Insurance Activities and Systemic Risk

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Abstract

This paper investigates the relation between insurance activities and systemic risk. We first analyze the systemic contribution of the insurance industry vis-à-vis other industries by applying three measures, namely the linear Granger causality test, conditional value at risk and marginal expected shortfall, to three control 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 *i)* that the insurance industry shows a persistent systemic relevance and plays a subordinate role in causing systemic risk compared to banks, and *ii)* that within the industry, those insurers which engage in more life business and those which engage in more non-insurance-related activities tend to pose more systemic risk. In addition, leverage, size and price to book ratio are also significant drivers of systemic risk. This is the first study to highlight empirically the importance of the relative weight of the life business in the insurer's liability portfolio.

Keywords: Systemic Risk, Insurance Activities, Systemically Important Financial Institutions

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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. 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 kind of activities that are the major source of systemic risk within the insurance industry.

To do so, we test three 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 control groups: 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*

[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.*

composition index. Finally, we investigate whether and to what extent the systemic relevance of insurers is driven by the type of activities held in portfolio by concentrating on the outstanding stock of business (liabilities) and the outstanding stock of assets.

Our evidence suggests that the insurance industry tends *i)* to pose persistently pose systemic risk over time and *ii)* 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, this is among the first studies able to provide empirical evidence on the relevance of the portfolio of activities held by the insurer as a determinant for systemic risk. We show that insurers with a relatively higher proportion of life business in their portfolio and a relatively larger proportion of non-insurance-related activities tend to pose more systemic risk. We also find and confirm previous evidence that size, leverage and price-to-book ratio are indeed of importance. 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. In particular, a wide range of new empirical methods for testing the systemic 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.[2]

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 consid-

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

ered the least systemically relevant. In addition, an ambiguous position is attributed to reinsurance activities.[3]

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 *i)* that traditional insurers do not pose systemic risk and, as a consequence, are neither too big nor too interconnected to fail, and *ii)* 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.[4] Equity-based measures aim to

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

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

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) (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 US 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 between 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 to insurance companies a systemic relevance comparable with 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 Weiss et al. (2014) 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 US 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. Weiss et al. (2014) 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.

In conclusion, 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. However, few studies attempt to analyze empirically the common characteristics of insurers which display a more prominent contribution to systemic risk. This contribution thus aims to bridge the gap between insurance activities as proxied by the relative weight of the different activities and the relative weight of main asset classes held in portfolio and their estimated systemic risk contribution.

3 Methodology & Data

Our analysis consists of two 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).[5]

[5] An extensive mathematical treatment of the 3 measures is provided in Appendix (A.1).

We identify 3 control groups, namely banks, insurers and non-financials. In addition, for each systemic risk measure and for each control group, we distinguish between 3 cases: the average contribution of the individual institution belonging to a single control group *a)* within its control group (*intra-industry*), *b)* towards the other 2 control groups (*other industries*) and *c)* towards all 3 control groups (*total system*).[6] We 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

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

[6] An extensive mathematical explanation of how the 3 cases are calculated is provided in Appendix (A.1).

Needless to say, 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 amount 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.[7] 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,[8] 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

[7] 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.

[8] 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.

tail events, which in turn have potential systemic implications.[9]

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 lag on the series.[10] For each control 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.[11] 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 three control 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 insurance activities 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.[12] The outstanding stocks, and therefore the underlying past and current underwriting decisions, thus have a profound

[9] 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.

[10] Data were downloaded from Datastream®.

[11] Within each control 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.

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

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.[13] Moreover, the fundamental differences between business lines and between different types of financial promises in the insurance business might make aggregate analyses less informative. It is therefore worth dissecting the different components of the insurance business in order to understand where potential sources of systemic risk are. In addition, the analysis focuses only on the business conducted at shareholders' risk, namely excluding items for which risk is borne by policyholders.[14] 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 risk measures, we run OLS regressions with yearly fixed effects of the lagged individual insurer balance sheet characteristics on the individual systemic risk measure: in particular, we specify a model for the *liability* side and a model for the *asset* side.[15] Such distinction is relevant for at least two sets of reasons: on the one hand, underwriting decisions tend to shape investment decisions consistently with the typical liability-driven business approach of the insurance industry; on the other hand, decisions on the asset allocation might be influenced by other factors, such as the need to deliver investment performances, and not being limited to the replication of the liability portfolio. Thus, it is crucial for our analysis to investigate whether underwriting decisions, i.e. insurance activities, are drivers of the systemic risk contribution, or if other factors, such as the asset allocation (and the riskiness thereto) play a role in determining the systemic risk contribution.

The baseline model for the asset side is the following:

$$\begin{aligned} systemic\ risk\ measure_{i,t} =& \beta_0 + \beta_1\ price-to-book_{i,t-1} + \beta_2\ leverage(assets)_{i,t-1} + \\ & \beta_3\ log(assets)_{i,t-1} + \beta_4\ log(assets)^2_{i,t-1} + \beta_5\ concentration_{i,t-1} + \\ & \beta_6\ investment\ quality_{i,t-1} + \beta_7\ fixed\ income\ assets_{i,t-1} + \\ & \beta_8\ equity\ assets_{i,t-1} + \beta_9\ cash_{i,t-1} + \epsilon_{i,t} \end{aligned} \tag{4}$$

[13] 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).

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

[15] A similar approach was presented, among others, in Adrian and Brunnermeier (2011).

where $price - to - book$ is the market-to-book ratio, $leverage(assets)$ is the ratio between tangible assets and tangible equity, $log(assets)$ and $log(assets)^2$ are the logarithm of tangible assets and the square thereof respectively, $concentration$ is an index of asset portfolio diversification, $investment\ quality$ is the amount of at least A-rated asset classes and $fixed\ income\ assets$, $equity\ assets$ and $cash$ are the amount of fixed income, equity and cash assets classes respectively.[16] Market-to-book ratio, leverage and the size of the company are usually identified as key drivers of systemic risk.[17] The remainder variables are different proxies for the aggregated degree of risk entailed in the asset allocation: more specifically, $investment\ quality$ is a direct proxy for the riskiness of the asset allocation, in particular credit risk, which we expect to display a negative sign with respect to the dependent variable, i.e. the systemic risk contribution; $fixed\ income\ assets$, $equity\ assets$ and $cash$ represent the 3 main asset classes: 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; finally, we expect cash to display a negative sign since it could be loosely interpreted as a proxy for liquidity. The last variable, $concentration$, is a proxy for the degree of diversification of the asset portfolio and there are at least 2 opposite but equally theoretically sound economic interpretations with respect to its systemic risk contribution: on the one hand, from classical portfolio selection theory, a higher degree of diversification could have a positive impact in terms of risk diversification, but on the other hand it could have a negative impact due to the systemic implications that a higher diversification has on the degree of interconnectedness among institutions as highlighted in Das and Uppal (2004), Raffestin (2014) and Wagner (2010).

The baseline model for the liability side is the following:

$$\begin{aligned} systemic\ risk\ measure_{i,t} = & \beta_0 + \beta_1\ price - to - book_{i,t-1} + \beta_2\ leverage(liabilities)_{i,t-1} + \\ & \beta_3\ log(liabilities)_{i,t-1} + \beta_4\ log(liabilities)^2_{i,t-1} + \\ & \beta_5\ insurance\ activities_{i,t-1} + \beta_6\ life\ business_{i,t-1} + \\ & \beta_7\ total\ debt_{i,t-1} + \beta_8\ separate\ accounts_{i,t-1} + \\ & \beta_9\ financial\ liabilities_{i,t-1} + \epsilon_{i,t} \end{aligned} \quad (5)$$

[16] Table 8 reports a detailed overview of the variables used throughout the analyses.
[17] See for instance Weiß and Mühlnickel (2014).

where $leverage(liabilities)$ is the ratio between liabilities and tangible equity, $log(liabilities)$ and $log(liabilities)^2$ are the logarithm of liabilities and the square thereof respectively, *insurance activities* is the amount of insurance activities among total activities, *life business* is the amount of life business among total activities, *total debt* is the amount of debt (i.e. non-policyholder-related liabilities), *separate accounts* is the amount of business which is not at shareholder risk and *financial liabilities* are other non-policyholder-related liabilities.[18] *Insurance activities* is a proxy for traditional business which we expect to exert a negative contribution to systemic risk; by contrast, we expect *life business* to be a key driver for systemic risk, since such business often entails financial guarantees or other contractual agreements which might become a too heavy burden as underlying market conditions change. *Total debt*, *separate accounts* and *financial liabilities* are the other main items in the balance sheet which we expect to contribute to systemic risk in different directions: the amount of debt (e.g. subordinated debt) is expected to positively contribute to systemic risk, financial liabilities as proxy for non-policyholders liabilities is also expected to positively contribute to systemic risk, whereas separate account or unit-linked business is expected to display a negative sign since all risks connected to such business are transferred to policyholders, thereby exerting a minor impact on the equity capital of the insurer.

3.2.1 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. Table 9 and table 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 fundamentals 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 two 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 vi-à-vis the system, which can be

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

proxied through a broad equity index.[19] Due to data availability, we use the FTSE All shares as proxy for the system.[20] 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.[21]

4 Empirical Results

4.1 Systemic Risk Measures and Rankings

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 control 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 control 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 increasing 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 control group towards

[19] A similar approach is proposed in Weiss et al. (2014) and Brunnermeier et al. (2012).

[20] 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.

[21] 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.

other industries. The upper graph displays the average number of receiving (Granger-causal) connections for a single institution in each control 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 control 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 control 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.[22]

2) **ΔCoVaR** (Adrian and Brunnermeier, 2011):

Figure 4 reports estimations of the average individual institutions' ΔCoVaR within its in-

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

dustry (*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 tend persistently 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.[23]

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 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.[24] 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

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

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

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 control group in posing systemic risk, insurers again tend to play a subordinated role compared to banks.

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 control 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.

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.

- **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 control 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) **Rankings**

In order to provide a straightforward representation of the systemic relevance of the 3 control 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 control 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.[25] 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).

4.2 Systemic Risk and Insurance Activities

Table 12 reports the results of the panel regressions specified for the asset side run on the ΔCoVaR and on the DMES.[26] The model has 2 specifications: the baseline specification as de-

[25] See equation 3.

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

scribed by equation 5 and a reduced specification in which *price-to-book*, *leverage*, *log(assets)* and $log(assets)^2$ are excluded. Moreover, both specifications are tested on 3 different panels, namely *i) full sample* (columns 1 and 2), *ii) sample without reinsurance companies* (columns 3 and 4) and *iii) sample without reinsurance companies and SIFIs* (columns 5 and 6). The choice of different specifications of both variables and samples is justified by the fact that the baseline model includes variables which were already found to be significant for financial institutions in the literature and thereby potentially increase the fit of the regression (Adrian and Brunnermeier (2011), Brunnermeier et al. (2012), Weiß and Mühlnickel (2014) and Weiss et al. (2014)), whereas the 3 different panels aim to exclude potential biases induced by institutions with specific characteristics, such as reinsurance companies and SIFIs, compared to the median insurer.

The reduced specification for both ΔCoVaR and DMES is neither statistically nor economically significant across all 3 panels. By augmenting the model to the baseline specification, we observe an increase in the explanatory power (F-test) and in the goodness of fit for both ΔCoVaR and DMES. When regressing on the ΔCoVaR, we observe a statistically and economically significant contribution of leverage and size (expressed as log(assets) and its squared value) as well as the asset class cash. Leverage has a positive highly significant coefficient, although the magnitude of the coefficient is relatively smaller; size has a positive contribution ($log(assets)$ has positive sign) but is marginally decreasing ($log(assets)^2$ has negative sign). The variables display similar coefficients and significant levels under both the full sample and the sample without reinsurance companies, whereas under the sample which also excludes the SIFIs, both leverage and size excluding its marginal effects become insignificant. In contrast, cash remains economically and statistically significant using all 3 panels: the interpretation of such a result might be that liquidity is of importance and is associated with a lower contribution to systemic risk. All other variables, i.e. concentration, investment quality, fixed income assets and equity assets appear to be economically and statistically insignificant. However, equity assets become statistically significant when excluding reinsurance companies: such results are difficult to interpret and might be driven by other factors, therefore we do not consider it as relevant for our purposes.

Turning now to the regressions on the DMES, we observe a similar pattern as observed for the ΔCoVaR, with a significant increase in the level of significance of the variables: in addition to leverage, size and cash, we can now observe economic and statistical significance of the price to book and the equity assets. Leverage and size have increased in both statistical significant and magnitude across all 3 panels: in particular, the magnitude of the coefficient has significantly increased compared to the model regressed on the ΔCoVaR; the price-to-book now signals a significantly positive relation between the growth in the market valuation of the insurers with respect to its book fundamentals and the amount of systemic risk posed to the system. A potential explanation for such a result might be that insurers that experience an increase in their valuation multiples due to business development or other underlying factors might turn out to be more systemically relevant and thereby more fragile as market conditions change. Moreover, cash has increased in magnitude and significance compared to the ΔCoVaR, which might reinforce the thesis according to which liquidity might play a positive role, especially around times of crisis. Finally, equity holdings surprisingly play a strong role in the systemic risk contribution measured through the DMES: the coefficient has a negative sign across all 3 panels and displays an important magnitude. However, although the economic reason for such a negative relation is not fully clear, a potential explanation could lie in the effects of the European sovereign crisis and the bias towards relatively higher holdings of European sovereign bonds. In fact, since insurers in general are large holders of bonds, especially sovereign bonds, those insurers with asset portfolios more exposed to stocks and (potentially) less exposed to sovereign bonds might have suffered less during the crises.

Table 13 reports the results of the panel regressions specified for the liability side: as for the asset side specifications, we calculate regressions for the baseline specification as described by equation 5 and a reduced specification in which *price-to-book*, *leverage*, *log(liabilities)* and $log(liabilities)^2$ are excluded.[27] Moreover, both specifications are tested on 3 different panels, namely *i) full sample* (columns 1 and 2), *ii) sample without reinsurance companies* (columns 3 and 4) and *iii) sample without reinsurance companies and SIFIs* (columns 5 and 6).

The results of the regressions on the ΔCoVaR show an economic and statistically significant role played by both insurance activities and life business across the 2 specifications and the 3 panels: in particular, a negative relation exists 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

[27] Please note that the leverage employed in the liability side model is calculated in a different way compared to the asset side model.

activities are potentially more systemic than the traditional insurance activities, and in line with the evidence from US insurers provided by Weiß and Mühlnickel (2014), in which non-policy holders' activities did cause systemic risk during the financial crisis. In addition, life business does cause more systemic risk: our results provide new evidence that among those insurers focused more on life business, the contribution to systemic risk is relatively larger. This is consistent with the fact that life business often entails certain financial characteristics, such as investment protections or return guarantees, which make the insurer more systemically relevant compared to those insurers which focus more on underwriting risk, such as property and casualty business. All other variables, i.e. total debt, separate accounts and financial liabilities, appear to be economically and statistically insignificant. The results of the baseline specification are substantially in line with the asset side model: here, it is worth noting how the values for the F-test are significantly higher compared to the value observed on the baseline specification for the asset side model, thereby adding robustness to the liability model.

From the regressions on the DMES, we can observe that insurance activities are now statistically insignificant, although the sign remains consistent: life business remains economically and statistically significant across the 2 specifications and the 3 panels. Such difference between ΔCoVaR and DMES is due to the fundamentally different concept applied to the measure itself: on the one hand, the ΔCoVaR measures the marginal contribution of an institution towards the system. We might conclude that those insurers engaging in fewer insurance activities, and putting more weight on life business within those insurance activities, pose more systemic risk to the system as a whole; on the other hand, the DMES measures the expected fall in equity values of an institution given that the entire system is in distress: such a result should thus be interpreted as indicating that those insurers engaging more in life business tend to be more fragile when the system is itself fragile. We should therefore not directly compare the 2 measures, but rather interpret the results as 2 faces of the same coin.

In conclusion, we do not find significant differences between the 3 panels, which might hint at the fact that economically significant variables do play a role in causing and reducing systemic risk, irrespective of the fact that an insurer is active in the reinsurance business or that it is labeled as SIFI.

4.3 Robustness of Results

In addition to the robustness check that we conducted by testing the different specifications across 3 different panels, we added two tests.

At first, we check for omitted variables by regressing ΔCoVaR and DMES on 2 different specifications built by merging the asset side and liability side models and applied to the 3 different panels. Table 14 displays the results of the aggregated model regression: the coefficients' sign and the level of significance of the regressors confirm what displayed in the asset model and in the liability model, hence, according to this test, our results are not biased by the omission of any variable.

Secondly we conduct a difference-in-differences (DiD) analysis to check for potential endogeneity issues: similar to Brunnermeier et al. (2012), we test the robustness of our findings around Lehman's filing for bankruptcy and subsequent AIG bailout.[28] Since Lehamn's failure came as an exogenous shock, it represents a good candidate for a natural experiment.[29]

For the DiD analysis, we focus on the activities held in portfolio and check whether *i)* the amount of insurance activities and *ii)* life business played a significant role around the 2 exogenous shocks, i.e. Lehman filing for bankruptcy and the AIG bailout and the European sovereign crisis. The model is thus specified as follows:

$$\begin{aligned} systemic\ risk\ measure =& \beta_0 + \beta_1\ shock\ dummy + \beta_2\ treatment\ dummy + \\ & \beta_3\ shock\ dummy \cdot treatment\ dummy + \beta_4\ price - to - book + \\ & \beta_5\ leverage(Liabilities) + \beta_6\ log(Liabilities) + \beta_7\ log(Liabilities)^2 + \\ & \beta_8\ total\ debt + \beta_9\ separate\ accounts + \beta_{10}\ financial\ liabilities + \epsilon \end{aligned} \tag{6}$$

where the *shock dummy* indicates the pre and post-shock period and the *treatment dummy* represents the control (or non-treated group) and the treatment group respectively. We specify 2 treatment groups, one for the amount of insurance activities and one for the amount of life business: the first dummy assumes value 1 (i.e. treatment group) if the insurer belongs to the

[28] 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).

[29] Lehman Brothers filed for bankruptcy on 15 September 2011, and AIG was bailed out by the US Government the next day.

bottom quartile in terms on insurance activities and value 0 if the insurer belongs the top quartile (i.e. control group); the second dummy assumes value 1 if the insurer belongs to the top 25% in terms of life business activities and 0 if the insurer has no life business in its portfolio.

Table 15 reports the results of the DiD around the Lehman bankruptcy and AIG bailout: the coefficient of interest is of course the interaction term between the shock dummy and the control group. Both insurance activities and life business display a significant and positive coefficient for both ΔCoVaR and DMES, which confirms the fact that during the crisis, those insurers with portfolios of activities less exposed to insurance business or more exposed to life business did cause more systemic risk.

In conclusion, this last set of results provides evidence that our results are not driven by omitted variables correlated to both insurance activity and life business, but are indeed driven by those variables specified in the models.

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 control 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 which activities within the insurance industry pose more systemic risk.

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 more life business and if they engage in more non-insurance activities. Furthermore, we find that systemic risk in the insurance industry is mainly driven by the liability side rather than the asset side: most asset classes play a non significant role, with cash holdings and equity holdings providing a positive (i.e. a reduced) contribution to systemic risk. In addition, variables such as leverage, size and price-to-book are of importance, which is in line with previous findings for other financial institutions as well. 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: we are among the first to provide empirical evidence on the subordinated role of non-life business compared to life business and of insurance activities compared to non-insurance activities. We are also 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. 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 better 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 additional capital charges they might face in the future. Moreover, 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 our 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 two 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 j.

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.[30]The *Degree of Granger Causality* thus represents the fraction of statistically significant relationships over the total number of possible connections among the full sample,

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

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

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

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

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. $C = \Phi^{-1}(0.95)r_m$.[31] The conditional standard deviations and the conditional correlation are estimated by means of a TARCH and a DCC model respectively.[32] 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

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

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

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

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

with

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

We then distinguish between 3 cases:

1) *intra-industry*:

$$r_{mt} = \frac{\sum_{j \neq i} w_{t-1}^{j} \cdot r_t^j}{\sum_{j \neq i} w_{t-1}^{j}} \tag{34}$$

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

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

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

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 control 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: List of the institutions included in the 3 control groups

Banks		
name	*ticker*	*country*
HSBC HDG.	HSBA	UK
BANCO SANTANDER	E:SCH	ES
UBS	S:UBSN	CH
BNP PARIBAS	F:BNP	FR
LLOYDS BANKING GROUP	LLOY	UK
ROYAL BANK OF SCTL.GP.	RBS	UK
BARCLAYS	BARC	UK
CREDIT SUISSE GROUP N	S:CSGN	CH
BBV. ARGENTARIA	E:BBVA	ES
DEUTSCHE BANK (XET)	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	SK
KBC GROUP	B:KB	BE
DANSKE BANK	DK:DAB	DK
COMMERZBANK (XET)	D:CBKX	DE
SVENSKA HANDBKN.	W:SVK	SK
SEB	W:SEA	SK
Insurers		
name	*ticker*	*country*
ALLIANZ	D:ALV	DE
PRUDENTIAL	PRU	UK
AXA	F:MIDI	FR
ZURICH INSURANCE GROUP	S:ZURN	CH
MUENCHENER RUCK.	D:MUV2	DE
SWISS RE	S:SREN	CH
ING GROEP	H:ING	ND
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 RUCK.	D:HNR1	DE
AGEAS (EX-FORTIS)	B:AGS	BE
RSA INSURANCE GROUP	RSA	UK
VIENNA INSURANCE GROUP	O:WNST	AU
SCOR SE	F:SCO	FR
SWISS LIFE HOLDING	S:SLHN	CH
BALOISE-HOLDING AG	S:BALN	CH
Non-Financials		
name	*ticker*	*country*
BP	BP.	UK
VODAFONE GROUP	VOD	UK
NOVARTIS	S:NOVN	CH
NESTLE	S:NESN	CH
GLAXOSMITHKLINE	GSK	UK
ROYAL DUTCH SHELL	H:RDSA	UK
TOTAL	F:TAL	FR
ROCHE HOLDING	S:ROG	CH
ENI	I:ENI	IT
TELEFONICA	E:TEF	ES
SANOFI	F:SQ@F	FR
NOKIA	M:NOK1	SK
SIEMENS (XET)	D:SIEX	DE
ASTRAZENECA	AZN	UK
L'OREAL	F:OR@F	FR
E ON (XET)	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

Name	**Sector**	**Industry Group**
BRITISH PETROLEUM	Energy	Energy
VODAFONE GROUP	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 HOLDING	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 TOB.	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.
Log returns are observed on a a) monthly frequency, 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 SCTL.GP.	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 GROUP	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 SCTL.GP.	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 GROUP	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.
Log returns are observed on a a) monthly frequency, 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
MUENCHENER RUCK.	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 RUCK.	D:HNR1	202	0.0100	0.0140	0.0999	-0.6683	0.3550
AGEAS (EX-FORTIS)	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 HOLDING	S:SLHN	216	-0.0005	0.0104	0.1456	-0.7104	0.6159
BALOISE-HOLDING AG	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
MUENCHENER RUCK.	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 RUCK.	D:HNR1	4,608	0.0005	0.0000	0.0218	-0.1989	0.1538
AGEAS (EX-FORTIS)	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 HOLDING	S:SLHN	4,608	0.0000	0.0000	0.0248	-0.2240	0.1877
BALOISE-HOLDING AG	S:BALN	4,608	0.0004	0.0000	0.0203	-0.1662	0.1891

Table 7: Non-Financials' log returns.
Log returns are observed on a a) monthly frequency, b) daily frequency. Observation period between January 1996 to December 2013.

Name	Ticker	Obs.	Average	Median	St.Dev.	Min	Max
BP	BP.	216	0.0058	0.0110	0.0742	-0.3714	0.1982
VODAFONE GROUP	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 HOLDING	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

Name	Ticker	Obs.	Average	Median	St.Dev.	Min	Max
BP	BP.	4,608	0.0003	0.0000	0.0173	-0.1404	0.1058
VODAFONE GROUP	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 HOLDING	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 OLS regressions. Balance sheet items are named according to SNL Financial definition.

Variable	Definition
Price to Book	$\frac{Equity\ Market\ Value}{Equity\ Book\ Value}$
Leverage (Assets)	$\frac{Tangible\ Assets - Separate\ Account\ Assets}{Tangible\ Equity}$
Tangible Assets (*Log*)	$ln(Tangible\ Assets)$
Tangible Assets^2 (*Log*)	$ln(Tangible\ Assets)^2$
Concentration†	$\frac{\sum_i Asset\ Class_i^2}{(\sum_i Asset\ Class_i)^2}$
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	$\frac{Cash\ \&\ Cash\ Equivalents}{Tangible\ Assets - Separate\ Account\ Assets}$
Leverage (Liabilities)	$\frac{Total\ Liabilities - Separate\ Account\ Liabilities}{Tangible\ Equity}$
Liabilities (*Log*)	$ln(Total\ Liabilities - Separate\ Account\ Liabilities)$
Liabilities^2 (*Log*)	$ln(Total\ Liabilities - Separate\ Account\ Liabilities)^2$
Insurance Activities	$\frac{Reserves\ for\ Insurance\ Contracts - Unit\ Linked\ Insurance}{Total\ Liabilities - Separate\ Account\ Liabilities}$
Life Business	$\frac{Life\ \&\ Health\ Insurance\ Reserves - Unit\ Linked\ Insurance}{Total\ Liabilities - Separate\ Account\ Liabilities}$
Total Debt	$\frac{Total\ Debt}{Total\ Liabilities - Separate\ Account\ Liabilities}$
Separate Accounts	$\frac{Separate\ Account\ Liabilities}{Total\ Liabilities}$
Financial Liabilities	$\frac{Total\ Financial\ Liabilities}{Total\ Liabilities - Separate\ Account\ Liabilities}$

† : $Asset\ Class_i$= 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.

Table 9: Insurance Companies Extended Panel.
Descriptive statistics of Daily log returns observed between January 1999 to December 2013.

Name	Obs.	Average	Median	St.Dev.	Min	Max
Admiral Group Plc	2,406	0.0008	0.0000	0.0207	-0.2958	0.2272
AEGON N.V.	3,892	-0.0004	0.0000	0.0302	-0.2768	0.3022
ageas SA/NV	3,892	-0.0005	0.0000	0.0377	-1.4949	0.2589
Aksigorta AS	3,892	0.0012	0.0000	0.0322	-0.2187	0.3176
Allianz Group	3,892	-0.0001	0.0000	0.0230	-0.1568	0.1781
Alm. Brand A/S	3,892	-0.0001	0.0000	0.0229	-0.2378	0.2492
Amlin Plc	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 AS	3,595	0.0007	0.0000	0.0313	-0.1707	0.1861
Assicurazioni Generali SpA	3,892	-0.0001	0.0000	0.0176	-0.0923	0.1231
Aviva Plc	3,892	0.0000	0.0000	0.0266	-0.4060	0.2239
Aviva Sigorta AS	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 Holding AG	3,892	0.0001	0.0000	0.0202	-0.1662	0.1891
Beazley Plc	2,889	0.0007	0.0000	0.0180	-0.1404	0.1361
Chesnara Plc	2,496	0.0007	0.0000	0.0202	-0.1075	0.1052
CNP Assurances SA	3,892	0.0004	0.0000	0.0189	-0.1444	0.1043
Delta Lloyd NV	1,080	0.0004	0.0006	0.0206	-0.0861	0.1088
Direct Line Insurance Group Plc	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 SA	3,892	-0.0002	0.0000	0.0374	-0.2176	0.1815
FBD Holdings Plc	3,892	0.0004	0.0001	0.0487	-1.9376	1.9386
Friends Life Group Limited	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 SA	3,310	-0.0028	0.0000	0.0608	-1.4674	0.8362
Gunes Sigorta AS	3,892	0.0009	0.0000	0.0331	-0.2356	0.1765
Hannover Ruch	3,892	0.0003	0.0000	0.0220	-0.1989	0.1538
Hansard Global Plc	1,828	-0.0002	0.0003	0.0219	-0.1550	0.1831
Helios Underwriting Plc	1,641	0.0003	0.0000	0.0223	-0.5216	0.3909
ING Groep N.V.	3,892	-0.0001	0.0000	0.0308	-0.3213	0.2565
Jadransko Osiguranje d.d.	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 Plc	3,892	0.0002	0.0000	0.0258	-0.3408	0.2430
Liberty Life Insurance Public Company Limited	3,892	-0.0008	0.0000	0.0489	-0.4158	0.4196
MAPFRE SA	3,892	0.0003	0.0000	0.0219	-0.1344	0.1618
Mediolanum SpA	3,892	0.0001	0.0000	0.0253	-0.1163	0.1710
Muenchener Rückversicherungs-Gesellschaft	3,892	0.0001	0.0000	0.0209	-0.1719	0.1653
Novae Group Plc	3,892	-0.0001	0.0000	0.0269	-0.5556	0.3212
NUERNBERGER Beteiligungs-AG	3,892	0.0000	0.0000	0.0176	-0.2289	0.2263
Partnership Assurance Group Plc	146	-0.0019	-0.0010	0.0307	-0.2374	0.1560
Personal Group Holdings Plc	3,396	0.0007	0.0000	0.0114	-0.1144	0.1173
Phoenix Group Holdings	1,070	0.0002	0.0000	0.0170	-0.0853	0.1059
Pozavarovalnica Sava d.d.	1,440	-0.0008	0.0000	0.0258	-0.1389	0.1389
Protector Forsikring ASA	1,712	0.0003	0.0000	0.0252	-0.1697	0.2230
Prudential Plc	3,892	0.0002	0.0000	0.0272	-0.2231	0.2107
RSA Insurance Group Plc	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 SE	3,892	-0.0003	0.0000	0.0266	-0.3622	0.1907
St. James's Place Plc	3,892	0.0003	0.0000	0.0253	-0.2329	0.2394
Standard Life Plc	1,940	0.0004	0.0000	0.0239	-0.1604	0.1865
Storebrand ASA	560	0.0026	0.0000	0.0147	-0.0666	0.0925
Swiss Life Holding Limited	3,892	-0.0002	0.0000	0.0249	-0.2240	0.1877
Swiss Re Limited	3,892	-0.0001	0.0000	0.0237	-0.3292	0.1957
Talanx AG	322	0.0009	0.0000	0.0140	-0.0471	0.0399
Topdanmark A/S	3,892	0.0006	0.0000	0.0180	-0.1133	0.1407
Tryg A/S	2,130	0.0005	0.0000	0.0160	-0.1361	0.1032
UNIQA Insurance Group AG	3,670	0.0001	0.0000	0.0170	-0.1729	0.0965
Vaudoise Assurances Holding SA	3,892	0.0003	0.0000	0.0198	-0.1801	0.1869
Vienna Insurance Group AG	3,892	0.0003	0.0000	0.0188	-0.1974	0.1529
Zavarovalnica Triglav. d.d.	1,377	-0.0005	0.0000	0.0217	-0.1076	0.0953
Zurich Insurance Group Ltd.	3,892	-0.0002	0.0000	0.0233	-0.2257	0.1920

Table 10: Balance sheet variables.
a) reports the summary statistics for the Asset Model related variables
b) reports the summary statistics for the Liability Model related variables.

a) Variable	Obs	Mean	Std. Dev.	Min	Max
Price to Book	470	2.8191	18.0788	-5.500	382.5900
Leverage (Assets)	473	11.8483	11.9591	-105.0035	55.8480
Tangible Assets (Log)	481	16.3540	2.8236	9.0328	21.0045
Tangible Assets (Sq-Log)	481	275.4091	88.9824	81.5913	441.1885
Concentration	482	0.3080	0.1047	0.1168	0.7074
Investment Quality	473	0.3674	0.2949	0.0000	1.0093
Fixed Income Assets	469	0.3987	0.2074	0.0000	0.7569
Equity Assets	466	0.0841	0.0982	0.0000	0.8354
Cash	473	0.0933	0.1237	0.0009	0.6619

b) Variable	Obs	Mean	Std. Dev.	Min	Max
Price to Book	470	2.8191	18.0788	-5.5	382.5900
Leverage (Liabilities)	461	7.9878	75.3346	-1502.0360	314.6381
Liabilities (Log)	461	1.5870	3.0018	4.5133	20.9111
Liabilities (Sq Log)	461	2.6085	90.7139	20.3697	437.2741
Insurance Activities	460	0.6516	0.2398	0.0000	0.9635
Life Business at SH Risk	421	0.3015	0.2687	0.0000	0.8372
Total Debt at SH Risk	453	0.1083	0.1625	0.0000	0.8099
Separate Accounts	461	0.1566	0.2349	0.0000	0.9280
Financial Liabilities	453	0.1342	0.1864	0.0000	0.8877

Table 11: Correlation Matrix

The tables reports the correlation among the balance sheet variables utilized in the panel regression.

	Price to Book	Leverage (Assets)	Tangible Assets (*Log*)	Tangible Assets^2 (*Log*)	Concen-tration	Investment Quality	Fixed Income Assets	Equity Assets	Cash	Leverage (Liabilities)	Liabilities (*Log*)	Liabilities^2 (*Log*)	Insurance Activities	Life Business	Total Debt	Separate Accounts	Financial Liabilities
Price to Book	1																
Leverage(Assets)	-0.0299	1															
Tangible Assets(*Log*)	-0.0233	0.6644	1														
Tangible Assets^2(*Log*)	-0.0303	0.6842	0.9945	1													
Concentration	-0.0782	0.1964	0.3462	0.3392	1												
Investment Quality	-0.0121	0.1367	0.476	0.4413	0.2721	1											
Fixed Income Assets	-0.0225	0.2552	0.5532	0.5204	0.5131	0.6792	1										
Equity Assets	0.0244	0.0952	-0.071	-0.0599	-0.0868	-0.0818	-0.1727	1									
Cash	0.01	-0.309	-0.4372	-0.4249	-0.0821	-0.3391	-0.4889	-0.1798	1								
Leverage (Liabilities)	-0.0306	0.9813	0.6654	0.6844	0.19	0.143	0.2414	0.0628	-0.3199	1							
Liabilities (*Log*)	-0.0174	0.6672	0.9871	0.9784	0.2983	0.478	0.5793	-0.0836	-0.5103	0.6721	1						
Liabilities^2 (*Log*)	-0.0252	0.6946	0.9854	0.9893	0.2996	0.4409	0.5393	-0.0738	-0.4895	0.6989	0.9917	1					
Insurance Activities	0.0437	-0.2453	-0.1225	-0.1626	-0.3441	0.2395	0.2405	0.0863	-0.1813	-0.2206	-0.0528	-0.1098	1				
Life Business	0.0129	0.5191	0.5962	0.5886	0.0694	0.3967	0.3303	0.1979	-0.3177	0.5447	0.5751	0.569	0.1851	1			
Total Debt	-0.0441	0.3134	0.286	0.3	0.2428	-0.1452	0.0027	-0.1789	-0.1926	0.3216	0.2894	0.3075	-0.5508	-0.0817	1		
Separate Accounts	-0.03	0.1835	0.3033	0.3	0.3294	0.0977	-0.0013	0.1315	0.2507	0.1604	0.1769	0.1723	-0.335	0.3832	0.0318	1	
Financial Liabilities	-0.0478	0.3538	0.3496	0.3677	0.2632	-0.1313	0.0218	-0.173	-0.1771	0.3593	0.3422	0.3634	-0.5774	-0.0426	0.9845	0.1117	1

Table 12: Panel regressions - Asset Models

The table reports the panel regression - fixed effect models. Model (1), (3) and (5) are the outcome of the rduced model; (2), (4) and (6) are the outcome of the extended model. Models are run on the following sample: (1) and (2) full sample; (3) and (4)excluding reinsurance companies; (5) and (6) excluding reinsurance companies and SIFI companies.
DeltaCoVar and DMES are reported with positive sign. Robust t-statistic in parentheses. $***\, p < 0.01$, $**\, p < 0.05$, $*\, p < 0.1$.

VARIABLES	(1) ΔCoVaR	(2) ΔCoVaR	(3) ΔCoVaR	(4) ΔCoVaR	(5) ΔCoVaR	(6) ΔCoVaR	(1) DMES	(2) DMES	(3) DMES	(4) DMES	(5) DMES	(6) DMES
Price to Book		-4.74e-07		-7.53e-07		-5.15e-07		1.07e-05**		9.14e-06**		8.76e-06**
		(-0.632)		(-1.015)		(-0.692)		(2.437)		(2.168)		(2.052)
Leverage (Assets)		5.95e-05***		5.93e-05***		3.69e-05		0.000421**		0.000397**		0.000385*
		(2.918)		(2.966)		(1.526)		(2.303)		(2.149)		(1.770)
Tangible Assets (*Log*)		0.00286*		0.00280*		0.00260		0.0430***		0.0414***		0.0411***
		(1.811)		(1.711)		(1.663)		(3.317)		(3.108)		(2.943)
Tangible Assets^2 (*Log*)		-0.000134***		-0.000132***		-0.000120**		-0.00156***		-0.00151***		-0.00150***
		(-2.955)		(-2.813)		(-2.530)		(-4.017)		(-3.771)		(-3.490)
Concentration	0.000883	0.000801	0.000676	0.000514	0.000306	9.76e-05	0.00279	-0.00338	0.00205	-0.00430	-0.000575	-0.00788
	(0.390)	(0.340)	(0.296)	(0.218)	(0.145)	(0.0454)	(0.252)	(-0.256)	(0.187)	(-0.327)	(-0.0544)	(-0.613)
Investment Quality	-0.000281	-0.000673	-0.000134	-0.000516	0.000139	-0.000127	-0.00136	-0.00385	-0.000750	-0.00315	0.00147	-0.000286
	(-0.704)	(-1.619)	(-0.318)	(-1.251)	(0.316)	(-0.333)	(-0.378)	(-1.078)	(-0.196)	(-0.852)	(0.335)	(-0.0700)
Fixed Income Assets	0.00184	0.000118	0.00140	-0.000291	0.00168	-0.000241	0.0194	0.00701	0.0179	0.00544	0.0185	0.00411
	(0.880)	(0.0630)	(0.668)	(-0.158)	(0.772)	(-0.140)	(1.553)	(0.683)	(1.450)	(0.533)	(1.482)	(0.405)
Equity Assets	-0.00198	-0.00320	-0.00229	-0.00351*	-0.00126	-0.00228	-0.00881	-0.0220**	-0.00975	-0.0227**	-0.00615	-0.0185*
	(-0.863)	(-1.630)	(-1.007)	(-1.794)	(-0.576)	(-1.196)	(-1.034)	(-2.133)	(-1.189)	(-2.203)	(-0.779)	(-1.844)
Cash	-0.000854	-0.00275*	-0.00129	-0.00319**	-0.000880	-0.00269*	-0.0113	-0.0181*	-0.0152	-0.0225***	-0.0138	-0.0223***
	(-0.513)	(-1.879)	(-0.785)	(-2.157)	(-0.556)	(-1.991)	(-0.968)	(-1.919)	(-1.398)	(-2.720)	(-1.301)	(-2.744)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	432	401	400	369	361	330	432	401	400	369	361	330
R-squared	0.480	0.514	0.479	0.515	0.426	0.449	0.494	0.531	0.490	0.526	0.455	0.489
Number of Insurers	60	58	56	54	51	49	60	58	56	54	51	49
Adjusted R-squared	0.464	0.493	0.462	0.491	0.405	0.419	0.479	0.510	0.473	0.503	0.435	0.461
F test	8.962	12.69	8.531	11.51	7.048	13.97	8.516	11.88	8.626	11.37	6.294	30.37

Table 13: Panel regressions - Liability Models

The table reports the panel regression - fixed effect models. Model (1), (3) and (5) are the outcome of the rduced model; (2), (4) and (6) are the outcome of the extended model. Models are run on the following sample: (1) and (2) full sample; (3) and (4)excluding reinsurance companies; (5) and (6) excluding reinsurance companies and SIFI companies.

DeltaCoVar and DMES are reported with positive sign. Robust t-statistic in parentheses. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.1$.

VARIABLES	(1) ΔCoVaR	(2) ΔCoVaR	(3) ΔCoVaR	(4) ΔCoVaR	(5) ΔCoVaR	(6) ΔCoVaR	(1) DMES	(2) DMES	(3) DMES	(4) DMES	(5) DMES	(6) DMES
Price to Book		-7.62e-07		-9.39e-07		-6.34e-07		1.09e-05**		1.07e-05**		1.14e-05**
		(-1.202)		(-1.493)		(-0.927)		(2.497)		(2.378)		(2.433)
Leverage (Liabilities)		4.90e-05**		4.76e-05**		3.61e-05		0.000430**		0.000413*		0.000428*
		(2.291)		(2.339)		(1.459)		(2.087)		(1.954)		(1.716)
Liabilities (*Log*)		0.00279***		0.00244**		0.00267***		0.0372***		0.0358***		0.0360***
		(3.066)		(2.578)		(3.020)		(3.951)		(3.682)		(3.819)
Liabilities^2 (*Log*)		-0.000131***		-0.000116***		-0.000123***		-0.00151***		-0.00146***		-0.00147***
		(-3.935)		(-3.425)		(-3.598)		(-4.364)		(-4.047)		(-4.131)
Insurance Activities	-0.00611***	-0.00720***	-0.00701***	-0.00799***	-0.00557**	-0.00635**	-0.0184	-0.0235	-0.0268	-0.0306	-0.0209	-0.0226
	(-2.672)	(-2.777)	(-2.740)	(-2.757)	(-2.320)	(-2.250)	(-1.176)	(-1.189)	(-1.528)	(-1.385)	(-1.338)	(-1.116)
Life Business	0.00638**	0.00656**	0.00744**	0.00750**	0.00614**	0.00584*	0.0420**	0.0408*	0.0536***	0.0509**	0.0522***	0.0484**
	(2.482)	(2.343)	(2.566)	(2.358)	(2.151)	(1.945)	(2.552)	(1.885)	(2.831)	(2.055)	(2.848)	(2.135)
Total Debt	-0.00390***	-0.000608	-0.00373***	-0.000813	-0.00350**	-0.000143	-0.00949	0.0205	-0.00831	0.0205	-0.0103	0.0202
	(-3.075)	(-0.322)	(-3.035)	(-0.429)	(-2.673)	(-0.0807)	(-1.015)	(1.292)	(-0.894)	(1.262)	(-1.228)	(1.133)
Separate Accounts	-0.000139	-0.00241	-0.000332	-0.00198	0.000789	-0.00185	-0.00633	-0.0255	-0.0103	-0.0274	-0.00503	-0.0274
	(-0.0424)	(-0.699)	(-0.0959)	(-0.559)	(0.230)	(-0.523)	(-0.214)	(-0.811)	(-0.349)	(-0.888)	(-0.169)	(-0.823)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	383	348	356	321	316	281	383	348	356	321	316	281
R-squared	0.537	0.557	0.543	0.562	0.488	0.500	0.501	0.542	0.500	0.539	0.470	0.505
Number of Insurers	54	51	51	48	46	43	54	51	51	48	46	43
Adjusted R-squared	0.522	0.536	0.527	0.539	0.468	0.469	0.485	0.520	0.483	0.514	0.449	0.475
F test	9.304	20.47	9.9	23.6	6.47	39.35	10.45	19.03	11.3	16.6	11.4	54.17

Table 14: Robustness Check - Panel regressions - Aggregated Model

The tables reports the panel regression - fixed effect of 2 models specified by mixing regressors picked from the asset side and the liability side. Model (1) and (3) are the outcome of the reduced model; (2) and (4) are the outcome of the extended model. DeltaCoVar and DMES are reported with positive sign. Robust t-statistic in parentheses. $***\ p < 0.01$, $**\ p < 0.05$, $*\ p < 0.1$.

VARIABLES	(1) ΔCoVaR	(2) ΔCoVaR	(3) ΔCoVaR	(4) ΔCoVaR	(5) ΔCoVaR	(6) ΔCoVaR	(7) DMES	(8) DMES	(9) DMES	(10) DMES	(11) DMES	(12) DMES
Price to Book	-6.71e-07	-7.02e-07	-8.79e-07	-9.23e-07	-7.93e-07	-8.45e-07	1.22e-05***	1.24e-05***	1.19e-05***	1.20e-05***	1.10e-05**	1.12e-05**
	(-0.866)	(-0.889)	(-1.126)	(-1.156)	(-0.962)	(-0.996)	(3.126)	(3.133)	(2.918)	(2.898)	(2.580)	(2.583)
Leverage (Assets)	5.47e-05***		5.33e-05**		3.69e-05		0.000420**		0.000405*		0.000462*	
	(2.679)		(2.679)		(1.441)		(2.088)		(1.950)		(1.830)	
Tangible Assets (*Log*)	0.00451**		0.00432**		0.00413**		0.0614***		0.0607***		0.0593***	
	(2.614)		(2.352)		(2.363)		(4.522)		(4.369)		(4.035)	
Tangible Assets^2(*Log*)	-0.000191***		-0.000180***		-0.000171***		-0.00231***		-0.00227***		-0.00224***	
	(-3.460)		(-3.101)		(-3.001)		(-5.096)		(-4.895)		(-4.487)	
Leverage (Liabilities)		5.86e-05***		5.63e-05***		4.15e-05		0.000441**		0.000420**		0.000471*
		(2.848)		(2.836)		(1.572)		(2.173)		(2.022)		(1.858)
Liabilities (*Log*)		0.00364***		0.00333***		0.00314***		0.0444***		0.0426***		0.0419***
		(3.569)		(3.067)		(3.065)		(4.623)		(4.438)		(4.080)
Liabilities^2(*Log*)		-0.000171***		-0.000157***		-0.000146***		-0.00181***		-0.00174***		-0.00172***
		(-4.492)		(-4.042)		(-3.762)		(-5.100)		(-4.878)		(-4.455)
Concentration	0.00229	0.00256	0.00245	0.00265	0.00153	0.00170	0.0239	0.0239	0.0240	0.0236	0.0130	0.0129
	(1.055)	(1.123)	(1.136)	(1.172)	(0.775)	(0.812)	(1.206)	(1.159)	(1.198)	(1.139)	(0.669)	(0.635)
Investment Quality	-0.000942*	-0.000924*	-0.000779*	-0.000782*	-0.000234	-0.000240	-0.00971***	-0.00951**	-0.00942**	-0.00937**	-0.00593*	-0.00579
	(-1.975)	(-1.976)	(-1.762)	(-1.787)	(-0.704)	(-0.704)	(-2.680)	(-2.558)	(-2.655)	(-2.553)	(-1.750)	(-1.563)
Equity Assets	-0.00335	-0.00372*	-0.00359	-0.00388*	-0.00203	-0.00233	-0.0402***	-0.0434***	-0.0407***	-0.0433***	-0.0334***	-0.0364***
	(-1.533)	(-1.763)	(-1.596)	(-1.762)	(-0.945)	(-1.107)	(-3.683)	(-4.211)	(-3.680)	(-4.024)	(-3.117)	(-3.437)
Fixed Income Assets	-0.00200	-0.00215	-0.00253	-0.00258	-0.00210	-0.00215	-0.0161	-0.0156	-0.0168	-0.0156	-0.0139	-0.0131
	(-0.823)	(-0.885)	(-1.005)	(-1.031)	(-0.856)	(-0.881)	(-1.058)	(-1.060)	(-1.052)	(-1.021)	(-0.823)	(-0.794)
Cash	-0.00304	-0.00329*	-0.00343*	-0.00367*	-0.00294	-0.00316*	-0.0229*	-0.0254**	-0.0260**	-0.0284**	-0.0240**	-0.0263**
	(-1.581)	(-1.813)	(-1.721)	(-1.924)	(-1.657)	(-1.881)	(-1.962)	(-2.279)	(-2.154)	(-2.427)	(-2.046)	(-2.297)
Insurance Activities	-0.00658***	-0.00686***	-0.00741***	-0.00768***	-0.00628**	-0.00655**	-0.0188	-0.0177	-0.0268	-0.0257	-0.0227	-0.0222
	(-2.973)	(-2.967)	(-2.918)	(-2.894)	(-2.433)	(-2.414)	(-1.188)	(-1.113)	(-1.508)	(-1.446)	(-1.296)	(-1.264)
Life Business	0.00803***	0.00800***	0.00908***	0.00903***	0.00696**	0.00693**	0.0545***	0.0510***	0.0659***	0.0623***	0.0607***	0.0567***
	(3.035)	(2.954)	(3.048)	(2.941)	(2.395)	(2.317)	(3.287)	(2.979)	(3.515)	(3.208)	(3.132)	(2.818)
Total Debt	0.000378	0.000229	9.86e-05	-3.09e-05	0.000525	0.000270	0.0325**	0.0256*	0.0323**	0.0254*	0.0322*	0.0239
	(0.199)	(0.125)	(0.0503)	(-0.0163)	(0.294)	(0.154)	(2.219)	(1.785)	(2.107)	(1.707)	(1.947)	(1.474)
Separate Accounts	-0.000279	-0.00390	9.79e-06	-0.00333	0.00108	-0.00187	-0.0146	-0.0417	-0.0169	-0.0429	-0.0125	-0.0372
	(-0.0914)	(-1.152)	(0.00314)	(-0.981)	(0.374)	(-0.565)	(-0.450)	(-1.331)	(-0.533)	(-1.392)	(-0.355)	(-1.078)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	344	344	317	317	279	279	344	344	317	317	279	279
Number of Insurers	51	51	48	48	43	43	51	51	48	48	43	43
Adjusted R-squared	0.540	0.542	0.544	0.546	0.466	0.468	0.539	0.532	0.537	0.528	0.494	0.483
F test	7.451	10.858	8.476	9.626	9.765	8.834	7.103	11.226	8.068	8.251	10.463	8.974

Table 15: Robustness Check - DiD.
Shock dummy computed around Lehman Brothers filing for bankruptcy and AIG bailout. Treatment groups defined on Insurance Activities and Life Business. Robust t-statistic in parentheses. $***p < 0.01$, $**\ p < 0.05$, $*p < 0.1$.

	ΔCoVaR				DMES			
VARIABLES	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Price to Book		0.001***		0.001*		0.001		0.001
		(3.487)		(1.866)		(1.115)		(0.371)
Leverage (Liabilities)		0.000		0.000		0.000		-0.001
		(-1.667)		(-1.010)		(-1.343)		(-1.091)
Liabilities (*Log*)		-0.002		0.000		-0.003		0.008
		(-1.623)		(0.264)		(-0.428)		(0.647)
Liabilities^2 (*Log*)		0.000**		0.000		0.000		0.000
		(2.676)		(0.402)		(1.123)		(-0.225)
Total Debt	-0.105**	-0.042	-0.004	-0.013	-0.675***	-0.469***	-0.054	-0.006
	(-2.613)	(-1.493)	(-0.437)	(-0.524)	(-4.220)	(-3.156)	(-1.058)	(-0.029)
Separate Accounts	-0.005	-0.001	0.001	0.000	-0.030**	-0.014	-0.006	-0.012
	(-1.654)	(-0.277)	(0.367)	(0.063)	(-2.451)	(-1.187)	(-0.403)	(-0.530)
Top Quantile Life Business	0.006***	0.000			0.019***	-0.002**		
	(3.690)	(-0.120)			(2.820)	(-0.160)		
Shock Dummy × Top Life Business	0.005*	0.004*			0.022**	0.019**		
	(1.930)	(2.030)			(2.190)	(2.050)		
Bottom Insurance Act's			0.004**	0.004**			0.023*	0.024*
			(2.140)	(2.330)			(1.950)	(1.950)
Shock Dummy × Bottom Insurance Act's			0.006**	0.005***			0.031**	0.027*
			(2.430)	(2.810)			(2.190)	(1.760)
Observations	49	46	42	39	49	46	42	39
R-squared	0.4502	0.7969	0.4511	0.7695	0.5221	0.687	0.3728	0.5243

C Figures

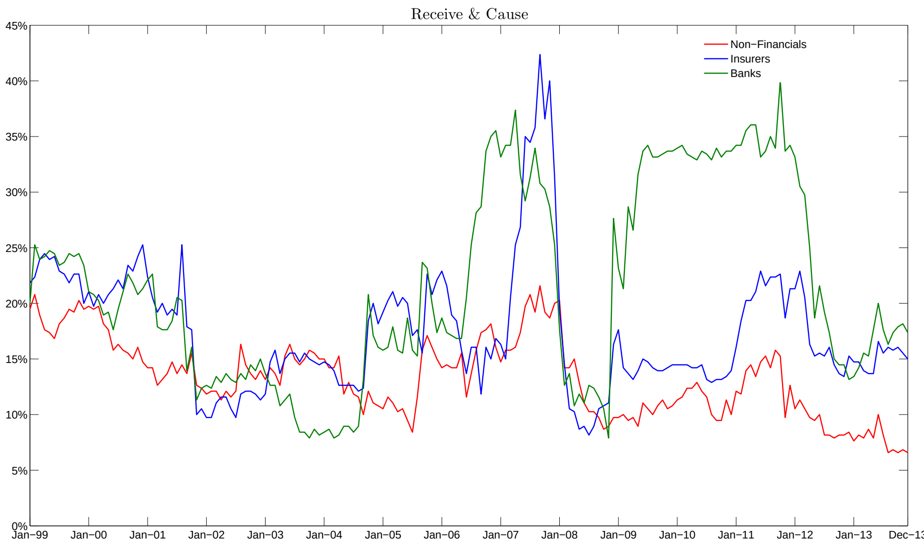

Figure 1: Total cause intra-industry.
The figure displays for each control group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is set at 5%. Results are calculated using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

Figure 2: Total cause/receive towards other industries.
The figure displays for each control 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.

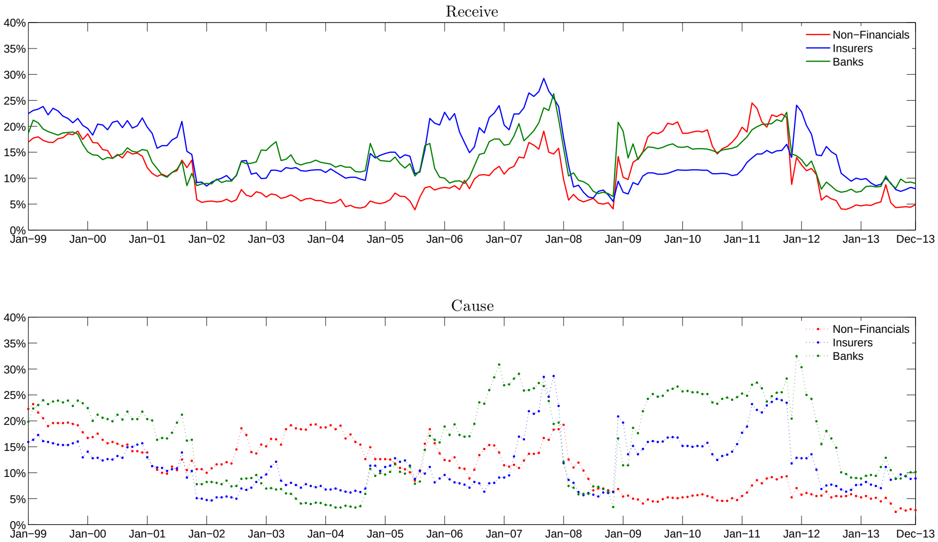

Figure 3: Total cause/receive towards total system.
The figure displays for each control group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is set at 5%. Results are calculated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

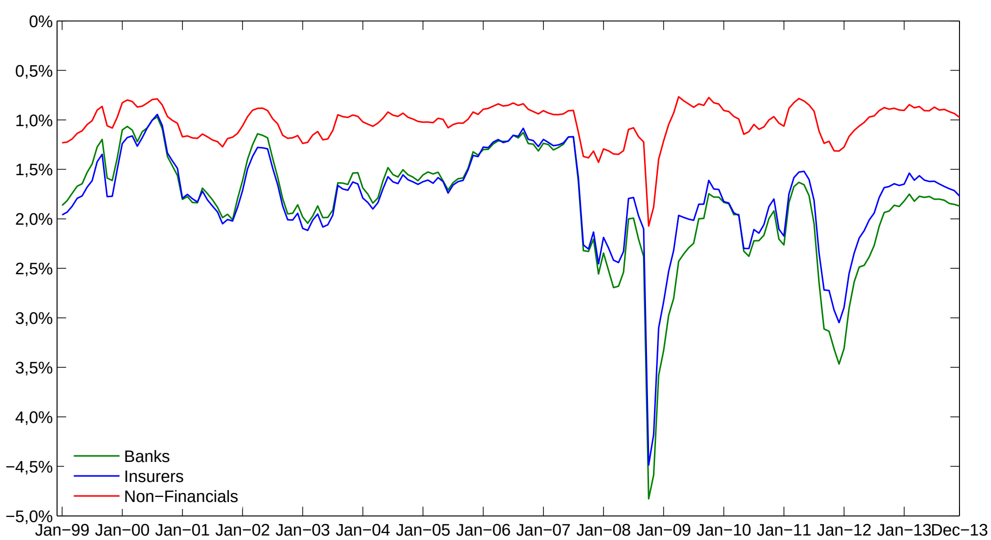

Figure 4: Average institutions' ΔCoVaR intra-industry.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

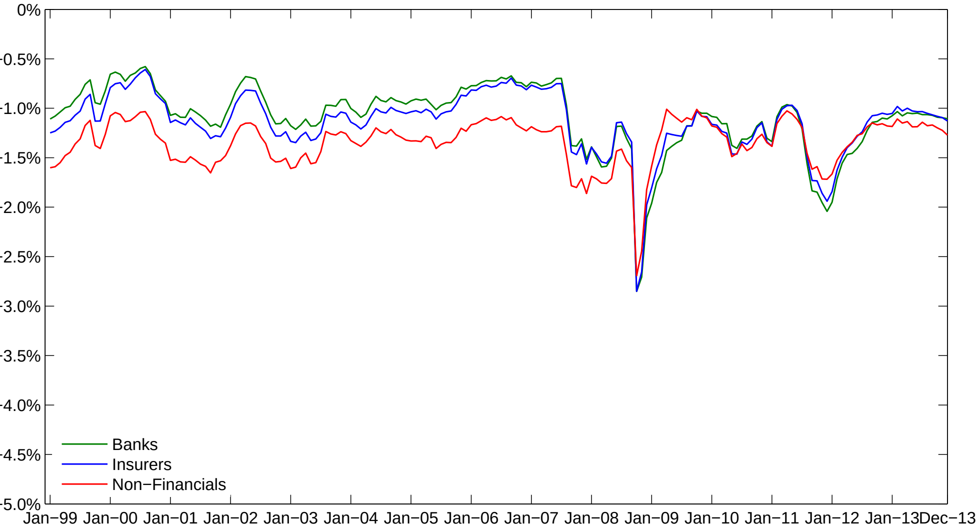

Figure 5: Average institutions' ΔCoVaR towards other industries.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

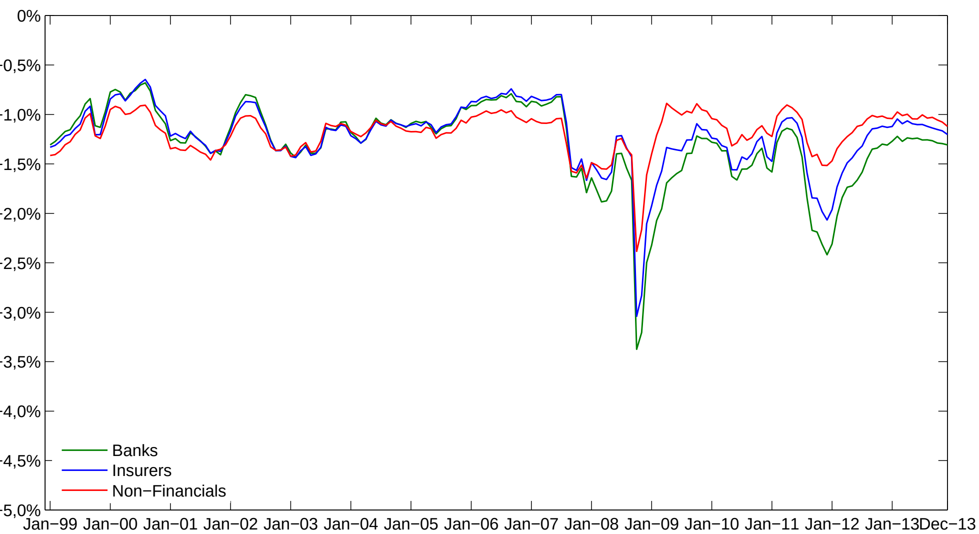

Figure 6: Average institutions' ΔCoVaR towards total system.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

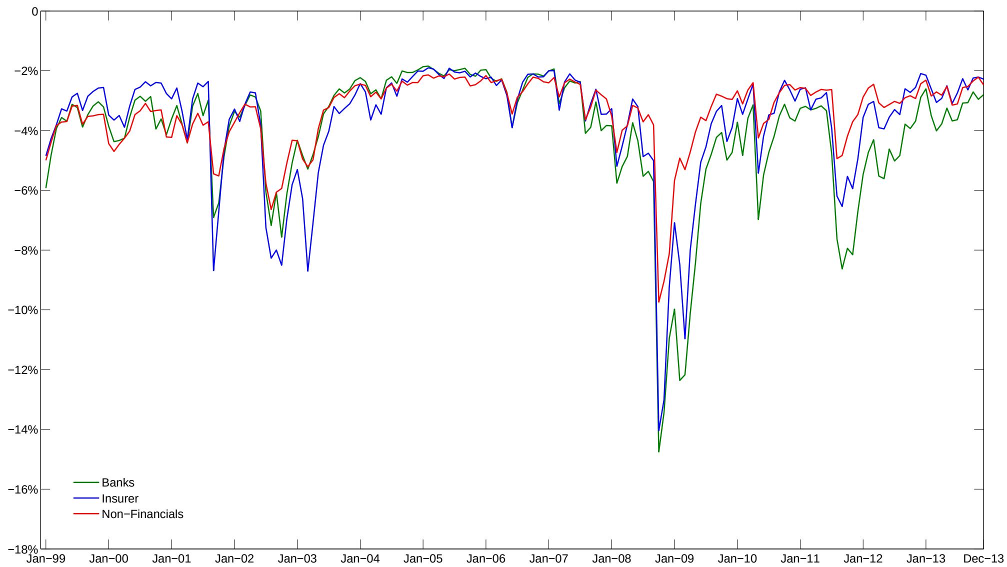

Figure 7: Average institutions' DMES intra-industry.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

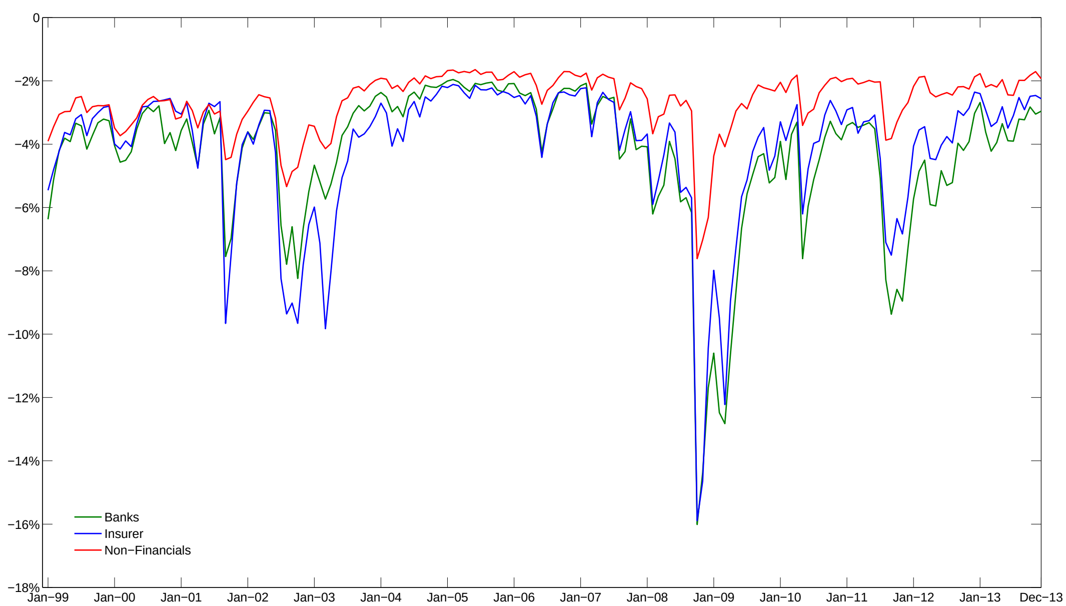

Figure 8: Average institutions' DMES towards other industries.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

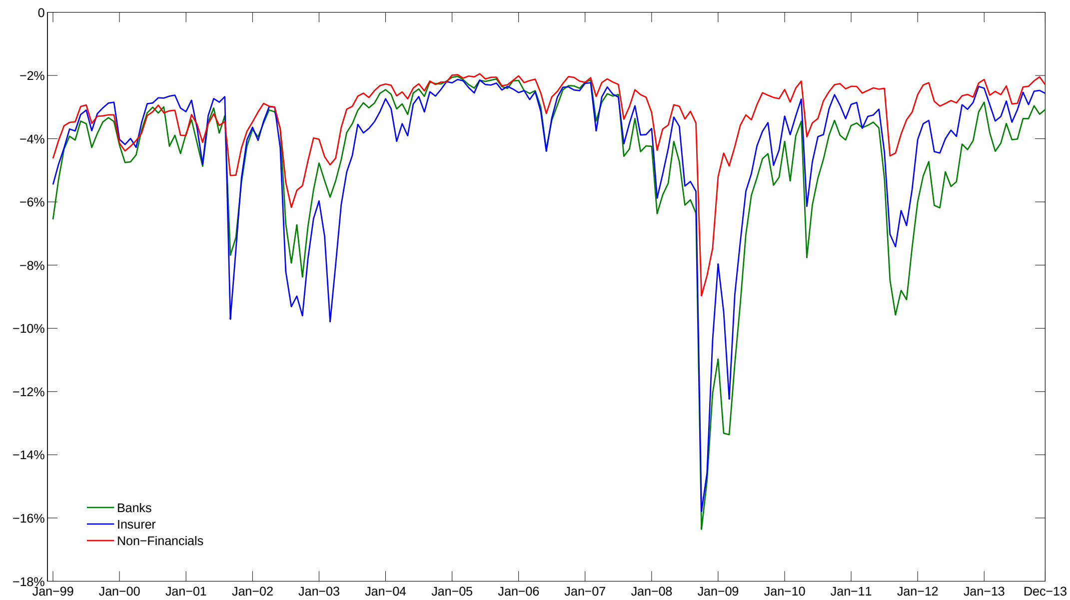

Figure 9: Average institutions' DMES towards total system.
The figure displays the industry monthly average calculated on the single institution's monthly median value.

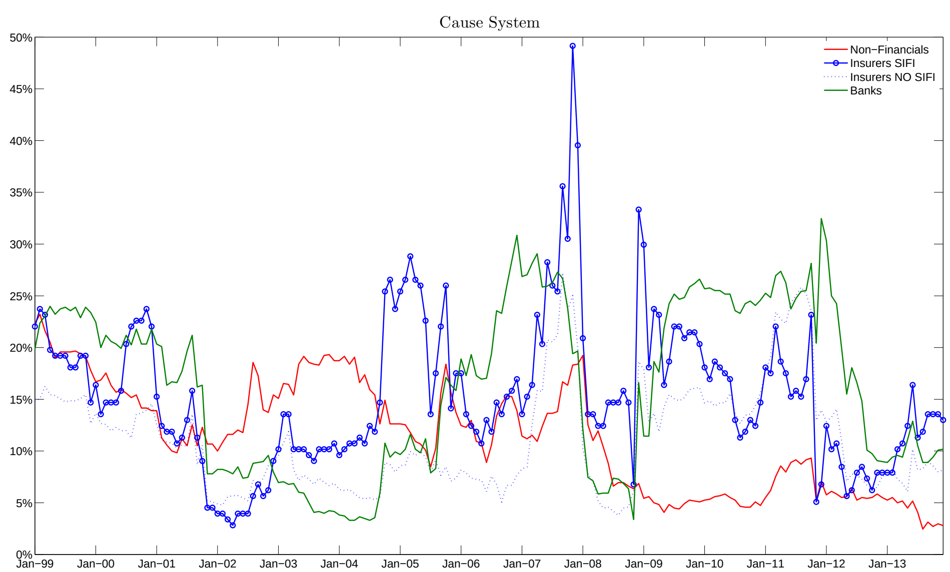

Figure 10: Total cause towards total system - focus on SIFI Insurance Companies
The figure displays for each control group the number of significant cause and receive linear Granger causality connections over the total number of possible cause and receive connections. Statistical significance level is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

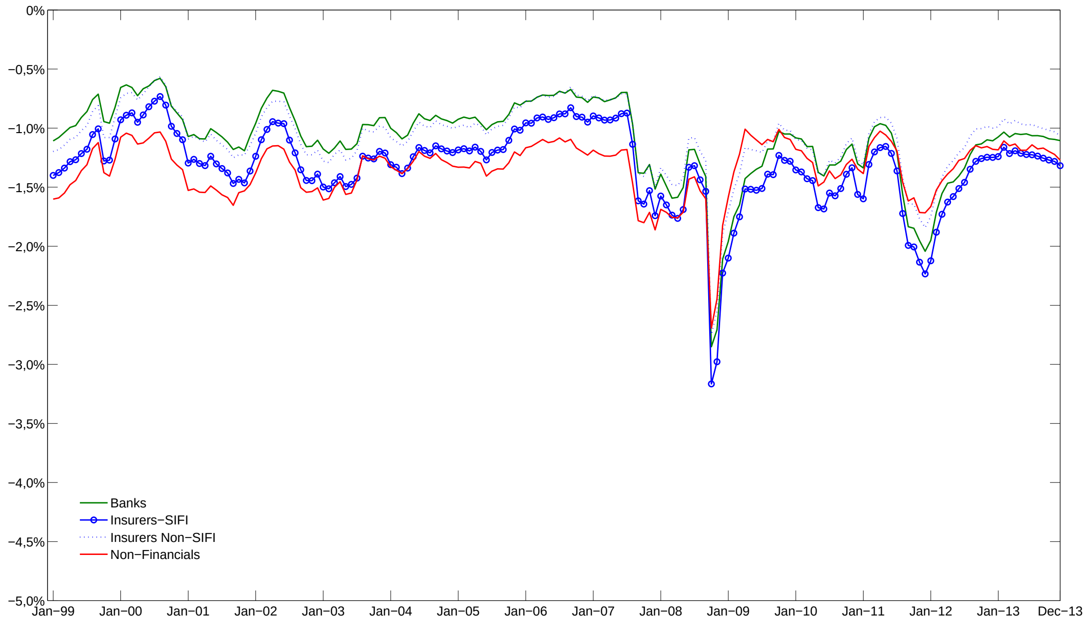

Figure 11: Average institutions' ΔCoVaR towards total system - focus on SIFI Insurance Companies. The figure displays the industry monthly average calculated on the single institution's monthly median value.

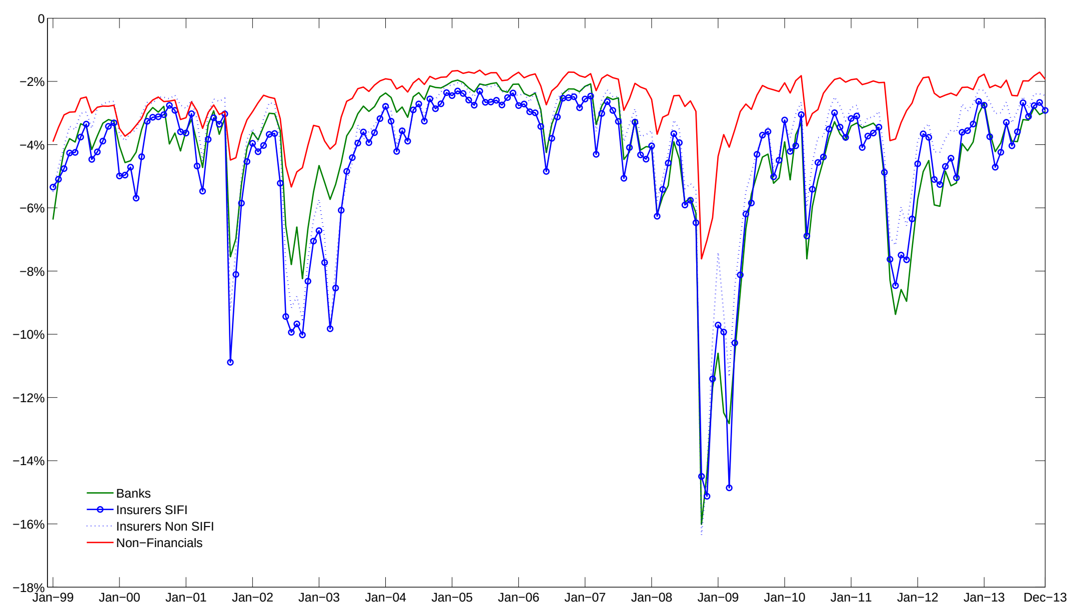

Figure 12: Average institutions' DMES towards total system - focus on SIFI Insurance Companies. The figure displays the industry monthly average calculated on the single institution's monthly median value.

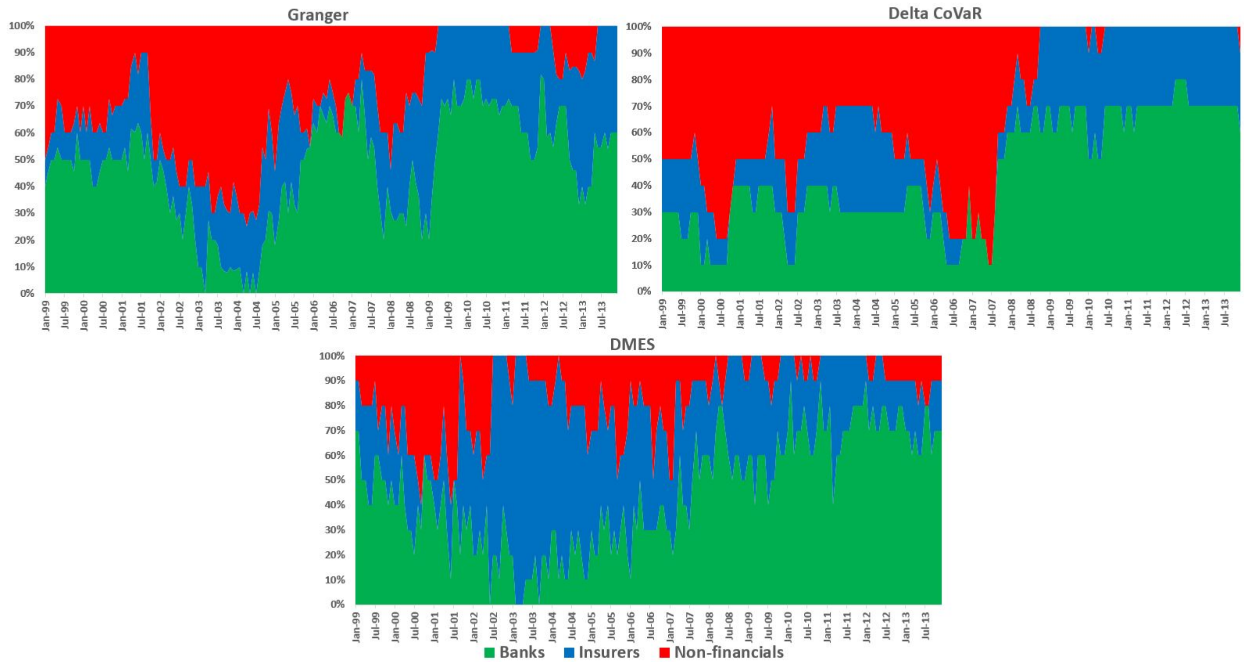

Figure 13: Most systemically relevant institutions.
The 3 graphs report the industry composition of the 10 most systemically relevant institutions at each point in time.

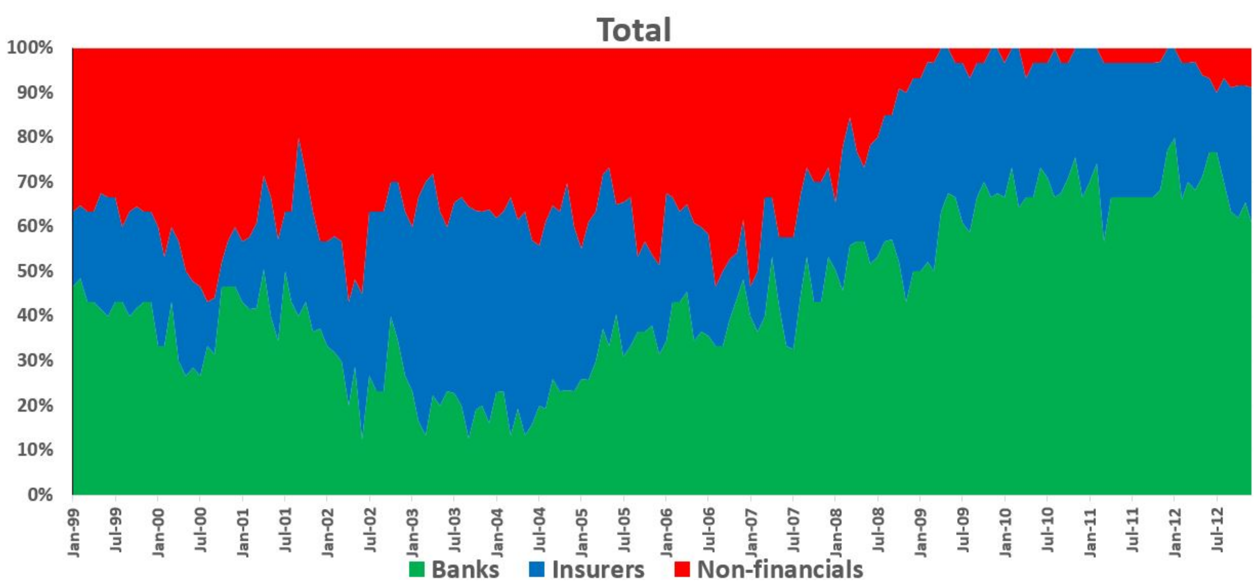

Figure 14: Cumulative index.
The graph reports the average industry composition of the 3 indices at each point in time.

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