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Exploring the market risk profiles of U.S. and European life insurers

Nicolaus Grochola[*], Mark J. Browne[†], Helmut Gründl[‡], Sebastian Schlütter[§]

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Abstract

Market risks account for an integral part of life insurers' risk profiles. This paper explores the market risk sensitivities of insurers in two large life insurance markets, namely the U.S. and Europe. Based on panel regression models and daily market data from 2012 to 2018, we analyze the reaction of insurers' stock returns to changes in interest rates and CDS spreads of sovereign counterparties. We find that the influence of interest rate movements on stock returns is more than 50% larger for U.S. than for European life insurers. Falling interest rates reduce stock returns in particular for less solvent firms, insurers with a high share of life insurance reserves and unit-linked insurers. Moreover, life insurers' sensitivity to interest rate changes is seven times larger than their sensitivity towards CDS spreads. Only European insurers significantly suffer from rising CDS spreads, whereas U.S. insurers are immunized against increasing sovereign default probabilities.

Keywords: Life insurance, interest rate risk, credit risk
JEL Classification: G01, G18, G22

[*] Contacting Author. Goethe University Frankfurt, Faculty of Economics and Business Administration, International Center for Insurance Regulation, House of Finance, Theodor-W.-Adorno-Platz 3, 60629, Frankfurt am Main, Germany; Phone: +49 69 798 33680; E-mail: grochola@finance.uni-frankfurt.de.

[†] St. John's University New York, School of Risk Management in the Tobin College of Business.

[‡] Goethe University Frankfurt, International Center for Insurance Regulation.

[§] Mainz University of Applied Sciences, School of Business.

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1 Introduction

Life insurers have not entirely hedged their balance sheet exposure to market risks, which are thus more threatening to them than biometric risks.[1] Given that U.S. and European life insurers' investment portfolios consist largely of bonds,[2] interest rate risk and counterparty credit risk are specifically relevant types of market risks. Movements in interest rates have a manifold impact on life insurers' performance, which stems from depreciations and appreciations of bond investments, but also from the liability portfolio of the insurer. Two main sources of interest rate exposures leading to balance sheet effects are duration gaps[3] and fixed guaranteed minimum returns[4] embedded in life insurance policies in most countries (cf. Table A1 in the Appendix). Counterparties' credit risk affects the default probabilities of fixed income investments directly. Thus, a substantial change in the creditworthiness of an issuer can influence an insurer's solvency position. The relevance of credit risk has grown with the decline of interest rates in the past years: in order to search for yield, the share of U.S. insurers' bond investments with an A-rating decreased between 2013 and 2020 by 6 percentage points (ppt), leading to the highest asset returns (7.7%) within 10 years in 2020.[5] Similarly, EU insurers have substantially extended their investments in bonds issued by counterparties with a credit rating below A by 19ppt.[6]

The aim of this paper is to estimate market risk sensitivities by their contribution to insurers' stock performance, taking several risk drivers and balance sheet characteristics into account. The scientific literature has studied how interest rates and credit risks affect (life) insurers. However, to our knowledge there is no holistic analysis at the international level that combines these risk types in a joint empirical model. In terms of insurers' sensitivities to interest rates, the majority of papers considers U.S. insurance companies. An early research article analyzing

[1] For example, 81% of European Union (EU) life insurers' prescribed regulatory capital requirement results from market risks (including counterparty default risk) for standard formula users under the European Solvency II regime in 2019 (cf. European Insurance and Occupational Pensions Authority (EIOPA) (2020)).

[2] 69% of U.S. life insurers' and 83.5% of European Economic Area (EEA) insurers' investments are allocated to bonds (cf. National Association of Insurance Commissioners (NAIC) (2021, p. 2) and EIOPA (2017, p. 8)).

[3] As technical provisions typically have a longer duration compared with fixed income securities, liabilities are more sensitive to interest rate changes than assets. As a result, falling rates increase the value of liabilities more strongly than the asset value. The width of the duration mismatch measured in years is called "duration gap".

[4] Policyholders with contractually guaranteed returns must receive benefits at least equaling previously paid premiums plus interest payments specified at the start of the contract. When the corresponding assets of life insurers mature, former investment strategies may not generate sufficient yields to cover previous guarantees.

[5] Between 2013 and 2020, the share of bonds with an A-rating fell from 68% to 61.8%, while the share increased for B-grade bonds from 27% to 32.1%. Asset returns were varying between 1% and 6% (cf. NAIC (2013, 2021)).

[6] Between 2011 to 2016, the share of EU insurers' investments in bonds with a rating between AAA and A- fell from 84% to 65%. Instead, the portion of bond investments with a BBB+ to BBB- rating has increased strongly from 11% to 26% (cf. EIOPA (2017, p. 12)).

interest rate sensitivities of life insurers resulting from a duration mismatch is by Samuelson (1945). At a later stage, Brewer et al. (1993) introduce a two-factor model derived from the finance literature (e.g., Flannery and James (1984)) to estimate interest rate sensitivities of stock listed insurers when controlling for the stock market.[7] Browne et al. (1999) find for the years 1972 to 1994 that increasing long-term interest rates have raised the insolvency risk of U.S. life-health insurers. Similarly, Brewer et al. (2007) and Carson et al. (2008) provide evidence that increasing interest rates reduce life insurers' stock returns (and vice versa) in the time from 1975 to 2001. Moreover, Brewer et al. (2007) demonstrate that equity prices are particularly impacted by interest rates with long maturities and that sensitivities vary over time and insurers. Park and Paul Choi (2011) show that also property and liability insurers', i.e., non-life insurers', stock returns are influenced by interest rate movements during the sample period from 1992-2001. Berends et al. (2013) find that the sensitivities of U.S. life insurers' stock returns to interest rate risks have changed over time: in a period before the 2007-2008 financial crisis, insurers were not significantly sensitive to interest rate changes, but in the low-yield environment after the crisis, they suffered from decreasing rates. In line with this empirical finding, Berdin and Gründl (2015) develop a multi-period simulation model with stochastic interest rate movements that indicates a substantial increase in a stylized life insurer's default probability when rates stay low in the long term. Kablau and Weiß (2014) make similar findings by performing a sensitivity analysis with prudential data.

Further articles focus on detecting the sources of interest rate risk. Siglienti (2000) analyzes the influence of policy changes on insurers' equity returns. Notably, a long time before the low interest rate environment prevailed, the paper has demonstrated that life insurers need to lower guaranteed minimum rates and avoid risky investments in order to generate sufficient returns. Similarly, Holsboer (2000) correctly predicts a switch to more unit-linked products,[8] where the investment risk is borne by policyholders, and emphasizes a higher awareness for market risks. The author also argues that the life insurance sector has been exposed to interest rate movements since its origins, while they affect the non-life insurance industry to a lower degree. In an empirical top-down approach, Hartley et al. (2017) compare stock-listed insurers of the U.S., the UK and some continental European countries in terms of their sensitivities to interest rates

[7] Controlling for stock markets is necessary, because insurers' equity prices are strongly correlated with economic growth (cf. Kessler et al. (2017)). Thus, as most firms, insurers have significantly lower stock returns in a recession. Potential reasons for this relationship are insurers' investment returns, their interconnectedness with other industries as well as higher claims and shortfalls in premium payments in times of economic downturns.

[8] In 1997, 10.6% of premiums stemmed from unit-linked products (cf. Holsboer (2000)) compared to 25% in 2017 (cf. Insurance Europe (2019)). Unit-linked insurance products typically do not include minimum return guarantees. Thus, in terms of their balance sheets, unit-linked insurers should be less sensitive to interest rate movements.

in the low yield environment. For the UK, where life insurance contracts typically do not include guaranteed returns, the authors find that insurers' stock returns are not significantly connected to interest rate movements. In contrast, they find a negative relationship for U.S. insurers and for firms with large exposures to the German life insurance market, where fixed minimum returns are common. In line with these findings, Koijen and Yogo (2021) show that U.S. insurers offering variable annuities suffer from the implied guaranteed returns for policyholders. Such guarantees are also implemented in participating (or "traditional") products that account for 75% of life insurance premiums in Europe (cf. Insurance Europe (2019)).[9] The guaranteed returns in Europe are however typically backed by capital reserves and allow for a smoothing of returns over different generations of policyholders rather than cross-sectional risk sharing as in the U.S. (cf. Hombert and Lyonnet (2017)). In a further empirical paper, Möhlmann (2017) reveals that insurers' vulnerability to interest rate movements is negatively related to the firms' size, growth rates and solvency. Liu et al. (2020) show that U.S. life insurers with large exposures to interest rate risk tend to use interest rate derivatives disproportionately. They infer that the derivatives are used as alternative instruments for duration matching, because of the high costs related to restructuring balance sheets.[10]

Regarding the channels of interest rate risk, Czaja et al. (2009) provide evidence that beyond actual changes in interest rates, German insurers' equity returns are influenced by the level and the curvature of the yield curve. Akhtaruzzaman and Shamsuddin (2017) make similar findings regarding the term structure of interest rates for Australian insurers. More recently, Killins and Chen (2020) demonstrate a negative effect of a rising yield curve slope on insurers. The authors further detect asymmetric sensitivities across countries and time as well as higher interest rate risk for life insurers compared with other insurer types. Using a German sample, Möhlmann (2021) finds an aggregate modified duration gap of six years between the asset and the liability side of insurers' balance sheets.[11] He argues that life insurers do not aim for adequate duration matching, because they prefer illiquid long-term investment strategies.[12] Similarly, Koijen and Yogo (2021) argue that insurers deliberately choose to have a duration gap, even though they could select adequate hedging strategies. Kubitza et al. (2021) show that the choice of the

[9] 80% of European life insurance policies include guaranteed surrender values, which policyholder receive in case of an early withdrawal (cf. EIOPA (2019a)).

[10] Table A2 in the Appendix summarizes the methodology and the findings of related research articles empirically analyzing the interest rate risk of insurance companies.

[11] Thus, on average a decrease in interest rates by 1ppt results in a rise in the market value of liabilities that is 6ppt higher compared with the corresponding increase in the market value of assets.

[12] This argument goes back Chodorow-Reich et al. (2021) and the concept of so called "asset insulation". According to this theory, life insurers aim to dampen valuation effects resulting from short-term fluctuation in asset prices by holding risky assets until maturity.

duration mismatch can partly be explained by surrender options for policyholders. Nevertheless, Hartley et al. (2017) underline that even if the durations are matched, life insurers can suffer from falling interest rates due to an inconsistent convexity of assets and liabilities. Thus, interest rate movements would require a dynamic adaption of the asset portfolio to quickly adjust the durations. This convexity mismatch provides a potential explanation for the existence of interest rate risk in countries with low duration gaps such as the U.S. In line with this theory, Ozdagli and Wang (2019) find that U.S. insurers do not perfectly match their duration of assets and liabilities in every single period. In addition, Hartley et al. (2017) show that the sensitivity of U.S. life insurers to interest rate movements increases after a decline in interest rates. Lin et al. (2021) demonstrate empirically for a Japanese sample that the sensitivity of insurers' asset returns to interest rates movements is six times larger in a negative interest environment compared with a positive yield environment.

In terms of credit risk, most research articles have examined its relevance on banks and non-financial firms. For instance, Acharya et al. (2014) emphasize the existence of a loop between sovereign credit risk, the health of the financial sector and bank bailouts. Instead, there is only scarce literature analyzing the influence of credit risk on insurers as part of the financial services sector. Bégin et al. (2019) show for a sample of banks and insurers from 2005 to 2012 that the credit risk of both types of financial institutions is significantly affected by crisis periods. In times of increasing default probabilities, the authors observe a transmission effect of banks on insurers in line with Billio et al. (2012) and Chen et al. (2013). In addition, Billio et al. (2014) demonstrate that sovereign credit risk has a direct impact on insurance companies' losses, even before the European sovereign debt crisis of 2010 to 2012. Focusing on participating life insurance, Eckert et al. (2016) demonstrate with a simulation model that the value and risk situation of insurers is substantially influenced by the credit risk related to their bond investments. The authors also detect interaction effects between credit risk and other market risks, thereby underlining the relevance of considering credit risk exposures for adequate risk management. In an empirical approach, Düll et al. (2017) find that European insurance companies suffer from deteriorations in the creditworthiness of sovereign debt, which is measured by credit default swap (CDS) spreads of government bonds. Specifically, an increase in sovereign credit risk negatively affects insurers' financial strength in terms of their stock returns and firm-specific CDS spreads. Those results are alarming given that the Solvency II standard formula disregards credit risk for sovereign counterparties within the EEA[13] and thus

[13] Cf. Art. 180 (2) of European Commission (2015)

encourages riskier sovereign debt investments (cf. Wilson (2013)). Similarly, Becker and Ivashina (2015) as well as Becker et al. (2020) detect that the regulatory framework in the U.S. incentivizes insurance companies to take as much risk as possible conditional on the capital requirement. However, Ozdagli and Wang (2019) do not observe an increase in the credit risk of U.S. life insurers relating to an incentive to reach for higher yields.

Particularly in two respects, the existing literature leaves open questions. First, the empirical literature only takes an isolated view on the influence of interest rates or CDS spreads on the performance or the solvency situation of insurance companies. By only considering the stock market index as a control variable and leaving out other potential influences, the results can be affected by an omitted variable bias, meaning that the influence of the particular risk driver can be underestimated or overestimated. To overcome this issue and to answer the question on the influence of market risks on life insurers' return comprehensively, we empirically investigate the impact of various market risk drivers on U.S. and European insurers' stock returns for the period between 2012 and 2018, i.e., a time frame covering the low interest rate environment. Specifically, in the empirical models we include relative changes in 10-year and 1-year interest rates, national stock market indices and national stock market volatility. To measure insurers' sensitivities to sovereign counterparty credit risk[14], we design country-specific weighted government bond portfolios based on regulatory data from the NAIC and EIOPA and include the corresponding relative changes in CDS spreads in the empirical model. Notably, the correlations between the changes in interest rates and CDS spreads are low, which justifies the chosen empirical approach by lowering concerns about multicollinearity.

Second, although market risks constitute an integral part of the risk profiles of life insurance companies globally, so far there has not been a comparison which specific market risk (either interest rate or credit risk) is more influential for U.S. and European insurers. Most of the existing literature has measured market risk sensitivities of either U.S. or European insurance companies.[15] To our knowledge, only Hartley et al. (2017) compare the interest rate risk of U.S. and U.K. life insurers. We use their findings as a motivation to analyze the heterogeneity in interest rate sensitivities between U.S. and European insurers in more depth and to extend the research question by investigating the relevance of credit risk on both continents. In addition, we examine factors that can be responsible for differences in market risk sensitivities such as the share of life and unit-linked insurance business and solvency ratios.

[14] In the following, we will use the term credit risk to refer to sovereign counterparty credit risk.

[15] For instance, Brewer et al. (2007) and Berends et al. (2013) estimate interest rate sensitivities of U.S. life insurance companies, while Düll et al. (2017) analyze the exposure to credit risk for a European sample.

We study life insurers' sensitivities to market risk factors in a low interest rate environment based on stock market reactions. For this top-down approach, we choose a multivariate panel regression model in line with the related literature investigating interest rate risk (e.g., Hartley et al. (2017)). However, apart from considering credit risk we introduce several further adjustments compared with previous empirical papers. First, we use insurer fixed effects and cluster standard errors on the time level to strengthen the robustness of our results. Second, we introduce further macroeconomic market risk drivers such as short-term interest rate movements and the levels of long-term interest rates and CDS spreads in addition to daily returns. Third, we control for the insurer-specific variables size, leverage and the market-to-book-ratio. Fourth, we choose the cross-sectional previous year's median as a threshold for defining a life insurer, a unit-linked insurer or a solvent firm. Fifth, we include a wide range of alternative specifications (e.g., continuous insurer-specific variables only, weekly data, controls for autocorrelation, adjustments of binary thresholds) for robustness checks. In our approach, we combine the findings from several research papers including Brewer et al. (2007), Czaja et al. (2009), Hartley et al. (2017), Düll et al. (2017) and Killins and Chen (2020).

The empirical results illustrate that the sensitivities of stock returns towards long-term interest rate changes are seven times larger than the sensitivities to CDS spread changes. In line with the existing literature, we find that insurers significantly suffer from decreasing interest rates in the U.S. and Europe. The effect of interest rate movements on stock returns is however more than 50% larger for U.S. life insurers compared with European life insurers. In addition, we explore reasons for differences in risk exposures. We observe that firms focusing on life insurance business, offering unit-linked products and having a weak solvency level ceteris paribus react significantly more sensitively to fluctuations in interest rates. In terms of credit risk, European firms on average significantly suffer from increases in CDS spreads of government bonds. Again, this effect is particularly large for unit-linked and less solvent insurers. In contrast to European firms, U.S. insurers' stock returns do not significantly react to movements in sovereign CDS spreads as their share of government bonds is lower.

The findings are of importance for shareholders and managers of stock insurance companies. They benefit from our results as they get a profound basis for deciding how to structure their risk management activities efficiently, i.e., by taking interdependencies between market risk categories (in the sense of natural hedges) and differences in sensitivities across insurer types and countries into account. The results are also of importance for insurance regulation and supervision acting in the interest of policyholders. From a regulatory perspective, it matters whether the regulated entities across countries have relatively similar risk profiles or react differently to market movements. There are different approaches for protecting policyholders' interests by controlling life insurers' solvency levels or by reducing policyholders' losses through an insolvency. For refining insurance capital standards on both national and international levels, it is an indispensable prerequisite to gain empirical evidence about the impact of different market risks and their interplay on insurers' risk situation.

The remainder of the article is organized as follows. Section 2 discusses econometric issues and provides the empirical methodology. In this chapter, the hypotheses are outlined and all variables used to tackle the research question are presented. Section 3 provides the empirical results and robustness checks. Section 4 concludes.

2 Empirical methodology

2.1 Econometric issues

For the empirical analysis of the market risk sensitivities, we collect daily data on stock prices and market risk drivers for the time frame between 1 January 2012 and 30 June 2018. The sample period is characterized by historically low interest rates in the aftermath of the global financial crisis. The previous literature suggests that insurers' interest rate sensitivities are relatively homogenous within this market phase, but exhibited different patterns in earlier periods within or before the crisis (e.g., Brewer et al. (2007) and Hartley et al. (2017)). The chosen period comprises 1,658 trading days[16] for which returns can be observed. In line with Düll et al. (2017), we use daily data, which to our knowledge has only been done by Carson et al. (2008) in the empirical literature analyzing interest rate risk, however for a portfolio of firms rather than on an insurer level and for a different sample period (1991 – 2001).[17] The more granular approach of using daily data accounts for a higher frequency of risk transmissions and thus, allows for a smaller share of noises due to individual shocks and hence more accurate estimates.[18] A potential econometric concern when using daily data are correlated shocks. To tackle this issue, we use heteroskedasticity-robust standard errors clustered on the day level analogously to Düll et al. (2017). In addition, we use weekly data to check the robustness of the results in Section 3.2. Some previous articles focus on a portfolio of firms, mainly due to the lack of statistical significance for individual firms and idiosyncratic noise (e.g., Berends et al.

[16] We consider all weekdays, except for New Year's Day, Good Friday and December 25th, because then, stock markets are closed in all countries that we observe. The actual amount of trading days for a firm depends on the national holidays in its home country. For U.S. firms, the time span covers a total amount of 1,623 trading days.

[17] Brewer et al. (2007) and Killins and Chen (2020) use monthly data, while Berends et al. (2013) and Hartley et al. (2017) use weekly data.

[18] For instance, if a company-specific information drastically influences its stock price on one day, this results in a single high error term which is less disturbing when a higher data frequency is given.

(2013)). To ensure that the sensitivities measured in the panel regressions are not driven by individual insurers, we include firm fixed effects.

The methodology of using stock returns as a measure for market risk sensitivities in a top-down approach, in line with Berends et al. (2013) and Hartley et al. (2017), is associated with advantages and disadvantages. On the one hand, using stock returns allows for a high power of empirical testing. Stock market participants are assumed to be aware of insurers' product portfolios and their balance sheet characteristics. When considering investment decisions, relevant information reported in annual and analysts' reports or other publications such as Solvency and Financial Condition Reports (SFCRs) can be observed and should thus be priced into the equity value in line with the efficient market hypothesis. These sources of information include firm-specific data on risk management, the use of guaranteed products, the expected profitability and the financial health of insurers. Thus, we assume that stock price movements adequately reflect insurers' market risk exposures. On the other hand, there are some drawbacks. First, mutual insurance companies are not included in the sample because they are not listed on stock markets (cf. Berends et al. (2013)). Mutual insurers' market risk sensitivities could be estimated through a bottom-up approach, which is however impractical due to the lack of regular product and performance data.[19] Thus, it should be borne in mind that our findings only express market risk sensitivities of stock-listed insurers. Second, some firms may also engage in non-insurance business (cf. Berends et al. (2013)). To avoid misinterpreting sensitivities that are actually linked to other business areas, we include listed subsidiaries when their parent company's main income is not generated from insurance business.[20] In addition, we exclude subsidiaries when both parent and subsidiary company mainly engage in insurance business in order to avoid impairing the external validity of the results.[21]

2.2 Dependent variable

For the sample, we consider all publicly listed U.S. and European insurers for which daily stock data can be gathered from Thomson Reuters Eikon. Eight firms with less than 300 stock price observations in the sample period are excluded as they are subject to low data frequencies. The resulting sample consists of 98 U.S. and 69 European joint-stock insurance companies.[22]

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[19] Bottom-up approaches investigating the interest rate risk of insurers have been applied by Möhlmann (2021) and Kablau and Weiß (2014) by the use of regulatory data from the German Bundesbank.
[20] For instance, instead of the investment bank Natixis S.A. from France and the financial service company Unipol Gruppo S.p.A. from Italy, we include their respective subsidiaries Coface S.A. and UnipolSai S.p.A.
[21] For instance, the German insurer Hannover Rück SE (parent company: Talanx AG) and the French insurer Euler Hermes S.A. (parent company: Allianz SE) are excluded from the sample.
[22] The sample contains nine out of ten firms that have ever been marked as global systemically important insurers (G-SIIs) by the Financial Stability Board. The only G-SII that is not included is Ping An Insurance from China.

For the dependent variable in the regression models, we rely on the total return index (TRI). The TRI is set to 100 at the day of a firm's initial public offering. Notably, it accounts for stock price changes due to dividend payments and fluctuations in the number of a firm's outstanding shares. Thus, the TRI combines all relevant information to display a company's historical stock market performance in a single figure. We use the relative daily changes $r(TRI_{i,t})$ as a measure for the stock return. It is given for each firm i on each day t, where $t_{previous}$ is the last day for which stock data is available for a particular firm:

$$r(TRI_{i,t}) = \frac{TRI_{i,t}}{TRI_{i,t_{previous}}} - 1 \quad (1)$$

If $TRI_{i,t}$ is not available, e.g., due to a public holiday on day t in the country where firm i is listed, then $r(TRI_{i,t})$ is set to unavailable. In addition, we remove observations of $r(TRI_{i,t})$ if the stock price is unchanged for at least three consecutive days as this signals a lack in data availability. Lastly, we winsorize the stock return for the empirical analysis.[23]

Table A3 and Table A4 in the Appendix present the results of the descriptive analysis of daily stock returns $r(TRI_{i,t})$ of the 167 listed insurance companies in the final sample. In sum, U.S. insurers hold \$4 trillion of assets, in contrast to \$7.8 trillion of assets held by European firms according to SNL data. This corresponds to 48% of U.S. insurance companies' assets and two-thirds of all assets of insurers in the EEA.[24] The descriptive statistics in Table 1 show that on average an insurers' TRI increased by 0.09ppt per day with a high standard deviation of 2.45ppt.

2.3 Independent variables

In the empirical models, we use interest rates with 10-year-maturities as a measure for long-term interest rates. For U.S. insurers, we use the 10-year Treasury Constant Maturity Rate, which is gathered from the Federal Reserve Bank of St. Louis. For European firms, we use European Central Bank (ECB) estimates of the Euro yield curve based on sovereign debt from Eurozone countries with an AAA-rating.[25] To control for the term structure of interest rates, we also collect data on short-term rates with a maturity of 1 year from the respective sources. This

[23] The method of winsorizing is chosen for handling extreme outliers. The 0.5% of highest stock returns is downgraded to the 99.5% quantile. Analogously, the lowest 0.5% of returns is upgraded to the 0.5% quantile. The robustness checks in Section 3.2 demonstrate that the results still hold, if winsorizing is omitted.
[24] Altogether, U.S. insurers held \$9 trillion assets in 2016 according to statistical compilations published by the NAIC for life, health and property/casualty insurers. EEA insurers held 10.5 trillion € of assets in 2016 (cf. EIOPA (2016, p. 14.)). The calculation is based on an average Dollar-to-Euro currency rate of 0.904 in 2016.
[25] As rating deteriorations result in a different composition of government bonds, the Euro yield curve continuously represents safe long-term investment opportunities which are preferred by regulators (see e.g., own funds tiers in Solvency II). The term structure is calculated by applying the Svensson model.

allows us to analyze, for instance, how stock returns change after a decrease in long-term interest rates while keeping short-term rates constant. Thereby, the coefficients for the interest rate variables take into account changes in the slope of the yield curve, which has a negative relationship with stock returns of insurers according to Killins and Chen (2020). Considering short-term rates is also relevant due to the heterogeneity in the duration of insurers' assets.

	N	Mean	Median	SD	Min	Max
Insurer characteristics (insurer-day level)						
$r(TRI_{i,t})$ (stock return in ppt)	240,706	0.09	0.04	2.45	-75.00	200.00
Insurer characteristics (insurer-year level)						
Life $Share_{i,y-1}$	736	0.30	0.29	0.30	0.00	0.84
Unit-linked $Share_{i,y-1}$	736	0.10	0.00	0.19	0.00	0.54
RBC $Ratio_{i,y}$ (U.S.)	181	5.79	4.78	4.55	2.81	12.64
Solvency $Ratio_{i,y}$ (Europe)	118	2.09	2.01	0.50	1.46	3.03
$Life_{i,y-1}$ (binary)	736	0.29	0.00	0.46	0.00	1.00
$Unit_{i,y-1}$ (binary)	736	0.21	0.00	0.41	0.00	1.00
$Solvency_{i,y}$ (binary)	197	0.53	1.00	0.50	0.00	1.00
$\ln(Size_{i,y-1})$	736	16.20	16.13	2.37	12.05	20.17
$Leverage_{i,y-1}$ (ratio)	736	0.51	0.29	1.00	0.00	1.70
$Market\text{-}to\text{-}Book_{i,y-1}$ (ratio)	736	1.53	1.09	1.89	0.49	3.58
Macroeconomic characteristics (country-day level)						
r(Stock $index_{o,t}$) (return in ppt)	29,943	0.04	0.06	1.28	-1.87	1.88
r(Volatility $index_{o,t}$) (return in ppt)	11,451	0.26	-0.09	8.84	-8.84	10.83
$r(CDS_{o,t})$ (return in ppt)	31,566	-0.08	-0.05	3.15	-3.66	3.60
$CDS_{o,t}$ (level in ppt)	31,566	1.44	0.52	5.36	0.15	3.37
Macroeconomic characteristics (day level)						
$r(y10_t^{U.S.})$ (holding period return in ppt)	1,623	-0.00	0.00	0.43	-0.70	0.68
$r(y10_t^{Europe})$ (holding period return in ppt)	1,658	0.02	0.03	0.36	-0.60	0.54
$y10_t^{U.S.}$ (level in ppt)	1,623	2.22	2.23	0.40	1.59	2.88
$y10_t^{Europe}$ (level in ppt)	1,658	1.09	0.77	0.80	0.02	2.50
$r(y1_t^{U.S.})$ (holding period return in ppt)	1,623	-0.01	0.00	0.16	-0.30	0.20
$r(y1_t^{Europe})$ (holding period return in ppt)	1,658	0.01	0.01	0.13	-0.19	0.20

Note: The stock return, which is based on the total return index (TRI), is at insurer-day level retrieved from Thomson Reuters Eikon. Further firm characteristics are at insurer-year level and retrieved from SNL, apart from the RBC ratio (Bloomberg), and the solvency ratio (hand collected from SFCRs). Macroeconomic characteristics are partly at country-day level, retrieved from Thomson Reuters Eikon (stock and volatility indices), the Markit database in WRDS (CDS spreads) and the regulatory institutions NAIC & EIOPA (distribution of government bond investments) and partly at day level, retrieved from the FRED (interest rates in U.S.) and the ECB (interest rates in Europe). The sample starts in 2012 and ends in mid-2018; it includes 98 U.S. and 69 European insurers.

Table 1: Descriptive statistics for insurer-level data and macroeconomic characteristics

The central variable for relative interest rate changes is the holding period return (HPR) within one trading day, which is in line with Brewer et al. (2007). For long-term rates, the HPR equals the return that is achieved by buying a zero-coupon bond with the interest rate yield $y10_{t_{previous}}$ and then selling it on the next day. Assuming that the bond price is unchanged, the HPR is only positive after a decline in interest rates, i.e., when the insurer sells a bond guaranteeing higher yields than the market is currently offering.

$$r(y10_t) = \left(\frac{1 + y10_{t_{previous}}}{1 + y10_t}\right)^{10} - 1 \quad (2)$$

In addition to the HPR, we control for the level of 10-year interest rates given that stock returns may be influenced by the level of the term structure (cf. Czaja et al. (2009); Akhtaruzzaman and Shamsuddin (2017)). We only find a small positive correlation coefficient for the interest rate levels in the U.S. and Europe (0.10), however a larger one for the holding period returns (0.53) reflecting daily changes in the sample period. The descriptive statistics in Table 1 show that interest rates in the U.S. were on average larger (2.22% on average compared with 1.09% in Europe) and rising during the sample period, while they were falling in the Eurozone (a negative mean of $r(y10_t)$ implies rising interest rates).[26]

As a second market risk driver of interest, we consider default probabilities of sovereign debt. In line with Düll et al. (2017), we choose CDS spreads of government bonds denominated in USD with a 5-year maturity for detecting credit risk sensitivities. The choice of this variable is motivated by the large share of particularly European insurers' investments in sovereign debt, with governments as corresponding credit counterparties.[27] CDS spreads adequately reflect default probabilities of the bond issuer as they are tied to its credit quality. Thus, CDS spreads are also considered in empirical studies focusing on the systemic risk of insurers (e.g., Chen et al. (2014) and Bégin et al. (2019)) and are popular in banking research (e.g., Acharya et al. (2014)). The CDS spreads are obtained from the Markit database in WRDS and correspond to the probability of a country's default within 5 years after the issue date. Here, a default implies that a government does not fulfill its payment obligations.

To reflect a realistic government bond exposure, we design a weighted portfolio of sovereign debt for each country where insurers in the sample are headquartered. For this aim, we collect data from the EIOPA and the NAIC, who both report on the distribution of insurers' government bond investments per country of issuance on a home country level. We restrict the given shares to countries where CDS data is available and scale the sum of all shares per home country to one. The resulting shares illustrated in Table 2 reflect the government bond exposures which we assume for insurers in the empirical analysis for the second quarter (Q2) of 2018, i.e., the last 3 months of the sample period. For instance, according to our calculations, in these months German insurers (rows) invest 11% of their government bond exposure in

[26] To some extent, these differing interest rate movements in the U.S. and Europe can be explained by the timing and scope of central bank action. Pelizzon and Sottocornola (2018) argue that, apart from a positive effect on stock markets, quantitative easing campaigns result in lower yields of long-term fixed income securities. While the Federal Reserve Bank intensified its investments during the financial crisis ($4.5tn until 2014), the ECB has only started its quantitative easing program in 2015. Papadamou and Siriopoulos (2014) argue that central banks' monetary policy influences insurers' exposure to interest rates.

[27] 50% of EEA life insurers' bond investments are allocated to government bonds in Q4 2020. Across all insurers, 2.63bn € (≈ $3 bn) were invested in government bonds (cf. EIOPA Insurance Statistics). U.S. insurers invest $0.86bn in government bonds in 2020 (cf. NAIC (2021)).

French sovereign debt, 51% in German sovereign debt (columns) etc. In line with the findings of Düll et al. (2017), a home bias can be clearly observed for most countries (see the grey cells in Table 2). For instance, U.S. insurers invest by far the largest share (96%) of their sovereign bond assets into U.S. government debt. We consider a changing composition of portfolios over time, based on the availability of data on country-specific government bond exposures.[28]

	Austr.	Belg.	Denm	Finla.	Franc.	Germ.	Greec	Hung.	Irela.	Italy	Neth.	Norw.	Polan.	Slove.	Spain	UK	U.S.
Austria	34%	11%	0%	3%	12%	10%	0%	0%	5%	4%	4%	0%	6%	4%	6%	0%	0%
Belgium	5%	61%	0%	1%	13%	5%	0%	0%	2%	5%	1%	0%	1%	0%	5%	0%	0%
Denmark	0%	1%	42%	1%	5%	29%	0%	0%	1%	3%	2%	0%	0%	0%	6%	0%	10%
Finland	3%	2%	0%	30%	10%	35%	0%	0%	1%	0%	13%	0%	0%	0%	2%	1%	2%
France	3%	5%	0%	0%	72%	2%	0%	0%	1%	7%	1%	0%	0%	0%	6%	0%	0%
Germany	6%	8%	0%	1%	11%	51%	0%	0%	2%	3%	2%	0%	2%	1%	6%	2%	4%
Greece	1%	3%	0%	0%	11%	8%	56%	0%	2%	7%	2%	0%	1%	0%	6%	0%	1%
Hungary	0%	0%	0%	0%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ireland	4%	4%	0%	2%	19%	18%	0%	0%	8%	11%	4%	0%	1%	0%	6%	12%	11%
Italy	0%	1%	0%	0%	3%	1%	0%	0%	1%	87%	0%	0%	0%	0%	6%	0%	0%
Netherlands	9%	8%	0%	3%	14%	28%	0%	0%	2%	2%	30%	0%	0%	0%	3%	0%	1%
Norway	3%	4%	4%	4%	15%	8%	0%	0%	0%	0%	2%	49%	0%	0%	1%	2%	7%
Poland	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	99%	0%	0%	0%	0%
Slovenia	4%	3%	0%	1%	5%	13%	1%	2%	1%	7%	4%	0%	5%	46%	6%	0%	2%
Spain	0%	1%	0%	0%	1%	1%	0%	0%	0%	8%	0%	0%	0%	0%	88%	0%	0%
UK	0%	1%	0%	0%	2%	4%	0%	0%	0%	1%	1%	0%	0%	0%	0%	80%	10%
U.S.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	96%

Note: The table shows the allocation of government bond exposures of insurers in their home countries (rows) to countries of issuance (columns) for the second quarter of 2018. For instance, 11% of Austrian insurers' sovereign debt investments are allocated to Belgian government bonds, while 5% of Belgian insurers' exposure is invested in Austrian government bonds. The following asset classes are categorized as government bonds in line with the EIOPA Insurance Statistics: Central government bonds, supra-national bonds, regional government bonds, local authorities bonds, treasury bonds, covered bonds, national central bank bonds and other. For US insurers' exposure, the illustrated data stems from NAIC (2017).

Table 2: Distribution of government bond exposures per insurers' home country

We collect sovereign CDS data for all countries c listed as country of issuance in the columns of Table 2. Each insurer is assigned to CDS quotes based on the weighted portfolio of its (home) country of origin o in the given time frame p.[29] Thus, we use country-specific data as a measure for sovereign default probabilities. For each day t, we calculate the relative daily change in the government bonds' CDS spread of each country c and the resulting daily yield of the portfolio based on the weights w for each home country o where insurers in the sample are headquartered.

[28] The first available exposure data for European insurers stems from Q4 2013 (cf. EIOPA (2014)). We consider the reported weighting of government bond portfolios for the time period from mid-2012 to mid-2015, until an updated portfolio of country-specific exposures can be created based on data from Q4 2015 (cf. EIOPA (2016)). For the periods from 2017 Q4 to 2018 Q2. we use data from the EIOPA Insurance Statistics. Thus, for EU countries, we are able to gain information on the aggregate sovereign bond exposures per country of issuance for five points in time during our sample period. For U.S. insurers, we find regulatory data for the years 2014 (cf. NAIC (2015)) and 2016 (cf. NAIC (2017)), which we assume to stay constant in the years before and after.

[29] Additionally, we collect CDS spreads for government bonds from Iceland and Switzerland. We assume insurers from these two countries to invest all of their sovereign debt exposure in domestic government bonds due to the lack of data on the allocation of insurers' assets on a country level.

We then use the daily weighted portfolio return as an independent variable in the empirical models. It is denoted as $r(CDS_{o,t})$ and calculated accordingly:

$$r(CDS_{o,t}) = \frac{\sum CDS_{c,t} \cdot w_{c,o,p}}{\sum CDS_{c,t_{previous}} \cdot w_{c,o,p}} - 1 \quad (3)$$

Table A5 in the Appendix illustrates descriptive statistics for the independent variables measuring sovereign default probabilities $r(CDS_{o,t})$. The statistics are presented for each country of origin o of the insurers in the sample. After a peak during the European sovereign debt crisis in early 2012, CDS spreads were mostly falling ever since. Only in the U.S., credit spreads were on average rising during the sample period (by 0.15ppt per day), however they remained on a considerably low level.[30] Considering the entire sample, CDS spreads were on average falling by 8ppt per day with a mean level of 1.44% (cf. Table 1).

In order to control for overall economic conditions, we gather daily data from the Thomson Reuters Eikon database on national index and volatility index prices. For U.S. insurers, we choose daily returns of the S&P 500 index and of the S&P 500 Volatility index (VIX) to measure stock market movements. For those European countries for which we are not able to identify or gather data for a national (volatility) index, we use the well-established barometer stock Euro Stoxx 50 (Volatility) instead.[31] A macroeconomic shock affecting all firms simultaneously is typically reflected by stock market indices. Related literature investigating the influence of interest rates on stock prices (e.g., Brewer et al. (2007), Berends et al. (2013), Hartley et al. (2017)) also considers market returns in empirical models.[32] Instead, volatility indices reflect future expected stock price fluctuations. The implied volatilities are also included in the empirical models tested by Düll et al. (2017), because a larger frequency in market movements can influence stock returns. We use the relative daily changes of the indices as control variables in the empirical models:

$$r(Stock\ index_{o,t}) = \frac{Stock\ index_{o,t}}{Stock\ index_{o,t_{previous}}} - 1 \quad (4)$$

[30] In the entire sample period, the largest level of CDS spreads of U.S. government bonds is 1%. This is the lowest maximum value behind sovereign debt from Norway (0.6%) and Germany (0.9%).
[31] The relevance of the Euro Stoxx 50 index as an indicator of market developments in Europe is underlined by Brechmann and Czado (2013). We use the Euro Stoxx 50 index as a benchmark for insurers from Poland and Slovenia. For national volatility indices, data was successfully obtained for stock markets in France, Germany, the Netherlands, Switzerland, U.K. and the U.S.
[32] A firm's sensitivity to market returns can be defined as its Capital Asset Pricing Model beta or its cost of capital.

$$r(Volatility\ index_{o,t}) = \frac{Volatility\ index_{o,t}}{Volatility\ index_{o,t_{previous}}} - 1 \quad (5)$$

Table A6 in the Appendix presents the results of the descriptive analysis of the independent variables for market returns and volatilities on a country level. Accordingly, the highest average daily stock market returns were achieved in Denmark (0.06%) and the lowest in the Cyprus (-0.06%). The stock indices were also most volatile in Cyprus (standard deviation of 2.23%) and least volatile in the U.S. (standard deviation of 0.77%). On average, national stock market indices increased by 0.04% per day with a standard deviation of 1.28% (cf. Table 1).

The correlation coefficients of all previously introduced independent variables are shown in Table 3. Notably, the correlation between the measures for movements in long-term interest rates and CDS spreads is low (0.05) despite a potential multicollinearity issue as both measures are linked to government bonds. Instead, a strong negative correlation can be observed for returns of stock indices and the respective volatility indices (-0.60) in line with Giot (2005). The independent variables presented in Table 3 are included in all empirical models for estimating insurers' risk sensitivities. Apart from long-term interest rates, where we only differentiate between U.S. and European insurers, all market risk variables are country-specific.

Correlation coefficients	$r(y10_t)$	$r(y1_t)$	$r(CDS_{o,t})$	$r(Stock_{o,t})$	$r(Vola_{o,t})$	$y10_t$	$CDS_{o,t}$
$r(y10_t)$	1.00	0.42	0.05	-0.28	0.23	-0.04	0.01
$r(y1_t)$	0.42	1.00	0.02	-0.10	0.11	-0.07	0.01
$r(CDS_{o,t})$	0.05	0.02	1.00	0.42	0.04	-0.00	0.00
$r(Stock\ index_{o,t})$	-0.28	-0.10	0.42	1.00	-0.60	0.01	0.00
$r(Volatility\ index_{o,t})$	0.23	0.11	0.04	-0.60	1.00	0.00	-0.00
$y10_t$ (level)	-0.04	-0.07	-0.00	0.01	0.00	1.00	-0.01
$CDS_{o,t}$ (level)	0.01	0.01	0.00	0.00	-0.00	-0.01	1.00

Table 3: Correlation matrix of the independent variables for market risk drivers

To reflect insurance companies' product portfolio and financial strength, we consider balance sheet data on a firm level. Specifically, we examine three characteristics: the share of life insurance business, the share of unit-linked products and the solvency ratio. For each of these continuous measures, we create binary variables based on thresholds that are set according to previous year's median of the cross-sectional distribution from the sample x (either U.S., European or joint sample).[33] For instance, the median share of life insurance reserves by

[33] The U.S. sample contains far more insurers that are not engaged in life insurance business at all (34 out of 70 firms) compared with the European sample (12 out of 53 firms). Even stronger patterns can be observed for the unit-linked business in the U.S. (50 out of 70 firms) compared with Europe (only 18 out of 59 firms). To ensure the comparability of market risk sensitivities across samples, we add an additional specification for defining life

European insurers in the sample in 2012 is 40% (cf. Table A7 in the Appendix). If an insurer i's $Life\ Share_{i,2012}$ exceeded this value in year 2012 ($y-1$), it is considered a life insurer in 2013 (y) because the variable $Life_{i,y-1}$ is equal to 1 according to the definitions in Table 4.[34] Thus, a firm is defined as a life insurer if it belongs to the companies with the largest 50% of life insurance business across the given sample x.[35] This approach is different compared with previous empirical literature that has chosen concrete thresholds.[36]

Variable	**Definition**
$Life\ Share_{i,y}$	$\frac{Life\ and\ Health\ Insurance\ Reserves_{i,y}}{Total\ Liabilities_{i,y}}$
$Life_{i,y}$	$\begin{cases} 1, if\ Life\ Share_{i,y} > p_{50}(Life\ Share^{x}_{.,y}) \\ 0, otherwise \end{cases}$
$Unit\text{-}linked\ Share_{i,y}$	$\frac{Separate\ Account\ Liabilities_{i,y}}{Total\ Liabilities_{i,y}}$
$Unit_{i,y}$	$\begin{cases} 1, if\ Unit\ linked\ Share_{i,y} > p_{50}(Unit\ linked\ Share^{x}_{.,y}) \\ 0, otherwise \end{cases}$
$RBC\ Ratio_{i,y}$	$\frac{Adjusted\ Capital_{i,y}}{Risk\ based\ Capital_{i,y} \cdot 2}$
$Solvency^{US}_{i,y}$	$\begin{cases} 1, if\ RBC\ Ratio_{i,y} > p_{50}(RBC\ Ratio_{.,y}) \\ 0, otherwise \end{cases}$
$Solvency\ Ratio_{i,y}$	$\frac{Eligible\ Own\ Funds_{i,y}}{Solvency\ Capital\ Requirement\ (SCR)_{i,y}}$
$Solvency^{EU}_{i,y}$	$\begin{cases} 1, if\ Solvency\ Ratio_{i,y} > p_{50}(Solvency\ Ratio_{.,y}) \\ 0, otherwise \end{cases}$
$Size_{i,y}$	$ln\ (Total\ Assets_{i,y})$
$Leverage_{i,y}$	$\frac{Total\ Debt_{i,y}}{Total\ Equity_{i,y}}$
$Market\text{-}to\text{-}Book_{i,y}$	$\frac{Stock\ Price_{i,y}}{Book\ Value\ per\ Share_{i,y}}$

Table 4: Balance sheet variables (binary and continuous)

and unit-linked insurers in the U.S. and in the joint sample: In order to avoid getting a median equal or close to zero, we calculate the medians of life or unit-linked business of insurers where $Life\ Share_{i,y} > 0$ or respectively $Unit\ linked\ Share_{i,y} > 0$. This approach provides similar thresholds across all samples (cf. Table A7).

[34] For choosing relevant definitions, we consider some variables used by Pelizzon and Sottocornola (2018).

[35] We use further definitions based on the mean and the 75th percentile for the robustness checks in Section 3.2.

[36] For instance, Brewer et al. (2007) define a life insurer if 60% of its assets stem for life insurance business. Hartley et al. (2017) assume a high interest rate risk exposure if more than 25% of an insurer's premiums stem

In terms of the solvency, we use different ratios for U.S. and European insurers: the risk based capital (RBC) and the solvency ratio based on the Solvency II framework. The corresponding binary variable $Solvency_{i,y}$ displays the 50% most solvent firms according to the respective regulatory measure. The distribution of the ratios differs widely (e.g., $RBC\ Ratio_{i,y}$ has a mean of 579% in contrast to 209% for the $Solvency\ Ratio_{i,y}$). Thus, we use the values of the binary variables from the respective subsamples for the joint sample.

We introduce further insurer-specific characteristics similar to Killins and Chen (2020). These are continuous control variables that have an influence on stock returns based on related finance literature such as Fama and French (1992): size, leverage and the market-to-book ratio. All yearly balance sheet data apart from the solvency ratio is collected from SNL Financial Database (the variables in the definition part of Table 4 reflect the supplier's item names). Solvency ratios are obtained from Bloomberg for U.S. insurers and hand-collected from SFCRs for EU insurers. The firm-specific binary variables $Life_{i,y-1}$ and $Unit_{i,y-1}$ will further be denoted as $X_{i,y-1}$. Instead, the insurer-level continuous control variables $Size_{i,y-1}$, $Leverage_{i,y-1}$ and $Market\ to\ Book_{i,y-1}$ will be denoted as $Y_{i,y-1}$.

2.4 Hypotheses

To tackle the research question on how market risks contribute to insurers' stock performance, we examine the influence of relative changes in interest rates and CDS spreads on stock returns. In addition, we combine the binary variables $Life_{i,y-1}$, $Unit_{i,y-1}$ and $Solvency_{i,y}$ with the measures for relative changes in long-term interest rates $r(y10_t)$ and CDS spreads $r(CDS_{o,t})$ in order to create interaction terms that allow to detect characteristics substantially influencing market risk sensitivities. In the following, we describe all main influences and respective hypotheses that we test empirically.

$r(y10_t)$: We investigate the influence of changes in returns achieved from bond investments in a prolonged period of low interest rates. Arguably, interest rate reductions after 2007 spurred economic growth. However, Berends et al. (2013), Hartley et al. (2017) and Lin et al. (2021) demonstrate empirically that in the low rate environment following the financial crisis, insurance companies in general benefit from rising yields. Similarly, while controlling for economic growth we expect a positive impact on the insurers' stock returns in the regression results. Our hypothesis is as follows:

H_1*: Insurers suffer from falling interest rates.*

$r(y10_t) \cdot Life_{i,y-1}$: According to practioners' views, life insurers tend to have a positive duration gap, because markets do not provide sufficient long-term investment opportunities (e.g., Frey (2012)). In addition, Caballero et al. (2017), Greenwood and Vayanos (2010) underline that long-term bonds typically offer unattractive yields. While the academic literature (e.g., Koijen and Yogo (2021), Möhlmann (2021), Kubitza et al. (2021)) argues that life insurers do not aim for perfect hedging, clearly, a fraction of interest rate risk remains unhedged. Two main sources of interest rate exposures are duration gaps[37] and fixed guarantees[38] embedded in life insurance policies in most countries (cf. Table A1). As corresponding assets mature, guarantees are putting insurers under great pressure in the current low yield environment.[39] In the U.S., contractually promised rates are implemented in cash surrender values for universal life and whole life insurance products. If interest rates fall below these guarantees, they get "in the money". As a result, surrender rates will go down and as a consequence, liability duration, and thus the interest rate risk exposure, rise (cf. Kubitza et al. (2021)). It is therefore also the (difficult to predict) policyholder behavior that influences the interest rate risk of life insurers. Also, deposit-type products, which are mere savings policies, contain investment guarantees and are therefore another source for interest rate risk exposure.[40] According to the ESRB (2015), guaranteed life insurance products are also popular in several European countries (mainly Germany, Italy, Netherlands, Switzerland, Austria, Spain, Denmark, Norway and Sweden).[41] Due to the exposure of life insurers' balance sheets to interest rate risk, we expect:

H_2: Insurers with a high share of life insurance reserves suffer more from falling interest rates.

$r(y10_t) \cdot Unit_{i,y-1}$: Policyholders of unit- and index-linked insurance products[42] can influence the investment allocation relating to their contracts. The share of unit-linked products offered by life insurers in Europe keeps on growing as the low interest rate environment prevails (cf. EIOPA (2019b)). One reason might be that the investment risk is borne by policyholders and particularly in Europe, guarantees are less common. Thus, switching from participating to unit-linked business allows life insurers to lower their balance sheets' sensitivities to interest

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[37] Duration gaps imply a structural mismatch between the duration of assets and liabilities. In most countries, the duration of insurers' fixed income securities exceeds those of technical reserves (cf. Table A1). Thus, interest rate movements have a larger effect on the market value of liabilities than assets.

[38] As guaranteed minimum returns shield policyholders from interest rate movements, they provide an insurance against market risks (cf. Koijen and Yogo (2021)).

[39] When the firms' investment income falls below their expenses, insurers can face liquidity issues and thus, have an incentive to hold riskier portfolios.

[40] Deposit-type products make up for around 9% of U.S. life insurers' reserves (cf. Berends et al. (2013, p. 54)).

[41] Guaranteed returns are also popular in France, but typically not binding (cf. Hombert and Lyonnet (2017)). For further information regarding the use of guaranteed returns in different countries see Eling and Holder (2013a,b).

[42] In the following, we will use the term unit-linked products as an umbrella term.

rate movements.[43] While this argument suggests lower interest rate risk for unit-linked insurers, there are other arguments in favor of a high exposure. First, a part of the balance sheet advantages for unit-linked insurers can be offset by foregoing regulatory requirements designed to facilitate the situation of participating life insurers. For instance, the so called "long-term guarantee measures" of Solvency II facilitate the compliance with capital requirements for life insurers with long-term guarantees.[44] Arguably, unit-linked insurers benefit relatively less from these regulatory measures enabling financial reliefs and from current accounting standards[45]. Second, firms shifting towards more unit-linked products are often life insurers that are particularly exposed to the low interest rate environment. For example, some German life insurers decided to stop offering guaranteed products in order to decrease their interest rate exposure as their existing stock of guaranteed contracts gradually expires.[46] In addition, stressed insurers might cut benefits and increase prices for all types of products. Such circumstances can lead to the observation that offering more unit-linked products characterizes firms that are in fact more exposed to interest rate risk due to their remaining guaranteed obligations. Third, many unit-linked products are saving instruments with long-term commitments for pension plans. As a result, unit-linked insurers have a long duration of liabilities and potentially a convexity mismatch relative to the asset side of their balance sheets. In the U.S., variable annuities even combine mutual funds with fixed guarantees (cf. Koijen and Yogo (2021)).[47] Relating to interest rate sensitivities, we expect that the effect of long durations and stressed life insurers switching to unit-linked business outreaches the advantages of lower balance sheet exposures as the investment risk is borne by policyholders. Therefore, we hypothesize:

H_3: Insurers with a high share of reserves relating to unit-linked products suffer more from falling interest rates.

$r(y10_t) \cdot Solvency_{i,y}$: In the EEA, the solvency ratio is a key measure reflecting the insurers' solvency position and financial strength in a single figure ever since Solvency II went into force

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[43] This goes along with the small average duration gaps in countries focusing on unit-linked insurance, such as the UK and Ireland (cf. Table A1).

[44] These long-term guarantee measures can be split into transitionals, which allow insurers to adjust slower to new market conditions such as lower interest rates, and adjustments, which are leading to smaller effects of short-term market conditions or lower capital requirements for spread risk.

[45] For example, the discount rate for liabilities in Germany is very slowly being adjusted to interest rate developments. Between 2011 and 2021, the rate has only been set downwards three times and is consistently larger than the German 10-year government bond yield since 2014. This slow pass-through of interest rates to insurers prevents a market-oriented increase in liabilities.

[46] E.g., Generali Deutschland and Ergo, which belongs to MunichRe, sell parts of their stock of guaranteed insurance contracts to so-called run-off insurance companies.

[47] During the last 30 years, variable annuities have gained great importance in life insurers' portfolios and make up around one third of U.S. life insurers' reserves (cf. Berends et al. (2013, p. 51)).

in 2016. The experimental literature demonstrates that insurers' solvency risk substantially influences policyholders' willingness to pay.[48] By analyzing the effectiveness of market discipline under Solvency II in an event study, Gatzert and Heidinger (2020) find that insurers' stock returns react significantly to the published solvency ratios. For U.S. insurers, we consider the RBC ratio as a measure for solvency, which we also collect for the years 2016 to 2018. We expect less solvent insurers to react particularly sensitive to interest rate fluctuations, because they have smaller capital buffers and are thus closer to undergo supervisory measures, which influence the demand for insurance products and limit investment opportunities. Consequently, it follows:

H_4*: Less solvent insurers suffer more from falling interest rates.*

$r(CDS_{o,t})$: According to Acharya et al. (2014), CDS spreads of government bond portfolios adequately reflect the default risk of a country. Düll et al. (2017) find that European insurance companies' financial positions are negatively impacted by increases in a weighted portfolio of sovereign CDS spreads. In line with this finding, we expect:

H_5*: Insurers suffer from rising default probabilities of sovereign debt.*

$r(CDS_{o,t}) \cdot Life_{i,y-1}$: For life insurers, we expect two different effects to exist in terms of their stock return sensitivities to sovereign default probabilities. On the one hand, firms might benefit from higher future returns for sovereign debt going along with increased CDS spreads. This is particularly relevant within the Solvency II framework, which does not prescribe additional capital requirements for investments in sovereign debt from EU countries with large default probabilities.[49] On the other hand, market values of bonds decrease as CDS spreads increase. The decrease is larger, the longer the duration of the bond is. Thus, life insurers, which tend to hold long-term government bonds, suffer more from increased CDS spreads compared with non-life or composite insurers. Due to opposed implications, the resulting effect of the interaction between sovereign default probabilities and life insurance business on stock returns is rather ambiguous. Our hypothesis carries out the latter market-value based aspect:

H_6*: Insurers with a high share of life insurance reserves suffer more from rising default probabilities of sovereign debt.*

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[48] Cf. Zimmer et al. (2009, 2018) and Lorson et al. (2012).

[49] Cf. Art. 180 (2) of European Commission (2015)..

$r(CDS_{o,t}) \cdot Unit_{i,y-1}$: Rising CDS spreads signal higher uncertainties, which, from policyholder perspective, make insurance contracts with embedded guarantees relatively attractive over unit-linked products, where they bear the investment risk. In addition, the variable $Unit\text{-}linked\ Share_{i,y}$ can, to some extent, identify life insurers particularly suffering from market risks and trying to solve this issue by lowering the share of guaranteed life insurance contracts. For these reasons, we derive:

H_7: Insurers with a high share of reserves relating to unit-linked products suffer more from rising default probabilities of sovereign debt.

$r(CDS_{o,t}) \cdot Solvency_{i,y}$: For solvent insurers, an increase in CDS spreads has less negative effects as the rising market uncertainty has a relatively smaller impact on the firm's market capitalization. Solvent companies can even try to seize the opportunity to invest in riskier government bonds as they are robust enough to face potential losses through a longer period. Thus, we hypothesize:

H_8: Less solvent insurers suffer more from rising default probabilities of sovereign debt.

2.5 Empirical model and tackling of research question

To test the hypotheses, we consider three panel regression models, which we extend successively. In all models, we include insurer fixed effects u_i and standard errors clustered by time. In addition to the main variables of interest, i.e., relative changes in interest rates $r(y10_t)$ and credit spreads $r(CDS_{o,t})$, we consider several control variables. First, economic developments are introduced by daily returns in national stock and volatility indices $r(Stock\ index_{o,t})$ and $r(Volatility\ index_{o,t})$. Second, we control for movements in short-term interest rates $r(y1_t)$ and the level of long-term interest rates $y10_t$. By doing so, we ensure that sensitivities measured by β_3 are driven by changes in interest rates rather than levels, which also significantly influences equity returns according to Czaja et al. (2009). Third, analogously we control for the level of CDS spreads $CDS_{o,t}$. With the given specifications, Model I measures the sensitivity of stock returns to relative changes in interest rates and CDS spreads of weighted country-specific portfolios of sovereign bonds:

$$
\begin{aligned}
r(TRI_{i,t}) = {} & \beta_0 + \beta_1 \cdot r(Stock\ index_{o,t}) + \beta_2 \cdot r(Volatility\ index_{o,t}) \\
& + \beta_3 \cdot r(y10_t) + \beta_4 \cdot y10_t + \beta_5 \cdot r(y1_t) + \beta_6 \cdot r(CDS_{o,t}) \\
& + \beta_7 \cdot CDS_{o,t} + u_i + \varepsilon_{i,t}
\end{aligned}
\qquad \text{Model I}
$$

Model II extends Model I by incorporating insurer-specific information. In particular, we include interaction terms by multiplying each of the market risk variables, $r(y10_t)$ and $r(CDS_{o,t})$, with each binary variable $X_{i,y-1}$ where X represents life or unit-linked insurers according to the definitions in Table 4. In addition to the interaction terms we include the main effects $X_{i,y-1}$ (i.e., $Life_{i,y-1}$ and $Unit_{i,y-1}$) into the empirical model for being able to measure ceteris paribus effects (cf. Angrist and Pischke (2009, p. 51)). We introduce further insurer-specific control variables $Y_{i,y-1}$. These are characteristics which might have an influence on stock returns based on related finance literature such as Fama and French (1992): $Size_{i,y}$ (calculated as the natural logarithm of total assets), $Leverage_{i,y}$ (debt-to-equity-ratio) and $Market\text{-}to\text{-}Book_{i,y}$ (stock price divided by book value per share). It follows:

$$\begin{aligned} r(TRI_{i,t}) = {} & \beta_0 + \beta_1 \cdot r(Stock\ index_{o,t}) + \beta_2 \cdot r(Volatility\ index_{o,t}) + \beta_3 \cdot r(y10_t) \\ & + \beta_{4-5} \cdot r(y10_t) \cdot X_{i,y-1} + \beta_6 \cdot y10_t + \beta_7 \cdot r(y1_t) + \beta_8 \cdot r(CDS_{o,t}) \\ & + \beta_{9-10} \cdot r(CDS_{o,t}) \cdot X_{i,y-1} + \beta_{11} \cdot CDS_{o,t} + \beta_{12-13} \cdot X_{i,y-1} \\ & + \beta_{14-16} \cdot Y_{i,y-1} + u_i + \varepsilon_{i,t} \end{aligned} \qquad \text{Model II}$$

Model III extends Model II by introducing $Solvency_{i,y}$ as a sample-specific binary variable together with its interaction with the relative changes of long-term interest rates $r(y10_t)$ and CDS spreads $r(CDS_{o,t})$. We use a separate model for introducing the solvency because it can only be consistently observed after the introduction of Solvency II in Europe in 2016. Thus, the sample period in Modell III comprises the years 2016 to mid-2018. The sample of U.S. insurers for Model III is smaller, because RBC ratios could be obtained for 27 companies.

$$\begin{aligned} r(TRI_{i,t}) = {} & \beta_0 + \beta_1 \cdot r(Stock\ index_{o,t}) + \beta_2 \cdot r(Volatility\ index_{o,t}) + \beta_3 \cdot r(y10_t) \\ & + \beta_{4-5} \cdot r(y10_t) \cdot X_{i,y-1} + \beta_6 \cdot r(y10_t) \cdot Solvency^x_{i,y} + \beta_7 \cdot y10_t + \beta_8 \cdot r(y1_t) \\ & + \beta_9 \cdot r(CDS_{o,t}) + \beta_{10-11} \cdot r(CDS_{o,t}) \cdot X_{i,y-1} + \beta_{12} \cdot r(CDS_{o,t}) \cdot Solvency^x_{i,y} \\ & + \beta_{13} \cdot CDS_{o,t} + \beta_{14-15} \cdot X_{i,y-1} + \beta_{16-18} \cdot Y_{i,y-1} + u_i + \varepsilon_{i,t} \end{aligned} \qquad \text{Model III}$$

To detect differences in sensitivities of stock returns to market risk drivers between U.S. and European insurers and to test which effects are robust across all samples, we apply the empirical Models I - III to three different samples x: first only to U.S. firms, then only to European firms, and finally to a joint sample including all 167 insurance companies.

3 Results

3.1 Empirical Models I-III

The coefficients and p-values from Model I, which focuses on the effects of market risk drivers on stock returns while controlling for their levels and economic growth, are illustrated in Table 5. In line with hypothesis H_1, we find that across all samples insurers suffer from falling long-term interest rates.[50] Thus, the empirical model confirms previous findings by Berends et al. (2013) and Hartley et al. (2017), when comprising several market risks in a single regression with daily data and introducing further specifications such as insurer fixed effects and standard errors clustered at the day level. Notably, the size of the beta coefficients for $r(y10_t)$ is identical for the initial U.S. and European samples (columns (1) and (2)), indicating a similar degree of stock return sensitivity to interest rate changes by insurance companies in general (including life and non-life insurers). Thus, a one-day holding period return (HPR) of 10-year rates of 1ppt (for instance, due to a fall of interest rates from roughly 0.1% to 0%) decreases the stock return of insurers by 0.21ppt on average, while keeping all other variables constant.

	(1)	(2)	(3)	(4)	(5)	(6)
Sample:	U.S.	Europe	joint	U.S. life	Europe life	joint life
Dependent variable:			r($TRI_{i,t}$) (stock return)			
r(Stock $index_{o,t}$) (return)	0.830***	0.558***	0.644***	1.002***	0.729***	0.811***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
r(Volatility $index_{o,t}$) (return)	0.000	-0.006***	-0.009***	0.002	-0.005***	-0.008***
	(0.847)	(0.005)	(0.000)	(0.420)	(0.010)	(0.000)
r($y1_t$) (holding period return)	-0.148*	0.159**	-0.056	-0.253**	0.239**	-0.043
	(0.052)	(0.045)	(0.353)	(0.030)	(0.025)	(0.608)
r($y10_t$) (holding period return)	-0.205***	-0.205***	-0.240***	-0.469***	-0.295***	-0.421***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
r($CDS_{o,t}$) (return)	0.001	-0.037***	-0.000	0.002	-0.031***	0.000
	(0.306)	(0.000)	(0.713)	(0.144)	(0.000)	(0.911)
Insurer Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
$y10_t$ and $CDS_{o,t}$ (levels)	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	141,001	99,705	240,706	28,047	38,739	58,349
No. of insurers	98	69	167	20	29	43
Adj. R^2	0.159	0.179	0.163	0.315	0.301	0.307
Adj. R^2 within	0.159	0.179	0.163	0.316	0.301	0.307
Standardized beta coefficients						
Interest rate	-.05	-.05	-.06	-.13	-.07	-.1
CDS	0	-.01	0	0	-.01	0

Note: Fixed effect regressions of insurers' stock returns on market risk drivers from 2012 to mid-2018. Sources: Thomson Reuters Eikon (insurer-level daily stock returns measured by total return indices (TRI), country-level stock and volatility indices), FRED (daily interest rates U.S.), ECB (daily interest rates Europe), Markit database in WRDS (daily CDS spreads) and NAIC & EIOPA (distribution of government bond investments as a measure for country-specific CDS exposure). Standard errors are clustered at the day level. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively. P-values are in parentheses.

Table 5: Regression results for the empirical Model I

The coefficient for $r(y10_t)$ is, however, higher when we restrict the sample only to insurers with a high life insurance share, i.e., with the requirement that $Life_{i,y-1} = 1$ (columns (4)-(6)).

[50] As we use the holding period return as independent variable measuring changes in interest rates, a negative sign in the Tables 5-7 showing the regression results implies a positive impact of rising interest rates on stock returns.

Then, a HPR of 1ppt on average decreases stocks returns of U.S. life insurers by 0.47ppt and of European life insurers by 0.3ppt. We make similar findings when considering standardized beta coefficients, which provide a more accurate comparison of the effects of variables with differing volatilities. Thus, ceteris paribus, a one standard deviation increase in the one-day HPR for long-term interest rates (0.43ppt, cf. Table 1) leads to an average fall in stock returns of U.S. life insurers by 0.13 standard deviations (0.32ppt) (column (4)). Instead, a one standard deviation increase in the HPR for 10-year interest rates in Europe (0.36ppt) on average lowers stock returns of European life insurance companies by only 0.07 standard deviations (0.17ppt) (column (5)). Comparing the sensitivities shows that the effect of interest rate movements on the stock performance is 58% higher for U.S. than for European life insurers. These findings indicate that interest rate risk is more relevant for U.S. life insurers.[51] A potential reason for these large sensitivities of U.S. might be the wide-spread use of guaranteed minimum returns (cf. Table A1). Regarding the European sample, the difference in the interest rate sensitivities between all insurers and only life insurers is comparatively smaller (columns (2) and (5)).

In terms of short-term interest rates, we again observe differing sensitivities between U.S. and European life insurers. The former significantly benefit from falling 1-year rates, while European firms significantly suffer from rising 1-year yields and thus seem to prefer a steep yield curve (columns (4) and (5)). Due to the varying sensitivities across the subsamples, the coefficients for $r(y1_t)$ are insignificant for the joint sample (columns (3) and (6)).

Substantial differences between the sensitivities measured in the samples are also given in terms of credit risk. European insurers significantly suffer from increasing default probabilities of sovereign debt, which are measured by weighted country-specific portfolios of CDS spreads of government bonds. Thus, hypothesis H_5 is supported for the European sample. In general, an increase in weighted CDS spreads by 1ppt lowers the stock return by 0.04ppt on average (column (2)). Regarding standardized beta coefficients, we find that an increase in CDS spread by one standard deviation (5.36ppt) on average leads to a fall in the stock performance by 0.01 standard deviations (0.025ppt) (columns (2) and (5)). Thus, for European life insurers the effect of a one standard deviation change is 7 times larger for interest rates compared with CDS spreads of government bonds.[52] In contrast to European firms, U.S. life insurance companies

[51] The ratio of ceteris paribus average decreases in stock prices by changes in the HPR is 0.744 (=0.32ppt / 0.43ppt) for life insurers in the U.S. and 0.472 (= 0.17ppt / 0.36ppt) for life insurers in Europe. Taking these ratios as sensitivity measures, the relative difference in the sensitivities is 57.63%. Similarly, the beta coefficients for $r(y10_t)$ are -0.469 for U.S. life insurers and -0.295 for European life insurers, implying a difference of 59%.

[52] For the means of better comparison, we consider the ceteris paribus average effect of a one standard deviation increase in the underlying variables on stock returns. For the HPR (weighted portfolio of CDS spreads), the effect is a fall in stock returns by 0.07 (0.01) standard deviations (column (5)).

do not benefit from decreasing CDS spreads, but rather from increasing default probabilities of sovereign debt, however only to a marginally small degree and not to a significant level (column (4)). A channel through which U.S. insurers benefit from rising CDS spreads can be higher expected market returns that compensate for the negative effect of credit deteriorations on existing bonds. We interpret the difference in sensitivities between U.S. and European life insurers to be linked to the relatively low share of U.S. insurers' investments in government bonds[53] and to the large home bias towards U.S. sovereign debt that typically has a high degree of creditworthiness (cf. Table 2). Based on the measured sensitivities, credit risk is substantially more relevant for European insurers than for U.S. insurers. The latter are immunized against increasing sovereign default probabilities in terms of stock price reactions. For the combined sample, the impact of changes in CDS spreads on stock returns is not significant due to the different effects it has on the two subsamples (columns (3) and (6)).

Regarding the size of the coefficients, national stock market developments have the largest impact on the stock returns of life insurance companies among all market risk drivers. A 1ppt increase in stock indices results in an average insurer's stock return rise by 1ppt in the U.S. and 0.73ppt in Europe (columns (4) and (5)). As for long-term interest rates, the coefficients are higher for life insurers than for the initial samples in columns (1) – (3). In summary, Model I shows that stock returns are substantially influenced by market risk drivers. Interest rate movements and stock market returns have a highly significant impact on the stock return of all insurers, while CDS spreads for sovereign debt only influence the European firms in the sample.

In Model II, we introduce the insurer-specific binary variables $X_{i,y-1}$ (i.e., $Life_{i,y-1}$ and $Unit_{i,y-1}$), which we interact with the market risk drivers $r(y10_t)$ and $r(CDS_{o,t})$. Additionally, we introduce the continuous control variables $Y_{i,y-1}$. The coefficients and p-values in Table 6 reveal that insurers' sensitivities towards interest rate movements are significantly linked to firm-specific balance sheet variables. Hypothesis H_2 is supported, as insurers with a higher share of life insurance business significantly suffer more from decreasing interest rates. On average, a HPR within one day of 1ppt (implying a falling interest rate) lowers the stock return of a life insurer ceteris paribus by 0.186ppt more compared with a non-life insurer (column (3)). The result is robust across all subsamples and is closely linked to the negative effects of interest rate declines on the balance sheet of life insurers due to the duration mismatch and the use of guarantees. Again, the corresponding coefficients are larger for U.S. insurers (column (1)).

[53] The share of corporate bonds is roughly three times larger compared with government bonds for U.S. insurers according to NAIC (2021). This indicates lower sovereign counterparty default risk, but also riskier investments.

	(1)	(2)	(3)
Sample:	U.S.	Europe	joint
Dependent variable:	$r(TRI_{i,t})$ (stock return)		
$r(\text{Stock index}_{o,t})$	0.853***	0.544***	0.638***
	(0.000)	(0.000)	(0.000)
$r(\text{Volatility index}_{o,t})$	0.001	-0.008**	-0.011***
	(0.704)	(0.016)	(0.000)
$r(y1_t)$	-0.141*	0.219**	-0.026
	(0.078)	(0.016)	(0.688)
$r(y10_t)$	-0.052	-0.021	-0.119***
	(0.117)	(0.613)	(0.000)
$r(y10_t) \times \text{Life}_{i,y-1}$ (binary)	-0.237***	-0.171***	-0.186***
	(0.000)	(0.000)	(0.000)
$r(y10_t) \times \text{Unit}_{i,y-1}$ (binary)	-0.804***	-0.235***	-0.455***
	(0.000)	(0.000)	(0.000)
$r(CDS_{o,t})$	0.001	-0.018***	0.000
	(0.406)	(0.004)	(0.831)
$r(CDS_{o,t}) \times \text{Life}_{i,y-1}$ (binary)	0.002	-0.018***	-0.002
	(0.285)	(0.003)	(0.267)
$r(CDS_{o,t}) \times \text{Unit}_{i,y-1}$ (binary)	-0.002	-0.038***	-0.006**
	(0.456)	(0.000)	(0.019)
Insurer Fixed Effects	Yes	Yes	Yes
$y10_t$ and $CDS_{o,t}$ (levels)	Yes	Yes	Yes
Insurer controls (binary) $X_{i,y-1}$	Yes	Yes	Yes
Insurer controls (continuous) $Y_{i,y-1}$	Yes	Yes	Yes
No. of obs.	95,918	67,741	163,659
No. of insurers	64	49	113
Adj. R^2	0.176	0.196	0.177
Adj. R^2 within	0.175	0.195	0.177

Note: Fixed effect regressions of insurers' stock returns on market risk drivers from 2012 to mid-2018. Binary insurer controls $X_{i,y-1}$ are based on previous year's median of the cross-sectional distribution of the shares of life insurance reserves and unit-linked reserves. Continuous insurer controls $Y_{i,y-1}$ are the size, the leverage and the market-to-book ratio at the insurer-year level lagged by one year relative to the stock return. Sources: Thomson Reuters Eikon (insurer-level daily stock returns measured by total return indices (TRI), country-level stock and volatility indices), FRED (daily interest rates U.S.), ECB (daily interest rates Europe), Markit database in WRDS (daily CDS spreads), NAIC & EIOPA (distribution of government bond investments), SNL (insurer-level yearly life insurance share, unit-linked business share, leverage, size and market-to-book ratio) and SFCRs (insurer-level yearly solvency ratio). Standard errors are clustered at the day level. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively. P-values are in parentheses.

Table 6: Regression results for the empirical Model II

Also, in line with H_3, insurers with a high share of unit-linked business suffer more from falling interest rates compared with firms with no or only a little share of unit-linked reserves. Presumably due to variable annuities with embedded minimum returns, the effect is particularly large in the U.S., where a HPR of 1ppt additionally lowers unit-linked insurers' stock returns by 0.804ppt (column (1)). As outlined in Section 2.4, other reasons for large interest rate risk of unit-linked insurers are the long duration of liabilities for savings instruments, underlying accounting standards and a correlation between firms with large previously guaranteed returns and those with an increasing share of unit-linked products as insurers are aiming at lowering their balance sheets' exposure to interest rate risk. The findings suggest that regulators globally should not only closely monitor interest rate sensitivities of life insurers with guarantees, but also those of unit-linked insurance companies.

In terms of credit risk, Model II reveals that the impact of the interaction term $r(CDS_{o,t}) \cdot Life_{i,y-1}$ on stock returns is significantly negative for European insurers (column (2)). This supports H_6, as the stock returns of life insurers are twice as much negatively affected by increasing CDS spreads than the stock prices of composite or non-life insurers. The main reason is presumably the difference in the investment strategy as life insurers typically hold a high share of fixed income securities with longer durations, which makes them more exposed to counterparty credit risk. The stock market reactions to CDS movements are more robust and even larger for insurers offering unit-linked products. In line with H_7, these firms significantly suffer more from rising default probabilities of sovereign debt compared with other insurers. Thus, a 1ppt increase in CDS spreads additionally lowers unit-linked insurers' stock returns by 0.04ppt ceteris paribus on top of the effect of 0.02ppt for insurers in general. The sensitivity to default probabilities of government bonds can be explained by an increased preference of customers for guaranteed insurance products when future market developments seem less predictable. As U.S. sovereign debt is considered to be very secure during the sample period between 2012 and 2018, the effects of interaction terms of the credit risk measure with firm-specific variables are not significant in Model II for the U.S. sample (column (1)). Previous findings from Model I regarding sensitivities of insurers towards movements of stock indices and short-term interest rates are robust in terms of the sign of coefficients and their significance.

In Model III, we additionally introduce $Solvency_{i,y}$ as a further insurer-specific binary characteristic to interact with the variables for relative changes in long-term interest rates $r(y10_t)$ and CDS spreads $r(CDS_{o,t})$. As outlined in Section 2.5, Model III is limited to a smaller sample period from 2016 to mid-2018 because of the lack of a key solvency figure for EU insurers before the introduction of Solvency II in 2016. The coefficients and p-values are illustrated in Table 7. The regression results from the European sample support hypothesis H_4 that less solvent insurers suffer more from falling interest rates (column (2)). Thus, for the 50% of most solvent firms a 1ppt HPR on average lowers stock prices by 0.22ppt less compared with the 50% less solvent insurers. The sensitivities can be explained by a smaller ability to cope with the challenges caused by interest rate reductions, if a company has smaller capital buffers. This effect is, however, insignificant for the U.S. sample (column (1)), which is an indicator that the RBC ratio is not as much perceived by capital markets as the solvency ratio in Europe.

We find however, that across all samples more solvent insurers suffer less from rising CDS spreads of sovereign debt, which is in favor of H_8. While the finding is borderline insignificant for the U.S. sample (p-value of 10.9%), the effect is particularly pronounced and robust in the European and the joint sample (columns (2) and (3)). For European insurers we find that, ceteris paribus, the negative effect of a 1ppt increase in CDS spreads on stock prices is 0.02ppt is smaller. Again, even though the number of observations in Model III is smaller, all previous findings from Model II are still significant with the given specifications.

	(1)	(2)	(3)
Sample:	U.S.	Europe	joint
Dependent variable:	$r(TRI_{i,t})$ (stock return)		
$r(\text{Stock index}_{o,t})$	0.931***	0.643***	0.706***
	(0.000)	(0.000)	(0.000)
$r(\text{Volatility index}_{o,t})$	0.006**	-0.003**	-0.004**
	(0.042)	(0.048)	(0.016)
$r(y1_t)$	-0.130	0.281*	-0.022
	(0.264)	(0.064)	(0.812)
$r(y10_t)$	-0.122*	-0.183**	-0.216***
	(0.082)	(0.035)	(0.000)
$r(y10_t) \times \text{Life}_{i,y-1}$ (binary)	-0.231***	-0.285***	-0.182***
	(0.001)	(0.000)	(0.000)
$r(y10_t) \times \text{Unit}_{i,y-1}$ (binary)	-1.168***	-0.290***	-0.712***
	(0.000)	(0.000)	(0.000)
$r(y10_t) \times \text{Solvency}_{i,y}$ (binary)	0.060	0.221***	0.058
	(0.335)	(0.002)	(0.239)
$r(\text{CDS}_{o,t})$	-0.008	-0.028***	-0.012**
	(0.117)	(0.004)	(0.016)
$r(\text{CDS}_{o,t}) \times \text{Life}_{i,y-1}$ (binary)	0.002	-0.015*	-0.004
	(0.647)	(0.061)	(0.322)
$r(\text{CDS}_{o,t}) \times \text{Unit}_{i,y-1}$ (binary)	-0.004	-0.015*	-0.004
	(0.390)	(0.062)	(0.410)
$r(\text{CDS}_{o,t}) \times \text{Solvency}_{i,y}$ (binary)	0.008	0.018**	0.011**
	(0.109)	(0.032)	(0.039)
Insurer Fixed Effects	Yes	Yes	Yes
$y10_t$ and $\text{CDS}_{o,t}$ (levels)	Yes	Yes	Yes
Insurer controls (binary) $X_{i,y-1}$	Yes	Yes	Yes
Insurer controls (continuous) $Y_{i,y-1}$	Yes	Yes	Yes
No. of obs.	16,310	23,967	40,277
No. of insurers	27	42	69
Adj. R^2	0.203	0.214	0.203
Adj. R^2 within	0.204	0.215	0.204

Note: Fixed effect regressions of insurers' stock returns on market risk drivers from 2012 to mid-2018. Binary insurer controls $X_{i,y-1}$ are based on previous year's median of the cross-sectional distribution of the shares of life insurance reserves, unit-linked reserves and the corresponding solvency ratio measures. Continuous insurer controls $Y_{i,y-1}$ are the size, the leverage and the market-to-book ratio at the insurer-year level lagged by one year relative to the stock return. Sources: Thomson Reuters Eikon (insurer-level daily stock returns measured by total return indices (TRI), country-level stock and volatility indices), FRED (daily interest rates U.S.), ECB (daily interest rates Europe), Markit database in WRDS (daily CDS spreads), NAIC & EIOPA (distribution of government bond investments), SNL (insurer-level yearly life insurance share, unit-linked business share, leverage, size and market-to-book ratio), Bloomberg (RBC ratio as solvency measure of U.S. insurers) and SFCRs (insurer-level yearly solvency ratio as solvency measure of European insurers). Standard errors are clustered at the day level. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively. P-values are in parentheses.

Table 7: Regression results for the empirical Model III

The findings demonstrate that an insurer's share of life and unit-linked business are characteristics that significantly influence interest rate sensitivities of insurers across all samples. Additionally, in Europe insurance companies with low solvency ratios are particularly prone to interest rate movements in general. However, U.S. life insurers' sensitivities to changes in interest rates are more than 50% larger. In terms of credit risk, we find that European insurers significantly suffer from rising CDS spreads of government bonds, however to a seven times lower degree compared with interest rates. Again, particularly less solvent life insurers and firms offering unit-linked products are more exposed. In contrast, U.S. insurers' stock returns do not seem to be significantly influenced by changes in default probabilities of sovereign debt.

3.2 Robustness

To test the robustness of the empirical findings, we use several alternative models and alternative variable definitions. Table 8 shows whether the hypotheses elaborated in Section 2.4 are still supported by the regression results after implementing the following thirteen individual adjustments to the original specifications for the empirical Models I-III:[54]

1. **Continuous variables for interaction terms instead of binaries in Model II and III**: While, initially, we have chosen binary variables $X_{i,y-1}$ to allow for an easier interpretation of coefficients, an alternative specification with the continuous variables $Life\ Share_{i,y-1}$, $Unit\text{-}linked\ Share_{i,y-1}$ and $Solvency\ Ratio_{i,y}^{x}$ instead of $Life_{i,y-1}$, $Unit_{i,y-1}$ and $Solvency_{i,y}^{x}$ is also reasonable from an econometric point of view. Again, we include the main effects of these continuous firm-specific characteristics in the model and combine them with $r(y10_t)$ and $r(CDS_{o,t})$ in line with Models II-III. The empirical results of these alternative models (see corresponding columns in Table 8) confirm previous findings in terms of the sign of the coefficients for the variables of interest. Only regarding the influence of the interaction term $r(CDS_{o,t}) \cdot Unit_{i,y-1}$ relating to H_7, the robustness check does not show significant coefficients for the restricted sample period in Model III. This can be explained by the smaller amount of observations (data only from 2016 to mid-2018). Instead, the effect of this interaction term on stock returns under the given specification is highly significant for the larger sample in Model II including all observations from 2012 to mid-2018.
2. **Standard errors clustered at day and firm level**: While most of the empirical literature investigating the market risks of insurance companies does not include clustered standard errors, we cluster standard errors at the day level to handle correlated shocks in line with Düll et al. (2017). However, previous finance-related literature has shown that stock returns and their variance display autocorrelation (see Mech (1993), Campbell et al. (1997) and Kim et al. (2011)). To handle this issue and to ensure obtaining heteroskedasticity-robust coefficients, we additionally cluster standard errors on an insurer and day level in a robustness check. The summarized empirical results illustrated in Table 8 indicate that the majority of coefficients is still highly significant on a 10% level. Only the interaction term $r(CDS_{o,t}) \cdot Life_{i,y-1}$ is insignificant after

[54] Regression tables including the coefficients and p-values of the empirical models used for the alternative specifications in Section 3.2 are available upon request.

additionally clustering standard errors at the firm level, which can be explained by opposing effects of rising CDS spreads on life insurers (see Section 2.4).

3. **Weekly data**: We test whether the hypotheses are supported by significant regression coefficients after adjusting the data frequency to weekly data in line with Berends et al (2013) and Hartley et al. (2017). For this robustness test, we use end-of-week data for stock returns and all market risk variables. The adjustment results in a lower power of empirical testing. Assumingly, due to the resulting small amount of observations for the empirical Model III,[55] performing the initial regressions with weekly data does not result in significant coefficients for the interaction term $r(CDS_{o,t}) \cdot Solvency_{i,y}$. Instead, the coefficients measured in Models I and II significantly confirm all previous findings.
4. **Without winsorizing**: In order to deal with outliers, we initially winsorize the 0.5% of the highest and lowest stock returns in each sample in the original specifications for Models I-III. For a robustness check, we omit this approach to show the empirical results for the unadjusted dataset. Compared with the results from the original models, all hypotheses are still supported at the 10% level of significance.
5. **Considering the number of days passed**: For this robustness check, we use an alternative specification for variables measuring daily stock returns and movements in market risk drivers. We consider the amount of days that has passed since the last stock price of a firm has been observed. For instance, we define the stock return as $r(TRI_{i,t}) = \left(\frac{TRI_{i,t}}{TRI_{i,t_{previous}}}\right)^{\frac{1}{t-t_{previous}}} - 1$ instead of $r(TRI_{i,t}) = \frac{TRI_{i,t}}{TRI_{i,t_{previous}}} - 1$. Thus, if an insurer's stock price is missing for a certain trading day (where stock markets globally are trading), but available for the following trading day, $t - t_{previous} = 2$ applies. We adjust the calculations for the independent variables analogously. The regression results after applying this specification are all in line with previous findings.
6. **Only observations where exactly one day has passed**: In this specification, we test whether we find different market risk sensitivities when removing all stock return observations for an insurer i after a missing $r(TRI_{i,t})$. Thus, this limited sample only considers changes in stock prices within one trading day and allows to lower concerns regarding national holidays. Even though some observations are removed (1,439 in the U.S. and 2,778 in the European sample), the coefficients for all variables of interest are still significant across all samples.

[55] For instance, the number of observations in the European sample in Model III falls from 23,967 to 4,871.

Hypothesis	Variable of interest	Robustness check	Original models			1.Continuous variables instead of binaries			2. Std. err. clustered at firm and day level			3. Weekly data			4. Without winsorizing			5. Considering the number of days passed			6. Only observations with one day passed		
		Sample	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint
H1	$r(y10_t)$	Modell 1	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***
H2	$r(y10_t) \cdot Life_{i,y-1}$	Modell 2	✓***	✓***	✓***	✓***	✓***	✓***	✓**	✓**	✓**	✓***	✓'	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***
		Modell 3	✓***	✓***	✓***	✓**	✓***	✓***	✓	✓**	✓	✓**	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***
H3	$r(y10_t) \cdot Unit_{i,y-1}$	Modell 2	✓***	✓***	✓***	✓***	✓**	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***
		Modell 3	✓***	✓***	✓***	✓***	✓'	✓'	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***
H4	$r(y10_t) \cdot Solvency_{i,y}$	Modell 3	-	✓***	-	✓**	✓***	✓***	-	✓*	-	-	✓	-	-	✓***	-	-	✓***	-	-	✓***	-
H5	$r(CDS_{o,t})$	Modell 1	-	✓***	-	-	✓***	-	-	✓*	-	-	✓***	-	-	✓***	-	-	✓***	-	-	✓***	-
H6	$r(CDS_{o,t}) \cdot Life_{i,y-1}$	Modell 2	-	✓***	-	-	✓***	-	-	✓	-	-	✓*	-	-	✓**	-	-	✓'	-	-	✓**	-
		Modell 3	-	✓*	-	-	✓**	-	-	✓	-	-	✓	-	-	✓*	-	-	✓'	-	-	✓*	-
H7	$r(CDS_{o,t}) \cdot Unit_{i,y-1}$	Modell 2	-	✓***	-	-	✓***	-	-	✓**	-	-	✓**	-	-	✓***	-	-	✓***	-	-	✓***	-
		Modell 3	-	✓*	-	-	✓	-	-	✓	-	-	✓	-	-	✓**	-	-	✓***	-	-	✓**	-
H8	$r(CDS_{o,t}) \cdot Solvency_{i,y}$	Modell 3	✓'	✓**	✓**	✓	✓'	✓'	✓**	✓*	✓*	✓	X	✓	✓	✓**	✓*	✓	✓**	✓***	✓'	✓*	✓*

Hypothesis	Variable of interest	Robustness check	7. Life insurers only			8. Stock market interactions included			9. Interactions with size included			10. Mean as binary threshold			11. European median as binary threshold			12. 75th percentile as binary threshold			13. Median above 0 as threshold		
		Sample	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint	U.S.	Europe	Joint
H2	$r(y10_t) \cdot Life_{i,y-1}$	Modell 2	✓***	✓***	✓***	✓***	✓**	✓***	✓***	✓**	✓***	✓***	✓***	✓***	✓***	✓**	✓***	✓***	✓***	✓***	✓***	✓***	✓***
		Modell 3	✓***	✓***	✓***	✓***	✓***	✓*	✓**	✓	✓	✓'	✓***	✓***	✓**	✓**	✓**	✓*	✓***	✓**	✓***	✓***	✓***
H3	$r(y10_t) \cdot Unit_{i,y-1}$	Modell 2	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***
		Modell 3	✓***	✓'	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓***	✓**	✓***	✓***	✓***	✓***	✓***	✓***	✓***
H4	$r(y10_t) \cdot Solvency_{i,y}$	Modell 3	-	✓***	-	-	✓***	-	-	✓**	-	✓***	✓***	✓***	-	✓*	-	✓***	✓***	✓***	-	✓***	-
H6	$r(CDS_{o,t}) \cdot Life_{i,y-1}$	Modell 2	-	✓*	-	-	X	-	-	X	-	-	✓***	-	-	✓	-	-	✓***	-	-	✓***	-
		Modell 3	-	✓	-	-	X	-	-	X	-	-	✓*	-	-	✓	-	-	✓	-	-	✓*	-
H7	$r(CDS_{o,t}) \cdot Unit_{i,y-1}$	Modell 2	-	✓***	-	-	✓	-	-	✓***	-	-	✓***	-	-	✓**	-	-	✓***	-	-	✓***	-
		Modell 3	-	✓*	-	-	✓	-	-	✓	-	-	✓***	-	-	✓	-	-	✓***	-	-	✓**	-
H8	$r(CDS_{o,t}) \cdot Solvency_{i,y}$	Modell 3	✓	✓	✓**	✓'	✓	✓**	✓*	✓**	✓**	✓	✓*	✓	✓*	✓*	✓**	✓	✓	✓	✓'	✓'	✓**

Note: Each robustness test stands for an adjustment compared with the original empirical models I-III. ***, **, *, ' indicate significance at the 1%, 5%, 10% and 15% levels, respectively. The checkmark symbol implies that under the given specification the coefficient of the variable of interest from the panel regression analysis has a sign that is in line with the hypothesis formulated in Section 2.4. Instead, X implies that the sign is not in line with the given hypothesis. The minus sign marks coefficients that are included in the respective empirical models, however they are not significant according to the original models and thus not reported any further (e.g., sensitivities of U.S. life insurers to sovereign CDS spreads).

Table 8: Main regression results for the robustness checks

7. **Life insurers only**: In the original sample, we include all types of listed insurance companies, i.e., also non-life insurers. This allows analyzing how market risk sensitivities are linked to the product portfolio of an insurer. In this further step, we only keep firms in the sample when they are engaged in life insurance business, i.e., where the requirement $Life\ Share_{i,y-1} > 0$ is fulfilled. As a result, the thresholds for the binary variables change. For instance, $Life_{i,y-1}$ is now equal to one for the 50% of firms with highest share of life insurance business among all insurers offering life business in a given sample x (not in relation to all firms including pure non-life insurers). While again, the sign of all coefficients is in line with the previous findings, the influence of CDS movements is lower compared with interest rates and thus, the respective interaction terms are insignificant in the limited sample period in Model III.
8. **Stock market interactions included**: In their empirical models, Hartley et al. (2017) include the interaction of life insurance business with stock market movements as a control variable. Based on their approach, we choose to additionally introduce the interactions of the variable $r(Stock\ index_{o,t})$ with the market risk drivers $Life_{i,y-1}$, $Unit_{i,y-1}$ and $Solvency_{i,y}^{x}$ in a robustness check. By doing so, we ensure that previously observed significant sensitivities related to market risk drivers are not influenced by overall economic conditions. In terms of interest rate sensitivities, the empirical results are significantly in line with the hypotheses $H_1 - H_4$. However, for equity price reactions to CDS spread of government bonds, we find that this specification, which includes a wider range of independent variables (18 in total in Model II and 21 in Model III), does not support H_6 regarding the credit risk of life insurers in Europe. We assume these results to be driven by the large set of variables with counteracting effects on stock returns. Further coefficients measuring the influence of the interaction terms with the credit risk measure, i.e., $r(CDS_{o,t}) \cdot Unit_{i,y-1}$ and $r(CDS_{o,t}) \cdot Solvency_{i,y}^{X}$ are in line with the formulated hypotheses.
9. **Interactions with size included**: Previous research articles have analyzed market risk sensitivities depending on the size of insurance companies. While Möhlmann (2017) shows that large insurers face lower interest rate risk, Brewer et al. (2007) find that life insurers with a larger asset size react less sensitive to movements in stock market than to interest rates. In the original models, we control for the size of insurers by the continuous variable $Size_{i,y-1}$. For a robustness check, we use a binary variable instead, which we define analogously to other dummy variables $X_{i,y-1}$ (i.e., based on the previous year's median in the cross-sectional distribution). We interact the binary

variable for size with the measures for relative changes of interest rates $r(y10_t)$ and CDS spreads $r(CDS_{o,t})$ in the same way as other potential market risk characteristics, such as $Life_{i,y-1}$. Similar to the previous specifications with stock market interactions, all hypotheses apart from H_6 are robust after introducing this adjustment.

10.-13. **Adjustments to the binary thresholds**: In these four specifications, we choose alternative definitions for the binary variables $Life_{i,y-1}$, $Unit_{i,y-1}$ and $Solvency_{i,y}^{x}$ compared with the definitions illustrated in Table 4. Initially, the dummy variables are set to be equal to one when the respective continuous share $Life\ Share_{i,y-1}$, *Unit-linked* $Share_{i,y-1}$ or $Solvency\ Ratio_{i,y}^{x}$ is above the median for a given sample. For the robustness checks, we use the use following four uniform requirements across all samples for defining the respective binary variables to be equal to one based on previous year's characteristics:

10. mean (i.e., the average) of all observations,
11. the median of all observations in the European sample (which has a substantially larger share of insurers offering life insurance and unit-linked products compared with the U.S. sample) [56],
12. 75th percentile of all observations,
13. median (i.e., 50th percentile) of all observations for which $Life\ Share_{i,y} > 0$ or respectively $Unit\ linked\ Share_{i,y} > 0$ applies.

The results of the robustness tests illustrated in Table 8 show that for all given adjustments for the definitions of the binary variables, the coefficients of the variables of interest are in line with previous findings. Excluding H_6 and H_8, the influence on the stock returns is always highly significant.

In summary, the results from the thirteen alternative specifications indicate that the vast majority of initial findings can be confirmed by significant coefficients supporting the hypotheses. Only regarding the interaction term $r(CDS_{o,t}) \cdot Life_{i,y-1}$, two adjustments do not confirm the robustness of H_6, which implies higher credit risk sensitivities for life insurers. One reason could be the existence of a positive effect of rising CDS spreads on the demand for secure pension planning and potentially higher future investment returns. Instead, we can observe that previous findings indicating higher interest rate sensitivities for life insurers, unit-linked insurers and less solvent firms are very robust. Due to the larger absolute size of the

[56] This adjustment only applies to the variables $Life_{i,y-1}$, $Unit_{i,y-1}$. The varying definitions of the solvency measures for European and U.S. insurers (i.e. the solvency ratio and RBC ratio) result in a different scaling of the corresponding observations (cf. Table 1).

coefficients illustrated in Tables 5-7 and due to the more significant sensitivities in the robustness tests in Table 8, our analysis indicates that capital market investors perceive interest rate risk as a more severe threat for insurers compared with credit risk.

4 Conclusion

In this article, we examine the impact of market risk drivers on the stock return of life insurers in the U.S. and in Europe in the prolonged low yield environment from 2012 to 2018. We design an empirical model in which we analyze the simultaneous influence of daily changes in interest rates, CDS spreads of government bonds and stock market indices. The findings indicate that interest rate changes affect stock returns by factor seven more strongly than movements in sovereign CDS spreads. For U.S. life insurers, a one standard deviation decrease in the daily holding period return for long-term interest rates (0.43ppt), leads to an increase in the stock return by 0.13 standard deviations (0.32ppt). Thus, the effect of an increase in interest rates is more than 50% larger compared with European life insurers. When analyzing the drivers of insurers' market risk sensitivities, we find that interest rate movements are particularly relevant for less solvent firms with a high share of life insurance business. Unit-linked insurers are also strongly affected by falling interest rates, signaling that regulators should pay close attention to their market risk sensitivities. In contrast to interest rates, only European insurers are affected by movements in sovereign CDS spreads. European insurers significantly suffer from rising default probabilities of government bonds, particularly when they are less solvent and when they offer unit-linked products. Due to the low share of government bond investments, U.S. insurers' stock prices are immunized against increasing sovereign default probabilities..

Given that our paper has identified substantial differences between U.S. and European insurers, it would be interesting for future research to extend the empirical analysis to other life insurance markets. For instance, Japan has experienced an interest environment with particularly low and even negative interest rates for a relatively long period (cf. Lin et al. (2021).[57] Moreover, one should keep in mind that our empirical analysis is based on stock insurers and the results cannot easily be transferred to companies that are not listed on stock markets, such as mutual insurers. For those companies, however, performance measures such as return on assets are observable only at much longer time intervals.

[57] In Japan, different historical market patterns can be observed at the beginning of the millennium. In these years, Japanese 10-year government bond yields were below 1%, while they were above 5% in the U.S. and Germany.

Appendix

Country	Average duration gap	Spread of investment return over guaranteed rate	Guaranteed products as % of reserves
Germany	10.7 years	-1.6%	75%
Austria	10.09 years	-1.5%	58%
Norway	> 10 years*	1.1%	60% - 80%*
Slovenia	8.34 years		
Netherlands	5.43 years	0.7%	40%
Finland	5.36 years	1.0%	
France	4.82 years	-0.7%	> 80%*
Denmark	4.74 years	-1.9%	74%
Poland	3.44 years	3.0%	
Hungary	3.03 years	-2.8%	
Switzerland	< 2 years*		> 80%*
Greece	1.98 years		
Belgium	1.37 years	-0.1%	
U.S.	< 1 year*		60% - 80%*
Italy	0.81 years	-1.8%	60% - 80%*
Spain	0.75 years	-0.7%	> 80%*
Ireland	-0.63 years	0.0%	< 20%*
UK	−1.05 years	-0.5%	19%

Note: The average duration gap is obtained from EIOPA (2014) and the amount of guaranteed products as a share of reserves is obtained from the European Systemic Risk Board (ESRB) (2015). For otherwise missing values, the data is collected from Moody's (2015) and marked with the symbol *. The spread of the investment return over the guaranteed rate is obtained from EIOPA (2019b).

Table A1: Characteristics of interest rate risk sources in life insurance markets

	Browne et al. (1999)	Brewer et al. (2007)	Carson et al. (2008)	Berends et al. (2013)	Hartley et al. (2017)	Möhlmann (2019)	Killins and Chen (2020)
Sample	U.S. life-health insurers	Publicly-traded U.S. life insurance companies (60)	U.S. life (17-37), health (5-11), and property and casualty (21-46) insurers	Publicly-traded U.S. life insurance companies (26)	• Publicly-traded U.S. and U.K. life and non-life insurers • Sample of continental European insurers for robustness check	German life insurers (83)	U.S. insurers (95) and Canadian insurers (8)
Main Data Sources	Best's Review: Life/Health Editions, A.M. Best, Federal Reserve Bulletin, Life Insurance Fact Book, U.S. Dept. of Labor	Center for Research in Securities Prices (CRSP)	CRSP	Compustat, French (2013), Haver Analytics, SNL Financial, CRSP	SNL Financial	Federal Financial Supervisory Authority (BaFin)	DataStream, AQR, FRED
Period	Q1/1972 - Q4/1994	01/1975 - 12/2000	01/1991 - 12/2001	08/2002 - 12/2012	01/2002 - 07/2015	01/2014 - 12/2014	01/2000 - 06/2019
Data frequency	quarterly	monthly	daily	weekly	weekly	yearly	monthly
Model	• Poisson regression presented as a log-linear model - DV: no. of insolvencies by quarter - IV: average bond rate, slope of yield curve, change in T-bill rate, disposable personal income per capita, rate of unemployment, returns on real estate, S&P 500, unanticipated inflation, total number of insurers - CV: number of quarters (time), Q2 (seasonal variation)	• Generalized autoregressive conditionally heteroskedastic in the mean (GARCH–M) model - return equation that includes the market return, the interest rate index, and the volatility measure - volatility equation that includes the ARCH and GARCH factors	• 8-equation System-GARCH model of stock return movements for portfolios - 3 return equations which include a market facor, an interest rate factor, and two return spillover factors across insurer segments - 3 volatility equations which include the ARCH and GARCH factors, risk spillover factors across different insurer categories, and a variable for the passage of the GLBA	• Two - factor model (panel regression) - DV: insurer stock returns - IV: return on a Treasury bond with a 10-year constant maturity - CV: return on a value-weighted stock market portfolio	• Two - factor model (panel regression) - dependent variable (DV): insurer stock returns - independent variable (IV): return on U.S./U.K. government bonds with a 10-year constant maturity - controll variable (CV): value-weighted stock market index • Building on the two-factor model, two-stage difference-in-difference approach.	• Estimation of the historical modified duration gap using accounting data • Cross-sectional regression as well as panel regression: - DV: historical duration gap - IV: planned premium growth, run-off, size, subsidiary of a group, mutual insurance company, public ownership, interest rate derivatives • Robust-to-outliers regression of investment duration on liability duration	• Two - factor model (panel regression) - DV: insurer equity returns with different measures (e.g. 10Y - 3M rates) - IV: slope of the yield curve - CV: Fama and French (1993) factors for market, size and value • U.S. and Canadian sample • Pooled OLS and models with fixed and random effects
Extension of the basic model		• Smaller subsamples sorted by risk and asset size • Subsample periods based on changes in the monetary policy strategy of the FED	• Smaller subsamples sorted by market capitalization and geographic and product diversification	• Three subsample periods • Division into small and large firms • Firm level and portfolio level	• Division into life and non-life insurers • Division into insurers with high and low exposures to the German and U.S. insurance market	• Subsection using robust-to-outliers regression to examine effect of insurers' duration gap on the Solvency II capital ratio	• Lagged impact of the yield curve • Subsamples sorted by insurer type • Tests for asymmetric sensitivities
Hypotheses	• Relationship between the rate of insolvency and several exogenous factors, e.g. rate of insolvency is either positively or negatively realted to long-term interest rates	• No interest rate effects • Interest rate sensitivity does not change across varying interest rate environments	• Significance of interest rate sensitivity of insurers • Equality of systematic risk and interest rate sensitivity across insurer segments	• Higher interest rate risk as interest rates decrease • Lower stock returns as interst rates decrease	• U.S. life insurers should be more sensitive to interest rates compared to U.K. life insurers as interest rates decrease	• Presence of interest rate risk for life insurers • Interest rate risk differs significantly between insurers with different attributes	• The yield curve has a direct and lagged influence on the equity returns of insurance companies • The impact of yield curve changes on equity returns differs across insurers
Results							
Effect of interest rate decrease	• Decrease in the rate of insolvency	• Increase in the stock returns of life insurers • Affects equity values of life insurers • Stronger effect on life insurers with low market betas	• Rising stock returns of all insurers • Life insurers with largest sensitivities • Lower interest rate sensitivities for insurance companies who have higher geographic and product diversification	• Increase in the interest rate risk stronger for firms holding more assets • Risk exposure varies for large firms • Risk exposure remains balanced for small firms	• Increase in the interest rate risk for U.S. life insurers • Interest rate risk for U.K. life insurers remained roughly unchanged	• Significant effect on insurers • Interest rate movements are negatively related to insurers' size, growth rate and solvency ratios	• Falling yield curve slope (e.g., through a decrease in long-term rates) significantly increases equity returns • Larger sensitivities for life insurers
Effect of different monetary policy regimes		• Interest rate sensitivity of life insurer stock returns varies across regimes					• Asymmetric sensitivities towards changes in the yield curve slope

Table A2: Overview of chosen empirical literature on the interest rate risk of insurance companies

Name	Country	Observations	Mean stock returns	SD of stock returns	Min. stock return	Max. stock return
Aetna Inc New	USA	1623	0.11%	1.47%	-8.20%	11.54%
Affirmative Insurance Hldgs Inc	USA	664	1.83%	26.98%	-75.00%	200.00%
Aflac Inc	USA	1621	0.06%	1.13%	-7.36%	7.76%
Alleghany Corp De	USA	1623	0.05%	1.05%	-4.56%	6.79%
Allstate Corp	USA	1623	0.09%	1.04%	-10.15%	6.12%
Ambac Financial Group	USA	1290	0.03%	2.54%	-16.61%	18.28%
American Equity Invt Life Hldg C	USA	1621	0.10%	1.96%	-15.34%	11.23%
American Financial Group Inc New	USA	1623	0.08%	0.94%	-4.61%	6.31%
American Independence Corp	USA	902	0.26%	3.46%	-15.75%	42.03%
American National Ins Co	USA	1623	0.05%	1.24%	-8.39%	9.13%
Ameriprise Financial Inc	USA	1623	0.09%	1.56%	-10.22%	12.42%
Amerisafe Inc	USA	1617	0.08%	1.55%	-12.00%	11.94%
Amtrust Financial Services Inc	USA	1619	0.06%	2.35%	-19.23%	25.03%
Anthem Inc	USA	1623	0.10%	1.47%	-12.07%	7.68%
Assurant Inc	USA	1623	0.07%	1.33%	-13.41%	7.59%
Atlantic American Corp	USA	1445	0.06%	2.66%	-14.69%	22.07%
Atlas Financial Holdings Inc	USA	1321	0.06%	2.38%	-40.96%	16.34%
Berkley W R Corp	USA	1623	0.06%	0.96%	-4.65%	5.54%
Berkshire Hathaway Inc Del	USA	1623	0.06%	0.95%	-5.89%	3.90%
C N A Financial Corp	USA	1617	0.06%	1.15%	-6.91%	6.93%
Cigna Corp	USA	1623	0.10%	1.46%	-11.45%	11.74%
Cincinnati Financial Corp	USA	1623	0.07%	1.03%	-6.65%	4.70%
Citizens Inc	USA	941	0.08%	1.68%	-9.81%	6.00%
Cno Financial Group	USA	1623	0.09%	1.70%	-8.75%	7.70%
Conifer Holdings Inc	USA	681	-0.03%	2.99%	-16.20%	10.71%
Danielson Holding Corp	USA	1603	0.04%	1.49%	-12.41%	11.11%
Donegal Group Inc	USA	1623	0.02%	1.48%	-9.27%	10.78%
E M C Insurance Group Inc	USA	1623	0.07%	1.66%	-10.03%	8.92%
Eastern Insurance Holdings Inc	USA	488	0.13%	1.39%	-4.62%	15.41%
Employers Holdings Inc	USA	1623	0.07%	1.71%	-15.35%	18.70%
Erie Indemnity Co	USA	1623	0.05%	1.17%	-8.99%	5.86%
F B L Financial Group Inc	USA	1623	0.08%	1.50%	-7.29%	9.61%
Fidelity National Finl Inc New	USA	1623	0.10%	1.21%	-4.65%	6.17%
First Acceptance Corp	USA	1551	0.07%	3.96%	-24.02%	23.21%
First American Finl Corp New	USA	1621	0.11%	1.35%	-6.97%	6.49%
Fortegra Financial Corp	USA	710	0.08%	2.22%	-8.45%	40.60%
Foundation Health Systems Inc	USA	1190	0.21%	4.76%	-27.66%	95.33%
Gainsco Inc	USA	486	0.47%	5.14%	-20.00%	20.00%
Genworth Financial Inc	USA	1615	0.04%	3.44%	-38.45%	27.63%
H C C Insurance Holdings Inc	USA	954	0.13%	1.42%	-3.71%	36.44%
Hallmark Financial Services Inc	USA	1612	0.04%	1.77%	-8.38%	10.21%
Hartford Financial Svcs Grp Inc	USA	1622	0.09%	1.45%	-9.29%	7.64%
Heritage Insurance Holdings Inc	USA	1026	0.07%	2.51%	-16.96%	21.56%
Horace Mann Educators Corp New	USA	1619	0.09%	1.38%	-6.15%	6.89%
Humana Inc	USA	1623	0.09%	1.65%	-12.69%	20.31%
Independence Holding Co New	USA	1623	0.12%	2.07%	-8.26%	15.15%
Infinity Property & Casualty Cor	USA	1623	0.07%	1.40%	-5.80%	19.78%
Investors Title Co	USA	1582	0.12%	1.84%	-9.07%	12.10%
Kansas City Life Ins Co	USA	1530	0.03%	1.43%	-11.57%	11.00%
Kemper Corp De	USA	1623	0.08%	1.63%	-19.21%	14.85%
Kingstone Companies Inc	USA	1546	0.14%	2.41%	-13.84%	20.79%
Kinsale Capital Group Inc	USA	481	0.25%	1.89%	-6.01%	9.44%
Lincoln National Corp	USA	1623	0.09%	1.82%	-13.30%	9.21%
Loews Corp	USA	1623	0.02%	0.98%	-5.18%	4.90%
Lorillard Inc	USA	859	0.10%	1.38%	-10.49%	10.40%
M B I A Inc	USA	1621	0.03%	3.20%	-23.44%	45.37%
M G I C Investment Corp Wis	USA	1619	0.13%	3.44%	-64.08%	27.76%
Markel Corp	USA	1621	0.06%	1.01%	-10.25%	6.22%
Meadowbrook Insurance Group Inc	USA	848	0.01%	2.17%	-20.66%	18.66%
Mercury General Corp New	USA	1623	0.03%	1.28%	-12.39%	8.84%
Metlife Inc	USA	1623	0.05%	1.61%	-10.71%	7.10%
Molina Healthcare Inc	USA	1623	0.13%	2.57%	-31.02%	26.40%
National General Holdings Corp	USA	1074	0.07%	1.58%	-7.27%	15.08%
National Interstate Corp	USA	1209	0.06%	2.16%	-17.67%	30.85%
National Security Group Inc	USA	1304	0.10%	3.10%	-12.38%	18.66%
National Western Life Ins Co	USA	1622	0.06%	1.36%	-6.97%	6.29%
Navigators Group Inc	USA	1614	0.06%	1.36%	-12.06%	17.16%
Old Republic International Corp	USA	1621	0.08%	1.32%	-12.05%	8.29%

Table A3: Descriptive stock return statistics of 98 U.S. insurers in the sample (first part)

Name	Country	Observations	Mean stock returns	SD of stock returns	Min. stock return	Max. stock return
P I C O Holdings Inc	USA	1610	0.00%	1.92%	-11.29%	11.51%
Phoenix Cos Inc	USA	1105	0.11%	5.48%	-22.23%	149.49%
Primerica Inc	USA	1621	0.11%	1.56%	-7.58%	12.45%
Principal Financial Group Inc	USA	1623	0.07%	1.47%	-10.24%	6.25%
Proassurance Corporation	USA	1619	0.03%	1.07%	-12.55%	8.03%
Progressive Corp Oh	USA	1622	0.09%	1.03%	-4.96%	5.79%
Protective Life Corp	USA	766	0.17%	1.56%	-7.27%	18.12%
Prudential Financial Inc	USA	1623	0.06%	1.58%	-10.06%	6.97%
R L I Corp	USA	1622	0.07%	1.26%	-12.00%	7.34%
Radian Group Inc	USA	1623	0.15%	2.64%	-15.83%	22.42%
Reinsurance Group Of America Inc	USA	1623	0.07%	1.16%	-10.83%	5.06%
Safety Insurance Group Inc	USA	1619	0.07%	1.16%	-6.74%	5.59%
Selective Insurance Group Inc	USA	1621	0.09%	1.33%	-7.86%	8.38%
Stancorp Financial Group Inc	USA	1042	0.13%	1.92%	-11.03%	47.93%
State Auto Financial Corp	USA	1621	0.08%	2.03%	-11.02%	26.53%
Stephan Company	USA	673	0.22%	5.78%	-29.03%	54.55%
Stewart Information Svcs Corp	USA	1620	0.10%	1.70%	-10.23%	16.05%
Symetra Financial Corp	USA	1013	0.15%	1.47%	-7.10%	10.27%
Torchmark Corp	USA	1623	0.07%	0.99%	-4.92%	3.97%
Travelers Ppty Casualty Corp New	USA	1623	0.06%	1.00%	-6.05%	4.96%
Triple S Management Corp	USA	1621	0.07%	2.32%	-17.86%	23.81%
Unico American Corp	USA	1275	0.01%	2.60%	-13.56%	21.88%
United Fire Group Inc	USA	1619	0.09%	1.88%	-11.86%	15.13%
United Insurance Holdings Corp	USA	1469	0.15%	2.81%	-23.98%	33.33%
Unitedhealth Group Inc	USA	1623	0.11%	1.29%	-5.65%	6.90%
Universal American Financial Cor	USA	1296	0.04%	2.16%	-19.28%	14.05%
Universal Insurance Holdings Inc	USA	1618	0.20%	2.72%	-30.73%	16.74%
Unum Group	USA	1623	0.05%	1.47%	-16.95%	7.69%
Voya Financial Inc	USA	1291	0.08%	1.70%	-10.55%	11.19%
Wellcare Health Plans Inc	USA	1623	0.12%	2.09%	-19.83%	18.42%

Table A3: Descriptive stock return statistics of 98 U.S. insurers in the sample (second part)

Name	Country	Observations	Mean stock returns	SD of stock returns	Min. stock return	Max. stock return
UNIQA Insurance Group AG	Austria	1603	0.02%	1.59%	-10.10%	9.84%
Vienna Insurance Group AG	Austria	1607	0.01%	1.58%	-17.93%	7.15%
Ageas SA	Belgium	1658	0.11%	1.53%	-9.75%	10.65%
KBC Groep NV	Belgium	1658	0.15%	2.21%	-13.88%	10.71%
Jadransko Osiguranje dd	Croatia	494	0.15%	4.23%	-29.83%	47.19%
Atlantic Insurance Company	Cyprus	525	0.29%	3.85%	-10.00%	11.61%
Alm Brand A/S	Denmark	1472	0.17%	1.74%	-7.17%	14.08%
Topdanmark A/S	Denmark	1604	0.08%	1.19%	-7.03%	8.92%
Tryg A/S	Denmark	1604	0.08%	1.23%	-6.63%	7.75%
Sampo Plc	Finland	1627	0.08%	1.17%	-9.40%	4.86%
April SA	France	1633	0.03%	1.57%	-6.38%	10.03%
Axa SA	France	1658	0.08%	1.75%	-15.48%	7.55%
CNP Assurances SA	France	1654	0.08%	1.58%	-8.49%	11.73%
Coface SA	France	1024	0.03%	2.05%	-29.73%	8.87%
Scor SE	France	1655	0.06%	1.25%	-6.93%	5.61%
Allianz SE	Germany	1644	0.08%	1.29%	-10.17%	6.04%
Muenchener Rueckversicherungs G. AG	Germany	1644	0.07%	1.15%	-7.05%	4.94%
Nuernberger Beteiligungs AG	Germany	1527	0.04%	1.22%	-6.17%	7.31%
Rheinland Holding AG	Germany	1063	0.11%	3.44%	-12.34%	16.36%
Talanx AG	Germany	1451	0.06%	1.38%	-5.59%	5.23%
Wuestenrot & Wuerttembergische AG	Germany	1612	0.04%	1.64%	-7.87%	7.48%
European Reliance General Ins. Com. SA	Greece	1337	0.23%	3.29%	-16.43%	19.90%
CIG Pannonia EletBiztosito Nyrt	Hungary	1503	0.02%	2.44%	-12.83%	14.99%
Vatryggingafelag Islands hf	Iceland	1213	0.06%	1.18%	-5.49%	9.22%
FBD Holdings Plc	Ireland	1605	0.06%	2.04%	-20.54%	14.84%
Permanent TSB Group Holdings plc	Ireland	1528	0.15%	5.66%	-25.70%	39.16%
Assicurazioni Generali SpA	Italy	1645	0.04%	1.79%	-16.77%	9.35%
Societa Cattolica di Assicurazione Sc	Italy	1638	0.02%	1.94%	-17.43%	17.30%
UnipolSai Assicurazioni SpA	Italy	1643	0.15%	5.20%	-58.82%	119.81%
Vaudoise Assurances Holding SA	Italy	1607	0.06%	1.26%	-5.05%	8.52%
Vittoria Assicurazioni SpA	Italy	1628	0.12%	1.52%	-8.14%	19.73%
Mapfre Middlesea Plc	Malta	388	0.34%	3.38%	-16.25%	14.93%
Aegon NV	Netherlands	1658	0.07%	1.98%	-11.37%	13.32%
ASR Nederland NV	Netherlands	526	0.14%	1.37%	-7.43%	6.76%
Delta Lloyd NV	Netherlands	371	0.03%	5.38%	-32.72%	47.89%
NN Group NV	Netherlands	1018	0.08%	1.40%	-8.03%	8.77%
Gjensidige Forsikring ASA	Norway	1624	0.08%	1.22%	-8.15%	12.28%
Insr Insurance Group ASA	Norway	1001	-0.11%	3.89%	-54.56%	22.42%
Protector Forsikring ASA	Norway	1484	0.16%	2.02%	-9.91%	15.61%
Storebrand ASA	Norway	1627	0.07%	2.15%	-14.25%	12.36%
Powszechny Zaklad Ubezpieczen SA	Poland	1652	0.05%	1.49%	-6.59%	7.13%
Pozavarovalnica Sava dd	Slovenia	1399	0.12%	2.07%	-10.47%	12.39%
Zavarovalnica Triglav dd	Slovenia	1587	0.12%	1.59%	-7.94%	8.91%
Grupo Catalana Occidente SA	Spain	1652	0.09%	1.70%	-7.94%	13.26%
Mapfre SA	Spain	1656	0.04%	1.88%	-9.30%	14.14%
Baloise Holding Ltd	Switzerland	1623	0.08%	1.12%	-7.41%	4.57%
Chubb Ltd	Switzerland	1625	0.05%	0.99%	-4.83%	4.54%
Helvetia Holding AG	Switzerland	1619	0.06%	1.16%	-6.96%	5.65%
Swiss Life Holding AG	Switzerland	1621	0.11%	1.38%	-8.10%	8.73%
Swiss Re AG	Switzerland	1620	0.07%	1.10%	-5.63%	4.26%
Zurich Insurance Group AG	Switzerland	1627	0.05%	1.13%	-10.82%	6.57%
Admiral Group PLC	UK	1634	0.09%	1.43%	-7.68%	10.00%
Aon PLC	UK	1632	0.08%	1.07%	-5.76%	6.11%
Aviva PLC	UK	1634	0.06%	1.63%	-15.68%	8.13%
Beazley PLC	UK	1632	0.13%	1.39%	-8.96%	6.85%
Chesnara PLC	UK	1624	0.09%	1.77%	-14.51%	8.85%
Direct Line Insurance Group PLC	UK	1436	0.08%	1.23%	-7.16%	12.62%
esure Group PLC	UK	1317	0.04%	1.74%	-21.02%	9.82%
Hansard Global PLC	UK	1632	0.01%	2.37%	-14.36%	13.67%
Hastings Group Holdings PLC	UK	682	0.08%	1.53%	-12.03%	6.82%
Legal & General Group PLC	UK	1633	0.09%	1.48%	-20.26%	7.88%
Old Mutual PLC	UK	1634	0.05%	1.65%	-10.83%	6.92%
Personal Group Holdings PLC	UK	1079	0.10%	1.44%	-6.98%	11.56%
Phoenix Group Holdings	UK	1607	0.07%	1.43%	-11.54%	11.17%
Prudential PLC	UK	1632	0.09%	1.60%	-10.53%	9.33%
RSA Insurance Group PLC	UK	1633	0.05%	1.49%	-20.84%	18.43%
Saga PLC	UK	1029	-0.01%	1.60%	-21.41%	10.78%
St. James's Place PLC	UK	1630	0.10%	1.63%	-16.18%	7.24%
Standard Life Aberdeen PLC	UK	1634	0.06%	1.59%	-17.30%	8.07%

Table A4: Descriptive stock return statistics of 69 European insurers in the sample

Country	Mean CDS return	SD of CDS returns	Min. CDS return	Max. CDS return
Austria	-0.09%	3.69%	-89.27%	53.93%
Belgium	-0.14%	2.89%	-75.37%	31.95%
Denmark	-0.09%	3.45%	-72.49%	39.26%
Finland	-0.12%	3.05%	-26.19%	34.71%
France	-0.11%	2.97%	-82.49%	33.01%
Germany	-0.14%	3.18%	-60.16%	41.14%
Greece	-0.10%	2.96%	-83.96%	13.89%
Hungary	-0.06%	1.94%	-12.51%	25.26%
Iceland	-0.10%	1.62%	-10.19%	12.88%
Ireland	-0.07%	4.45%	-93.66%	65.55%
Italy	-0.14%	1.76%	-11.26%	13.12%
Netherlands	-0.12%	2.92%	-26.10%	36.00%
Norway	-0.16%	2.42%	-15.86%	32.09%
Poland	-0.09%	1.43%	-14.55%	9.69%
Slovenia	-0.07%	1.68%	-24.58%	25.67%
Spain	-0.09%	1.77%	-19.46%	19.60%
Switzerland	-0.09%	1.83%	-10.37%	18.05%
UK	-0.08%	2.43%	-13.39%	39.81%
USA	0.15%	6.97%	-31.49%	106.19%

Table A5: Descriptive statistics of insurers' CDS exposures per country

Variable	r(Stock index$_{o,t}$)				r(Volatility index$_{o,t}$)			
Country	Mean	SD	Min	Max	Mean	SD	Min	Max
Austria	0.04%	1.13%	-7.04%	4.79%	-	-	-	-
Belgium	0.04%	0.95%	-6.40%	3.87%	-	-	-	-
Denmark	0.06%	1.04%	-6.56%	5.28%	-	-	-	-
Croatia	0.00%	0.57%	-3.06%	3.45%	-	-	-	-
Cyprus	-0.06%	2.23%	-14.38%	17.19%	-	-	-	-
Finland	0.05%	1.11%	-8.38%	4.32%	-	-	-	-
France	0.04%	1.11%	-8.04%	4.75%	0.20%	7.04%	-39.68%	71.43%
Germany	0.04%	1.11%	-6.82%	4.97%	0.15%	6.12%	-30.93%	50.81%
Greece	0.03%	2.07%	-16.23%	11.27%	-	-	-	-
Hungary	0.05%	1.05%	-6.07%	5.09%	-	-	-	-
Ireland	0.06%	1.02%	-9.89%	4.55%	-	-	-	-
Italy	0.03%	1.48%	-12.48%	6.59%	-	-	-	-
Netherlands	0.04%	0.97%	-5.70%	4.05%	0.19%	6.75%	-27.53%	54.61%
Norway	0.05%	1.02%	-5.20%	4.51%	-	-	-	-
Spain	0.01%	1.31%	-12.35%	6.06%	-	-	-	-
Switzerland	0.03%	0.89%	-8.67%	3.42%	0.15%	5.79%	-27.42%	43.63%
UK	0.02%	0.84%	-4.67%	3.58%	0.03%	0.95%	-5.19%	5.33%
Europe	0.03%	1.06%	-7.66%	4.61%	0.19%	6.82%	-35.26%	60.05%
US	0.05%	0.77%	-4.10%	3.90%	0.28%	8.10%	-25.91%	115.60%

Table A6: Descriptive statistics of variables measuring stock index returns

	Life Share$_{i,y}$			Unit-linked Share$_{i,y}$			Solvency Ratio$_{i,y}$	RBC Ratio$_{i,y}$
Sample	Europe	U.S.	joint	Europe	U.S.	joint	Europe	U.S.
2011	0.432	0.532	0.5115	0.088	0.096	0.147	-	-
2012	0.4	0.529	0.51	0.105	0.097	0.163	-	-
2013	0.416	0.5	0.501	0.125	0.11	0.174	-	-
2014	0.408	0.499	0.502	0.12	0.185	0.174	-	-
2015	0.403	0.456	0.515	0.135	0.174	0.172	1.943	4.619
2016	0.408	0.475	0.524	0.125	0.137	0.16	2.022	4.486
2017	0.463	0.562	0.534	0.105	0.143	0.18	2.069	4.15

Table A7: Medians from insurer-specific balance sheet variables

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