Institute of Insurance Economics

University of St.Gallen

Basis Risk, Procyclicality, and Systemic Risk in the Solvency II Equity Risk Module

Martin Eling
David Pankoke

Working Papers on Risk Management and Insurance No. 128

Edited by Hato Schmeiser

Chair for Risk Management and Insurance

April 2013

Basis Risk, Procyclicality, and Systemic Risk in the Solvency II Equity Risk Module

Martin Eling, David Pankoke[1]

University of St. Gallen, Institute of Insurance Economics, Kirchlistrasse 2, 9010 St. Gallen, Switzerland

Abstract

This paper analyzes the equity risk module of Solvency II, the new regulatory framework in the European Union. The equity risk module contains a symmetric adjustment mechanism called equity dampener which shall reduce procyclicality of capital requirements and thus systemic risk in the insurance sector. We critically review the equity risk module in three steps: we first analyze the sensitivities of the equity risk module with respect to the underlying technical basis, then work out potential basis risk (i.e., deviations of the insurers actual equity risk from the Solvency II equity risk), and—based on these results—measure the impact of the symmetric adjustment mechanism on the goals of Solvency II. The equity risk module is backward looking in nature and a substantial basis risk exists if realistic equity portfolios of insurers are considered. Both results underline the importance of the own risk and solvency assessment (ORSA) under Solvency II. Moreover, we show that the equity dampener leads to substantial deviations from the proposed 99.5% confidence level and thereby reduces procyclicality of capital requirements. Our results are helpful for academics interested in regulation and risk management as well as for practitioners and regulators working on the implementation of such models.

Keywords: Solvency II, procyclicality, systemic risk, CoVaR, MES
JEL classification: G22; G28; G32

1. Purpose and Motivation

In light of the ongoing financial crisis, the scope and structure of insurance regulation is the subject of intense discussions, both in academia and practice. Regulators around the world are revising their regulatory frameworks, including in the United States (Klein and Wang, 2009), the European Union (Eling et al., 2007), and Switzerland (Filipović and Vogelpoth, 2008). A new and important aspect that has been added to the regulatory agenda is the question of whether the insurance industry exposes

[1] Corresponding author. Tel.: +41 71 2247983; fax: +41 71 2247990.
E-mail addresses: martin.eling@unisg.ch (M. Eling), david.pankoke@unisg.ch (D. Pankoke).

systemic risk and, if so, how regulation might help mitigating undesired outcomes arising from such risk (Klein, 2011; Cummins and Weiss, 2011; Harrington, 2009; Harrington and Miller, 2011; Grace, 2011).

This paper contributes to the discussion by focusing on the equity risk module of Solvency II. The module consists of a capital requirement for equities based on a standard capital stress scenario which is the 0.5% quantile of past returns and an additional adjustment term to counteract systemic risk (CEIOPS, 2010a).[2] The idea of the adjustment term is that capital requirements are tightened or relaxed depending on the market environment. Due to the "one size fits it all" approach of the standard formula it is likely that the capital requirements for equities suit not precisely the risks of insurers. Neither this potential deviation nor the proposed mechanisms for counteracting systemic risk have been the subject of academic research to date.

The design of Solvency II has been subject of a fair amount of research during the past few years. One prominent discussion is the option to choose between a regulatory standard model and an internal risk model. Liebwein (2006), Albarrán et al. (2011) as well as Gatzert and Martin (2012) argue that companies should use internal risk models since they better reflect the actual risk of the company than the standard formula.[3] Christiansen et al. (2012) review the aggregation formula used to sum up the capital requirements for different risk classes; they find that the aggregation formula can be supported theoretically, but that the underlying correlation matrix is highly questionable.[4] Pfeifer and Strassburger (2008) show that if the individual risks are skewed, then the solvency capital requirements can be largely under- or overestimated. According to Savelli and Clemente (2011) the proposed aggregation formula produces correct results only for a restricted class of independent distributions and can lead to an underestimation of the diversification effect. As an alternative, they propose using copula functions to model the dependencies of distributions and to derive more appropriate capital requirements. Van Laere and Baesens (2010) discuss the calculation of the capital requirement for credit risk and suggest an approach similar to that of Basel II to predict credit ratings

2 In 2011, CEIOPS (Committee of European Insurance and Occupational Pensions Supervisors) was renamed EIOPA (European Insurance and Occupational Pensions Authority).

3 Our paper contributes to this discussion by empirically showing the differences between the actual risk and the standard model risk for the equity risk module of Solvency II.

4 Our results also contribute to this discussion in that we empirically analyze the time-varying nature of the correlations between asset classes considered in the equity risk module.

for non-rated companies. Mittnik (2011) analyzes the calibration of the equity risk module and points out flaws in the return definition based on a rolling window of daily measured annual returns. Braun et al. (2013) show that private equity investments are overly penalized by the standard formula for equity risk.

Some authors have claimed that regulation can increase systemic risk (see, e.g., Keller, 2011 and Huerta de Soto, 2009 with regard to Solvency II), which is the motivation behind introducing an additional adjustment term in the equity risk module. One often mentioned argument is that in case of an economic downturn or a stock market crash, risk-based capital standards might force insurers to sell risky assets, which might cause a run in the market and thus intensify the crisis (Eling et al., 2007). To our knowledge the symmetric adjustment mechanism of the Solvency II equity risk module has not been analyzed in the academic literature.

The goal of this paper is a thorough analysis of the equity risk module of Solvency II. We therefore use a three-step analysis design. We first analyze the sensitivities of the equity risk module based on the empirical data used to calibrate the model. Then, we consider more realistic investment portfolios of insurance companies in order to identify potential basis risk in the Solvency II model. In our context we define basis risk as the risk that the Solvency II risk measure deviates from the actual risk of the insurance company due to the simplified portfolio construction used in the standard formula. Finally, we analyze if the symmetric adjustment mechanism reduces procyclicality of capital requirements.

We are interested in the research questions in light of the goals of Solvency II which are the protection of polcyholders and financial stability.[5] We analyze the fulfillment of these goals by empirically backtesting the equity risk module. Our work shall contribute to the academic discussion on the optimal design of insurance regulation and also help practitioners in their efforts to develop a framework for a safe and sound insurance industry. Table 1 summarizes the two main goals of Solvency II, the analysis done in this paper with respect to these goals, the results and the conclusion that we derive from the results.

[5] According to Article 16 and 64 of the directive written by the European Parliament and the European Council (2009) the primary goal of Solvency II is to protect policyholders and guarantee a solvency probability of 99.5% for insurers. In addition, Article 16 calls also for "[f]inancial stability and fair and stable markets…".

Table 1
Goals of Solvency II, contribution, results, and conclusion of this paper.

Goal of Solvency II	Contribution of this paper	Result	Conclusion
1. Safety at confidence level of 99.5%	Analysis of sensitivities and of basis risk with respect to the confidence level	Substantial deviations from the 99.5% confidence level depending on the data (e.g., time horizon) and portfolio composition	Need for thorough ORSA and internal risk models
2. Financial stability	Analysis of procyclicality	Symmetric adjustment mechanism reduces procyclicality of capital requirements	Equity dampener helps to avoid fire sale in the market

Our results complement the known shortcomings of the Solvency II standard formula (Christiansen et al., 2012; Pfeifer and Strassburger, 2008; Savelli and Clemente, 2011) with a detailed empirical analysis of the equity risk module. The sensitivity analysis of the equity risk module illustrates the backward looking nature of the new Solvency II capital requirements since the capital charges only reflect past crisis. Our analysis of the basis risk shows that the proposed standard capital stress for equity risk can substantially deviate from the individual insurers' portfolio risk; in our case the actual capital stress measured on more realistic empirical data can be 29.7 percentage points lower or 11.6 percentage points higher than the standard capital stress. All these results emphasize the need for an own risk and solvency assessment (ORSA) under Solvency II.[6] Finally, we show how the symmetric adjustment mechanism alters the regulators goal to set a confidence level of 99.5%[7], but contributes to financial stability by reducing procyclicality of capital requirements.

The remainder of this paper is structured as follows. In Section 2 we shortly explain the calculations behind the capital requirements of the equity risk module, i.e. the standard capital stress, and the symmetric adjustment mechanism. In Section 3 we discuss the results of the sensitivity analyses of the capital requirements with respect to their technical basis. The basis risk is then evaluated in Section 4 and Section 5 focuses on procyclicality and systemic risk. Section 6 concludes and outlines ideas for potential future research.

6 ORSA requires the insurers to document deviations of the actual risk from the risk shown under the Solvency II standard model.

7 A confidence level of 99.5% is equivalent to a one-year bankruptcy probability of less than 0.5%.

2. Capital Requirements for Equity Risk and the Symmetric Adjustment Mechanism

The calculation of the capital requirement for the Solvency II equity risk module is set out in three publications. Directive 2009/138/EC, the bill passed by the European Parliament and European Council (2009), sets the general outline of Solvency II. It determines the 0.5% risk level for capital requirements and the cap for the symmetric adjustment mechanism. The symmetric adjustment mechanism is the algorithm which determines the capital requirement according to the market environment. The QIS5 Technical Specifications (CEIOPS, 2010b) set out the guidelines for the fifth test run of Solvency II which took place in 2010. The Solvency II Calibration Paper (CEIOPS, 2010a) presents the reasoning behind algorithms set out in the specifications. The three mentioned publications are the latest publically available information about the application of Solvency II. However, discussions between European institutions are ongoing and further changes in the specifications as well as in the directive itself are likely (e.g., see proposed changes in the directive by the European Commission, 2011, called Omnibus II or the new time schedule for the introduction of Solvency II suggested by the European Commission, 2012).

The standard capital stress shall be calibrated according to a Value at Risk measure with a confidence level of 99.5% (European Parliament and European Council, 2009, Article 104(4)). It differentiates between two classes of equities. Equities listed in EEA or OECD countries are considered under the class “global”. Equities not listed in EEA or OECD countries, hedge funds, commodities, private equities and other alternative investments are categorized as “other” equities. Thus, the 0.5% quantile of annual returns from different benchmark indices are taken into account. For “global” equities the MSCI World Price index is used[8] and for “other” equities the LPX 50 Total Return index, the HFRX Hedge Fund Total Return index, the MSCI BRIC Price index and the S&P GSCI Commodities Total Return index are considered. The calculations done by CEIOPS are based on a rolling window of daily measured annual returns for the longest period from which data are available.[9]

[8] In addition, CEIOPS presents results for the MSCI Americas, MSCI Europe, and MSCI Pacific Price index. Also, the historical quantiles are compared with quantiles assuming a normal distribution. For a critical discussion of assuming normal distributions, see, e.g., Sandström (2007).

[9] The capital requirement for the equity risk class “global” is based on the MSCI World Price index. For this index daily data is available from January 1970 until January 2012. Capital requirements for “other” equities

The capital requirement for equity risk (Mkt_{eq}) is calculated per equity category as follows:

$$Mkt_{g \vee o} = \max(\Delta NAV | \, equity \; shock; 0) \tag{1}$$

where

$$Mkt_g = capital\ requirement\ for\ the\ equity\ category\ "global"$$
$$Mkt_o = capital\ requirement\ for\ the\ equity\ category\ "other"$$
$$NAV = net\ value\ of\ assets\ minus\ liabilities$$
$$equity\ shock = prescribed\ fall\ in\ the\ value\ of\ equities$$

The symmetric adjustment mechanism is the algorithm determining the adjusted capital stress.

$$equity\ shock = adjusted\ capital\ stress = standard\ capital\ stress + adjustment\ term \tag{2}$$

$$adjustment\ term = min\left\{max\left\{\frac{I_t - \frac{1}{n}\sum_{s=t-1}^{t-n} I_s}{\frac{1}{n}\sum_{s=t-1}^{t-n} I_s} * \beta, -0.1\right\}, 0.1\right\} \tag{3}$$

where

$$I_t = value\ of\ the\ MSCI\ World\ Price\ index\ at\ time\ t$$
$$n = number\ of\ days\ of\ the\ reference\ period$$
$$\beta = regression\ coefficient\ in\ the\ OLS\ regression\ of\ the\ MSCI\ World\ Price\ index\ on\ its\ average$$[10]
$$standard\ capital\ stress = 39\%\ for\ equities\ listed\ in\ EEA/\ OECD\ countries,\ for\ other\ equities\ 49\%$$

It is important to mention that the final standard capital stress is not exactly the result of the 0.5% quantile of historical returns, but is determined by CEIOPS in a political decision making process. CEIOPS proposes a standard capital stress of 39% for “global” equities and 49% for “other“ equities as mentioned in QIS5. Looking at the empirical data would result in a standard capital stress of 45% for “global” equities (CEIOPS, 2010a).

Procyclicality and the risk of asset price contagion in the equity risk module are addressed by an adjustment term (Eq. (3)), which increases or decreases the capital requirements by up to 10% depending on the market environment. The standard capital stress and the adjustment term together constitute the adjusted capital stress, which determines the stress scenario and thus the capital requirement. These calculations have to be done separately for “global” equities and “other” equities.

consider four indices approximating alternative investments: the LPX 50 Total Return index (Private Equity) from January 1994 to January 2012, the HFRX Hedge Fund Total Return index (Hedge Funds) from April 2003 until January 2012, the MSCI BRIC Price index (Emerging Markets) from June 1994 until January 2012 and the S&P GSCI Total Return index (Commodities) from January 1970 until January 2012. All data can be obtained via Datastream.

10 The regression equation is as follows: $I_t = \propto + \beta * \frac{\sum_{t-n}^{t} I_t}{n} + \varepsilon_t$. For the regression analysis the time period from January 1971 until January 2012 is considered. If not otherwise indicated, we assume a β of one in this paper for further analysis, since in all regressions it is close to one regardless of the reference period. For more details see the analysis about the length of the reference period and its impact on the symmetric adjustment mechanism in Appendix A.

In order to derive the capital requirement for the equity risk module, the capital requirements for "global" and "other" equities are aggregated as follows:

$$Mkt_{eq} = \sqrt{{Mkt_g}^2 + 2 * c * Mkt_g * Mkt_o + {Mkt_o}^2} \quad (4)$$

where

$$Mkt_{eq} = \textit{overall capital requirement for the equity risk module}$$
$$c = \textit{constant for approximating the diversification effect, set to 0.75 by CEIOPS}$$

A constant is used to consider the diversification effect between the two equity categories. It is based on the tail correlations between the different benchmark indices, but finally determined by CEIOPS. Diversification effects within an equity category are not considered.

3. Sensitivity Analyses

The purpose of this section is to review the calculation of the equity risk module. We therefore look at the assumptions behind the standard capital stress (Eq. (2)), the symmetric adjustment mechanism (Eq. (3)), and the aggregation formula (Eq. (4)). Numerous other aspects could be looked at. We restrict ourselves to the above mentioned three aspects, while results for other tests (e.g., definition of returns, risk measures, β calculation) are given in Appendix A of the paper.

The calculation of the **standard capital stress** is based on a predefined time period. CEIOPS uses the full period of data available as basis for the standard capital stress. We analyze the impact of the chosen time horizon in Fig. 1. That is, for each trading day from January 1971 to January 2012 the standard capital stress based on the longest time period available on that specific date is given.[11] An important result from Fig. 1 is that the recent financial crisis significantly increased the standard capital stress which would have been much lower if Solvency II would have been introduced before 2008. This emphasizes the backward looking nature of the model since only past risks are considered.[12]

[11] In the graph we neglect the first three years because too few data points would result in misleading insights. Moreover, for Private Equity, Hedge Funds and Emerging Markets less data is available and therefore these start later in Fig. 1.

[12] The Quantitative Impact Studies (QIS) done for Solvency II exactly reflect this problem. In QIS 4, the capital stress for "global" equities was set to 32% and for QIS 5 it was already set to 39%. The capital stress for QIS 4 was published in March 2008, the one for QIS 5 in March 2010. Further information regarding the

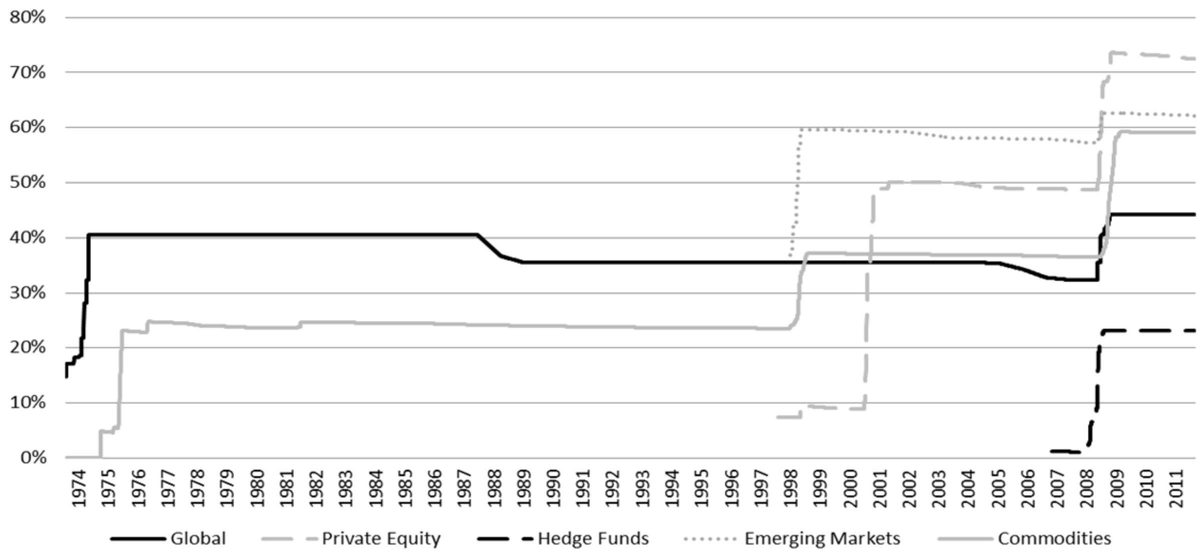

Fig. 1. Standard capital stress over time.

We empirically compare the proposed correlations within the **aggregation formula** with actual correlations of the different asset classes. In QIS5 a correlation between "global" and "other" equities of 0.75 is considered. Empirically we find that the correlations range from 0.09 to 0.95 if the maximum time period is considered. In order to illustrate the time-varying nature of the correlation, Fig. 2 shows the correlations between the MSCI World Price index and the other four indices used to define the standard capital stress. Returns are calculated annually based on a one year rolling window with daily data; the correlation coefficients are based on a 5 year rolling window. The horizontal line indicates the assumed correlation of 0.75 between the equity class "global" and "others" in the aggregation formula. Notable is the extreme variation for the commodity index and the MSCI World index. From July 1990 to July 1995 the correlation has been lowest with a coefficient of -0.69 and it has been highest from March 1977 to March 1982 with a coefficient of 0.64. These results clearly illustrate that the assumption of a fixed correlation of 0.75 which is not time-varying is not an optimal solution. Another important aspect which can be observed in Fig. 2 is that in times of crisis the correlations are higher.[13]

---

results of this analysis, if time windows are considered instead of increasing time horizons, can be found in Table A1 in the first row in Appendix A.

13 For this reason, CEIOPS (2010a) focuses on tail correlations in QIS 5, i.e., conditional correlations are calculated. We also repeated the analysis shown in Fig. 2 for tail correlations (see Appendix A). They show the same result (correlations are time-varying and typically far away from the proposed 0.75), but are more difficult to interpret since there are jumps. For this reason we present the unconditional correlations in the main part of the analysis.

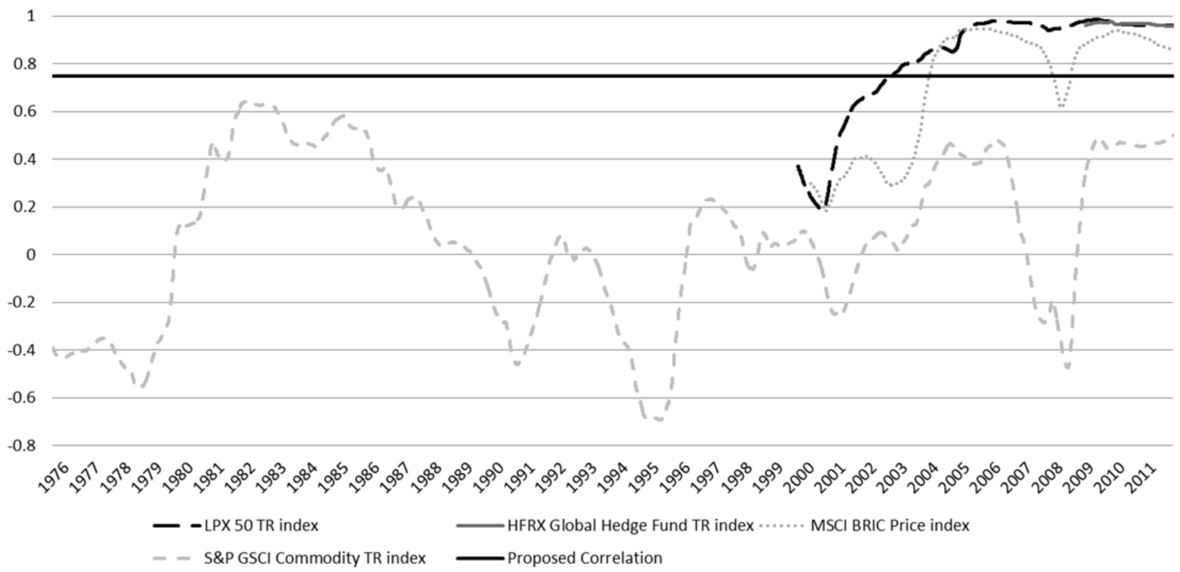

Fig. 2. Pearson-correlations over time for rolling windows of 5 years between MSCI World Price index and indices considered for the equity category "other".

Another crucial part of the equity risk module is the length of the reference period in the **symmetric adjustment mechanism**. We analyze the impact of different reference periods on overall capital requirements. This analysis is motivated by ongoing discussions between regulators as to which reference period is most appropriate. In Fig. 3, we compare the most discussed reference periods – one year and three years – and analyze their impact on the capital requirements.[14] The adjustment term as well as the standard capital stress are calibrated based on the MSCI World Price index. It can be seen that a longer reference period of three years has two effects. First, on average higher adjusted capital stresses are applied and second, the adjusted capital stress becomes binominal – either the highest or the lowest possible adjusted capital stress is applied. For example, if a three year reference period is applied and the MSCI World Price index is considered, in 56.6% of the time an adjusted capital stress of 49% is applied and only 13.0% of the time an adjusted capital stress of 29%.

The sensitivity analysis presented in this Section are not more than a "what if" sensitivity analysis, but we believe that the results are important especially to empirically backtest and illustrate

[14] CEIOPS (2010a) points out in its calibration paper the longer the reference period, the more frequently the 10% band is hit and the risk sensitivity is reduced. CEIOPS concludes that a longer reference period on the one hand alters the empirical default probability and on the other hand leads to lower capital requirements in falling markets which could create moral hazard. Insurance companies might shift their investments from asset classes without an adjustment mechanism to equities. Therefore the majority of regulators proposes a one year reference period. However, a minority still argues that a three year reference horizon is more appropriate, because capital requirements fluctuate a lot if a short reference period is chosen and argue that it is not the goal of the symmetric adjustment mechanism to respond to temporary market movements.

the dynamics of the modeling approach chosen for Solvency II. One of the drawbacks of the new Solvency II regime is that it has not been tested over time. Our results illustrate how the equity risk model would behave over time if Solvency II was already running for years: it would result in a backward looking adaption to historical crisis, an insufficient approximation of the true correlations with an underestimation of the risk especially in crisis, and risk insensitive and binomial capital requirements if the reference period is chosen to be three years long.

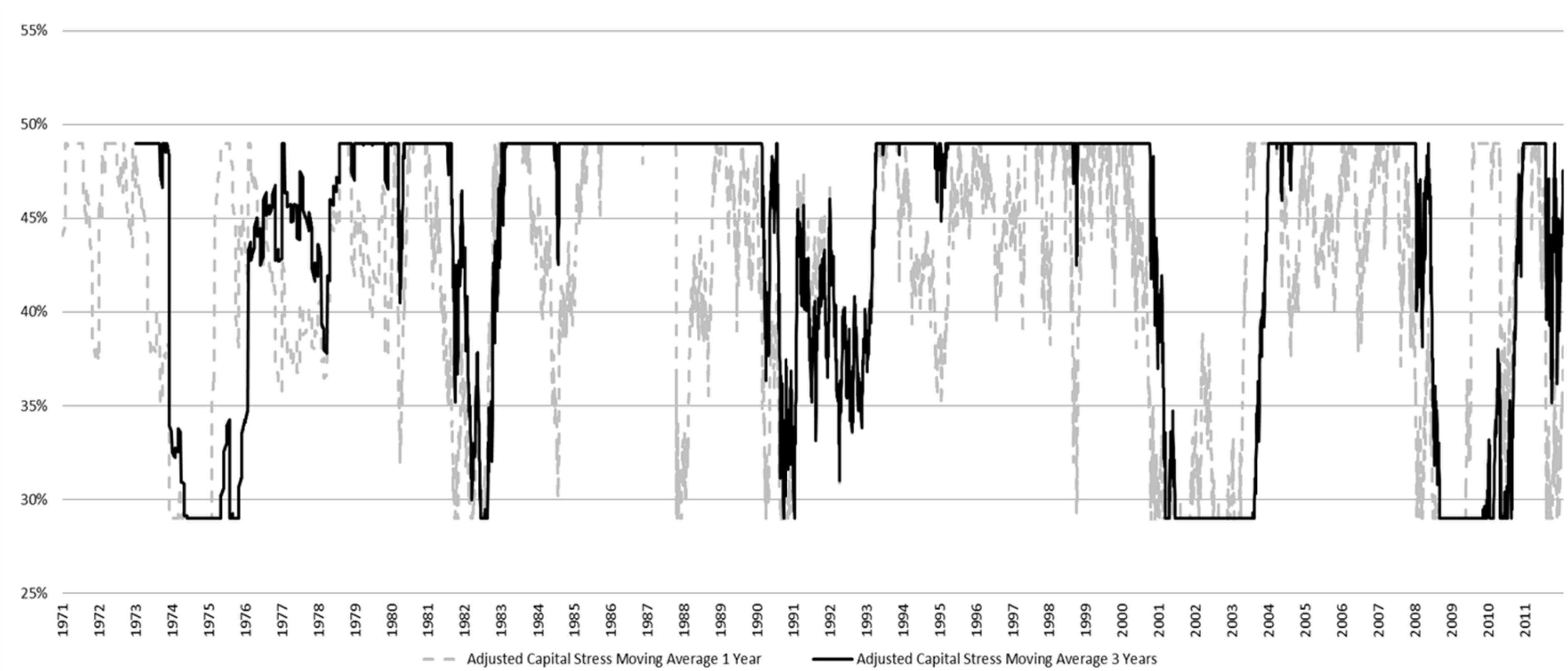

Fig. 3. Adjusted capital stress based on one and three year reference periods.

4. Solvency II Basis Risk

Under Solvency II, a uniform standard capital stress must be applied by all insurance companies, regardless of their actual portfolio composition. This requirement raises the question of how good this approximation is and how substantial deviations from this proxy are if we consider more realistic portfolios. Depending on the true portfolio composition of the individual insurer the standard capital stress might substantially deviate from the actual one and thus basis risk emerges. Our interpretation of basis risk in a Solvency II context is thus deviations of the actual insurers portfolio risk from the risk measured by the standard regulatory model.

To analyze basis risk, we model the investment portfolio of 16 insurance companies from 16 European countries. Rather than analyzing 16 real portfolios, we have set up 16 stylized country portfolios which proxy the typical allocation of insurers from these countries. To keep the analysis simple and comprehensible, the 16 country portfolios are equally composed of the MSCI country index, the MSCI Europe index excluding the respective country and the MSCI World index excluding Europe (only price indices are considered). 33.3% of each portfolio is thus invested in the home market, 33.3% in Europe outside the home market and 33.3% worldwide outside Europe. This approach follows Gatzert and Martin (2012) who use a stylized portfolio consisting of indices to approximate the stock portfolio of a typical insurance company as well and calculate the standard capital stress of the equity risk module.[15] Due to the home bias for investment decisions (Tesar and Werner, 1995) we believe these portfolios might better approximate the actual equity allocation of insurers in Europe than the MSCI World Price index. Table 2 gives some descriptive information on the MSCI World Price index and the 16 country portfolios.

[15] Stylized portfolios consisting of indices are also used by Eling and Schuhmacher (2007) as representative investment portfolios of a typical institutional investor. The composition of country portfolios is based on representative investment opportunities as described by Eling et al. (2009).

Table 2
Compositions of country portfolios and descriptive statistics.

	Portfolio Constituents				Descriptive Statistics			
	MSCI World	MSCI World ex Europe	MSCI Europe ex Country Index	MSCI Country Index	Mean	Standard Deviation	VaR_0.05	VaR_0.005
MSCI World	100.00%	0.00%	0.00%	0.00%	8.21%	17.80%	21.92%	44.24%
Country Portfolios								
Austria	0.00%	33.33%	33.33%	33.33%	7.92%	18.59%	20.57%	48.91%
Belgium	0.00%	33.33%	33.33%	33.33%	7.77%	18.04%	24.96%	48.73%
Denmark	0.00%	33.33%	33.33%	33.33%	9.66%	18.85%	24.14%	41.69%
Finland	0.00%	33.33%	33.33%	33.33%	9.49%	25.86%	32.21%	46.62%
France	0.00%	33.33%	33.33%	33.33%	8.45%	18.64%	25.79%	41.28%
Germany	0.00%	33.33%	33.33%	33.33%	7.97%	18.13%	24.41%	41.88%
Greece	0.00%	33.33%	33.33%	33.33%	0.67%	23.54%	43.43%	51.30%
Ireland	0.00%	33.33%	33.33%	33.33%	4.52%	19.95%	33.05%	52.24%
Italy	0.00%	33.33%	33.33%	33.33%	8.59%	20.84%	24.18%	43.43%
Netherlands	0.00%	33.33%	33.33%	33.33%	7.95%	17.87%	25.63%	42.69%
Norway	0.00%	33.33%	33.33%	33.33%	9.51%	19.66%	24.31%	45.07%
Portugal	0.00%	33.33%	33.33%	33.33%	1.57%	19.87%	34.01%	45.96%
Spain	0.00%	33.33%	33.33%	33.33%	8.25%	18.69%	22.66%	41.50%
Sweden	0.00%	33.33%	33.33%	33.33%	10.72%	21.05%	25.18%	41.40%
Switzerland	0.00%	33.33%	33.33%	33.33%	8.09%	17.77%	22.46%	42.62%
UK	0.00%	33.33%	33.33%	33.33%	9.08%	18.08%	22.24%	42.86%

Notes**:** returns are calculated by using a rolling window of daily measured annual returns. VaR_0.05 and VaR_0.005 indicate the maximal losses within the confidence level of 95.0% and 99.5%. The time horizon is January 1971 to January 2012 except for the country portfolios of Finland (January 1989 – January 2012), Greece (May 2002 – January 2012), Ireland (May 1994 – January 2012) and Portugal (December 1998 – January 2012).

For these 16 country portfolios we calculate the standard capital stress over time and compare it with the Solvency II standard capital stress which only considers the MSCI World index. Fig. 4 illustrates the results of this analysis for the German, Greek, Irish and Austrian country portfolios for the years 2000 to 2012. The black thick line illustrates the Solvency II standard capital stress based on the MSCI World Price index (it corresponds to the line “global” in Fig. 1). The other lines represent the results, if the capital stress is based on the country portfolios. We see that the risk of the country portfolios can substantially deviate from the one proposed by Solvency II. For example, the standard capital stress based on the MSCI overestimates the risk of the German portfolio, but underestimates the one of the Greek portfolio. We also see that for all portfolios the risk significantly increased after 2008. As illustrated in Fig. 4, these effects can be very substantial and they can occur in both directions (over- and underestimation of the actual risk). For example, on the 19th December 2000, the proposed standard capital stress is 29.7 percentage points higher than the standard capital stress of the

Irish portfolio. On the 30th October 2008 the Greek portfolio was underestimated by 10.97 percentage points. In general the standard capital stress based on the MSCI World index seems to overestimate the risk in normal market conditions and underestimates it in times of crisis. This is a meaningful finding, since the MSCI World index is more diversified than the individual country portfolios. In contrast, individual country portfolios rely more on a specific geographic area and thus inhibit idiosyncratic risks attached to single European countries, which were subject to specific crisis during the investigation period (especially Ireland and Greece). A regulatory question that thus arises is which of these two alternatives – a global standardized view or the more country specific one - is more adequate to account for the equity risk of insurance companies. Moreover, the findings emphasize the need for a careful own risk and solvency assessment (ORSA). Under this provision, insurance companies are obliged to report systematic deviations of their true risk from the Solvency II standard model. Our results emphasize that the deviations can be very substantial.

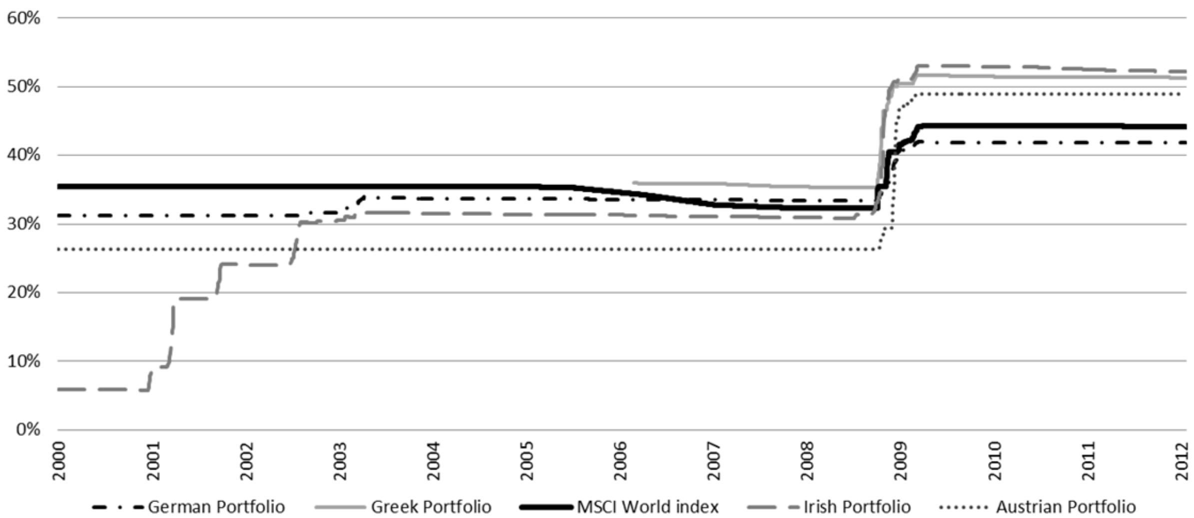

Fig. 4. Standard capital stress over time based on the 0.5% quantile for the MSCI World index and different country portfolios.

Table 3 shows the corresponding results for all 16 country portfolios. The second column shows the standard capital stress set by CEIOPS as described in QIS5. Since all country portfolios only invest in OECD countries, for all portfolios a standard capital stress of 39% would apply. The third column shows the standard capital stress based on the 0.5% quantile of the returns based on the MSCI World index. In the fourth column the standard capital stresses are shown calibrated according to the country portfolios.[16] The maximal positive and negative deviation of the standard capital stress of a country portfolio from the capital stress based on the MSCI index over time is shown in column five and seven. A positive deviation means that the standard capital stress of the MSCI index underestimates the risk of the country portfolio and a negative one that the risk is overestimated. Looking at the results we see that the maximum deviation is -29.7 percentage points for the Irish country portfolio.[17]

[16] The observed time horizon ranges from January 1974 until January 2012. Different maximal time periods are used in the case of Finland (March 1993 – January 2012), Greece (March 2006 – January 2012), Ireland (May 1998 – January 2012) and Portugal (December 2002 – January 2012).

[17] Deviations would be even larger if we would compare the results for the country portfolios with the standard capital stress of 39% set by CEIOPS instead of the one based on the 0.5% quantile of the MSCI World Price index.

Table 3
Basis risk of country portfolios.

	Total Time Period			Extending Time Period			
	Proposed CEIOPS Standard Capital Stress	Standard Capital Stress based on MSCI World Index	Standard Capital Stress based on Country Portfolio	Maximal Positive Deviaton of Country Portfolio Stress from MSCI World Stress in Percentage Points	Date of Maximal Positive Deviation	Maximal Negative Deviaton of Country Portfolio Stress from MSCI World Stress in Percentage Points	Date of Maximal Negative Deviation
Austria	39%	44.25%	48.91%	5.88	Februar 2009	-11.11	January 1975 - November 1987 November 2008 - December 2008
Belgium	39%	44.25%	48.73%	5.88	December 2008	-3.46	January 1975 - November 1987 November 2008 - December 2008
Denmark	39%	44.25%	41.69%	3.02	October 2007	-2.78	January 1975 - November 1987 & November 2008 - December 2008
Finland	39%	44.25%	46.62%	6.34	October 2007	-7.19	March 2001
France	39%	44.25%	41.28%	5.58	January 2007	-3.03	April 2009
Germany	39%	44.25%	41.88%	1.07	October 2007	-8.18	January 1975 - November 1987
Greece	39%	44.25%	51.30%	10.97	October 2008	-	
Ireland	39%	44.25%	52.24%	11.63	November 2008	-29.70	December 2000
Italy	39%	44.25%	43.43%	2.74	October 2007	-3.93	January 1975 - November 1987 November 2008 - December 2008
Netherlands	39%	44.25%	42.69%	3.90	October 2007 - October 2008	-2.14	January 1975 - November 1987 November 2008 - December 2008
Norway	39%	44.25%	45.07%	3.11	October 2007 - October 2008	-1.17	January 1975 - November 1987 November 2008 - December 2008
Portugal	39%	44.25%	45.96%	7.14	November 2008	-2.57	March 2003
Spain	39%	44.25%	41.50%	-		-7.24	January 1975 - November 1987 November 2008 - December 2008
Sweden	39%	44.25%	41.40%	0.65	October 2008	-12.08	January 1975 - November 1987
Switzerland	39%	44.25%	42.62%	1.79	August 1988	-1.71	November 2008
UK	39%	44.25%	42.86%	5.07	August 1988	-1.44	April 2009

Notes: extending time period means that in order to calculate the standard capital stress based on the MSCI World Price index/ country portfolios, for each point in time the maximal time period is considered up to this date.

5. Procyclicality and Systemic Risk

5.1. Impact of the Symmetric Adjustment Mechanism on the Confidence Level of Capital Requirements

In this section we analyze the extent to which the symmetric adjustment mechanism affects the predefined goal of Solvency II of a 99.5% confidence level. Relaxing capital requirements in bad markets will systematically decrease the confidence level, while raising capital requirements in good markets should systematically increase the confidence level. We are especially interested in the possible range of outcomes; for the overall goals of Solvency II (e.g., creating a safe industry) it might be relevant to know if this range is between 99% and 99.9% or between 90% and 99.99%.

We calculate the impact of the symmetric adjustment mechanism on the confidence level as follows. First, we take the standard capital stress which is calibrated according to a 99.5% confidence level based on the MSCI World Price index and set to 39% by CEIOPS. Second, we calculate the adjusted capital stress according to the symmetric adjustment mechanism as described in Eq. (2) and (3) in Section 2. Third, we derive the confidence level based on this adjusted capital stress. For each point in time, the confidence level is simply the percentage of how many annual losses of the benchmark portfolio so far are lower than the adjusted capital stress at this point in time. Fig. 5 shows the confidence level of the adjusted capital stress for the MSCI World Price index over time.

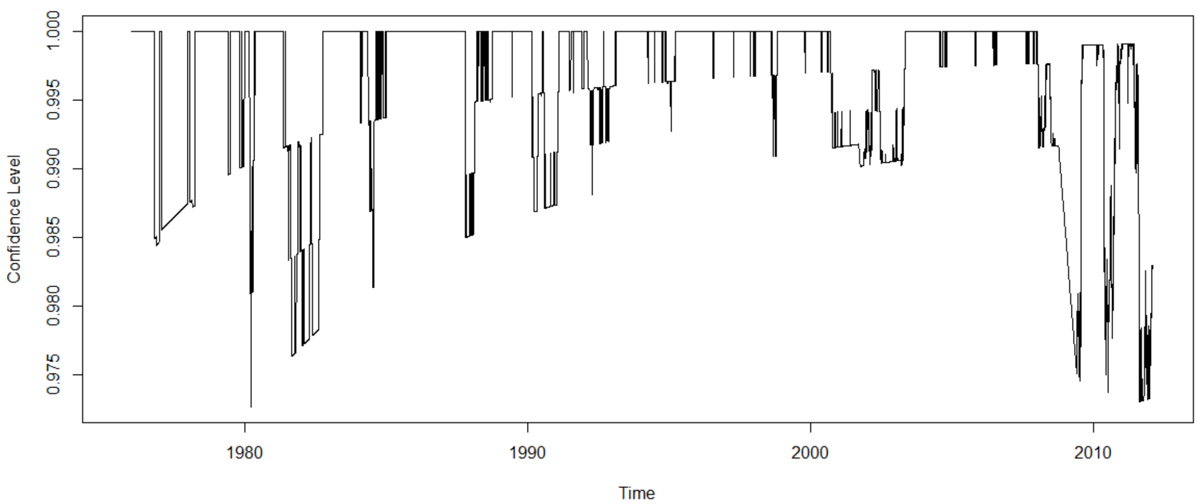

Fig. 5. Confidence level of the applied adjusted capital stress over time for the MSCI World Price index.

It can be seen in Fig. 5 that most of the time a confidence level of 1 is reached with temporary deviations from this level. The lowest confidence level is 97.26%. After 2008, the confidence level of 1 is not reached anymore, which can be explained by the characteristics of the adjustment term. Before 2008, there is no incident where the MCSI portfolio exceeds an annual loss of 49%. So, when the maximum adjusted capital stress of 49% is employed, the confidence level is 1 per definition. Only when the adjusted capital stress turns out to be below the maximum, the confidence level sometimes cannot meet the 99.5% threshold. After 2008, the maximal loss exceeds 49% and consequently, as seen in Fig. 5, a confidence level of 1 cannot be reached anymore.[18]

The confidence level thus from time to time substantially deviates from the required confidence level when capital requirements are relaxed. Especially, during the financial crisis the goal of Solvency II to ensure that insurers can meet their obligations with a 99.5 % confidence level would have been violated. The symmetric adjustment mechanism thus reduces the capital requirements in times of financial distress and thus reduces procyclical behavior.

5.2. Alignment of the Symmetric Adjustment Mechanism with Systemic Risk

Besides the protection of policyholders and beneficiaries, Solvency II has the objective to maintain financial stability and fair and stable markets as stated in Article 16 of the directive from the European Parliament and the European Council (2009). In this section we analyze if the symmetric adjustment mechanism is contributing to this second goal of stability. Therefore we employ two systemic risk measures – CoVaR (Adrian and Brunnermeier, 2011) and Marginal Expected Shortfall (MES; Acharya et al., 2012) – to our country portfolios and review if the symmetric adjustment mechanism is pro- or anticyclical in regard to systemic risk.

CoVaR can be used to measure the VaR of a system conditional on an institution being at its VaR level. Thus, basically it is a measure to what extent the distress of the whole system coincides with the distress of a single institution. CoVaR can be calculated as time-invariant, time-variant or forward-looking measure. Since we want to compare current systemic risk with the current capital requirements of the equity risk module over time we use the time-variant version in this paper. In

[18] We also repeated the analysis from Fig. 5 for all 16 country portfolios. The results are available upon request.

contrast to Adrian and Brunnermeier (2011) we adopt the CoVaR for the European market by using state variables fitting to a European environment. As Adrian and Brunnermeier (2011) we use weekly data for our evaluation. The time period ranges from May 1999 to January 2012. For further details about the calculation of the CoVaR measure in this paper we refer to Appendix B.

MES is the average return of a company during the 5% worst days of the whole market. Acharya et al. (2012) show that it can be used to approximate the losses of a company if a crisis occurs and therefore indicates its potential systemic risk. As Acharya et al. (2012) we use daily data to calculate the time-variant MES version. After transforming the daily time series into a weekly one, MES and CoVaR can be compared. The time period we use for the MES ranges from April 1999 to January 2012. Further details regarding the calculation of MES can be found in Appendix C.

Fig. 6 shows the capital requirements of the equity risk module in comparison with the average CoVaR and the average MES. We first calculate the CoVaR and MES for each country portfolio over time. In this way we approximate the contribution of a typical insurance company in a country to systemic risk of the whole system. Second, we derive the systemic risk of the whole system according to both risk measures by calculating the arithmetic average of the individual results for the 16 country portfolios at each point in time.[19]

[19] We consider the capital requirements based on the adjusted capital stress, which includes the symmetric adjustment mechanism. If the symmetric adjustment mechanism is omitted and only the standard capital stress is considered, capital requirements are 39% for all portfolios at all times. Thus, correlations between the systemic risk measures and the capital requirements cannot be calculated.

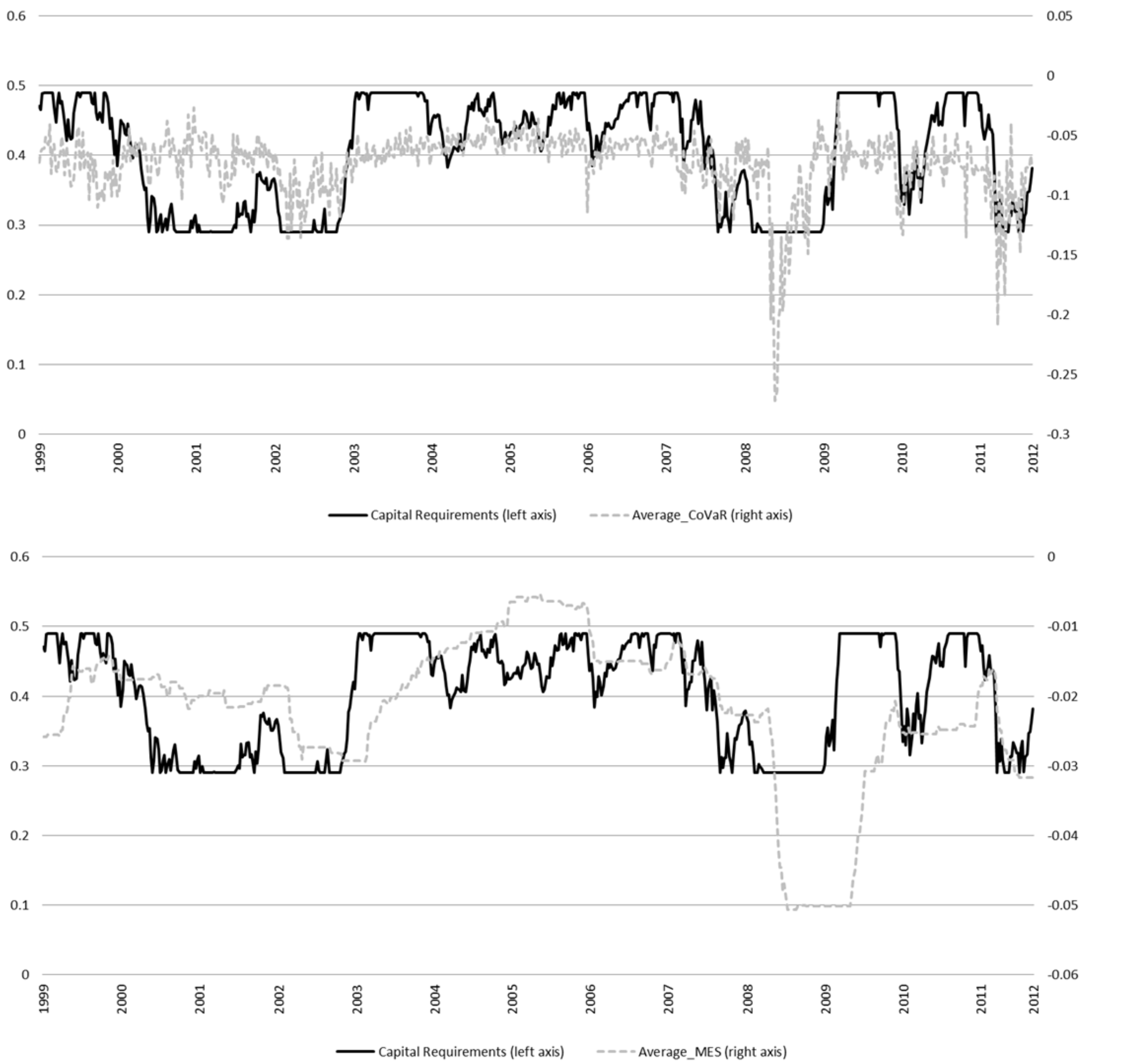

Fig. 6. Capital requirements according to the equity risk module of Solvency II in comparison with the average CoVaR and MES risk measure based on the 16 country portfolios over time.

It can be seen that low capital requirements coincide with a strongly negative average CoVaR and high capital requirements appear synchronously with a high average CoVaR. This impression is confirmed by the correlation coefficient of 0.43 between the capital requirements and the CoVaR measure and a correlation of 0.46 if the capital requirements are lagged by one week. The same is true for MES. The correlation between the capital requirements and the risk measure is 0.36 and increases to 0.38 if capital requirements are lagged as well. All coefficients are significant at a 1% confidence level.

Table 4 shows that this relationship also holds for each country portfolio. The CoVaR conditional of the Greece country portfolio has the lowest correlation coefficient (0.35) and the

Portuguese one the highest (0.48) with regard to the capital requirements. For the MES, Finland and Sweden show the highest correlation with the capital requirements (0.42) and the coefficient of Greece is the smallest (0.27). In this paper only the Pearson correlation coefficients are shown. However, we also use the Spearman rank-order correlation in order to check if the correlation is heavily influenced by outliers, which is not the case.[20]

Table 4
Correlations between capital requirements and CoVaR as well as MES.

	Correlation Coefficients			Correlation Coefficients	
	CoVaR	MES		CoVaR	MES
Total Average	0.429***	0.361***	Ireland	0.423***	0.343***
			Italy	0.442***	0.360***
Austria	0.403***	0.290***	Netherlands	0.441***	0.359***
Belgium	0.461***	0.345***	Norway	0.419***	0.323***
Denmark	0.444***	0.391***	Portugal	0.483***	0.375***
Finland	0.419***	0.419***	Spain	0.428***	0.355***
France	0.405***	0.373***	Sweden	0.364***	0.419***
Germany	0.421***	0.373***	Switzerland	0.364***	0.355***
Greece	0.354***	0.274***	UK	0.421***	0.380***

Notes: the CoVaR considers the 1% VaR Level. ***, **, * indicate a significance level of 1%, 5%, and 10%, respectively.

We further analyze the relationship between the systemic risk measures and the capital requirements by employing statistical tests and regressions which are shown in Table 5. In the remaining section we report only the results for the average CoVaR and average MES. We do not report the risk measures for each country portfolio individually, since we are interested in the relationship between the capital requirements and the systemic risk of the whole system.

[20] When interpreting the results, one has to keep in mind that by construction there is a relation between the CoVaR of the system and the VaR of the country portfolios, since the system is defined as the average return of the country portfolios. Moreover, the capital requirements are based on the MSCI World Price index which has a significant impact on the country portfolios as well. The same is true for the MES measure.

Table 5
Statistical tests regarding the relationship between CoVaR/ MES and capital requirements.

Chi^2 Test for Independence		Unit Root Test	
		Capital Requirements	-2.72*
Capital Requirements & CoVaR	100.85***	CoVaR	-5.34***
Capital Requirements & MES	157.89***	MES	-1.78
		ΔCapital Requirements	-27.49***
		ΔMES	-10.88***
Granger Causality Test		**OLS Regression Coefficients**	
Capital Requirements -> CoVaR	34.95***	CoVaR <- Capital Requirements	0.15***
CoVaR -> Capital Requirements	0.85	CoVaR <- Capital Requirements (lag)	0.15***
ΔCapital Requirements -> ΔMES	1.30	ΔMES <- ΔCapital Requirements	0.01**
ΔMES -> ΔCapital Requirements	0.37	ΔMES <- ΔCapital Requirements (lag)	0.01***

Notes: Chi^2 test statistics for H_0: stochastic independence. Unit root t-test statistics for H_0: unit root. Granger Causality f-test statistics for H_0: no granger causation. (lag) indicates a lagged variable by one week. Δ indicates the first difference in the time series and ***, **, * the 1%, 5%, and 10% significance level, respectively.

Chi^2 tests for independence reveal that stochastic independence between the risk measures and the capital requirements can be rejected at a 1% significance level. Augmented Dickey-Fuller tests (unit root tests) show that the capital requirements and CoVaR are not non-stationary at a significance level of 10% and 1%. For MES non-stationarity cannot be rejected. In order to avoid spurious regressions we use the first difference in the time series for MES analysis. Granger Causality tests show that capital requirements seem to granger cause CoVaR, since the null hypothesis of no Granger Causality can be rejected at a 1% significance level. However, CoVaR does not granger cause capital requirements. Also, the tests show no relationships between MES and capital requirements. OLS regressions of the systemic risk measures on capital requirements show that there is a relationship between contemporary as well as lagged capital requirements by one week and the systemic risk measures. The results further indicate that the relationship between capital requirements and the systemic risk measures are not arbitrary. Especially, there appears to be a deferred relationship between CoVaR and capital requirements.[21]

[21] This deferred relationship can be explained by the construction of the risk measures which are not as sensitive as the symmetric adjustment mechanism. For example, CoVaR is based on state variables which are lagged by one week and therefore reacts not instantaneously to equity market changes, but the symmetric adjustment mechanism does. The deferred relationship should thus not be interpreted as a forecasting capability of the symmetric adjustment mechanism to anticipate future systemic risk.

To further analyze the relations between the time series, we employ a vector autoregressive (VAR) model in the case of CoVaR. For the MES analysis we build a vector error correction (VEC) model, since capital requirements and MES are non-stationary and seem to be cointegrated. Details about the VAR and VEC model can be found in Appendix D. Results of both models show that the optimal lag is three. Capital requirements lagged by one and two weeks explain CoVaR with a significance level of 1%. Capital requirements lagged by three weeks have no significant impact on CoVaR. In contrast, capital requirements lagged by one and three weeks can only explain MES with a significance level of 10%. Capital requirements lagged by two weeks have no significant explanatory power on MES. Furthermore, for the VAR model the adjusted R^2 is 0.63 and for the VEC model 0.01. This contributes to the previous findings. Lagged capital requirements by three weeks can explain CoVaR significantly and MES only slightly.

Our results show that capital requirements are low when CoVaR and MES indicate increased systemic risk and are high when the systemic risk measures are on a relatively low level. This pattern is an indication that the equity dampener in fact reduces procyclicality with respect to systemic risk. We can thus conclude that according to the time-variant CoVaR and MES the symmetric adjustment mechanism indeed contributes to stability of the financial system. According to our analysis it seems that in times of crisis capital requirements are low and in times of low systemic risk high. Also, the symmetric adjustment mechanism is more sensitive to equity market changes than the risk measures and therefore seems to lead them.

6. Conclusion and Future Research

The main goal of Solvency II is the protection of policyholders (European Parliament and European Council, 2009, Article 16). Therefore capital requirements should ensure that insurance companies possess enough economic capital so that they are able to meet their obligations to policyholders over the following twelve months with a probability of at least 99.5 % (European Parliament and European Council, 2009, Article 64). Moreover, financial stability and fair and stable markets are other objectives of insurance and reinsurance regulation (European Parliament and European Council, 2009, Article 16). In light of these two goals of Solvency II, the aim of this paper is to critically analyze the equity risk module.

By backtesting Solvency II using historical data we find that the standard capital stress is highly sensitive to the considered time period and the underlining definition of returns. In order to guarantee a confidence level of 99.5% for European insurers the standard capital stress should be substantially higher. Especially, after 2008 a set standard capital stress of 39% is not sufficient. Also, deviations between the individual insurers' risk and the one assumed by Solvency II are large. Furthermore, the aggregation formula might underestimate the true risk due to the fixed time-invariant correlations. Fixed correlation coefficients are problematic in general, because equity correlations are not stable over time. The application of the symmetric adjustment mechanism further decreases the confidence level in the case when capital requirements are relaxed.

We conclude that applying the standard model will lead to systematic deviations from the proposed 99.5% confidence level and that it is therefore not ensured that the main goal of Solvency II is achieved. This result poses a strong argument for using internal models and emphasizes the importance of a thorough own risk and solvency assessment (ORSA). We thus urge insurers to evaluate if the standard model is appropriate in their case and using an internal model if necessary. Alternatively, at least sensitivity analysis need to be undertaken on company level for the own risk and solvency assessment (ORSA) in order to document potential deviations of the own risk from the results of the standard model.

Moreover, we employ CoVaR and MES as systemic risk measures and find that capital requirements have explanatory power to anticipate systemic risk. Furthermore, they are more sensitive to stock market movements. These results indicate that the symmetric adjustment mechanism indeed reduces procyclicality.

For future research it would be rewarding to closer analyze the basis risk and the symmetric adjustment mechanism. It would be interesting to focus on the explaining factors behind the basis risk by focusing on the dependencies between and within the different equity categories. For the symmetric adjustment mechanism, one could distinguish between times of booming and falling markets. Also, to further analyze the potential procyclical nature of the adjusted capital stress it could be beneficial to model not only the effect of markets on insurer's capital requirements but also the vice versa effects. Analyses with historical data neglect the effects on the market by changed behavior of insurers following the introduction of new regulatory regimes. Another path of research could be to analyze ORSA information when they become available after the introduction of Solvency II. It would be interesting to evaluate if deviations are acknowledged of the same magnitude between the standard model and the actual risk assessment in practice, too. At last, research should focus on the question if it is possible to calibrate capital requirements on other factors than historical data in order to mitigate backward looking characteristics. Insurers should not only be ready for the last, but also for the next crisis.

Appendix A – Further Sensitivity Analysis

Table A1
Sensitivity analysis of the equity risk module.

		MSCI World Price index	LPX 50 TR index (Priavte Equity)	HFRX Global Hedge Fund TR index	MSCI BRIC Price index	S&P GSCI TR index (Commodities)
Standard Capital Stress based on Time Period	1971-1980	40.49%	n.a.	n.a.	n.a.	23.74%
	1980-1990	19.30%	n.a.	n.a.	n.a.	24.09%
	1990-2000	19.14%	n.a.	n.a.	n.a.	38.38%
	2000-2011	47.84%	74.82%	n.a.	62.81%	61.80%
Standard Capital Stress based on Return Definition	Daily Data	44.39%	73.34%	23.18%	62.56%	59.43%
	Monthly Data	43.79%	72.76%	22.98%	62.09%	58.36%
	Yearly Data	39.52%	63.68%	22.60%	59.77%	44.55%
Tail Correlation between MSCI World Price and other Indices	Proposed	1.00	0.84	0.45	0.77	-0.53
	0.005 Quantile	1.00	0.78	-	0.51	0.21
	0.01 Quantile	1.00	0.48	-0.84	0.11	0.30
	0.05 Quantile	1.00	0.85	0.27	0.45	0.08
	0.1 Quantile	1.00	0.95	0.78	0.81	0.50
Linear Return Correlation between ES and VaR	Total Period	0.96	0.95	1.00	0.91	0.97
	Maximum	0.99	0.98	n.a.	0.99	0.99
	Minimum	0.00	0.61	n.a.	0.75	0.06
Frequency of Adjusted Capital Stress reaching the Maximum and Minimum according to Reference Period	Max. (22 days)	0.09%	1.64%	0.00%	1.81%	0.66%
	Min. (22 days)	0.47%	2.73%	0.00%	4.10%	0.80%
	Max. (90 days)	4.12%	5.60%	0.00%	9.16%	10.64%
	Min. (90 days)	3.33%	5.12%	0.45%	7.04%	5.02%
	Max. (260 days)	22.66%	18.13%	0.00%	17.07%	34.52%
	Min. (260 days)	9.11%	9.59%	1.34%	10.13%	9.47%
	Max. (780 days)	56.61%	21.67%	2.04%	18.13%	54.13%
	Min. (780 days)	12.98%	11.25%	2.23%	10.30%	12.53%

The first row of Table A1 shows the capital requirements without the adjustment term based on different indices according to **different time periods**. It can be seen that the standard capital stress is not constant over time and the deviation can be up to 38.1 percentage points in case for commodities.

The second row of Table A1 considers the **definition of returns**. The calculations done by CEIOPS are based on a rolling window of daily measured annual returns, i.e. $r_d = \frac{I_d}{I_{d-260}} - 1$. We analyze whether different definitions of returns lead to alternative outcomes. We look at a rolling window of monthly measured annual returns ($r_m = \frac{I_m}{I_{m-12}} - 1$) and yearly data ($r_y = \frac{I_y}{I_{y-1}} - 1$). I_d, I_m and I_y denote the current index value at a specific date, month or year.[22] For all indices, fewer data

[22] For the MSCI World Price index as well as the S&P GSCI Commodities TR index data from January 1973 until December 2009 is used. For the LPX 50 Total Return index data from January 2000 until December 2009 is used. Calculations regarding the HFRX Global Hedge Fund Total Return index take the period from

points lead to a reduced standard capital stress. The maximum difference is observed for the LPX 50 index. A one-year rolling window of daily data leads to a standard capital stress of 73.3% and yearly data leads to 63.7%. We suppose this is due to the calculating method used by CEIOPS. Annual returns are calculated based on a one year rolling window of daily index values. In this way all fluctuations are considered, whereas by using only annual data points fluctuations within a certain year are ignored. So, the method used by CEIOPS seems to be appropriate since neglecting fluctuations within a year and within a month would mean underestimating the volatility of equity prices.

The standard formula recognizes a diversification effect between "global" and "other" equities by introducing a constant of 0.75 into the aggregation formula, as shown in Eq. (4). We calculate **tail correlation coefficients** between the MSCI World Price index and all other employed indices as in CEIOPS (2010a). Results are shown in the third row of Table A1. We use not only the 0.5% quantile to determine which returns to consider in our analysis, but also the 1%, 5%, and 10% quantiles. Mathematically, a 99.5% confidence level does not imply that any specific quantile must be used to determine tail correlations and therefore the decision is arbitrary. However, our results show that the impact of the chosen quantile is substantial.

Solvency II considers a 0.5% quantile for the risk factors, which corresponds to the Value at Risk (VaR) at a 99.5% confidence level as a **risk measure**. We are motivated to look further at this issue by other regulatory approaches using different risk measures. For example, the Swiss Solvency Test employs the Expected Shortfall at a 99% confidence level. Also, the fact that companies might use other risk measures for their internal decision making makes the issue worth to consider. We test whether the Expected Shortfall (ES) at a 99.5% confidence level leads to comparable results. We calculate the differences in the standard capital stress for each index by using the ES and VaR measure for the time period from December 1975 until January 2012. The standard capital stress is calculated according to a 5 year rolling period. Our results show that using Expected Shortfall (ES) as a risk measure instead of Value at Risk (VaR) leads to very comparable results (see Fig. A1). The standard capital stress increases about 6.5 percentage points on average and extreme stock price

April 2004 until December 2009 into account. For the MSCI Emerging Markets BRIC Price index the period from June 1995 until December 2009 is considered.

movements are anticipated more quickly. Both could be expected due to the fact that ES considers all tail values and not, like VaR, only the threshold. For all equity classes the correlation over time between VaR and ES are close to 1 over the total period as shown in the fourth row of Table A1.

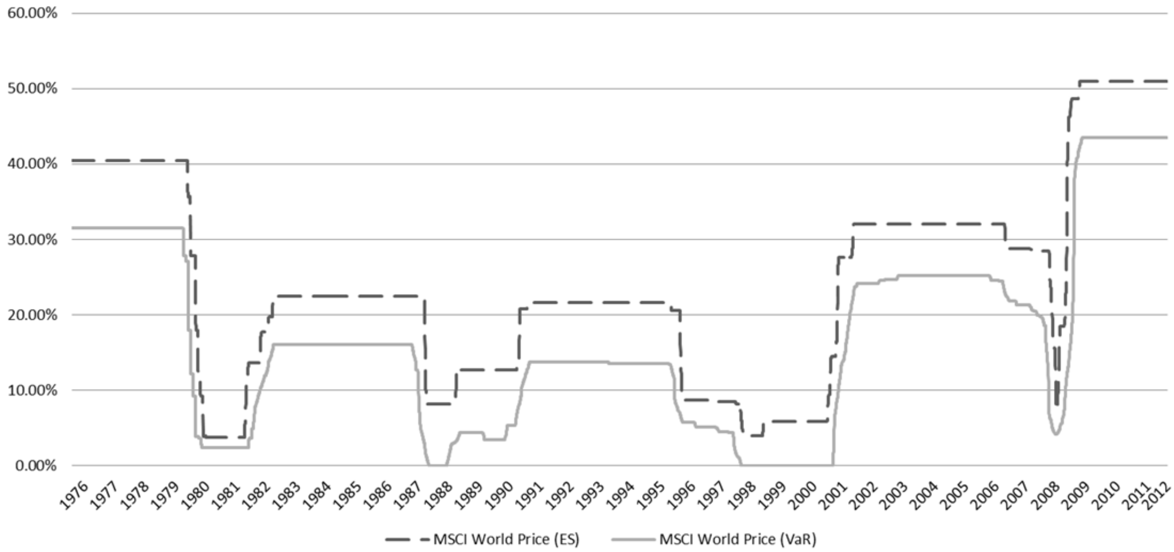

Fig. A1. VaR in comparison to ES for the MSCI World Price index

The last row of Table A1 shows the effect of considering different **reference periods in calculating the symmetric adjustment mechanism**. We compare the most discussed time horizons as mentioned by CEIOPS (2010c). It can be seen that the minimum and maximum of the symmetric adjustment mechanism are more likely to be reached the longer the reference period.

We analyze the impact of the reference period on **β of the adjustment term**, which is derived by a regression of the actual index level on the weighted average index level. Table A2 shows the results. As CEIOPS reports we find betas for the MSCI World indices and the S&P GSCI commodities Total Return indices are for all reference periods close to 1. Therefore we approximate beta in this paper by one.

Table A2
Adjustment term betas.

Reference period	MSCI World Price	MSCI World TR	GSCI TR
1 month (22 days)	1.00	1.00	1.00
4 months (90 days)	1.00	1.00	0.99
1 year (260 days)	0.99	1.01	0.98
3 years (780 days)	0.98	1.02	0.98

We empirically compare the proposed correlations within the **aggregation formula** with actual correlations of the different asset classes. In QIS5, a tail correlation between "global" and "other" equities of 0.75 is considered. CEIOPS (2010a) defines tail correlation as the Pearson-correlation of values below a certain quantile. Thus, the only returns considered are those that are simultaneously below the 0.5% quantile of the indices at hand. Empirically, we find that the correlations range from -1 to 1 depending on the indices and time period being considered. To illustrate the time-varying nature of the correlations, Fig. A2 shows the correlations between the MSCI World Price index and the other four indices used to define the standard capital stress. Returns are calculated annually based on a one-year rolling window with daily data; the correlation coefficients over time are based on the longest time period available on each specific date. In our analysis, only data below the 0.5% quantile are chosen, except for the HFRX Global Hedge Fund TR index, since there are not enough overlapping data points below this quantile. Instead, we chose the 1% quantile. Fig. A2 only shows the results for January 2000 to January 2012 because, previous to this period, returns from the different indices that are below the 0.5% quantile do not occur at the same time. As described by Mittnik (2011) the small number of data points is a general flaw of the CEIOPS method for calculating tail correlations. The horizontal line indicates the assumed correlation of 0.75 between the equity class "global" and "others" in the aggregation formula. Note the extreme variations during 2001 and 2009. In 2001, the tail correlation between the private equity index and the MSCI World Price index reached both its minimum and maximum. The same is true for the commodity and the emerging markets indices. These results clearly illustrate that the assumption of a fixed correlation of 0.75 that is not time-varying is not an optimal solution. Also, the figure illustrates that tail correlations fluctuate especially in times of crisis.

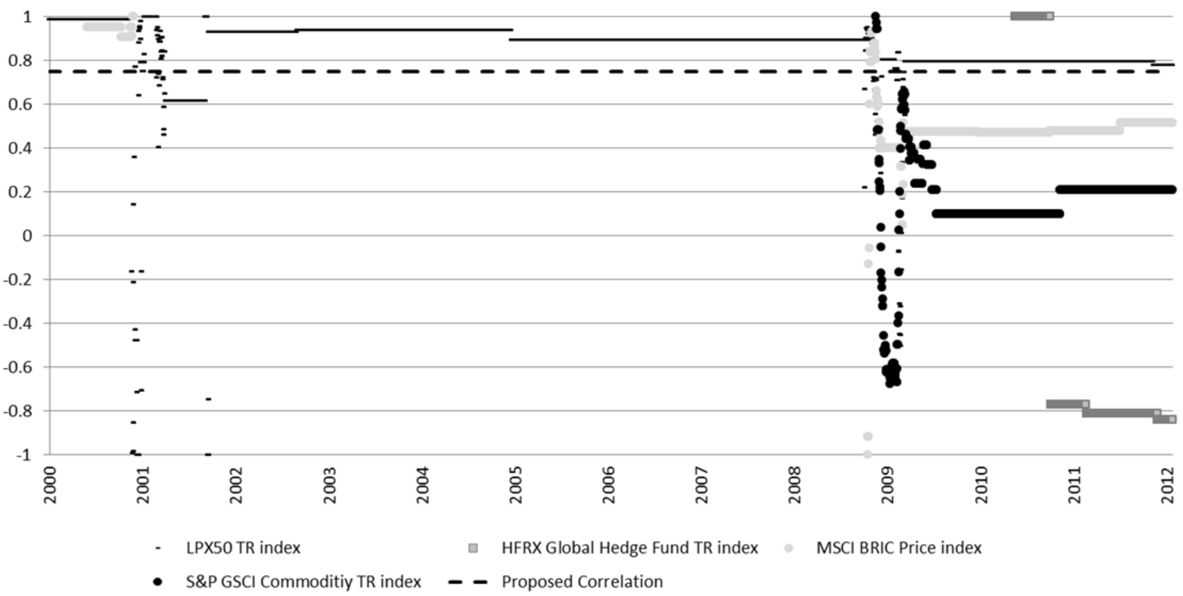

Fig. A2. Tail-correlations over time between MSCI World Price index and indices considered for the equity category “other”.

Appendix B – CoVaR Calculation

In order to project the time-variant CoVaR measure we use quantile regressions and seven state variables as Adrian and Brunnermeier (2011). We employ the following quantile regressions to estimate the joint distribution of X^i_t and X^{system}_t (see Eq. (5) and (6)), whereas X^i_t stands for the returns of the country portfolio i and X^{system}_t for the returns of the whole system. In contrast to Adrian and Brunnermeier (2011) a conversion of asset book-values into asset market-values before calculating the return series is omitted, since in our setting the portfolios are not leveraged and the values of the stylized insurance companies are equal to the values of their constitutive market-valued assets. We estimate the returns of the whole system as in the original paper by taking the arithmetic average over i.

$$X^i{}_t = a^i + \gamma^i M_{t-1} + \varepsilon^i{}_t \qquad (5)$$

$$X^{system}{}_t = a^{system|i} + \beta^{system|i} X^i{}_t + \gamma^{system|i} M_{t-1} + \varepsilon^{system|i}{}_t \qquad (6)$$

a^i and $a^{system|i}$ are the constants in both regressions and $\varepsilon^i{}_t$ and $\varepsilon^{system|i}{}_t$ are the error terms. System|i indicates that the system variable is conditional on i’s return. γ^i and $\gamma^{system|i}$ are vectors and indicate regression coefficients as well as $\beta^{system|i}$. M_{t-1} is a vector of state variables lagged by one week. The estimated coefficients are used to predict the time-variant risk measures as shown in Eq. (7) and (8).

$$VaR^{i}{}_{t}(q) = \hat{\alpha}^{i} + \hat{\gamma}^{i} M_{t-1} \qquad (7)$$

$$CoVaR^{system|i}{}_{t}(q) = \hat{\alpha}^{system|\,i} + \hat{\beta}^{system|i} X^{i}{}_{t} + \hat{\gamma}^{system|i} M_{t-1} \qquad (8)$$

q indicates the quantile which is used in the regressions and to which the VaR and CoVaR are referring to.

In this paper the following state variables are used.

- *Volatility of the stock markets*. Adrian and Brunnermeier (2011) use the VIX index, but we use the VSTOXX index in order to adjust to a European setting. The index is obtained from Datastream.
- *Liquidity spread,* which is defined as the difference between the three month general collateral repo rate and the three month US t-bill rate. For the repo rate we use the Euro Repo Benchmark from Datastream and for the t-bill rate the three month rate of German government bonds from Bloomberg.
- *Tails of market-valued asset returns*, which are explained in the original paper by the change in the three month US t-bill rate. In contrast, we use the change in the three month t-bill rate of German government bonds.
- *Change in the slope of the yield curve.* Originally, the variable is measured by the yield spread between ten year US government bonds and three month US t-bills. We use the change in the yield spread between ten year and three month German government bonds.
- *Change in the credit spread.* We use the change in the difference between the yield to maturity of bonds represented by the Barclays Euro Aggregate 7-10Y Corporate index and the yield to maturity of bonds represented by the Bank of America Merrill Lynch German Government 7-10Y index. Both indices are obtained from Datastream. Adrian and Brunnermeier (2011) use BAA-rated bonds and the US treasury rate.

- *Equity market return.* Adrian and Brunnermeier (2011) use the equity market return from CRSP. We use the MSCI Europe Price index obtained from Datastream in order to approximate the equity market return.
- *Real estate sector return.* Originally, the excess return above the market return of companies with a SIC code of 65 and 66 is used. In contrast, we simply employ the excess return of the MSCI Europe Real Estate Price index over the return of the MSCI Europe Price index.

Appendix C – MES Calculation

According to Acharya et al. (2012) the marginal expected shortfall of a company is defined as follows in Eq. (9).

$$MES^{i}{}_{5\%} = -E\left[\frac{w^{i}{}_{t}}{w^{i}{}_{t-1}} - 1 | I_{5\%}\right] \qquad (9)$$

$MES^{i}{}_{5\%}$ indicates the marginal expected shortfall of company i conditional on the 5% worst trading days of the market. $w^{i}{}_{t}$ stands for the equity value of company i at time t and $I_{5\%}$ denotes the 5% worst market outcomes. The time variant MES in this paper is following the same logic, but considers only the last year and is therefore more sensitive to recent stock market movements. The applied calculation is shown in Eq. (10).

$$MES(t)^{i}{}_{5\%} = \frac{1}{261}\sum_{t-261}^{t}\left[\frac{w^{i}{}_{t}}{w^{i}{}_{t-1}} - 1 | I_{5\%,261}\right] \qquad (10)$$

$MES(t)^{i}{}_{5\%}$ indicates the marginal expected shortfall at time t and $I_{5\%,261}$the 5% worst market returns during the last 261 trading days. As a reference for the equity market we use the MSCI World Price index.

As an alternative (not reported in this paper) we calculate the measure based on daily, annual rolling returns as used in the calculations for the symmetric adjustment mechanism CEIOPS (2010a). In this case $w^{i}{}_{t-1}$ in Eq. (9) and (10) changes to $w^{i}{}_{t-261}$. Our key results are the same for this version. However, due to a loss of intra-year variations the MES is reacting less sensitive and looks more smoothly over time.

Acharya et al. (2012) use leverage in addition to MES to predict expected losses. Since, the country portfolios are not leveraged; we omit the measure for leverage.

Appendix D – VAR and VEC Model

We model the interrelation between capital requirements and the average CoVaR in a simple autoregressive model as specified in Eq. (11). As endogenous variables we use capital requirements and CoVaR. A constant is the only exogenous variable.

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + c + \varepsilon_t \quad (11)$$

y_t is a column vector and denotes the capital requirements and CoVaR at time t. A_1, A_2, A_3 are the coefficient matrices which are to be estimated. c is a column vector and stands for the constants. ε_t is a column vector and stands for the error terms at time t. The lag length of three is estimated by the Hannan-Quinn and Schwarz criterion. Results of the coefficient matrices are shown in Table A3.

Table A3
Estimated coefficients of the vector autoregressive model.

	Capital Requirements	CoVaR
Capital Requirements (-1)	0.921***	0.472***
Capital Requirements (-2)	0.072	-0.43***
Capital Requirements (-3)	-0.02	-0.02
CoVaR (-1)	0.062**	0.368***
CoVaR (-2)	-0.004	0.202***
CoVaR (-2)	-0.019	0.244***

Notes: (-1), (-2) and (-3) indicate a lag of one, two and three weeks of the variables and ***, **, * the 1%, 5%, and 10% significance level of the coefficients, respectively.

We cannot apply a normal VAR model to evaluate the dynamics between capital requirements and MES, since MES is a non-stationary time series. However, the Johansen Cointegration test shows that capital requirements and MES are cointegrated. Therefore, we employ a vector error correction model as specified in Eq. (12). The model is based on the third deterministic trend case as described by Johansen (1995), p. 81.

$$\Delta y_t = \propto \beta'(y_{t-1} - c) + A_1 \Delta y_{t-1} + A_2 \Delta y_{t-2} + A_3 \Delta y_{t-3} + \varepsilon_t \quad (12)$$

$\propto$ is a column vector and $\beta = \begin{bmatrix} 1 \\ -\beta_1 \end{bmatrix}$, whereas β_1 is the coefficient denoting the linear relationship between the capital requirements and MES. c is a column vector of constants. Results of the coefficient matrices A_1, A_2, and A_3 regarding the differences in capital requirements and MES are shown in Table A4.

Table A4
Estimated coefficients of the error correction model regarding capital requirements and MES.

	ΔCapital Requirements	ΔMES
ΔCapital Requirements (-1)	-0.055*	0.002*
ΔCapital Requirements (-2)	0.056*	-0.001
ΔCapital Requirements (-3)	0.068*	-0.003*
ΔMES (-1)	-0.561	0.220***
ΔMES (-2)	-0.377	0.220***
ΔMES (-3)	0.659	0.061*

Notes: Δ stands for the first difference in the regarding time series. (-1), (-2) and (-3) indicate a lag of one, two and three weeks of the variables and ***, **, * the 1%, 5%, and 10% significance level of the coefficients, respectively.

References

Acharya, V.V., Pedersen, L.H., Philippon, T., Richardson, M., 2012. Measuring systemic risk. Working Paper. New York University. Available at: http://www.cepr.org/pubs/new-dps/dplist.asp?dpno=8824.

Adrian, T., Brunnermeier, M.K., 2011. CoVaR. Working Paper. Federal Reserve Bank of New York. Available at: http://www.princeton.edu/~markus/research/papers/CoVaR.pdf.

Albarrán, I., Marín, J.M., Alonso, P., 2011. Why using a general model in Solvency II is not a good idea: an explanation from a bayesian point of view. Working Paper. Universidad Carlos III de Madrid. Available at: http://e-archivo.uc3m.es/bitstream/10016/12703/1/ws113729.pdf.

Braun, A., Schmeiser, H., Siegel, C., 2013. The impact of private equity on a life insurer's capital charges under Solvency II and the Swiss Solvency Test. Journal of Risk and Insurance forthcoming.

Christiansen, M.C., Denuit, M.M., Lazar, D., 2012. The Solvency II square-root formula for systematic biometric risk. Insurance: Mathematics and Economics 50, 257-265.

Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS), 2010a. Solvency II calibration paper, European Commission, Brussels, available at: https://eiopa.europa.eu/fileadmin/tx_dam/files/publications/submissionstotheec/CEIOPS-Calibration-paper-Solvency-II.pdf.

Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS), 2010b. QIS5 technical specifications, European Commission, Brussels, available at: https://eiopa.europa.eu/consultations/qis/insurance/quantitative-impact-study-5/index.html.

Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS), 2010c. CEIOPS´ advice for level 2 implementing measures on Solvency II: article 111 and 304 equity risk sub-module, European Commission, Brussels, available at: https://eiopa.europa.eu/publications/sii-final-l2-advice/index.html.

Cummins, J.D., Weiss, M.A., 2011. Systemic risk and the U.S. insurance sector. Working Paper. Temple University. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1725512.

Eling, M., Gatzert, N., Schmeiser, H., 2009. Minimum standards for investment performance: a new perspective on non-life insurer solvency. Insurance: Mathematics and Economics 45, 113-122.

Eling, M., Schmeiser, H., Schmit, J.T., 2007. The Solvency II process: overview and critical analysis. Risk Management and Insurance Review 10, 69-85.

Eling, M., Schuhmacher, F., 2007. Does the choice of performance measure influence the evaluation of hedge funds? Journal of Banking and Finance 31, 2632-2647.

European Commission, 2011. ***I draft report on the proposal for a directive of the European Parliament and of the Council amending directives 2003/71/EC and 2009/138/EC in respect of the powers of the European Insurance and Occupational Pensions Authority and the European Securities and Markets Authority, 2011/0006(COD), Committee on Economic and Monetary Affairs, Brussels.

European Commission, 2012. Proposal for a directive of the European Parliament and of the Council amending directive 2009/138/EC on the taking-up and pursuit of the business of insurance and reinsurance (Solvency II) as regards the dates of its transportation and application and the date of repeal of certain directives, 2012/01100 (COD), Brussels.

European Parliament, European Council, 2009. On the taking-up and pursuit of the business of insurance and reinsurance (Solvency II) 2009/138/EC. Official Journal of the European Union, 155.

Filipović, D., Vogelpoth, N., 2008. A note on the Swiss Solvency Test risk measure. Insurance: Mathematics and Economics 42, 897-902.

Gatzert, N., Martin, M., 2012. Quantifying credit and market risk under Solvency II: standard approach versus internal model. Insurance: Mathematics and Economics 51, 649-666.

Grace, M.F., 2011. The insurance industry and systemic risk: evidence and discussion. Working Paper. Georgia State University.

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

Harrington, S.E., Miller, A.B., 2011. Insurance regulation and the Dodd-Frank act. Working Paper. University of Pennsylvania. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1783904.

Huerta de Soto, J., 2009. The fatal error of Solvency II. Economic Affairs 29, 74-77.

Johansen, S., 1995. Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford: Clarendon Press.

Keller, P., 2011. Solvency II and incentives for systemic risk exposure, Geneva Association, Geneva, available at: http://www.genevaassociation.org/Home/Results.aspx?mode=free&keyword=Solvency%20II%20and%20incentives%20for%20systemic%20risk%20exposure.

Klein, R.W., 2011. Insurance market regulation: catastrophe risk, competition and systemic risk. Working Paper. Georgia State University.

Klein, R.W., Wang, S., 2009. Catastrophe risk financing in the United States and the European Union: a comparative analysis of alternative regulatory approaches. Journal of Risk an d Insurance 76, 607-637.

Liebwein, P., 2006. Risk models for capital adequacy: applications in the context of Solvency II and beyond. Geneva Papers on Risk and Insurance - Issues and Practice 31, 528-550.

Mittnik, S., 2011. Solvency II calibrations: where curiosity meets spuriosity. Working Paper. University of Munich. Available at: http://www.cequra.uni-muenchen.de/download/cequra_wp_041.pdf.

Pfeifer, D., Strassburger, D., 2008. Solvency II: stability problems with the scr aggregation formula. Scandinavian Actuarial Journal 1, 61-77.

Sandström, A., 2007. Solvency II: calibration for skewness. Scandinavian Actuarial Journal 2, 126-134.

Savelli, N., Clemente, G.P., 2011. Hierarchical structures in the aggregation of premium risk for insurance underwriting. Scandinavian Actuarial Journal 3, 193-213.

Tesar, L.L., Werner, I.M., 1995. Home bias and high turnover. Journal of International Money and Finance 14, 467-492.

Van Laere, E., Baesens, B., 2010. The development of a simple and intuitive rating system under Solvency II. Insurance: Mathematics and Economics 46, 500-510.