0.0003	0.0000	0.0138	-0.0989	0.1824
NESTLE	S:NESN	4,608	0.0004	0.0000	0.0127	-0.0798	0.0926
GLAXOSMITHKLINE	GSK	4,608	0.0003	0.0000	0.0164	-0.1389	0.1881
ROYAL DUTCH SHELL	H:RDSA	4.608	0.0003	0.0004	0.0162	-0.1032	0.1310
TOTAL	F:TAL	4,608	0.0004	0.0006	0.0179	-0.1317	0.1279
ROCHE	S:ROG	4,608	0.0003	0.0000	0.0144	-0.1101	0.0987
ENI	I:ENI	4,608	0.0004	0.0005	0.0174	-0.1012	0.1614
TELEFONICA	E:TEF	4,608	0.0005	0.0003	0.0188	-0.0989	0.1326
SANOFI	F:SQ@F	4,608	0.0005	0.0000	0.0193	-0.1401	0.1368
NOKIA	M:NOK1	4,608	0.0003	0.0000	0.0304	-0.2599	0.2922
SIEMENS	D:SIEX	4,608	0.0004	0.0001	0.0225	-0.1873	0.2157
ASTRAZENECA	AZN	4,608	0.0004	0.0000	0.0169	-0.1257	0.1236
L'OREAL	F:OR@F	4,608	0.0005	0.0002	0.0185	-0.1179	0.1375
E ON	D:EONX	4,608	0.0002	0.0000	0.0191	-0.1223	0.1813
BAT	BATS	4,608	0.0007	0.0000	0.0184	-0.1220	0.3226
RIO TINTO	RIO	4,608	0.0004	0.0000	0.0260	-0.4578	0.1968
LVMH	F:LVMH	4,608	0.0004	0.0000	0.0209	-0.1308	0.1562
DIAGEO	DGE	4,608	0.0005	0.0000	0.0159	-0.0978	0.1540

Table 8: Balance Sheet Variables: the table provides details on the list of variables used in the panel. Balance sheet items are named according to SNL Financial definition.

Variable	**Definition**
$Price-to-book$	$\frac{Equity\ Market\ Value}{Equity\ Book\ Value}$
$Leverage^A$	$\frac{Tangible\ Assets - Separate\ Account\ Assets}{Tangible\ Equity}$
$Size^A$	$ln(Tangible\ Assets)$
$Leverage^L$	$\frac{Total\ Liabilities - Separate\ Account\ Liabilities}{Tangible\ Equity}$
$Size^L$	$ln(Total\ Liabilities - Separate\ Account\ Liabilities)$
$Concentration^\dagger$	$\frac{\sum_i Asset\ Class_i^2}{(\sum_i Asset\ Class_i)^2}$
$Investment\ Quality$	$\frac{Total\ Investment\ Grade\ Assets}{Tangible\ Assets - Separate\ Account\ Assets}$
$Fixed\ Income\ Assets$	$\frac{Total\ Debt\ Instruments}{Tangible\ Assets - Separate\ Account\ Assets}$
$Equity\ Assets$	$\frac{Total\ Equity\ Instruments}{Tangible\ Assets - Separate\ Account\ Assets}$
$Cash$	$\frac{Cash\ \&\ Cash\ Equivalents}{Tangible\ Assets - Separate\ Account\ Assets}$
$Insurance\ Activities$	$\frac{Reserves\ for\ Insurance\ Contracts - Unit\ Linked\ Insurance}{Total\ Liabilities - Separate\ Account\ Liabilities}$
$Total\ Debt^\ddagger$	$\frac{Senior;Debt + Subordinated\ Debt}{Total\ Liabilities - Separate\ Account\ Liabilities}$
$Separate\ Accounts$	$\frac{Separate\ Account\ Liabilities}{Total\ Liabilities}$

†: $Asset\ Class_i$= Cash & Cash Equivalents; Funds Withheld & Deposits; Primary Insurance Receivables; Reinsurance Receivables; Insurance Receivables; Other Loans; Total Debt Instruments; Total Equity Instruments; Securities Owned: Derivative Financial Instruments; Securities Owned: Other Investments; Total Investment in Real Estate; Investment in Partnerships; Reinsurance Recoverable on Loss & LAE Reserves; Fixed Assets; Total Other Assets.

‡: *Senior Debt* includes deposits from banking activities, whereas *Subordinated Debt* includes hybrid securities and other subordinated debt.

Table 9: Insurance Companies Extended Panel.
Descriptive statistics of Daily log returns observed between January 2005 to December 2013.

Name	Obs.	Average	Median	St.Dev.	Min	Max
Admiral	2,406	0.0008	0.0000	0.0207	-0.2958	0.2272
Aegon	3,892	-0.0004	0.0000	0.0302	-0.2768	0.3022
Ageas	3,892	-0.0005	0.0000	0.0377	-1.4949	0.2589
Aksigorta	3,892	0.0012	0.0000	0.0322	-0.2187	0.3176
Allianz	3,892	-0.0001	0.0000	0.0230	-0.1568	0.1781
Alm. Brand	3,892	-0.0001	0.0000	0.0229	-0.2378	0.2492
Amlin	3,892	0.0006	0.0000	0.0188	-0.3491	0.1659
Anadolu Anonim Türk Sigorta Sirketi	3,892	0.0010	0.0000	0.0301	-0.2336	0.1886
Anadolu Hayat Emeklilik	3,595	0.0007	0.0000	0.0313	-0.1707	0.1861
Generali	3,892	-0.0001	0.0000	0.0176	-0.0923	0.1231
Aviva	3,892	0.0000	0.0000	0.0266	-0.4060	0.2239
Aviva Sigorta	3,892	0.0014	0.0000	0.0343	-0.2267	0.2116
AXA	3,892	0.0000	0.0000	0.0274	-0.2035	0.1978
Bâloise	3,892	0.0001	0.0000	0.0202	-0.1662	0.1891
Beazley	2,889	0.0007	0.0000	0.0180	-0.1404	0.1361
Chesnara	2,496	0.0007	0.0000	0.0202	-0.1075	0.1052
CNP Assurances	3,892	0.0004	0.0000	0.0189	-0.1444	0.1043
Delta Lloyd	1,080	0.0004	0.0006	0.0206	-0.0861	0.1088
Direct Line Insurance Group	315	0.0014	0.0014	0.0115	-0.0396	0.0717
Euler Hermes	3,548	0.0004	0.0000	0.0214	-0.1641	0.1462
European Reliance General Insurance Company	3,892	-0.0002	0.0000	0.0374	-0.2176	0.1815
FBD Holdings	3,892	0.0004	0.0001	0.0487	-1.9376	1.9386
Friends Life Group	1,315	0.0002	0.0000	0.0182	-0.1580	0.1108
Globos osiguranje a.d.o. Beograd	1,227	-0.0012	0.0000	0.0479	-0.2235	0.1823
Grupo Catalana Occidente	3,310	-0.0028	0.0000	0.0608	-1.4674	0.8362
Gunes Sigorta	3,892	0.0009	0.0000	0.0331	-0.2356	0.1765
Hannover Re	3,892	0.0003	0.0000	0.0220	-0.1989	0.1538
Hansard Global	1,828	-0.0002	0.0003	0.0219	-0.1550	0.1831
Helios Underwriting	1,641	0.0003	0.0000	0.0223	-0.5216	0.3909
ING Groep	3,892	-0.0001	0.0000	0.0308	-0.3213	0.2565
Jadransko Osiguranje	1,734	-0.0005	0.0000	0.0290	-0.2653	0.1856
Lancashire Holdings Limited	2,088	0.0009	0.0000	0.0136	-0.0627	0.1162
Legal & General Group	3,892	0.0002	0.0000	0.0258	-0.3408	0.2430
Liberty Life Insurance	3,892	-0.0008	0.0000	0.0489	-0.4158	0.4196
Mapfre	3,892	0.0003	0.0000	0.0219	-0.1344	0.1618
Mediolanum	3,892	0.0001	0.0000	0.0253	-0.1163	0.1710
Munich Re	3,892	0.0001	0.0000	0.0209	-0.1719	0.1653
Novae Group	3,892	-0.0001	0.0000	0.0269	-0.5556	0.3212
Nuernberger	3,892	0.0000	0.0000	0.0176	-0.2289	0.2263
Partnership Assurance Group	146	-0.0019	-0.0010	0.0307	-0.2374	0.1560
Personal Group Holdings	3,396	0.0007	0.0000	0.0114	-0.1144	0.1173
Phoenix Group	1,070	0.0002	0.0000	0.0170	-0.0853	0.1059
Pozavarovalnica Sava	1,440	-0.0008	0.0000	0.0258	-0.1389	0.1389
Protector Forsikring	1,712	0.0003	0.0000	0.0252	-0.1697	0.2230
Prudential	3,892	0.0002	0.0000	0.0272	-0.2231	0.2107
RSA Insurance Group	3,892	-0.0002	0.0000	0.0240	-0.2426	0.1321
Sampo Oyj	3,892	0.0007	0.0000	0.0197	-0.1823	0.1367
Scor	3,892	-0.0003	0.0000	0.0266	-0.3622	0.1907
St. James's Place	3,892	0.0003	0.0000	0.0253	-0.2329	0.2394
Standard Life	1,940	0.0004	0.0000	0.0239	-0.1604	0.1865
Storebrand	560	0.0026	0.0000	0.0147	-0.0666	0.0925
Swiss Life	3,892	-0.0002	0.0000	0.0249	-0.2240	0.1877
Swiss Re	3,892	-0.0001	0.0000	0.0237	-0.3292	0.1957
Talanx	322	0.0009	0.0000	0.0140	-0.0471	0.0399
Topdanmark	3,892	0.0006	0.0000	0.0180	-0.1133	0.1407
Tryg	2,130	0.0005	0.0000	0.0160	-0.1361	0.1032
Uniqa Insurance	3,670	0.0001	0.0000	0.0170	-0.1729	0.0965
Vaudoise Assurances	3,892	0.0003	0.0000	0.0198	-0.1801	0.1869
Vienna Insurance Group	3,892	0.0003	0.0000	0.0188	-0.1974	0.1529
Zavarovalnica Triglav.	1,377	-0.0005	0.0000	0.0217	-0.1076	0.0953
Zurich Insurance Group	3,892	-0.0002	0.0000	0.0233	-0.2257	0.1920

Table 10: Balance sheet variables: the table reports the summary statistics for 3 samples: full, without reinsurers and without reinsurers and SIFIs.

Full Sample					
	Obs	Mean	Std. Dev.	Min	Max
Price to Book	445	2.8762	18.5761	-5.5000	382.5900
$Leverage^A$	443	12.9052	10.3963	2.0417	55.8480
$Size^A$	448	16.6411	2.5930	10.0355	21.0045
$Leverage^L$	428	13.3584	22.1188	1.0417	314.6381
$Size^L$	428	16.2179	2.6604	9.6472	20.9111
Concentration	449	0.3051	0.1017	0.1168	0.6099
Investment Quality	443	0.3752	0.2861	0.0000	1.0093
Fixed Income Assets	439	0.4136	0.1944	0.0000	0.7569
Equity Assets	436	0.0813	0.0858	0.0000	0.6269
Cash	443	0.0872	0.1215	0.0009	0.6619
Insurance Activities	427	0.6598	0.2383	0.0000	0.9635
Total Debt	420	0.1102	0.1660	0.0000	0.8099
Separate Accounts	428	0.1683	0.2398	0.0000	0.9280

Sample w/o Reinsurers					
	Obs	Mean	Std. Dev.	Min	Max
Price to Book	409	3.0416	19.3694	-5.5000	382.5900
$Leverage^A$	411	13.0744	10.7641	2.0417	55.8480
$Size^A$	416	16.5293	2.6453	10.0355	21.0045
$Leverage^L$	396	13.6578	22.9653	1.0417	314.6381
$Size^L$	396	16.0770	2.7050	9.6472	20.9111
Concentration	417	0.3106	0.1031	0.1168	0.6099
Investment Quality	411	0.3723	0.2897	0.0000	1.0093
Fixed Income Assets	407	0.4114	0.2009	0.0000	0.7569
Equity Assets	404	0.0848	0.0877	0.0000	0.6269
Cash	411	0.0912	0.1249	0.0009	0.6619
Insurance Activities	395	0.6495	0.2440	0.0000	0.9635
Total Debt	388	0.1145	0.1716	0.0000	0.8099
Separate Accounts	396	0.1793	0.2454	0.0000	0.9280

Sample w/o Reinsurers and SIFIs					
	Obs	Mean	Std. Dev.	Min	Max
Price to Book	364	3.2197	20.5261	-5.5000	382.5900
$Leverage^A$	368	11.2150	9.1015	2.0417	55.8480
$Size^A$	372	16.1192	2.4930	10.0355	21.0045
$Leverage^L$	356	12.0553	23.4185	1.0417	314.6381
$Size^L$	356	15.6598	2.5284	9.6472	20.9111
Concentration	372	0.3084	0.1073	0.1168	0.6099
Investment Quality	368	0.3612	0.2888	0.0000	1.0093
Fixed Income Assets	365	0.3996	0.2067	0.0000	0.7569
Equity Assets	365	0.0825	0.0894	0.0000	0.6269
Cash	368	0.0966	0.1306	0.0009	0.6619
Insurance Activities	355	0.6548	0.2543	0.0000	0.9635
Total Debt	348	0.1141	0.1784	0.0000	0.8099
Separate Accounts	356	0.1801	0.2579	0.0000	0.9280

Table 11: Correlation Matrix: the table reports the correlation among the variables for the 3 samples.

Full Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)*Price-to-book*	1												
(2) $Leverage^A$	-0.0297	1											
(3) $Size^A$	-0.0320	0.6417	1										
(4) $Leverage^L$	-0.0305	0.9748	0.6426	1									
(5) $Size^L$	-0.0274	0.6523	0.9873	0.6583	1								
(6) *Concentration*	-0.0743	0.2249	0.3667	0.2164	0.3216	1							
(7) *Investment Quality*	-0.0060	0.1454	0.4283	0.1445	0.4312	0.2607	1						
(8) *Fixed Income Assets*	-0.0263	0.2166	0.4887	0.1961	0.5141	0.5070	0.6141	1					
(9) *Equity Assets*	0.0334	0.1340	-0.0135	0.0947	-0.0307	-0.0477	0.0153	-0.1044	1				
(10) *Cash*	0.0134	-0.2576	-0.3597	-0.2699	-0.4268	-0.0884	-0.3320	-0.4825	-0.2168	1			
(11) *Insurance Activities*	0.0401	-0.3401	-0.2737	-0.3102	-0.2172	-0.4177	0.1339	0.1492	0.0514	-0.0751	1		
(12) *Total Debt*	-0.0424	0.3339	0.3133	0.3414	0.3226	0.2573	-0.1403	-0.0105	-0.1535	-0.2108	-0.5911	1	
(13) *Separate Accounts*	-0.0313	0.1521	0.2678	0.1241	0.1209	0.3262	0.0796	-0.0363	0.1654	0.2757	-0.3713	0.0254	1

Sample w/o Reinsurers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)*Price-to-book*	1												
(2) $Leverage^A$	-0.0317	1											
(3) $Size^A$	-0.0272	0.6675	1										
(4) $Leverage^L$	-0.0328	0.9747	0.6697	1									
(5) $Size^L$	-0.0219	0.6822	0.9871	0.6898	1								
(6) *Concentration*	-0.0835	0.218	0.4154	0.2082	0.3751	1							
(7) *Investment Quality*	-0.0062	0.1471	0.4401	0.1454	0.443	0.2661	1						
(8) *Fixed Income Assets*	-0.0259	0.2207	0.4901	0.2003	0.5181	0.5201	0.6274	1					
(9) *Equity Assets*	0.0289	0.1274	0.0128	0.0864	-0.0014	-0.0816	0.0184	-0.1005	1				
(10) *Cash*	0.0100	-0.2693	-0.3473	-0.2821	-0.4150	-0.1140	-0.3236	-0.4846	-0.2432	1			
(11) *Insurance Activities*	0.0459	-0.3387	-0.3109	-0.3078	-0.2576	-0.4009	0.1274	0.1528	0.0742	-0.0568	1		
(12) *Total Debt*	-0.0457	0.3326	0.3377	0.3402	0.3516	0.2467	-0.1279	-0.0094	-0.1708	-0.232	-0.5856	1	
(13) *Separate Accounts*	-0.0370	0.1462	0.3033	0.1172	0.1563	0.3038	0.1017	-0.0360	0.1461	0.2592	-0.3525	0.0037	1

Sample w/o Reinsurers and SIFIs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)*Price-to-book*	1												
(2) $Leverage^A$	-0.0236	1											
(3) $Size^A$	-0.0155	0.6315	1										
(4) $Leverage^L$	-0.0248	0.9590	0.6322	1									
(5) $Size^L$	-0.0090	0.6466	0.9836	0.6552	1								
(6) *Concentration*	-0.0824	0.2922	0.4477	0.2781	0.4052	1							
(7) *Investment Quality*	-0.0016	0.2177	0.471	0.2093	0.4767	0.2665	1						
(8) *Fixed Income Assets*	-0.0212	0.212	0.4798	0.1843	0.5152	0.5156	0.6351	1					
(9) *Equity Assets*	0.0300	0.0474	-0.021	-0.0031	-0.0388	-0.0766	0.0706	-0.11	1				
(10) *Cash*	0.0067	-0.2599	-0.3276	-0.2768	-0.4063	-0.1093	-0.3429	-0.4841	-0.2377	1			
(11) *Insurance Activities*	0.0445	-0.3668	-0.3143	-0.3236	-0.2537	-0.4202	0.1216	0.1557	0.0871	-0.0637	1		
(12) *Total Debt*	-0.0465	0.4461	0.3892	0.453	0.4084	0.2578	-0.1212	0.0033	-0.1764	-0.2386	-0.5904	1	
(13) *Separate Accounts*	-0.0370	0.1817	0.3392	0.1440	0.1745	0.3034	0.1130	-0.0482	0.1442	0.2632	-0.3612	0.0088	1

Table 12: Panel regressions: the table reports the panel regression for both asset and liability specifications across 3 different samples - fixed effect model. ΔCoVar and DMES are reported with positive sign and sclaed by 100.
Robust t-statistic in parentheses. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.1$.

	Full Sample				**Sample w/o Reinsurers**				**Sample w/o Reinsurers and SIFIs**			
Variables	**ΔCoVaR**	**ΔCoVaR**	**DMES**	**DMES**	**ΔCoVaR**	**ΔCoVaR**	**DMES**	**DMES**	**ΔCoVaR**	**ΔCoVaR**	**DMES**	**DMES**
Price − to − book	-0.00116***	-0.00116***	0.000719	0.000710	-0.00117***	-0.00117***	0.000286	0.000262	-0.00104***	-0.00103***	0.000381	0.000435
	(-5.068)	(-5.077)	(1.195)	(1.189)	(-5.076)	(-5.094)	(0.443)	(0.409)	(-5.169)	(-5.235)	(0.599)	(0.694)
$Leverage^A$	-0.00351*		-0.0113		-0.00334		-0.0194		-0.0101***		-0.0381**	
	(-1.790)		(-0.961)		(-1.615)		(-1.611)		(-4.143)		(-2.454)	
$Size^A$	0.146***		0.442***		0.147***		0.511***		0.135***		0.520***	
	(17.14)		(9.043)		(15.26)		(9.091)		(13.38)		(8.150)	
$Leverage^L$		-0.00556***		-0.0184		-0.00551**		-0.0277**		-0.0139***		-0.0527***
		(-2.638)		(-1.526)		(-2.488)		(-2.219)		(-5.423)		(-3.257)
$Size^L$		0.146***		0.443***		0.147***		0.514***		0.138***		0.527***
		(17.98)		(9.312)		(16.26)		(9.366)		(14.89)		(8.500)
Concentration	-0.844***	-0.773***	-3.090***	-2.876***	-0.759***	-0.696***	-3.652***	-3.403***	-0.537**	-0.400**	-3.208***	-2.682***
	(-4.102)	(-3.807)	(-3.199)	(-3.030)	(-3.554)	(-3.267)	(-3.669)	(-3.504)	(-2.475)	(-2.048)	(-3.081)	(-2.761)
Investment Quality	-0.0607	-0.0612	-0.704*	-0.707*	-0.0372	-0.0415	-1.018**	-1.026**	0.130	0.151*	-0.416	-0.327
	(-0.798)	(-0.789)	(-1.888)	(-1.845)	(-0.442)	(-0.480)	(-2.557)	(-2.507)	(1.425)	(1.716)	(-1.030)	(-0.816)
Equity Assets	-0.0863	-0.107	0.137	0.0844	-0.0711	-0.0926	-0.0999	-0.214	-0.239	-0.328**	-0.895	-1.234
	(-0.478)	(-0.580)	(0.156)	(0.0965)	(-0.388)	(-0.496)	(-0.108)	(-0.233)	(-1.380)	(-2.036)	(-1.012)	(-1.480)
Fixed Income Assets	0.312**	0.258*	1.221*	1.053	0.251	0.199	1.334*	1.113	0.0762	-0.0470	0.482	0.0209
	(2.169)	(1.842)	(1.681)	(1.475)	(1.626)	(1.330)	(1.746)	(1.500)	(0.445)	(-0.330)	(0.607)	(0.0298)
Cash	0.390**	0.417**	1.877*	1.948*	0.393**	0.419**	1.675	1.725*	0.287	0.257	1.288	1.167
	(2.096)	(2.239)	(1.859)	(1.948)	(2.066)	(2.213)	(1.600)	(1.669)	(1.502)	(1.387)	(1.239)	(1.152)
Insurance Activities	-0.499***	-0.513***	-1.595***	-1.642***	-0.465***	-0.480***	-1.630***	-1.666***	-0.434***	-0.415***	-1.664***	-1.596***
	(-4.794)	(-4.866)	(-3.630)	(-3.788)	(-4.424)	(-4.510)	(-3.656)	(-3.812)	(-4.486)	(-4.582)	(-3.830)	(-3.944)
Total Debt	-0.0189	-0.0375	1.527**	1.477**	-0.00982	-0.0303	1.276*	1.214*	0.213**	0.229**	1.670**	1.745***
	(-0.161)	(-0.321)	(2.305)	(2.217)	(-0.0845)	(-0.260)	(1.901)	(1.793)	(2.102)	(2.299)	(2.570)	(2.654)
Separate Accounts	-0.143*	0.0935	-0.783*	-0.0650	-0.156*	0.0832	-0.855*	-0.0256	-0.113	0.108	-0.976**	-0.119
	(-1.835)	(1.212)	(-1.666)	(-0.140)	(-1.963)	(1.054)	(-1.817)	(-0.0551)	(-1.541)	(1.496)	(-2.047)	(-0.252)
Observations	314	314	314	314	286	286	286	286	253	253	253	253
Adjusted R-squared	0.702	0.704	0.558	0.559	0.701	0.702	0.570	0.571	0.662	0.678	0.555	0.563
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F test	61.20	59.48	14.75	14.73	57.63	55.80	13.98	14.03	43.87	45.97	11.28	12.15

Table 13: DiD Variables and Expected Signs

VARIABLES	**dummy=0**	**dummy=1**	$\frac{\partial SR}{\partial d.X_z}$
Concentration	B	T	> 0
Investment Quality	T	B	< 0
Fixed Income	T	B	< 0
Equity	B	T	> 0
Cash	T	B	< 0
Insurance Activities	T	B	< 0
Total Debt	B	T	> 0
Separate Account	B	T	> 0

T=$\Phi^{-1}X_z \geq 0.5$

B=$\Phi^{-1}X_z < 0.5$

Table 14: Robustness Check - DiD for ΔCoVaR, asset side specification: Shock dummy computed around Lehman Brothers filing for bankruptcy and AIG bailout. Treatment groups defined in table 13.
Robust t-statistic in parentheses. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.1$.

VARIABLES	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR
Price − to − book	0.106***	0.0890***	0.0902***	0.0875***	0.0890***	0.0797***	0.0896***	0.0836***
	(7.594)	(7.235)	(6.793)	(6.359)	(5.932)	(6.651)	(6.713)	(5.935)
$Leverage^A$	-0.0210*	-0.0234***	-0.0126**	-0.0129**	-0.0111*	-0.0120**	-0.0124**	-0.0115*
	(-1.910)	(-4.296)	(-2.204)	(-2.398)	(-1.944)	(-2.337)	(-2.429)	(-1.781)
$Size^A$	0.238***	0.236***	0.207***	0.210***	0.213***	0.188***	0.199***	0.198***
	(7.089)	(6.665)	(7.813)	(7.769)	(8.059)	(8.480)	(7.885)	(7.974)
Concentration		-1.207*	-0.993**	-1.410**	-1.050	-1.033**	-1.276**	-1.602***
		(-1.806)	(-2.325)	(-2.340)	(-1.407)	(-2.246)	(-2.431)	(-2.980)
Investment Quality	-0.167		-0.177	-0.273	-0.221	-0.0916	-0.208	-0.254
	(-0.652)		(-0.927)	(-1.217)	(-0.950)	(-0.470)	(-1.124)	(-1.098)
Fixed Income Assets	-0.479	-0.214		0.306	0.207	0.0149	0.178	0.396
	(-1.205)	(-0.289)		(0.719)	(0.427)	(0.0443)	(0.425)	(0.911)
Equity Assets	-2.231**	-1.625*	-0.199		-0.105	-0.190	-0.0361	-0.399
	(-2.301)	(-1.953)	(-0.258)		(-0.152)	(-0.283)	(-0.0592)	(-0.531)
Cash	-1.278*	-0.949	-0.341	-0.228		-0.251	0.0197	-0.319
	(-1.783)	(-1.458)	(-0.651)	(-0.486)		(-0.595)	(0.0422)	(-0.673)
Insurance Activities	0.153	-0.315	-0.207	-0.366	-0.197		-0.110	-0.340
	(0.279)	(-1.100)	(-0.914)	(-1.199)	(-0.634)		(-0.545)	(-1.265)
Total Debt	-0.380	-0.166	-0.205	-0.274	-0.147	-0.0836		-0.183
	(-1.181)	(-0.785)	(-0.788)	(-0.908)	(-0.528)	(-0.439)		(-0.691)
Separate Accounts	0.151	0.170	-0.113	-0.139	-0.236	-0.224	-0.0763	
	(0.638)	(1.044)	(-0.684)	(-0.885)	(-1.535)	(-1.455)	(-0.528)	
d.shock	0.309*	0.471***	0.451***	0.361***	0.341***	0.255**	0.272***	0.312***
	(2.030)	(4.789)	(4.963)	(4.136)	(3.832)	(2.516)	(3.194)	(3.559)
d.Concentration	-0.0945							
	(-0.545)							
d.shock · d.Concentration	0.159							
	(0.874)							
d.Investment Quality		-0.0415						
		(-0.411)						
d.shock · d.Investment Quality		-0.150						
		(-1.027)						
d.Fixed Income Assets			0.0792					
			(0.757)					
d.shock · d.Fixed Income Assets			-0.0745					
			(-0.524)					
d.Equity Assets				-0.153				
				(-1.553)				
d.shock · d.Equity Assets				0.142				
				(1.004)				
d.Cash					-0.169			
					(-1.463)			
d.shock · d.Cash					0.144			
					(1.059)			
d.Insurance Activities						0.0604		
						(0.734)		
d.shock · d.Insurance Activities						0.299**		
						(2.355)		
d.Total Debt							-0.0545	
							(-0.616)	
d.shock · d.Total Debt							0.280**	
							(2.072)	
d.Separate Accounts								-0.127
								(-1.275)
d.shock · d.Separate Accounts								0.232*
								(1.674)
Observations	40	48	70	70	70	70	70	70
Adjusted R-squared	0.725	0.713	0.671	0.682	0.682	0.720	0.700	0.686
F test	16.86	22.10	15.74	16.47	15.16	19.35	15.82	18.29

Table 15: Robustness Check - DiD for ΔCoVaR, liability side specification: Shock dummy computed around Lehman Brothers filing for bankruptcy and AIG bailout. Treatment groups defined in table 13.
Robust t-statistic in parentheses. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.1$.

VARIABLES	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR	ΔCoVaR
Price − to − book	0.107***	0.0892***	0.0885***	0.0863***	0.0888***	0.0786***	0.0886***	0.0822***
	(7.845)	(7.579)	(6.321)	(5.892)	(5.670)	(6.320)	(6.319)	(5.364)
$Leverage^L$	-0.0234**	-0.0268***	-0.0141**	-0.0143**	-0.0127**	-0.0134**	-0.0140**	-0.0147**
	(-2.260)	(-4.557)	(-2.347)	(-2.441)	(-2.085)	(-2.455)	(-2.584)	(-2.097)
$Size^L$	0.237***	0.236***	0.200***	0.203***	0.206***	0.182***	0.193***	0.196***
	(7.736)	(6.713)	(7.543)	(7.433)	(7.847)	(8.281)	(7.579)	(7.434)
Concentration		-1.309**	-1.046**	-1.348**	-0.921	-0.973**	-1.184**	-1.474***
		(-2.089)	(-2.326)	(-2.255)	(-1.232)	(-2.071)	(-2.292)	(-2.763)
Investment Quality	-0.203		-0.192	-0.264	-0.207	-0.0843	-0.200	-0.232
	(-0.841)		(-0.986)	(-1.171)	(-0.882)	(-0.433)	(-1.085)	(-1.059)
Fixed Income Assets	-0.562	-0.263		0.220	0.0636	-0.0703	0.0742	0.289
	(-1.473)	(-0.371)		(0.524)	(0.132)	(-0.213)	(0.183)	(0.687)
Equity Assets	-2.204**	-1.648**	-0.137		-0.0207	-0.120	0.0244	-0.212
	(-2.222)	(-2.038)	(-0.176)		(-0.0299)	(-0.176)	(0.0395)	(-0.279)
Cash	-1.322*	-0.936	-0.196	-0.140		-0.166	0.110	0.0517
	(-1.905)	(-1.508)	(-0.358)	(-0.283)		(-0.376)	(0.223)	(0.102)
Insurance Activities	0.191	-0.264	-0.239	-0.368	-0.193		-0.103	-0.372
	(0.342)	(-0.940)	(-0.986)	(-1.138)	(-0.602)		(-0.502)	(-1.264)
Total Debt	-0.408	-0.0890	-0.194	-0.264	-0.148	-0.0776		-0.143
	(-1.184)	(-0.438)	(-0.726)	(-0.840)	(-0.526)	(-0.411)		(-0.502)
Separate Accounts	0.527**	0.537***	0.182	0.167	0.0783	0.0422	0.209	
	(2.209)	(3.734)	(1.087)	(1.031)	(0.501)	(0.271)	(1.396)	
d.shock	0.311**	0.477***	0.456***	0.370***	0.352***	0.255**	0.283***	0.313***
	(2.074)	(5.047)	(4.910)	(4.160)	(3.899)	(2.479)	(3.209)	(3.605)
d.Concentration	-0.0856							
	(-0.496)							
d.shock · d.Concentration	0.171							
	(0.943)							
d.Investment Quality		-0.0551						
		(-0.553)						
d.shock · d.Investment Quality		-0.162						
		(-1.149)						
d.Fixed Income Assets			0.0685					
			(0.656)					
d.shock · d.Fixed Income Assets			-0.0714					
			(-0.501)					
d.Equity Assets				-0.137				
				(-1.369)				
d.shock · d.Equity Assets				0.130				
				(0.902)				
d.Cash					-0.175			
					(-1.476)			
d.shock · d.Cash					0.130			
					(0.939)			
d.Insurance Activities						0.0627		
						(0.764)		
d.shock · d.Insurance Activities						0.304**		
						(2.363)		
d.Total Debt							-0.0312	
							(-0.353)	
d.shock · d.Total Debt							0.263*	
							(1.930)	
d.Separate Accounts								-0.0531
								(-0.529)
d.shock · d.Separate Accounts								0.243*
								(1.775)
Observations	40	48	70	70	70	70	70	70
Adjusted R-squared	0.732	0.732	0.666	0.674	0.677	0.716	0.693	0.682
F test	15.93	22.93	15.01	15.57	14.64	18.48	15.44	16.14

Table 16: Robustness Check - DiD for DMES, asset side specification: Shock dummy computed around Lehman Brothers filing for bankruptcy and AIG bailout. Treatment groups defined in table 13.
Robust t-statistic in parentheses. $***\ p<0.01$, $**\ p<0.05$, $*\ p<0.1$.

VARIABLES	DMES	DMES	DMES	DMES	DMES	DMES	DMES	DMES
Price − to − book	0.362***	0.207**	0.236***	0.206**	0.243***	0.217***	0.218***	0.204**
	(2.967)	(2.189)	(2.893)	(2.595)	(2.903)	(2.707)	(2.853)	(2.369)
$Leverage^A$	-0.201***	-0.111***	-0.0643**	-0.0559*	-0.0526*	-0.0614**	-0.0607**	-0.0459
	(-3.055)	(-3.165)	(-2.270)	(-1.924)	(-1.854)	(-2.380)	(-2.492)	(-1.484)
$Size^A$	1.162***	1.015***	0.740***	0.759***	0.764***	0.710***	0.720***	0.718***
	(4.334)	(4.184)	(3.907)	(4.207)	(4.298)	(3.795)	(4.080)	(3.924)
Concentration		-3.621	-7.211***	-9.316***	-5.766	-6.652**	-8.735***	-9.069***
		(-0.941)	(-2.930)	(-2.745)	(-1.584)	(-2.294)	(-2.879)	(-2.845)
Investment Quality	-1.690		-1.994*	-2.538*	-2.117	-1.502	-2.632**	-2.415*
	(-1.231)		(-1.775)	(-1.932)	(-1.671)	(-1.350)	(-2.533)	(-1.920)
Fixed Income Assets	-3.606	-0.620		2.260	0.472	0.286	1.422	2.471
	(-1.582)	(-0.164)		(1.001)	(0.187)	(0.136)	(0.756)	(1.101)
Equity Assets	-6.814	-5.292	2.106		2.893	3.333	1.608	2.367
	(-1.332)	(-1.239)	(0.506)		(0.824)	(0.945)	(0.559)	(0.601)
Cash	2.017	1.101	0.683	-0.180		1.862	0.763	1.003
	(0.403)	(0.227)	(0.220)	(-0.0664)		(0.684)	(0.302)	(0.376)
Insurance Activities	-0.808	-2.285*	-1.491	-2.395*	-1.127		-1.968	-1.743
	(-0.237)	(-1.731)	(-1.104)	(-1.818)	(-0.823)		(-1.626)	(-1.251)
Total Debt	1.518	1.937	1.074	-0.0952	1.026	2.182		1.020
	(0.644)	(0.880)	(0.649)	(-0.0568)	(0.683)	(1.453)		(0.604)
Separate Accounts	-1.225	-0.815	-1.218	-0.936	-1.601*	-1.495	-0.749	
	(-0.588)	(-0.476)	(-1.068)	(-0.866)	(-1.742)	(-1.457)	(-0.734)	
d.shock	2.059**	2.463***	2.599***	2.668***	2.339***	1.511***	1.674***	2.245***
	(2.690)	(4.669)	(4.520)	(4.495)	(4.553)	(3.026)	(3.817)	(3.901)
d.Concentration	-1.395							
	(-1.373)							
d.shock · d.Concentration	1.233							
	(1.025)							
d.Investment Quality		-0.435						
		(-0.610)						
d.shock · d.Investment Quality		0.581						
		(0.575)						
d.Fixed Income Assets			-0.143					
			(-0.271)					
d.shock · d.Fixed Income Assets			0.0240					
			(0.0285)					
d.Equity Assets				-0.502				
				(-0.975)				
d.shock · d.Equity Assets				0.0365				
				(0.0462)				
d.Cash					-1.106**			
					(-2.238)			
d.shock · d.Cash					0.536			
					(0.683)			
d.Insurance Activities						-0.561		
						(-1.104)		
d.shock · d.Insurance Activities						2.012**		
						(2.478)		
d.Total Debt							-0.400	
							(-0.852)	
d.shock · d.Total Debt							1.941**	
							(2.525)	
d.Separate Accounts								-1.140*
								(-1.943)
d.shock · d.Separate Accounts								0.773
								(0.974)
Observations	40	48	70	70	70	70	70	70
Adjusted R-squared	0.489	0.583	0.489	0.501	0.514	0.541	0.555	0.510
F test	5.232	4.059	5.964	5.150	6.218	5.180	4.995	5.854

Table 17: Robustness Check - DiD for DMES, liability side specification: Shock dummy computed around Lehman Brothers filing for bankruptcy and AIG bailout. Treatment groups defined in table 13.
Robust t-statistic in parentheses. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.1$.

VARIABLES	DMES	DMES	DMES	DMES	DMES	DMES	DMES	DMES
$Price - to - book$	0.358***	0.203**	0.232***	0.202**	0.242***	0.214***	0.214***	0.198**
	(2.971)	(2.085)	(2.821)	(2.493)	(2.853)	(2.683)	(2.789)	(2.246)
$Leverage^L$	-0.199***	-0.123***	-0.0715**	-0.0621*	-0.0594*	-0.0684**	-0.0669**	-0.0581*
	(-2.882)	(-3.156)	(-2.359)	(-1.968)	(-1.954)	(-2.451)	(-2.595)	(-1.707)
$Size^L$	1.102***	0.988***	0.718***	0.727***	0.736***	0.687***	0.692***	0.700***
	(4.062)	(4.129)	(3.825)	(4.050)	(4.198)	(3.745)	(4.030)	(3.739)
Concentration		-4.157	-7.459***	-9.124***	-5.397	-6.471**	-8.427***	-8.646***
		(-1.110)	(-3.025)	(-2.757)	(-1.513)	(-2.328)	(-2.864)	(-2.793)
Investment Quality	-1.818		-2.068*	-2.502*	-2.071	-1.484	-2.604**	-2.319*
	(-1.316)		(-1.807)	(-1.877)	(-1.620)	(-1.326)	(-2.482)	(-1.871)
Fixed Income Assets	-3.855	-0.790		1.962	0.000219	-0.0352	1.045	2.094
	(-1.649)	(-0.208)		(0.876)	(8.79e-05)	(-0.0168)	(0.562)	(0.947)
Equity Assets	-6.336	-5.469	2.320		3.217	3.613	1.776	3.063
	(-1.179)	(-1.259)	(0.552)		(0.911)	(1.010)	(0.612)	(0.750)
Cash	1.312	0.864	1.145	0.0494		2.087	0.980	2.247
	(0.264)	(0.178)	(0.363)	(0.0175)		(0.743)	(0.371)	(0.795)
Insurance Activities	-0.537	-2.118	-1.585	-2.418*	-1.115		-1.949	-1.888
	(-0.157)	(-1.558)	(-1.160)	(-1.793)	(-0.804)		(-1.613)	(-1.312)
Total Debt	1.425	2.260	1.164	-0.0157	1.072	2.238		1.194
	(0.581)	(1.022)	(0.700)	(-0.00917)	(0.703)	(1.486)		(0.709)
Separate Accounts	0.498	0.784	-0.170	0.172	-0.475	-0.492	0.280	
	(0.248)	(0.501)	(-0.148)	(0.155)	(-0.498)	(-0.482)	(0.269)	
$d.shock$	2.040**	2.482***	2.613***	2.700***	2.382***	1.514***	1.717***	2.245***
	(2.600)	(4.721)	(4.485)	(4.486)	(4.534)	(2.970)	(3.828)	(3.926)
$d.Concentration$	-1.314							
	(-1.262)							
$d.shock \cdot d.Concentration$	1.302							
	(1.053)							
$d.Investment\ Quality$		-0.513						
		(-0.712)						
$d.shock \cdot d.Investment\ Quality$		0.531						
		(0.524)						
$d.Fixed\ Income\ Assets$			-0.192					
			(-0.360)					
$d.shock \cdot d.Fixed\ Income\ Assets$			0.0400					
			(0.0474)					
$d.Equity\ Assets$				-0.433				
				(-0.835)				
$d.shock \cdot d.Equity\ Assets$				-0.00732				
				(-0.00911)				
$d.Cash$					-1.105**			
					(-2.184)			
$d.shock \cdot d.Cash$					0.477			
					(0.600)			
$d.Insurance\ Activities$						-0.550		
						(-1.092)		
$d.shock \cdot d.Insurance\ Activities$						2.028**		
						(2.471)		
$d.Total\ Debt$							-0.304	
							(-0.662)	
$d.shock \cdot d.Total\ Debt$							1.878**	
							(2.446)	
$d.Separate\ Accounts$								-0.859
								(-1.468)
$d.shock \cdot d.Separate\ Accounts$								0.814
								(1.023)
Observations	40	48	70	70	70	70	70	70
Adjusted R-squared	0.461	0.577	0.484	0.492	0.508	0.536	0.548	0.503
F test	4.598	4.030	5.679	5.089	6.134	5.014	4.934	5.818

C Figures

Figure 1: Total cause intra-industry.
The figure displays for each group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is set at 5%. Results are calculated using Newey West standard errors.

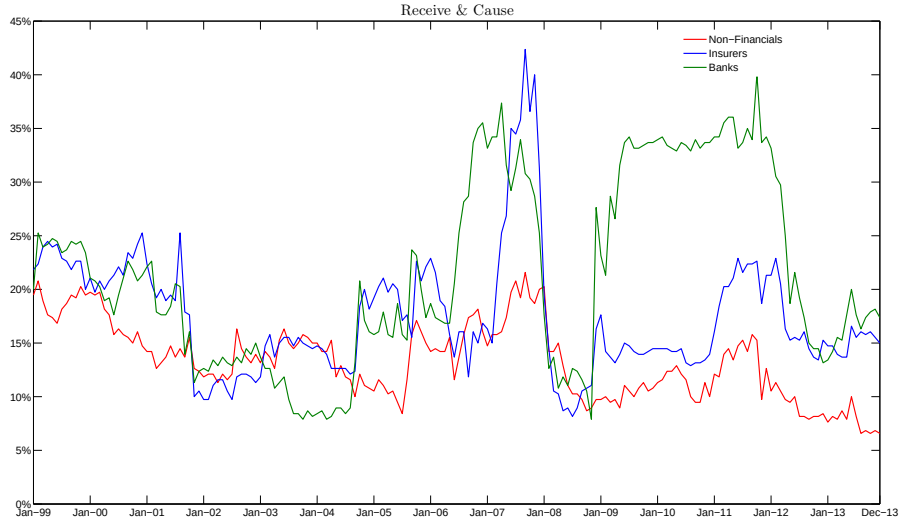


Figure 2: Total cause/receive towards other industries.
The figure displays for each group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is set at 5%. Results are calculated using Newey West standard errors.

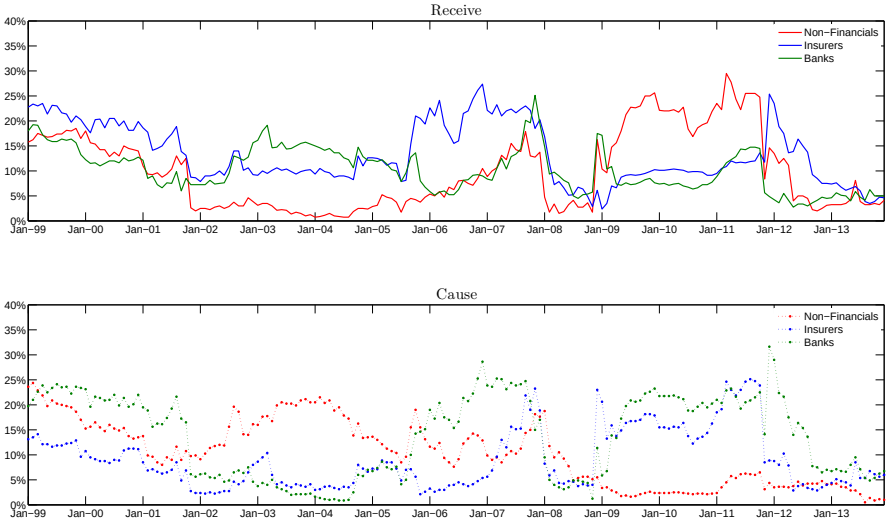


Figure 3: Total cause/receive towards total system.
The figure displays for each group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is set at 5%. Results are calculated using Newey West standard errors.

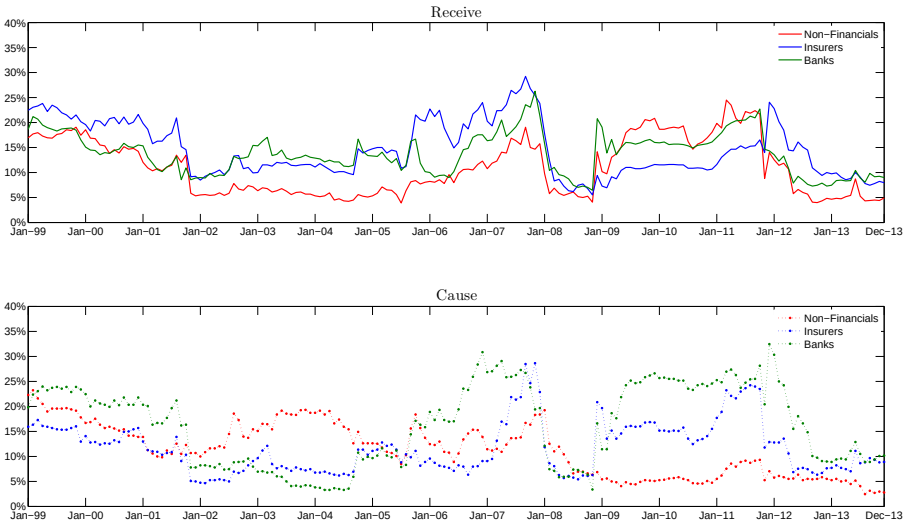


Figure 4: Average institutions' ΔCoVaR intra-industry.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

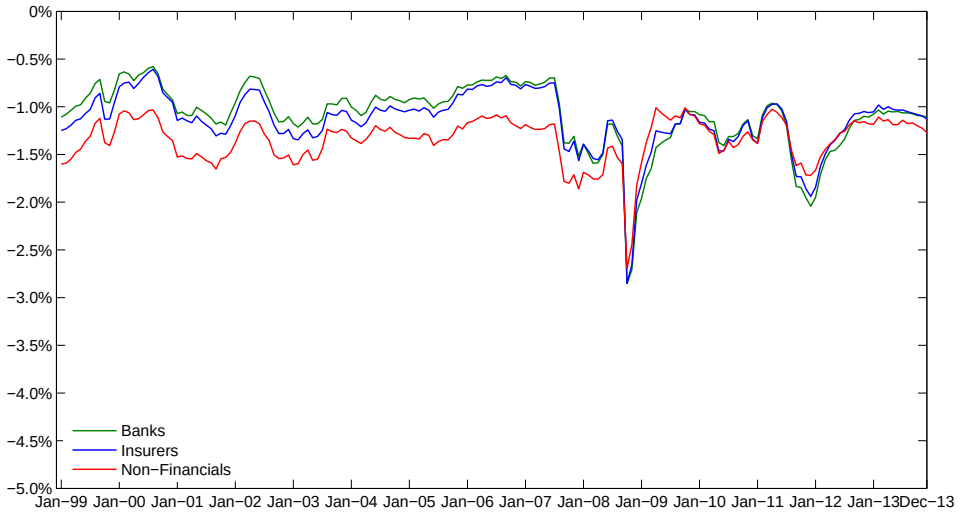


Figure 5: Average institutions' ΔCoVaR towards other industries.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

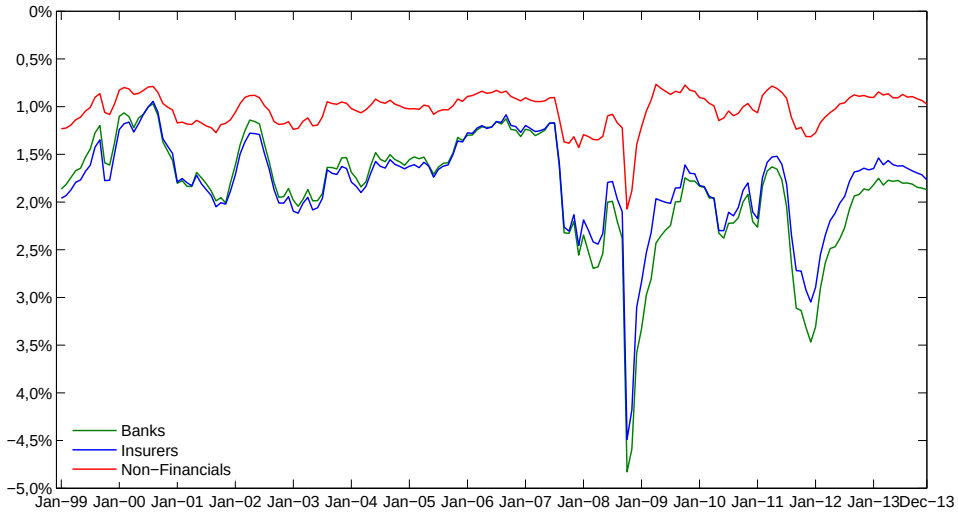


Figure 6: Average institutions' ΔCoVaR towards total system.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

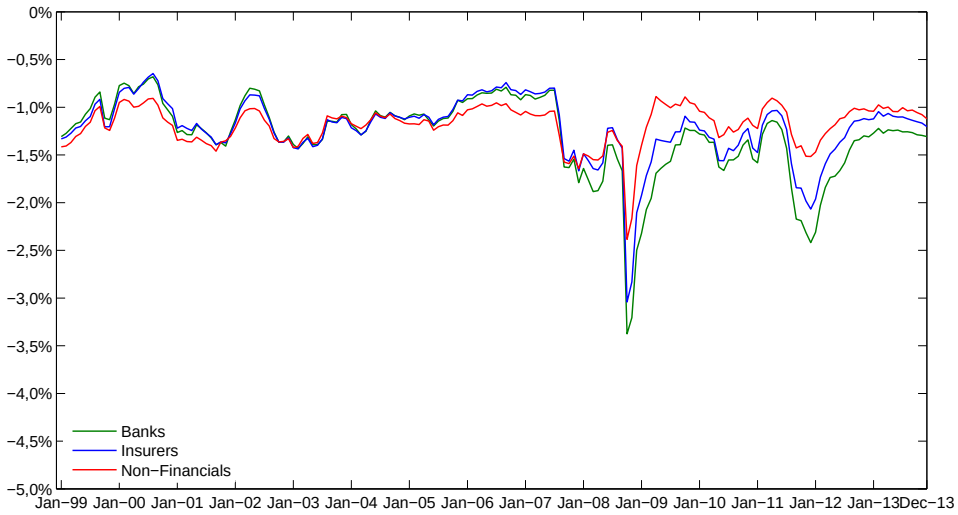


Figure 7: Average institutions' DMES intra-industry.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

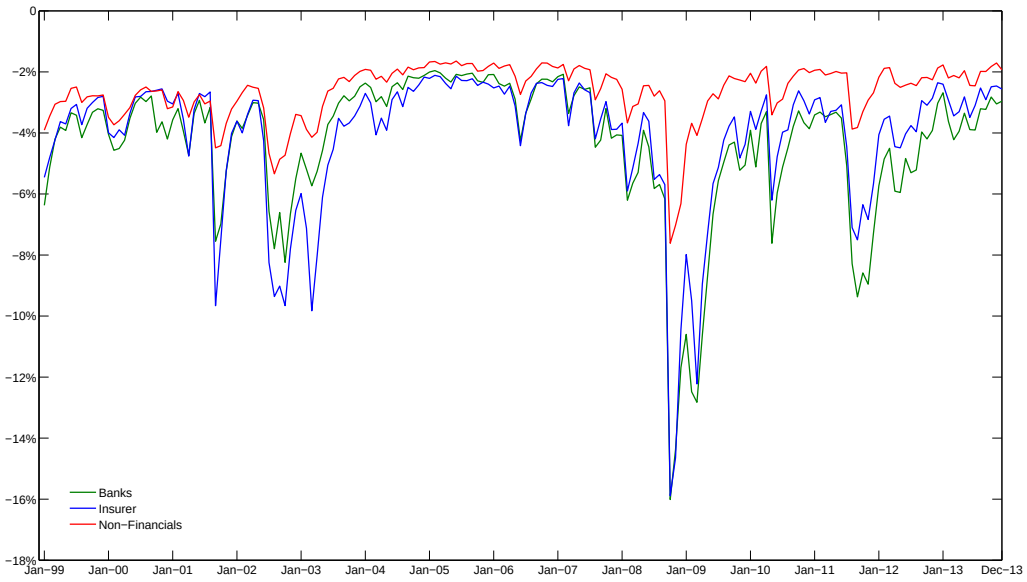


Figure 8: Average institutions' DMES towards other industries.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

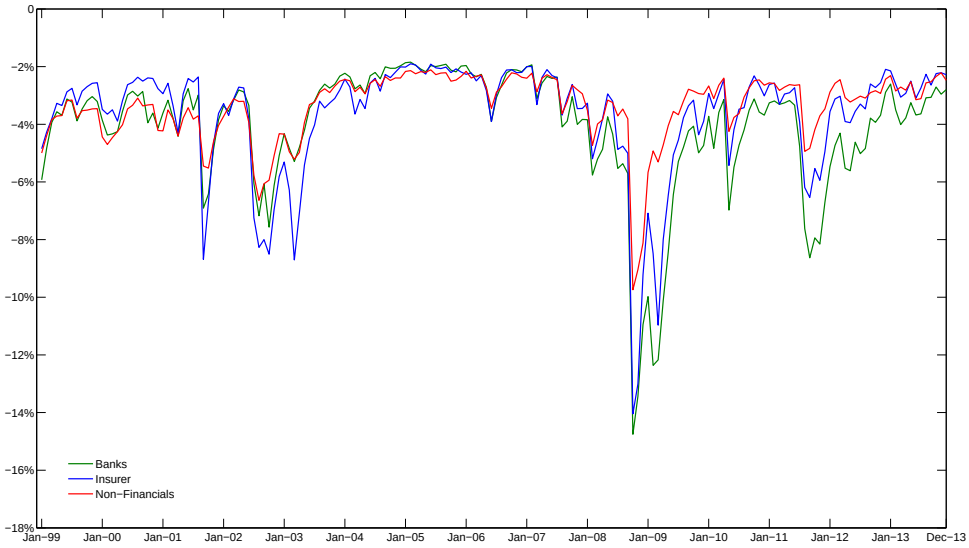


Figure 9: Average institutions' DMES towards total system.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

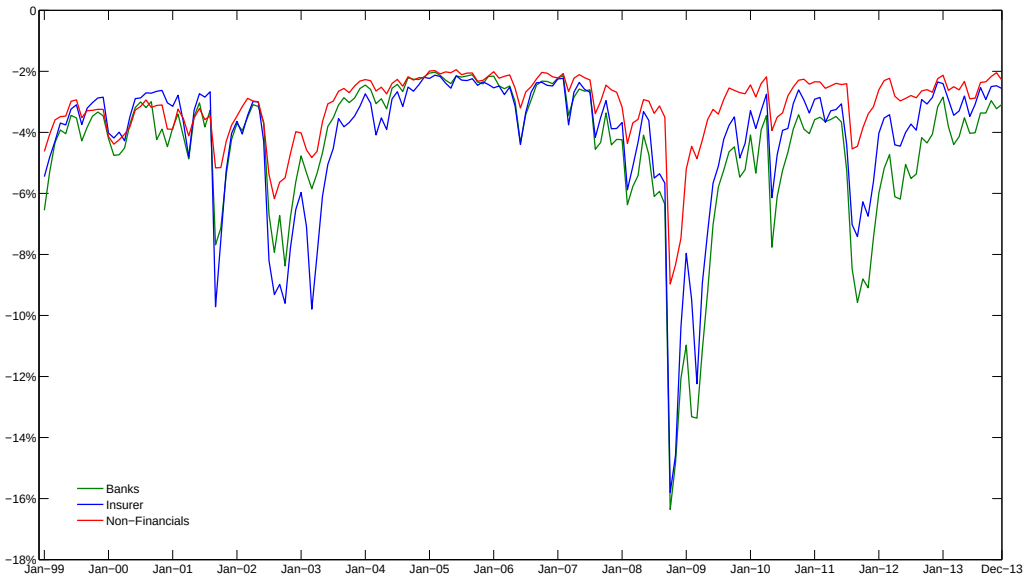


Figure 10: Total cause towards total system - focus on SIFI Insurance Companies
The figure displays for each group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is set at 5%. Results are calculated using Newey West standard errors.

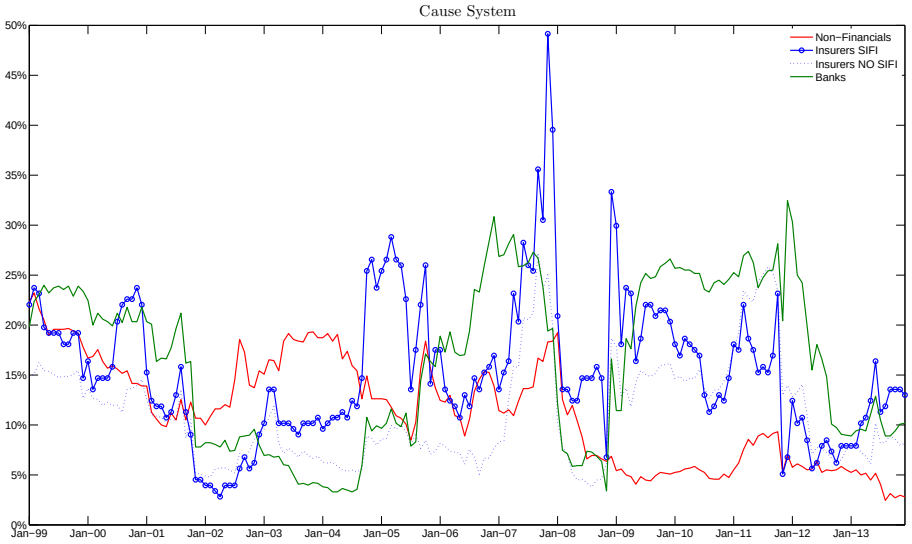


Figure 11: Average institutions' ΔCoVaR towards total system - focus on SIFI Insurance Companies. The figure displays the industry monthly average calculated on the single institution's monthly median value.

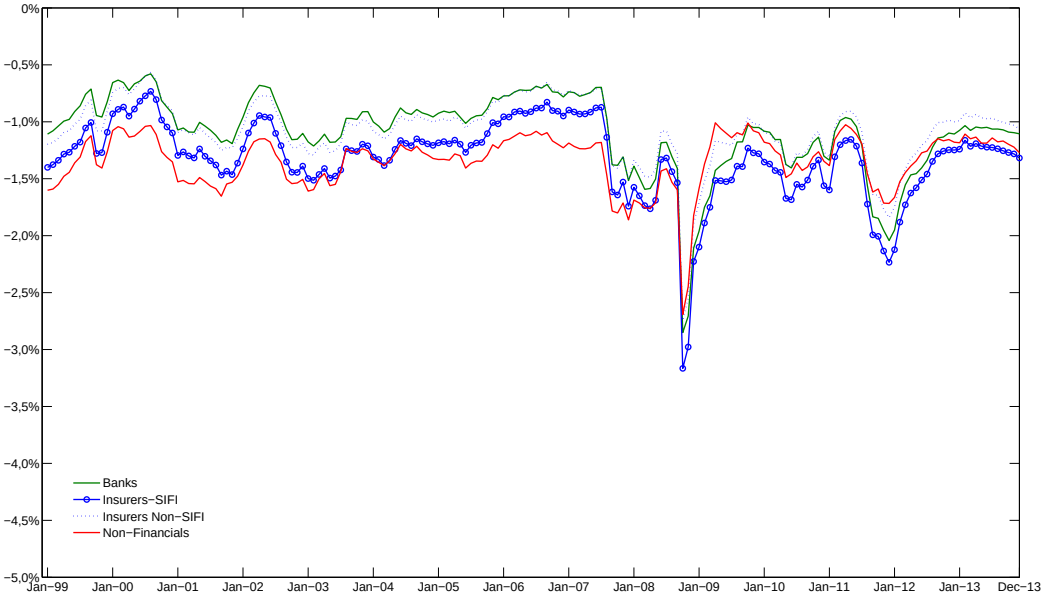


Figure 12: Average institutions' DMES towards total system - focus on SIFI Insurance Companies. The figure displays the industry monthly average calculated on the single institution's monthly median value.

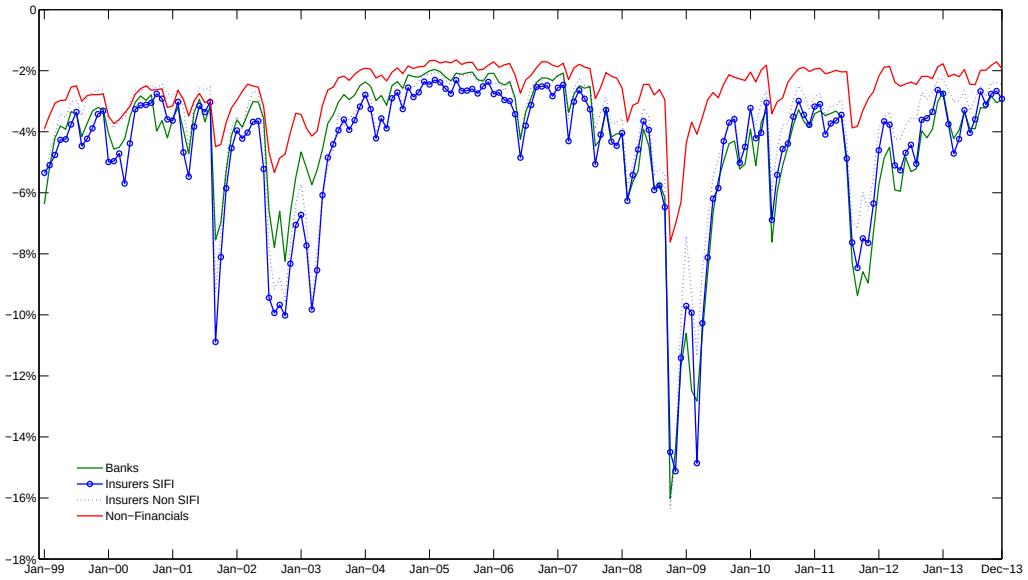


Figure 13: Most systemically relevant institutions.
The 3 graphs report the industry composition of the 10 most systemically relevant institutions at each point in time.

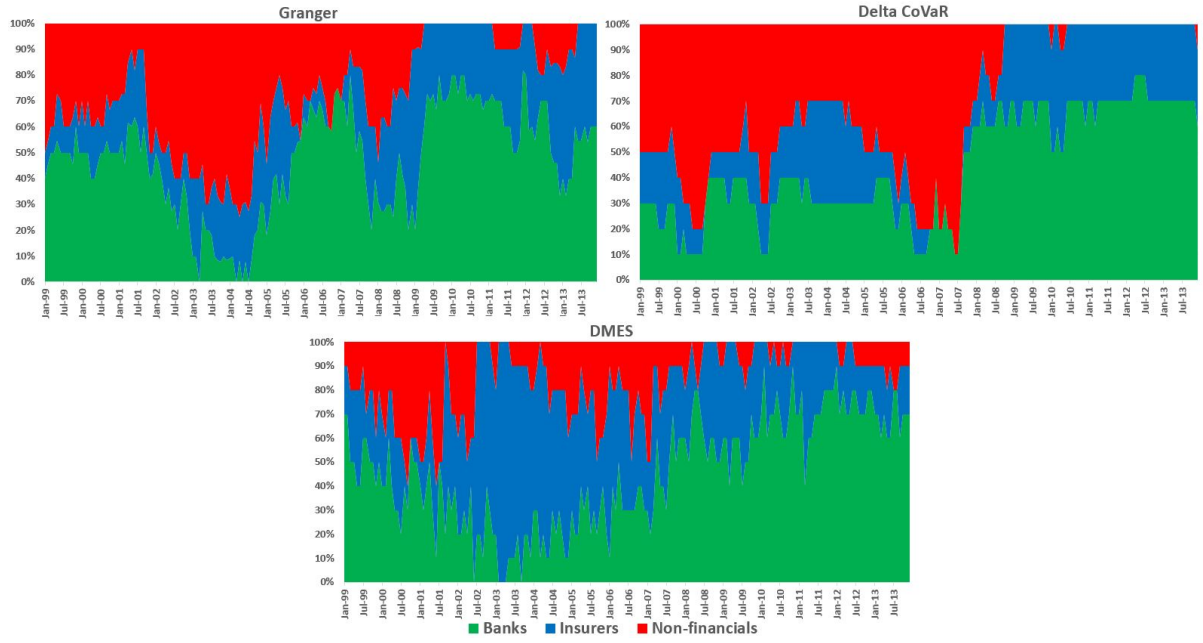
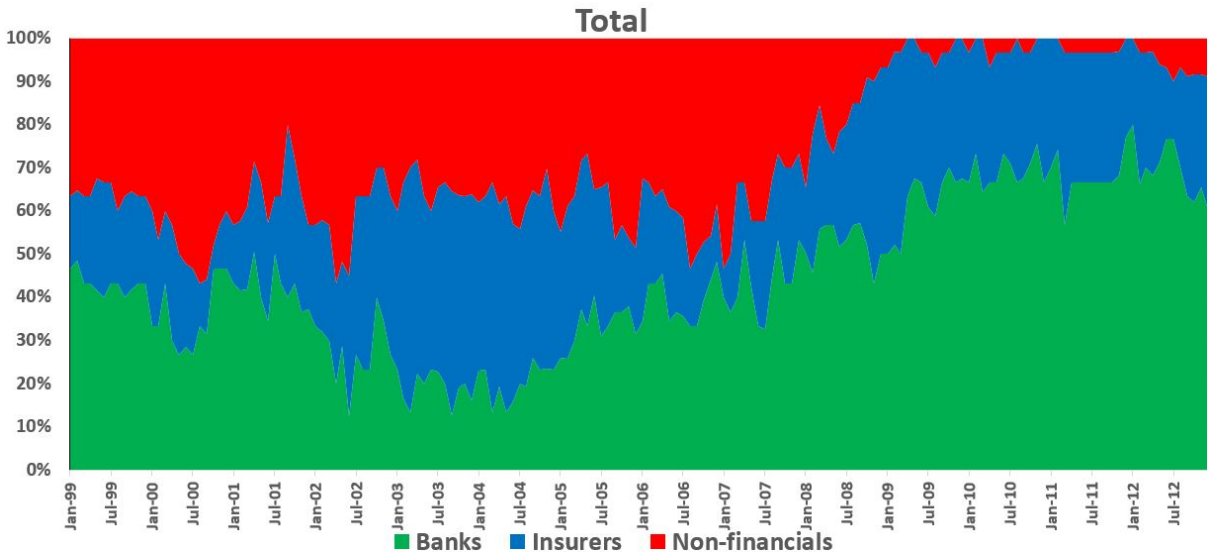


Figure 14: Cumulative index.
The graph reports the average industry composition of the 3 indices at each point in time.



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