Investigating the Effects of Interest Rate Movements on the Performance of Insurance Companies

Master's Thesis

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List of Abbreviations

ALM	Asset Liability Management
AoL	Assets over Liabilities
ARCH	Autoregressive Conditional Heteroscedasticity
BaFin	Bundesanstalt für Finanzdienstleistungsaufsicht
BCBS	Basel Committee on Banking Supervision
BoE	Bank of England
CDS	Credit Default Swap
CI	Confidence Interval
COVID-19	Coronavirus Disease 2019
EBA	European Banking Authority
ECB	European Central Bank
EIOPA	European Insurance and Occupational Pensions Authority
ESMA	European Securities and Markets Authority
ESRB	European Systemic Risk Board
ETF	Exchange-Traded Fund
FDIC	Federal Deposit Insurance Corporation
FED	Federal Reserve
FIO	Federal Insurance Office
FSOC	Financial Stability and Oversight Council
GAAP	Generally Accepted Accounting Principles
GARCH-M	Generalized Autoregressive Conditional Heteroscedasticity-in-Mean
G20	Group of Twenty
IAIS	International Association of Insurance Supervisors

ICPs	Insurance Core Principles
IFRS	International Financial Reporting Standards
IMF	International Monetary Fund
IOSCO	International Organization of Securities Commissions
MBS	Mortgage-Backed Security
NAIC	National Association of Insurance Commissioners
OECD	Organisation for Economic Co-operation and Development
ORSA	Own Risk and Solvency Assessment
P&C	Property and Casualty
QE	Quantitative Easing
RBC	Risk-Based Capital
RSR	Regular Supervisory Report
SCR	Solvency Capital Requirement
SFCR	Solvency and Financial Condition Report

List of Symbols

α	Intercept
β	Market return coefficient
β_1	Market return coefficient for non-life insurer sample
β_2	Market return coefficient for life to non-life difference
β_3	Market return coefficient for high German exposure to low German exposure difference
β_4	Market return coefficient for high German exposure to low German exposure × life to non-life difference
β_{normal}	Market return coefficient for normal-rate period
β_{low}	Market return coefficient for low-rate period to normal-rate period difference
γ	Bond return coefficient
γ_1	Bond return coefficient for non-life insurer sample
γ_2	Bond return coefficient for life to non-life difference
γ_3	Bond return coefficient for high German exposure to low German exposure difference
γ_4	Bond return coefficient for high German exposure to low German exposure × life to non-life difference
γ_{normal}	Bond return coefficient for normal-rate period
γ_{low}	Bond return coefficient for low-rate period to normal-rate period difference
C	Coupon payment
D	Macaulay duration
D_{Mod}	Modified duration
$\varepsilon_{i,t}$	Mean zero error term

F	Face value
$German_i$	Indicator variable for the exposure of insurer i to the insurance markets in Germany and the United States
$Life\ share_{i,t}$	Share of premiums earned from life and health insurance contracts of insurer i at time t
LTG_i	Indicator variable for the prevalence of long-term guarantees in the life insurance sector of the home country of insurer i
Mkt	Capital requirement for the Solvency II market risk module
Mkt_{int}	Capital requirement for the Solvency II interest rate risk submodule
NAV	Net asset value of assets minus liabilities
r	Interest rate p.a.
$R_{i,t}$	Stock return of insurer i at time t
$R_{m,t}$	Stock market index return at time t
$R_{10,t}$	Return on a 10-year government bond at time t
R^2	Coefficient of determination
t	Time index in years
T	Time to maturity in years

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1 Introduction

The global financial crisis of 2007 led central banks in many countries to decrease interest rates in order to facilitate borrowing activity and thereby stimulate their economies. This had mostly positive effects on large parts of the real economy, as it allowed businesses to obtain affordable funding and make necessary investments, which would otherwise not have been possible due to poor operating results. The decline in interest rate levels however also had a significant impact on insurance sectors around the world, which often were not prepared for a prolonged downturn in interest rates to an extent, as it materialized in the following decade.

With 15 percent of global assets under management[1], and a provision of systemically important services to other industries[2], the insurance sector plays an essential role for the functioning of the economy. Its business model revolves around the collection of unconditional premiums from policyholders in exchange for the promise to pay their claims in case of agreed-upon events. Because of this concept, insurers are typically exposed to substantial liabilities, which can last up to several decades for life insurers.

The ability of both life and non-life insurers to meet their obligations is dependent on their financial health. As for other financial service providers, the lower interest rates negatively affected the investment returns of both types of insurers in the years after the crisis. However, life insurers were particularly sensitive to changes in interest rates because of the long-term nature of their assets and liabilities. According to the related literature, this sensitivity is even higher if life insurers are involved in insurance products with minimum guaranteed rates of return or options for policyholders to change the duration of their contracts.

If life insurers are not prepared for a significant decrease in interest rates, a prolonged low-yield environment could hurt their solvency position, and thereby threaten their ability to meet their obligations towards policyholders. Mismatches between many insurers' asset and liability durations however indicate high exposures to interest rate risk. The situation, which arose in recent years, therefore, has the potential to sustainably impede financial stability.

[1] Boston Consulting Group (2020), p. 4.
[2] ECB (2009).

These circumstances have raised the attention of both policymakers and researchers on the topic of interest rate risk in the insurance industry. Works by Brewer, Carson, Elyasiani, Mansur, and Scott (2007), Carson, Elyasiani, and Mansur (2008), and Berends, McMenamin, Plestis, and Rosen (2013) have investigated the interest rate sensitivities of life insurers and find varying sensitivities over time and based on insurer size, as well as market risk and financial strength. Serra and Harris (2013), Kablau and Weiß (2014), Berdin and Gründl (2015), and Möhlmann (2017) studied interest rate risk of life insurers in the German market and find significant exposures, which have the potential to erode their solvency situation.

This work contributes to the research on interest rate risk in insurance companies through a detailed analysis of the sensitivities of life and non-life insurers' profitabilities to changes in available long-term interest rates. The analysis is based on a two-factor regression approach, provided by Hartley, Paulson, and Rosen (2016), who analyze the interest rate sensitivities of publicly listed insurers from the United States, the United Kingdom, and continental Europe between 2002 and 2015. They find higher sensitivities for life insurers that make use of guaranteed products and policyholder options than for those, which do not. The goal of this work is to replicate their results, while also extending their approach by including additional regression variables, a larger number of insurers from different locations, a longer timeframe of the analysis, and a second dataset, based on daily instead of weekly data.

The work is structured as follows: Chapter 2 provides an introduction to interest rate risk. Chapter 2.1 thereby discusses the causes and potential remedies for interest rate risk in insurance companies, while chapter 2.2 compares the regulatory frameworks for insurers in Europe and the United States. Chapter 3 describes the employed regression approach and presents information on the insurer samples, used in chapter 4. Chapter 4 then reports the regression results in four subchapters: Chapter 4.1 compares interest rate sensitivities in the United States and the United Kingdom. Chapter 4.2 implements a robustness check for the previous results with a sample of continental European insurers. Chapter 4.3 compares the sensitivities in the continental European sample with bottom-up measures of interest rate risk, provided by the European Insurance and Occupational Pensions Authority ("EIOPA"). Chapter 4.4 reports additional results for seven further samples of insurance companies from different regions around the world. Chapter 5 summarizes the results and concludes the work.

2 Institutional Background

2.1 Interest Rate Risk in the Insurance Sector

Insurance companies provide protection to their policyholders against a wide variety of hazards. Depending on the focus of their business, they can offer products that compensate policyholders in the case of accidents, damage to their property, declining health, or even loss of life. While property and casualty ("P&C") insurers typically provide short-term protection for tangible assets, life insurers rather engage in long-lasting contracts with their policyholders, including annuities, financing products, as well as traditional life insurance[3].

The business model for all of these products involves the collection of premiums from policyholders, which are then used to compensate them, should they become subject to a loss event that was predetermined in their contract. Insurance policies can therefore be compared to stochastic debt instruments, as the amount and timing of compensation payments are unknown at the beginning of the contract term. During the term, insurers thereby practically borrow money from their policyholders for a service, they have not yet delivered. This causes insurers to build up significant liabilities, which dictate the way, they invest their funds[4].

Life insurance products are often used as pension schemes or lifelong investment plans. The time span between their issuance and the associated reimbursements can therefore extend up to several decades. Accordingly, life insurers must ensure that premium payments are invested in a way that will benefit the likelihood of them being able to settle their future obligations. However, both the current values of insurers' assets and their liabilities are subject to change due to market forces. If changes in interest rates have the potential to increase the present value of an insurer's liabilities by a larger margin than the present value of its assets, this exposes the insurer to interest rate risk[5].

In the related literature, there is no explicit definition of interest rate risk. Brewer et al. define interest rate risk as "the degree of exposure, or elasticity, of insurer net worth to

[3] Berends et al. (2013, p. 49-55) provide a detailed overview of the most common life insurance products and the interest rate risk, attached to them.
[4] Berends et al. (2013), p. 47-49; Brewer et al. (2007), p. 403.
[5] Cf. Holsboer (2000). Quoted according to Kablau and Weiß (2014), p. 2.

changes in the interest rate" [6]. The insurer net worth thereby refers to the difference between the present value of an insurer's assets and its liabilities. Other sources provide different interpretations of the term[7]. However, this definition best describes interest rate risk in the sense, it is referred to in this study.

Since the advent of the low interest rate environment, during the 2007global financial crisis, many refer to interest rate risk as the most pressing threat to the solvency situation of life insurers[8]. To comprehend why life insurers are particularly vulnerable to it, it might be helpful to first understand how changes in interest rates influence the present value of assets and liabilities: Term 1 illustrates how the present value PV of a coupon bond depends on the applied discount rate r. For this example, r is assumed to follow a flat term structure[9].

$$PV = \sum_{t=1}^{T} \frac{C}{(1+r)^t} + \frac{F}{(1+r)^T}, \tag{1}$$

where

C	= Yearly coupon payment,
F	= Face value of the coupon bond,
t	= Time index in years,
T	= Time to maturity in years.

The equation demonstrates that a higher discount rate results in lower present values, and vice versa. This effect is amplified for higher maturities, making the present value of cash flows, which only take place at a point in time, far in the future, more sensitive to changes in the discount rate. The length of the time between now and the point in time, at which a cash flow takes place, is therefore suited to estimate the sensitivity of its present value to changes in interest rates. To estimate the interest rate sensitivity for assets, involving

[6] Brewer et al. (2007), p. 403.

[7] For example, the Federal Deposit Insurance Corporation ("FDIC", 2016, p. 61) distinguishes between interest rate risk in general and yield curve risk as "the possibility that an instrument's value will fluctuate in response to a nonparallel yield curve shift". As the causes for the sensitivities of insurers' stock returns to changes in bond returns, assessed in chapter 4, cannot be identified clearly, any form of change in interest rates hereafter is interpreted as a potential threat to insurers, which are subject to interest rate risk.

[8] Feodoria and Förstemann (2015), p. 3; Pelizzon and Sottocornola (2018, p. 0).

[9] Usually, interest rates increase for higher maturities, as investors are compensated for the flexibility, they give up, when making long-term investments. For further information on term structures and changes to them due to the global financial crisis, see Cox et al. (1985) and Medeiros and Rodríguez (2011).

multiple cash flows, however, different payment dates have to be taken into account. Here, the concept of the Macaulay duration D proves useful: It displays the average maturities for all cash flows, an asset represents, weighted by the present value of each cash flow. The Macaulay duration for the coupon bond, introduced earlier, is depicted in term 2[10]:

$$D = \frac{\sum_{t=1}^{T} \frac{t * C}{(1+r)^t} + \frac{T * F}{(1+r)^T}}{PV} \tag{2}$$

The concept of duration is the most commonly used measure of interest risk in the insurance sector. Insurers can use an asset's Macaulay duration to obtain its so-called "modified duration" D_{Mod}, following term 3[11]. This version of the duration describes the relative change in the present value of an asset due to a change in the relevant interest rate, as indicated by term 4[12]. From this measure, term 5 is derived[13]. This approximation allows insurers to estimate the relative change in the present value of their assets and liabilities for any given change in interest rates.

$$D_{Mod} = \frac{D}{(1+r)} \tag{3}$$

$$D_{Mod} = -\frac{\partial PV}{\partial r} * \frac{1}{PV} \tag{4}$$

$$\frac{\Delta PV}{PV} \approx -D_{Mod} * \Delta r \tag{5}$$

The modified duration aims at capturing the sensitivity of an asset's present value to changes in the applied discount rate. The relationship between these two variables is illustrated in figure 1, employing a 10-year zero-coupon bond with a face value of USD 100 at an assumed interest rate level of 5 percent p.a. The black line depicts the actual change in the present value of the bond, while the grey line displays the approximated price change when using term 5. It becomes apparent that the approximation describes a linear relationship, while the true relationship is of a convex nature. For low changes in the applied interest rate, the approximation still provides relatively good estimations. If

[10] For further information on the origin of the duration concept, see Weil (1973).
[11] Kritzman (1992), p. 18.
[12] Möhlmann (2017), p. 3.
[13] Möhlmann (2017), p. 4.

the employed rate change however increases in magnitude, the approximation underestimates the increase in value or overestimates the decrease in value. This estimation error is commonly referred to as the “convexity problem”. This issue can have a significant influence on the interest rate sensitivity of insurers’ portfolios if these disregard the convex nature of the relationship between prices and interest rates[14]. In theory, the convexity problem should force insurers to rebalance their portfolios frequently to avoid large changes in interest rates, relative to those, available at the last rebalancing date. In practice, however, it usually only plays a secondary role in the management of interest rate risk[15].

In order to reduce interest rate risk, insurers mostly focus on “duration matching”: Changes in interest rates only pose a risk to an insurance business, if they have the potential to decrease the present value of its assets, relative to the present value of its liabilities. If insurers are able to invest received policy premiums in a way that creates a portfolio, which reacts to interest rate changes in the same way, their liabilities react, this should cancel out this possibility. In practice, this is approximately achieved through an equal duration of insurers’ assets and liabilities. By matching both durations, insurers can thereby practically “immunize” their net worth against changes in interest rates.

Duration matching plays a much more important role for life insurers than for property and casualty insurers. Contracts, signed by P&C insurers, oftentimes are only valid for one year. The duration of their liabilities is, therefore, very low, limiting their sensitivity to changes in interest rates. The short contract terms furthermore enable P&C insurers to adjust contracts to changing market conditions from year to year. Thereby, they only run a limited risk of incurring significant losses through wrong predictions regarding changes in interest rate levels. Moreover, some of the contract types, offered by P&C insurers, like motor or home insurance, are mandatory for policyholders. While the attractiveness of many life insurance products depends on the returns, they offer, demand for P&C insurance products is relatively independent of the level of available interest rates[16]. Despite their liability-driven operations, P&C insurers, therefore, are only subject to limited amounts of interest rate risk.

[14] Cf. Kritzman (1992), p. 19.
[15] Cf. Brewer et al. (2007), p. 418; Santomero and Babbel (1997), p. 245. Quoted according to Brewer et al. (2007), p. 406.
[16] Berends et al. (2013, p. 68); Moody’s (2015), p. 4.

Life insurers, on the other hand, offer insurance products with much longer contract terms, often involving profit participation mechanisms or guaranteed returns. Domanski, Shin, and Sushko[17], for example, report an average duration of German life insurers' liabilities of 25.2 years in 2014. The present value of life insurers' future obligations is therefore highly sensitive to changes in long-term interest rates. For this reason, the interest rate sensitivity of life insurance companies became the subject of numerous studies and analyses. Overall, most studies conclude a significant positive relationship between the profitability of life insurance companies and available long-term interest rate levels[18].

Duration matching, therefore, is an essential tool for the asset liability management ("ALM") of life insurance companies. Despite their efforts to close the divergence between the durations of their assets and liabilities, many life insurers still show substantially higher durations on their liability sides than on their asset sides. This phenomenon is typically referred to as the "duration gap". Positive duration gaps make life insurers vulnerable to unanticipated and sustained decreases in long-term interest rates[19], as they were observed following the global financial crisis. A decline in the discount rate, used for the valuation of assets and liabilities, raises the present value of long-term liabilities by a larger margin than the present value of shorter-term assets, thereby diminishing the available capital of life insurers. Moreover, duration matching, since it is subject to the convexity problem, is inappropriate to hedge portfolios against severe drops in interest rates, as they occurred after the global financial crisis[20]. Insurers were given only little time to rehedge their portfolios accordingly. Even insurers with low duration gaps thereby might have faced considerable losses.

Since the interest rates in the United States and Europe began to fall, research regarding duration gaps and the influence of the low interest rate environment on life insurance companies picked up the pace. Kablau and Wedow (2011), Kablau and Weiß (2014), and

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[17] Domanski et al. (2017), p. 128.

[18] Cf. Brown et al. (1999, 2001); Briys and Varenne (1997); Cummins and Lamm-Tennant (1994); Staking and Babbel (1995). Quoted according to Brewer et al. (2007, p. 403). Berends et al. (2013); Brewer et al. (2007).

[19] Duration gaps in the insurance sector are defined as the duration of liabilities minus the duration of assets. Although, empirically, life insurance industries in some countries show insignificant or even negative duration gaps, as reported by EIOPA (2014a, p. 17), negative duration gaps are typically only of low magnitude. Interest rate risk due to duration mismatches, therefore, originates mostly in the potential of decreases in interest rates, rather than increases (cf. Möhlmann, 2017).

[20] Hartley et al. (2016, p. 12).

Berdin and Gründl (2015) for example investigate the potential effects of a prolonged low interest rate environment on the solvency situation of German life insurers. These are known to show particularly high duration gaps[21]. While Kablau and Wedow, at a relatively early point in time during the low-rate period, provide a slightly more positive outlook[22], Kablau and Weiß, as well as Berdin and Gründl, report significant increases in the default probabilities for some German life insurers, should the low interest rates persist. As noted by Moody's, these effects however typically only become visible to the public after a delay. In fact, due to differing accounting rules regarding the valuation of liabilities, insurers in some jurisdictions might at first even show a growth in net worth, caused by increases in the present value of their assets. The true consequences of decreased interest rate levels are then only revealed gradually[23].

Other studies examine the homogeneity with which risk management practices are implemented in insurance markets. Möhlmann (2017), for example, finds a wide dispersion between duration gaps of German life insurers. An insurance stress test, conducted by the European Insurance and Occupational Pensions Authority[24], further reveals structural differences between the magnitude of duration gaps between insurers, operating in different member states of the European Union. These results indicate that insurers make use of duration matching to varying degrees[25].

Besides its impact on the value of insurance assets and liabilities, the low-rate environment negatively influenced the performance of life insurers through several other channels: First, life insurers typically hold high amounts of fixed-income securities, like sovereign and corporate bonds. These match their demands, as they can provide safe and predictable cash flows at high maturities. Gründl, Dong, and Gal report that most life insurers in 2014 held on average around 90 percent of their assets in fixed-income securities and loans[26]. Lower interest rates therefore directly affect the future returns on life insurers' investments[27].

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[21] Cf. EIOPA (2014a), p. 17); Moody's (2015), p. 10.
[22] Kablau and Wedow (2011). Quoted according to Pelizzon and Sottocornola (2018, p. 2).
[23] Moody's (2015), p. 4. These accounting practices should not have a significant impact on the results, presented in chapter 4. As this study only focuses on publicly traded insurers, the valuation of liabilities in the used samples is conducted using market values, following the rules of the International Financial Reporting Standards ("IFRS"). Effects of changes in interest rates should therefore be priced in correctly.
[24] EIOPA (2014a, p. 17).
[25] Möhlmann (2017, p. 10) reports that the highest duration gaps occur in the smaller insurers in his sample.
[26] Gründl et al. (2016), p. 11-13.
[27] Briys and Varenne (1997); Staking and Babbel (1995). Quoted according to Brewer et al. (2007, p. 403).

In some countries, these circumstances are aggravated by substantial amounts of outstanding policies with guaranteed return components. As life insurance contracts typically last several decades, large parts of life insurers' currently active policies were written in times with considerably higher interest rates. Guaranteed rates of return on these contracts were designed to yield incomes, which were achievable in the markets at that time. However, interest rates fell considerably since then due to monetary policy interventions by central banks, reacting to the financial crisis. Nowadays, insurers find it much more difficult to reach investment incomes that can match their obligations from contracts with guaranteed returns.

While currently, the returns on some government bonds are even negative, life insurers in many countries on average still have guaranteed rates above 3 percent in their portfolios[28]. If life insurers had prepared for these conditions accordingly, by buying long-term securities with sufficient returns at the time, these contracts were written, guaranteed returns would not pose a major problem today. Many life insurers, however, only partly hedged themselves against falling interest rates. Now, they run the risk of generating investment returns, which fall short of the average promised returns in their portfolios[29]. The difference is directly subtracted from their capital. For this reason, the related literature today refers to disproportionately high guaranteed rates of return as one of the main drivers of interest rate risk[30].

The severity of their impact however is not only dependent on the guaranteed rate and the volume of affected liabilities. Many studies point out reciprocal influences between guaranteed products and options for policyholders to prolong or terminate insurance contracts early[31]. In the case of rising interest rates, these allow policyholders to withdraw from contracts, which were profitable for the insurer, in order to switch to investment products, which offer higher rates of return. In the case of falling interest rates, policyholders are likely to rather prolong their contracts. They thereby can continue to earn high rates of return, even in weak markets. In both cases, policyholder options negatively impact insurer profitability.

[28] Moody's (2015), p. 8.
[29] Holsboer (2000) and Li and Wei (2013) state that the risk, originating from guaranteed products, is amplified by duration mismatches (quoted according to Pelizzon and Sottocornola (2018, p. 2).
[30] Cf. Berends et al. (2013), p. 58; EIOPA (2014a), p. 17; Feodoria and Förstemann (2015), p. 3; Kablau and Weiß (2014), p. 0; Moody's (2015); Pelizzon and Sottocornola (2018, p. 2).
[31] Berdin and Gründl (2015), p. 395; Berends et al. (2013), p. 48, 55, 58; Feodoria and Förstemann (2015), p. 3; Hartley et al. (2016), p. 2.

Beyond the immediate effect on life insurers' profits, policyholder options can raise their interest rate sensitivities: The prolongation of insurance contracts during falling interest rate levels inevitably raises the duration of life insurers' liabilities[32]. Simultaneously, high-yield long-term securities, which were bought at contract issuance, run out. Life insurers thereby both widen their duration gap and the gap between promised and earned returns. Under rising interest rates, this effect would be reversed. In this case, insurers cannot profit from the comparably low guaranteed rates on their outstanding policies. Policyholder options thus shift interest rate sensitivities of life insurers in unfavorable directions. As Hartley et al. point out, their analyses indicate that US-American insurers are likely to have hedged their portfolios against interest rate risk, based on the current duration of their liabilities. They, however, suspect that insurers did not anticipate the exacerbating effects, policyholder options would have on their portfolios in face of substantial shifts in interest rates like they materialized following the financial crisis[33].

Apart from effects on existing life insurer assets and liabilities, several studies identify additional channels through which changes in interest rates can influence the profitability of life insurance companies: Cummins and Lamm-Tennant mention increased costs of capital due to increased leverage if insurance liabilities grow faster than insurance assets[34]. Furthermore, Browne, Carson, and Hoyt note a significant relationship between insurer financial strength and interest rate sensitivities[35]. These results are supported by Möhlmann, who finds a negative correlation between interest rate sensitivity and the size, growth, and solvency situation of insurance companies[36].

Finally, changing interest rates affect the attractiveness of life insurance products towards potential customers. While returns on fixed-income securities are low, life insurers can only offer minimal guaranteed returns. This decreases demand for traditional life insurance products and thereby reduces future income[37]. With global economies currently weakened through the coronavirus disease 2019 ("COVID-19") pandemic, interest rate levels remain low, and life insurers, therefore, look for new ways to create value for their policyholders.

[32] Cf. Berends et al. (2013), p. 49.
[33] Hartley et al. (2016), p. 6.
[34] Cummins and Lamm-Tennant (1994). Quoted according to Brewer et al. (2007), p. 403.
[35] Browne et al. (1999, 2000). Quoted according to Brewer et al. (2007), p. 412.
[36] Möhlmann (2017), p. 0, 3.
[37] Berends et al. (2013), p. 48; Hartley et al. (2016), p. 12f.

In the light of weakened financial conditions of many life insurers, properly implemented ALM and corporate governance processes have risen in importance to prevent further deteriorations of insurer net worth[38]. Besides an appropriate maturity structure, investments of life insurers need to cater to a wide range of other factors that are taken into consideration by portfolio managers. As stated earlier, life insurers typically rely on high amounts of liquid long-term and low-risk fixed-income securities. The current market conditions however make it difficult for them to find instruments that match all of these criteria, while simultaneously delivering returns, which are sufficient to fulfill their financial obligations.

Berends et al. and Hartley et al. add that assets with maturities, which are as high as those of many life insurance liabilities, are much sought after, and may not always be available at acceptable prices[39]. Due to decreasing interest rates, the returns on low-risk corporate and government bonds have fallen substantially since the global financial crisis[40]. This trend was amplified by quantitative easing ("QE") campaigns, through inter alia the European Central Bank ("ECB") and the US Federal Reserve Bank ("FED"), putting additional pressure on prices of long-term debt instruments[41].

Low returns on long-term assets, combined with high guaranteed returns, have led insurers to shift their investments towards other asset classes and bonds with lower ratings, but higher yields[42]. Standard & Poor's (2020) reports that, since the beginning of the financial crisis, US-American insurers have shifted 10 percent of their bond holdings from highly rated categories down to the lower end of the investment grade. Increased risk-taking can however lower average asset durations for life insurers, increase volatility, or expose them to credit risk[43]. Riskier asset classes moreover typically receive less favorable regulatory treatment in risk-based capital systems, as discussed in chapter 2.2. Life insurers, therefore, continue to search for alternative long-term and sufficiently yielding investment opportunities[44].

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[38] Cf. Bezzina et al. (2014); Pritsch et al. (2008). Quoted according to Grima et al. (2017), p. 183. Grima et al. (2017), p. 182-184.
[39] Swiss Re (2012). Quoted according to Möhlmann (2017), p. 16; Berends et al. (2013), p. 48; Hartley et al. (2016), p. 2.
[40] Cf. Greenwood and Vayanos (2010). Quoted according to Möhlmann (2017), p. 16.
[41] Pelizzon and Sottocornola (2018), p. 0, 2.
[42] Becker and Ivashina (2015). Quoted according to Möhlmann (2017), p. 1; Trichet (2005). Quoted according to Kablau and Weiß (2014), p. 2. Assekurata (2015), p. 5.
[43] Kablau and Weiß (2014), p. 2.
[44] ECB (2019).

Since the traditional ALM approach experiences difficulties under the current market conditions, insurers also turn towards other options for the management of financial risks. Especially derivatives, like interest rate swaps, are popular among life insurers[45]. In fact, for 2015, the National Association of Insurance Commissioners ("NAIC") reported 49 percent of derivatives, owned by US-American insurance companies, to fall into the category of interest rate derivatives[46]. But also other types, including options, futures, or – in the case of P&C insurers – catastrophe bonds, are used[47]. Derivatives are available in a wide spectrum of variations, offering insurers the opportunity to find products, which target specific risks at a detailed level. On the other hand, the use of derivatives can entail considerable costs, further lowering the already meager investment income[48].

The current situation of life insurance companies in the persistent low-rate environment forces them to face a trade-off between profitability and security. If an insurer tips too far into one of these directions, this will either expose it to the risk of substantial losses through unanticipated market swings or to a slow decline in its financial condition until all of its capital is used up. Asset managers are therefore challenged to find a balance that both protects the funds, the firm was trusted with by its policyholders, and that can reliably provide the returns, necessary to settle their future claims. As several studies pointed out, this middle way oftentimes involves partial hedges[49], that can protect insurers against moderate changes in interest rates, but which are likely to fail, in the scenario of a further deterioration of available interest rates[50].

[45] Cf. Bloomberg (2019); Liu et al. (2020); NAIC (2018b).
[46] Cf. Berends et al. (2013), p. 58; NAIC (2018b).
[47] NAIC (2018b).
[48] Hoyt (); Colquitt and Hoyt (). Quoted according to Brewer et al. (2007), p. 403.
[49] Quoted according to Möhlmann (2017), p. 16: Timmer (2016) refers to countercyclical investments of insurance companies. Insurers sell debt securities at high prices and buy them at low prices. They intentionally lower their asset duration in regimes of falling interest rates, and thereby expose their portfolio to the risk of further decreases in interest rates.
[50] Cf. Santomero and Babbel (1997). Quoted according to Papadamou and Siriopoulos (2012), p. 47; Berends et al. (2013), p. 58; Brewer et al. (2007), p. 406.

2.2 Insurance Regulation in Europe and the United States

The 2007 global financial crisis not only changed the market environment for financial corporations – it also revealed structural deficiencies in financial regulatory frameworks worldwide. The insurance sector alone suffered losses of an estimated amount of USD 261 billion[51], putting regulators around the globe under pressure to restore its stability and secure the entitlements of policyholders. Since then, the insurance sector has seen a surge in regulatory and supervisory activity, triggering a series of reformation initiatives on national, as well as transnational levels.

From 2007 onwards, the Group of Twenty ("G20") demonstrated its efforts to modernize and harmonize the approach to insurance regulation in a series of semi-annual to annual summits[52]. Representing the world's twenty largest and wealthiest countries, the G20 made far-reaching advancements in the fields of capital and solvency standards, financial group supervision, corporate governance, and the monitoring of systemic risk[53]. While regulatory changes for the banking sector and financial markets were channeled through the Basel Committee on Banking Supervision ("BCBS") and the International Organization of Securities Commissions ("IOSCO"), insurance regulation was primarily handled by the International Association of Insurance Supervisors ("IAIS") in cooperation with the Organisation for Economic Co-operation and Development ("OECD")[54].

The IAIS, through the Insurance Core Principles ("ICPs"), provides a framework for an effective design of insurance supervision with wide global recognition[55]. The ICPs, first released in 2003, are formulated on a basic level that allows laying the foundation for insurance regulation in any country, irrespective of its present economic condition, characteristics of its insurance market, and its maturity of regulatory structures[56]. For this reason, they are suited to promote international regulatory convergence, and became the basis for the changes to the regulatory frameworks in the European Union and the United States, following the global financial crisis[57].

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51 OECD (2011), p. 12.
52 Cf. Bradford and Linn (2011).
53 NAIC (2018a).
54 Marano and Siri (2017), p. 8.
55 Brown (2009), p. 964ff. Quoted according to Marano and Siri (2017), p. 7.
56 Grima et al. (2017), p. 185.
57 Grima et al. (2017), p. 186; Lowry and Rawlings (2005), p. 15f. Quoted according to Marano and Siri (2017), p. 7; Marano and Siri (2017), p. 9.

In 2009, the European Parliament enacted its new framework for insurance regulation and supervision in the form of Directive 2009/138/EG, commonly referred to as "Solvency II"[58]. The updated framework, at its core, assumes many of the topics, addressed by the IAIS' ICPs, but emphasizes policyholder protection as the main goal of all regulatory amendments[59]. While the framework was enacted as early as 2009, it first entered a transitional period, with the full regulatory scope only coming into force by January 2016[60]. During this time, the newly created European Insurance and Occupational Pensions Authority, entrusted with the supervision of Europe's insurance sector, worked in close cooperation with insurance companies to develop and refine the new risk-based approach for the assessment of European insurers' capital adequacy.

With the ultimate goal of financial stability, the European Union created further supervisory institutions for the areas of banking and financial market supervision. In 2010, EIOPA, the European Banking Authority ("EBA"), and the European Securities and Markets Authority ("ESMA") replaced the former "level 3" committees, and since then coordinate their activities in the Joint Committee of the European Supervisory Authorities[61]. Through cooperation, the Committee tries to achieve regulatory and supervisory convergence across all three sectors[62].

Following the model of the Basel II and III frameworks, Solvency II's changes are organized in a three-pillar structure: The first pillar includes quantitative requirements that specify how insurers can assess their individual solvency situations and how to measure a wide range of risk exposures. EIOPA, as the main supervisor for the European insurance sector, here pays particular attention to consider all types of risks, an insurance company could be subject to[63]. In the Solvency II framework, these risks are allocated to a set of risk modules, where the main modules for market risk, counterparty default risk, and underwriting risk each contain multiple submodules, covering specific risk categories[64].

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[58] Cf. European Parliament (2009); European Parliament (2019).
[59] Braunmüller and Warzilek (2011), p. 67. Quoted according to Marano and Siri (2017), p. 7.
[60] Cf. Grima et al. (2017), p. 188.; Solvency kompakt (2014).
[61] Cf. Committee of European Securities Regulators (2005). Quoted according to Marano and Siri (2017), p. 8. The document attests the cooperation between the previous European supervisory authorities. These authorities were absorbed by ESMA, EBA, and EIOPA in 2010.
[62] Joint Committee of the European Supervisory Authorities (2016), p. 1. Quoted according to Marano and Siri (2017), p. 8.
[63] Naghi (2013). Quoted according to Grima et al. (2017), p. 179.
[64] CEIOPS (2010b), p. 26-372.

The capital requirements and solvency assessments in the Solvency II framework focus on the Solvency Capital Requirement ("SCR"), which is calculated via a value at risk approach for each risk module. In the standard model, the value at risk is calculated at a confidence level of 99.5 percent over one year for all risk submodules and then aggregated. The final SCR takes into account risk management practices and is, therefore, smaller than the sum of all modules. Besides the standard model, EIOPA allows insurance companies to use self-developed internal models after an approval process, in which their adequacy is proven. The use of internal models is beneficial for both parties, as insurance companies can lower their SCR, while EIOPA is able to collect more data to refine the standard model. Half measures in the form of partial internal models are possible, it should however be noted that, wherever feasible, Solvency II prescribes strict market-consistent pricing of assets and liabilities[65].

Solvency II's second pillar implements incentives to promote efficient and proactive risk management practices[66]. European policymakers acknowledged risk mitigation effects that come from qualitative, in addition to the existing quantitative requirements. For this reason, they expanded the scope of internal and supervisory review processes to include sound and consistently applied corporate governance standards[67]. The pillar further introduced new reporting requirements, most notably concerning the Own Risk and Solvency Assessment ("ORSA"), which provides detailed information on insurers' internal views regarding their current and future solvency situation[68].

The third pillar addresses general market discipline and disclosure requirements. Insurers are obligated to submit confidential quantitative and qualitative information in the form of Regular Supervisory Reports ("RSR") to insurance supervisors, as well as an annual Solvency and Financial Condition Report ("SFCR"), which is openly available to the public. The reporting requirements are designed to increase transparency in the insurance sector for all kinds of stakeholders, including supervisors, investors, and policyholders. These practices create further incentives for a sound conduct of business in insurance companies[69].

[65] BaFin (2018); Institute and Faculty of Actuaries (2016), p. 1, 7; Grima et al. (2017), p. 188.
[66] Naghi (2013). Quoted according to Grima et al. (2017), p. 181.
[67] Grima et al. (2017), p. 187; Institute and Faculty of Actuaries (2016), p. 2.
[68] BaFin (2017); Institute and Faculty of Actuaries (2016), p. 2, 14.
[69] Cf. BCBS (2001), p. 2f; Grima et al. (2017), p. 181; Institute and Faculty of Actuaries (2016), p. 2, 14; Naghi (2013). Quoted according to Grima et al. (2017), p. 181.

The regulatory reaction in the United States, following the global financial crisis, in many aspects resembles the European reaction: As both the EU and the US held significant power in the G20, the ICPs were strongly influenced by their visions, and their frameworks, therefore, follow them closely[70]. Legislative changes on a nationwide level were driven mainly by the National Association of Insurance Commissioners, featuring the chief insurance regulators from all US-American states and territories. Regulatory and supervisory practices however differ from state to state[71].

In the US, capital requirements are calculated via the Risk-Based Capital ("RBC") system, following similar concepts like Solvency II's economic risk-based approach. NAIC introduced the system already in the early 1990s to replace the previous regime of fixed capital requirements[72]. Despite being updated regularly, the system still earns criticism, inter alia for its use of statutory accounting measures, as opposed to Solvency II's market-consistent valuation[73].

Financial market reforms in the US were implemented primarily through the Wall Street Reform and Consumer Protection Act of 2010, also known as the "Dodd-Frank Act". In addition to stricter regulation for investment banks, dealings in financial derivatives, corporate governance, and group supervision, the Dodd-Frank Act introduced significant changes for the (re-)insurance sector. The NAIC states some of its goals include a consolidation of financial regulation in the US, a focus on systemic risk, market discipline through higher transparency, financial stability, and improving international cooperation. The main goal, however, is the protection of American consumers, similar to Solvency II's efforts to achieve policyholder protection [74].

To help achieve these goals, the Federal Insurance Office ("FIO") was founded within the US Department of Treasury. It was entrusted with the task to negotiate regulatory matters on an international level, as well as with the responsibility to inform the US Congress about insurance-related issues[75]. Furthermore, the Financial Stability and Oversight Council ("FSOC") was created to monitor sources of systemic risk from a

[70] Harrington (2013), p. 2.
[71] NAIC (2011), p. 2f.
[72] NAIC (2009). Quoted according to Berends et al. (2013), p. 56; NAIC (2020).
[73] Cf. Cummins and Phillips (2009); Cummins et al. (1995); Cummins et al. (1999); Eling and Holzmüller (2008); Eling et al. (2006); Grace et al. (1998); Pottier and Sommer (2002). Quoted According to Harrington (2013), p. 9.
[74] Cf. Harrington (2013), p. 7; NAIC (2018a).
[75] Harrington (2013), p. 2; NAIC (2011), p. 2.

nationwide perspective. FSOC has the ability to declare non-bank institutions, like insurance companies, as systemically important, thereby having the potential to shift the responsibility for insurance oversight from the state level to the federal level[76].

Both the European and the US-American model recognize the dependency of insurers on currently available interest rates as one of their most important drivers of risk[77]. In the face of the historically low interest rates, following the financial crisis, the role of interest rate risk was therefore emphasized in both frameworks. In the following, an outline is provided on the handling of interest rate risk in Solvency II's standard formula.

As with other risk factors, the standard formula accounts for interest rate risk by raising the SCR based on its potential effect on an insurer's balance sheet. In the interest rate risk module, this is reflected by the change in the net value of assets and liabilities after applying an upward or downward shock in the relevant interest rate. EIOPA provides a simplified presentation for the calculation of capital requirements in the interest rate risk module[78]:

$$Mkt_{int}^{Up} = \Delta NAV|_{Up} \tag{6}$$

$$Mkt_{int}^{Down} = \Delta NAV|_{Down}, \tag{7}$$

where

Mkt_{int}^{Up}	= Market risk module capital requirement for interest rate risk after upward shocks,
Mkt_{int}^{Down}	= Market risk module capital requirement for interest rate risk after downward shocks,
$\Delta NAV\|_{Up}$	= Change in net asset value of assets minus liabilities after upward shocks,
$\Delta NAV\|_{Down}$	= Change in net asset value of assets minus liabilities after downward shocks.

[76] Harrington (2013), p. 6.
[77] Cf. EIOPA (2013); EIOPA (2014b); EIOPA (2015b). Quoted according to Pelizzon and Sottocornola (2018), p. 1.
[78] Cf. Boonen (2017), p. 411f; EIOPA (2012a), p. 86; Institute and Faculty of Actuaries (2016), p. 7f. According to Braun et al. (2015), p. 3, EIOPA since 2012 switched the term, used, from "Net Asset Value" to "Basic Own Funds". Herefore, see also CEIOPS (2010b). Quoted according to Boonen (2017), p. 411.

In the following step, the model adjusts the capital requirement based on the firm's loss-absorbing capacity and the potency of its security mechanisms[79]. After the capital requirements for the interest rate risk submodule, as well as all other submodules of the market risk module, have been calculated, the capital requirement for the market risk module is derived. Finally, after the capital requirements for all modules are available, the Solvency Capital Requirement of an insurance firm can be calculated[80]. The overall requirement thereby is lower than the sum of the capital requirements of the individual modules[81].

For the interest rate risk module, EIOPA uses two stress scenarios, which each apply a relative positive and negative shock to interest rates of different maturities[82]. The capital requirement of this module therefore only reflects the change in the value of assets and liabilities, due to the change in the applied discount rate. Other aspects, which influence an insurers' dependency on interest rates[83], are however covered by additional risk modules or are being accounted for by the mentioned SCR adjustments. Policyholder optionality, for example, is addressed through the lapse risk module. Capital requirements for this module are based on simulated shocks to the frequency of policy lapses in an insurers' portfolio[84].

Regarding duration gaps, EIOPA observes the situation in European insurance companies through the ORSA report[85]. For this measure, however, no additional adjustments in the interest rate risk module are necessary. The duration gap influences its capital requirement through the simulated changes in net asset value. Guaranteed products, however, are represented by a package of measures. These, in combination, have an influence on the risk-free rate, which insurers use to discount their liabilities in the framework. This mechanism allows the standard formula to capture risk from long-term guarantees by increasing the discounted value of liabilities. This, in turn, negatively affects the amount of available own funds[86].

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[79] EIOPA (2012a), p. 86-88; cf. EIOPA (2014a); EIOPA (2019).

[80] EIOPA and the former European insurance regulation authority CEIOPS provide guidelines for the calculation of the Solvency Capital Requirement in the standard formula: Cf. CEIOPS (2010a); CEIOPS (2010b); EIOPA (2012a); EIOPA (2012b); EIOPA (2015b).

[81] BaFin (2018); Boonen (2017), p. 410.

[82] BaFin (2018); Boonen (2017), p. 411f.

[83] The sensitivity of insurance companies' profitability to changes in interest rates can be amplified by several factors. For further information on this topic, please refer to chapter 2.1.

[84] CEIOPS (2009), p. 19-33; cf. Burkhart (2018).

[85] Cf. EIOPA (2011), p. 22.

[86] EIOPA (2020), p. 19f.

Regulation concerning the use of long-term guarantees in the EU differs from country to country. Germany, to name one example, uses a scheme, which prescribes a maximum guaranteed interest rate for all types of life insurance contracts[87]. Regarding the US-American system, NAIC reports that interest rates for insurance products are not regulated on a nationwide level. Individual states may however limit rates, and local supervisors may decide to verify the ability of insurance providers to adhere to their promises on a case-by-case basis[88].

The issue of unproportionally high guaranteed returns in comparison to low available interest rates on investment-grade assets has been part of the regulatory debate since the advent of the low interest rate regime. EIOPA's 2013 Financial Stability Report states that the insurers, most affected by the low interest rate environment, include those who are particularly exposed to insurance contracts with long-term guarantees[89]. Their contractual obligations push these insurers to take on riskier products in order to achieve investment returns, which can match the returns, they promised to policyholders in the past[90]. Regarding an increase in insurers' risk-taking behavior, Berdin and Gründl note that elevated levels of risk could be accompanied by a reduction in the average duration of assets, further raising insurers' sensitivities to changing interest rates. The positive effect, caused by a reduction of the gap between promised and earned returns, is therefore counteracted by an increase in vulnerability to falling interest rates. Therefore, the overall effect of increased risk-taking on insurers' solvency situations is unclear[91].

In the years, following the financial crisis, policymakers and researchers alike were occupied with the question, how insurers would deal with the exacerbated market conditions. They were concerned not only with the fact, that insurers might default, but also with the effects that defaults could have on other market participants. Considering the repercussions, caused by several bank defaults during the crisis, the goal was to find out, whether similar consequences had to be expected if major insurance or reinsurance providers could not meet their obligations.

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[87] Berdin and Gründl (2015), p. 386, 394. German life insurers are subject to an exceptional amount of interest rate risk. Further information on the German situation is provided in chapter 4.2.

[88] NAIC (2011), p. 4f.

[89] EIOPA (2013). Quoted according to Berdin and Gründl (2015), p. 385.

[90] Cf. Becker and Ivashina (2015). Quoted according to Möhlmann (2017), p. 1.

[91] Berdin and Gründl (2015), p. 412.

While the first major event of the 2007 financial crisis, which raised public attention, was the default of Lehman Brothers, New York-based American Insurance Group was bailed out by the US Federal Reserve in the same week due to entanglements in so-called Credit Default Swaps ("CDS"), for which Lehman Brothers was one of the largest suppliers[92]. At the time, insurers were also among the most frequent buyers of highly-rated tranches of mortgage-backed securities ("MBS")[93]. Analyzing the circumstances, which led to the financial crisis, would be beyond the scope of this work. It should however be clarified that the US insurance sector had substantial connections to the practices, leading to its emergence.

With the creation of the European Systemic Risk Board ("ESRB") in Europe and the Financial Stability Oversight Council ("FSOC") in the US, both regimes reinforced the supervision of systemic risk in the banking, as well as the non-banking sector, including (re-)insurance providers. Cummins and Weiss define systemic risk as "the risk that an event will trigger a loss of economic value or confidence in a substantial segment of the financial system that is serious enough to have significant adverse effects on the real economy with a high probability"[94]. At the same time, researchers approached the topic, trying to interpret the role of insurance companies in the emergence of the financial crisis.

Factors, used by FSOC, to determine whether insurers could be a source of systemic risk include their size, low substitutability through competitors, interconnectedness with other financial corporations, leverage, liquidity risk, duration gaps, and the quality of applied regulations[95]. Evaluating his study on duration gaps in German life insurance companies, Möhlmann suggests that the homogeneity of insurers' behaviors in times of market stress, should also be considered[96]. If many insurers, operating in the same declining market, decide to buy liquid and low-risk instruments, while at the same time laying off illiquid positions, this can reduce returns on acquired assets, while prices of sold assets fall simultaneously[97].

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[92] Handelsblatt (2008); New York Times (2008); Stein (2012), p. 99; Cf. Stolz and Wedow (2010). Quoted according to Kablau and Weiß (2014), p. 1.

[93] Baranoff and Sager (2009), p. 102f state that the top ten percent of insurers – those who could potentially contribute to systemic risk – all had at least one quarter of their capital invested in MBS.

[94] Cummins and Weiss (2013), p. 746. Quoted according to Harrington (2013), p. 4.

[95] Harrington (2013), p. 5.

[96] Möhlmann (2017), p. 1.

[97] Ben-Raphael (2017, p. 43) investigates the flight-to-liquidity of different types of investors during times of market uncertainty. He finds that insurers are among the two groups of investors, which show statistically significant reductions in illiquidity in their portfolios.

The International Monetary Fund ("IMF") notes that duration gaps incentivize insurers to take similar decisions under pressure, thereby raising the probability of fire sales, and increasing the level of systemic risk[98]. Möhlmann's results however yield a wide dispersion of duration gaps between German life insurers, with the largest gaps being associated with comparably small insurers. If the German situation also applies to other international markets, the risk of timing effects due to similar maturity structures is, therefore, limited[99].

According to a literature review, conducted by Harrington in 2017, the overall opinion of researchers, engaged in the field, is that insurers pose a very limited amount of systemic risk, if any. Reasons for this conclusion are numerous: In contrast to the banking industry, insurers hold relatively high amounts of capital, when compared to the size of their liabilities. Their exposure to short-term liabilities is much smaller, bolstering their resilience against shocks[100]. Further, defaults in the insurance sector do not influence payment systems or the availability of short-term liquidity. The interconnectedness in the insurance sector, in comparison to the banking industry, is therefore much weaker, and individual insurer defaults are unlikely to pose a substantial threat to the real economy[101]

Reviewing the regulatory changes after the global financial crisis, discussed in this chapter, the European and US-American regimes overall had a similar approach to reforms regarding insurance regulation. Especially in the field of interest rate risk and the topics, which are associated with it, insurers can expect to experience similar regulatory treatment in both regimes. While clearly, some differences exist, the comprehensive risk-based approach of both frameworks, and the reflection of IAIS' Insurance Core Principles, create comparable conditions for insurers in both regions. Structural differences in the interest rate sensitivities of European and US-American insurers, which will be discussed in chapter 4, are therefore unlikely to be caused by diverging regulatory treatment.

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98 Cf. IMF (2016). Quoted according to Möhlmann (2017), p. 1.

99 Möhlmann (2017), p. 15f. Furthermore, Kablau and Wedow (2012) note that, under a prolonged period of low interest rates, problems in German life insurance companies would materialize at different points in time. Quoted according to Kablau and Weiß (2014), p. 2.

100 Cf. Cummins and Weiss (2013); Geneva Association (2010); Geneva Association (2012a); Harrington (2004); IAIS (2011); Swiss Re (2003). Quoted according to Harrington (2013), p. 4.

101 Harrington (2013), p. 4.

3 Empirical Methodology

This work aims at evaluating the changing interest rate sensitivities of life and non-life insurers worldwide in the time before, during, and after the 2007 global financial crisis. The covered analyses thereby focus on insurers from different regions, comprising the United Kingdom, the United States, as well as continental Europe, and a series of international samples. The methodology of the analyses, conducted in this work, closely follows the approach, employed by Daniel Hartley, Anna Paulson, and Richard J. Rosen in their 2016 paper "Measuring Interest Rate Risk in the Life Insurance Sector: the U.S. and the U.K.". In the following, an overview of the regression analyses, carried out by Hartley et al., as well as the changes and extensions, made to them in this study, are presented.

Hartley et al. measure the interest rate risk exposure of insurers, located in the UK, US, and continental Europe between 2002 and 2015. They find significant differences between life and non-life insurers, between insurers from different regions, as well as between insurers, operating in different countries within continental Europe. Their results indicate higher dependencies between changes in long-term interest rates and insurer profitability (1) for life insurers; (2) for insurers which are exposed to high amounts of contracts with long-term guarantees and policyholder options; and (3) in the low-rate period, following the global financial crisis, for these particularly exposed insurers[102].

Hartley et al.'s approach uses a two-factor model, which estimates changes in insurer stock prices based on changes in a stock market index and changes in long-term interest rates. In the related literature, this is a commonly applied approach, when assessing interest rate risks of insurance companies. Similar methods were implemented by Stone (1974), Lloyd and Shick (1977), Flannery and James (1984), Brewer, Mondschean, and Strahan (1993), Brewer et al. (2007), Carson, Elyasiani, and Mansur (2008) and Berends et al. (2013)[103]. Other possible approaches include ARCH models (Song, 1994), GARCH-M models (Elyasiani and Mansur, 1998) [104], or multi-factor models (Papadamou and Siriopoulos, 2014).

[102] Hartley et al. (2016), p. 13-18.
[103] Quoted according to Berends et al. (2013), p.58f; Brewer et al. (2007), p. 403; Hartley et al. (2016), p. 7.
[104] Quoted according to Brewer et al. (2007), p. 403. "ARCH" refers to autoregressive conditional heteroscedasticity, while "GARCH-M" refers to generalized autoregressive conditional heteroscedasticity-in-mean.

This approach implements stock returns as a top-down measure for insurer profitability. While a bottom-up measure would better reflect individual characteristics of insurers, data with a sufficient level of detail is not publicly available[105]. The stock returns of an insurance company, however, are well-suited to analyze its interest rate risk: Stock prices reflect the public opinion on the profitability of an insurance company. This measure takes into account the size of insurers' assets and liabilities, potential exposures to contracts with guaranteed returns or policyholder options, and the effectiveness of a company's risk management. As investors include financial analysts and other well-informed market participants, the reactions in the stock price to changes in long-term interest rates are assumed to be a good indicator for a firm's exposure to interest rate risk[106].

The regression approach includes a bond return variable to represent the effect of changes in long-term interest rate levels on insurer stock returns. Accordingly, the underlying government bonds have a relatively high maturity of ten years. The second variable adds a market return measure, based on a local stock market index. This variable captures the sensitivity of insurer stock returns to changes in the current state of the local economy. The basic regression model, following the example by Hartley et al., is depicted in term 8[107].

$$R_{i,t} = \alpha + \beta R_{m,t} + \gamma R_{10,t} + \varepsilon_{i,t}, \tag{8}$$

where

α	= Intercept,
β	= Market return coefficient,
γ	= Bond return coefficient,
$\varepsilon_{i,t}$	= Mean zero error term,
$R_{i,t}$	= Stock return of insurer i at time t,
$R_{m,t}$	= Stock market index return at time t,
$R_{10,t}$	= Return on a 10-year government bond at time t.

[105] For studies, using bottom-up data, see e.g. Kablau and Weiß (2014); Möhlmann (2017).
[106] Berends et al. (2013), p. 58; Hartley et al. (2016), p. 3.
[107] Hartley et al. (2016), p. 8.

All analyses are conducted both with weekly and daily data. This allows for a direct comparison to Hartley et al.'s results, which are based on weekly data, but adds the benefit of more reliable regression results due to higher frequency data. Stock returns are calculated based on day-to-day or Friday through Friday changes in a total return index. Bond data is obtained in a yield notation. The yields are used to derive bond prices for all observations, which are then converted into day-to-day or Friday to Friday returns. All regression results are generated using the ordinary least squares method.

The use of two-factor models, which are based on publicly available data, has been criticized by several researchers: Berends et al. (2013), for example, note that mutual insurance companies cannot be included in assessments, based on stock market data, as they do not have traded stocks. Moreover, stocks are only available for parent companies. If insurers are subsidiaries of publicly traded companies, including their parent companies in the sample, can introduce unwanted characteristics from the parent company's non-insurance-related business into an analysis[108]. Maher (1997) adds the concern that long-term analyses on insurer interest rate sensitivity cannot properly reflect the time-varying nature of insurers' exposures to interest rate risk[109].

In this work, most of these problems are resolved either during the data selection process or through design choices for the regression approach. Non-insurance-related business activities of companies in the samples are limited by the fact that only companies that are classified as P&C, life, health, multi-line, or managed care insurers were included in the samples. Other insurance-related enterprises, like reinsurers or insurance brokers, were excluded. Furthermore, insurers that are known to exhibit high amounts of non-traditional insurance activities were excluded from the samples. These activities can expose insurers to significant non-insurance-related risks, which are likely to bias regression results. Therefore, following the suggestion of Düll, König, and Ohls, the US-American insurers American International Group and MBIA were excluded from the US sample[110]. Finally, only insurers, which were publicly listed for a minimum of five years during the sample period, were included.

[108] Berends et al. (2013), p. 59f. Similar arguments are made by Möhlmann (2017, p. 1), who points to the limited scope and widely spread business activities of publicly listed insurance companies.
[109] Quoted according to Brewer et al. (2007), p. 403.
[110] Düll et al. (2017), p. 96.

Hartley et al. address the time-varying nature of insurers' interest rate sensitivities through a rolling regression approach, using time windows of two years length. With every iteration, the start and end points of the time window are shifted by one week, or one day, respectively. This method yields time-varying bond return coefficients and thereby allows the model to capture slow changes in interest rate sensitivities of assessed insurance companies. The length of the timeframes of two years was chosen as a trade-off between a long enough timeframe to yield reliable regression results, and a short enough timeframe to adequately capture changes in the market environment as well as the business characteristics of the assessed insurance companies[111]. For this reason, as well as to provide comparable results, this study implements the same approach. The timeframe, it is applied to, is however extended from January 2002 through July 2015 to January 2002 through October 2020.

Regarding the evaluation of movements in the market and bond return coefficients over this period, the results in chapter 4 will be limited to analyses of the bond return coefficient. While the market return coefficient is useful to explain changes in insurer profitability, caused by macroeconomic shocks, the focus of this study lies on the investigation of interest rate sensitivities of insurance companies. At this point, it is important to note that a positive relationship between insurer profitability and long-term interest rates is reflected by a negative bond return coefficient. This is a result of the conversion of available bond yields into day-to-day or week-to-week bond returns: If the interest rate level rises from one observation to the following, this increases the discount rate for the bond's future cash flows, decreasing its present value and thereby causing a negative return. If negative bond returns occur simultaneously with increasing stock returns, the market believes an insurer to be more profitable when bond returns fall, that is when interest rates rise[112].

All regressions are conducted on a company-level. Sample coefficients are then aggregated as the average coefficient over all companies in a sample, weighted by the participating insurers' average market capitalizations during the respective two-year timeframe. In contrast to other approaches, making use of stock portfolios[113], this method allows companies to be flexibly allocated to new samples, based on different character-

[111] Hartley et al. (2016), p. 8.
[112] Cf. Hartley et al. (2016), p. 8f. This design for an interest rate variable is in line with the holding period return, implemented by Brewer et al. (2007, p. 407).
[113] Cf. Fama and French (1992; 1993). Quoted according to Hartley et al. (2016), p. 7.

istics. In this study, this advantage is exploited to split insurers, stemming from the same region, into multiple subsamples. This enables the separation of life and non-life insurance companies, based on their share of earned insurance premiums from life and health or non-life insurance business lines. Chapter 4.2 will introduce additional criteria to further separate insurers based on their exposure to policies with long-term guarantees.

The data for the analyses was taken from three sources: SNL Financial, Refinitiv Eikon ("Datastream"), and Bloomberg. These sources show different levels of coverage for different types of data. For many small companies, data from different sources proved contradictory. In order to select the most detailed and reliable set of time series, the primary data source varied between different types of data, and the available time series from all three sources were compared against each other based on a set of criteria to ensure a high quality of the used data.

Stock index and government bond data was obtained from Datastream. The United States sample uses the S&P 500 as the market index and yields on 10-year US treasury bonds reflect the available long-term interest rates. The United Kingdom sample uses the FTSE 100 stock price index, as well as yields on 10-year UK government bonds. For the continental European sample, the German DAX 30 and yields on the German 10-year government bond were chosen in order to avoid picking up unwanted credit risk, involved in the government bonds of some of the other countries, included in the sample. These choices are consistent with those, made by Hartley et al.[114]. The developments of the mentioned indices and bond yields over the complete January 2002 to October 2020 timeframe are depicted in figure 2. The figure also reports the development of comparable insurance indices in the three markets to provide an estimation of insurer performance, relative to the performance of the overall markets.

For the seven international samples, each company is regressed against returns based on local stock indices and government bond yields. An overview of the stock indices and bonds per country is provided in table 1. For some countries, yields on the respective 10-year government bonds were unavailable. In these cases, government bonds with lower maturities were chosen. This, however, only affects 18 out of 116 companies over all international samples.

[114] Hartley et al. (2016), p. 13, 17.

Stock market data is obtained from a combination of all three data sources. Insurer stock returns are calculated as day-to-day or Friday through Friday changes of total return indices, obtained from Datastream and Bloomberg. For companies, for which no total return indices were available, or for which a longer coverage based on unadjusted closing prices was available, stock price returns were used to supplement the total return index returns.

To investigate the interest rate sensitivity of life and non-life insurers separately, the regional insurance samples are split into two groups. Insurers, which collect at least 50 percent of their written premiums from life and health insurance policies, are classified as life insurers. The share of written life and health premiums varies over time for most insurance companies. Insurers could therefore have both shares below and above 50 percent at different points in time during the 19-year sample period. However, in order to prevent them from migrating between the life and non-life insurer samples, the allocation to these samples is based on the average share over the period, in which they participate in regression analyses. The composition of life and non-life insurer samples is thereby constant over the complete timeframe of the analysis[115]. If premium data was not available with sufficient quality, the allocation is based on reserves for life, health, and non-life policies instead. Both premium and reserve data was primarily obtained from SNL Financial.

In order to avoid biases in stock returns due to changes in currency exchange rates, the chosen currency for time series data differs from sample to sample. Data for the United States sample is obtained in US dollars, for the United Kingdom in pounds sterling, and for continental Europe in euros. The international samples use local currencies for each country. A set of basic statistics for the ten regional samples, assessed in this study, is provided in table 2. The composition of the samples, as well as the shares of premiums, earned from life and health insurance products in 2019, the number of observations during the 19-year timeframe of the analysis, and market capitalizations as of the year-end of 2019, are reported in tables 3 to 12. For the sake of comparability, total asset sizes and market capitalizations are reported in US dollars for all samples.

[115] The described time-varying share of premiums, collected from life and health insurance policies, will be integrated into the regressions as $Life\ share_{i,t}$ (see Hartley et al., 2016, p. 14). While the allocation to the life and non-life insurer samples is fixed, the $Life\ share_{i,t}$ of each insurer is able to fluctuate over time, and thereby can reach levels that would be associated with an allocation to the other sample, if they persisted.

Table 2 reveals significant differences in the sizes, as well performances of insurance sectors, between the ten regional samples. Combining data from SNL Financial, Datastream, and Bloomberg, the sample sizes for the three main samples – US, UK, and continental Europe – increased from 78, 10, and 25 companies in Hartley et al.'s analysis[116] to 100, 15, and 59 companies. The particularly high growth in the European sample is caused by an expansion of the range of underlying countries from 6 in Hartley et al.'s paper[117] to 24 in this study. The extended sample also includes 14 insurers from countries, which are not part of the European Union, namely Russia, Serbia, Switzerland, and Turkey. The coverage of a higher number of insurers in each region is expected to yield results, which are more representative of the actual conditions, under which insurance companies operated between 2002 and 2020.

The expansion especially introduced many smaller insurers to the samples. This fact should partly compensate for the bias of this study towards large insurance companies, which is natural for analyses, based exclusively on data from publicly listed companies. Mutual insurance companies and very small insurers are still excluded from the analysis. Compared to the analysis by Hartley et al., however, the results in this study are likely to provide estimations for interest rate risk exposures, which are closer to the exposures, an analysis based on data, covering complete industries would produce.

Table 2 provides insights into the characteristics of the ten insurer samples, examined in this work. The combined size of the insurance sectors in the three main samples, as measured by held total assets, amounts to more than twice the combined size of the seven international samples. Especially the United States and continental Europe with assets around USD 5 tn. and USD 6 tn. stand out. Insurers in the United Kingdom, as well as in East Asia, hold assets of about half the value of the US and European sample, followed by Canada, and Japan and South Korea. The four remaining regions have much smaller insurance industries.

Considering the number of insurers per sample, a different impression is created: The average size of life insurers is the highest in the United Kingdom, Canada, and East Asia. For non-life insurers, Japan and South Korea and Europe show average sizes of more than twice the value of all other samples. In the United Kingdom, Canada, and East Asia, the

[116] Hartley et al. (2016), p. 26-29.
[117] Hartley et al. (2016), p. 16.

non-life insurance sector only amounts to a small fraction of the size of the life insurance sector. In general, the average size of non-life insurers is significantly smaller than the size of life insurers in almost all regions. Only the Middle East and Australia and Oceania samples show comparable sizes for both types. This is consistent with the business model of life insurers: As described in chapter 2.1, life insurers hold large amounts of assets with high maturities to offset their substantial liabilities, incorporated from long-term life and health insurance policies.

As a rough measure of leverage, table 2 reports the ratio of held assets to equity for insurers in all regions. Consistent with Hartley et al.'s dataset, the US sample shows lower ratios than the UK and EU samples, and non-life insurers overall tend to show lower leverage ratios than life insurers[118]. The performance of insurers in most of the more developed regions was similar in 2019. The samples for UK, EU, Canada, and Japan and South Korea show life insurer profitabilities of 10 to 13 percent, with non-life profitabilities being lower by 2 to 3 percentage points. The only outlier here is the United States sample, with profitabilities of 9 and 15 percent. Hartley et al.'s samples show similar profitabilities in 2014, with the exception of the United Kingdom[119]. The five remaining samples mostly feature lower profitabilities, with non-life insurers outperforming life insurers.

Overall, table 2 reveals structural differences between the insurance sectors in the regions, assessed by this work. While some regions, like Australia and Oceania, show a relatively strong usage of non-life insurance products, other regions, like the United Kingdom, focus primarily on long-lasting life and health insurance products. For the assessment of interest rate risk exposures in different regions, however, also other factors have to be considered: EIOPA, Hartley et al., and Moody's report significant differences in average duration gaps and the usage of long-term guarantees and policyholder options, not only between different regions, but also between countries within these regions[120]. The following chapter will investigate whether the profitabilities of insurers from regions and countries, which are more exposed to these factors, show higher sensitivities to changes in interest rates, and whether these sensitivities change under different interest rate environments.

[118] Hartley et al. (2016), p. 10, 25.
[119] Hartley et al. (2016), p. 25.
[120] EIOPA (2014a), p. 17; Hartley et al. (2016), p. 10f; Moody's (2015).

For the assessment of changes of interest sensitivities over time, Hartley et al. split the timeframe of their analysis into three distinct periods[121]: The first years of the analysis are characterized by interest rates, which were closer to historical average levels around 4 to 5 percent p.a., as displayed in figure 2. This period, labeled "normal-rate period", starts in January 2002 and ends in June 2007 before the emergence of the global financial crisis. The "crisis period" from July 2007 to June 2010 exhibits significant decreases in interest rates due to monetary policy interventions in the regions of the three main samples US, UK, and EU. As the insurance indices suggest, insurers in these samples were all immediately affected by the crisis, however, the UK sample shows lower losses in value than they appeared in the other two samples. The "low-rate period", starting in July 2010, shows historically low interest rates in all samples. In comparison, the interest rates in the US remained the highest. In recent years, however, they also approached zero. The United Kingdom and Germany show interest rates below two percent since several years, with Germany even offering negative interest rates on 10-year treasury bonds since early 2019. The effect of the low-rate environment on insurers becomes evident when inspecting the development of the insurance indices, relative to the overall stock market. In the United States and continental Europe, the gap between insurance and general stock market performance has widened since the start of the low-rate period. Only in the United Kingdom, insurers were able to recover from the shock of the financial crisis in 2015.

Due to the extension of the investigated period to October 2020, the influence of the COVID-19 pandemic on insurer interest rate sensitivities is picked up by the analysis. The pandemic had a clearly distinguishable impact on interest rate sensitivities in most samples from March 2020 onwards. For this reason, the introduction of a fourth period appears useful. However, the timeframe of the analysis only covers the first half-year, in which the pandemic had a noticeable influence on international stock markets. The results are therefore only able to provide an estimation for the first impact of the pandemic, preventing a sound and reliable interpretation for this period. The impact of the pandemic will therefore be mentioned in the next chapters, when appropriate. Due to the uncertainty of its long-term effects, the analysis will however mostly focus on the three previously described periods.

[121] Hartley et al. (2016), p. 9, 13.

4 Results

4.1 Interest Rate Risk in the United States and the United Kingdom

The insurance sectors in the United States and the United Kingdom differ from each other in several essential characteristics: Many insurance products, sold by life insurers in the United States, feature guaranteed rates of return and policyholder options[122]. Life insurers from the United Kingdom, on the other hand, rather focus on with-profit policies, unit-linked products, and annuities[123]. Considering the consensus in the related literature, the contract features, employed by US-American life insurers, should strongly tie their performance to the developments of available long-term interest rates, while UK life insurers should be much more independent in this regard. The following chapter will exploit these differences between the two markets to evaluate whether the mentioned contract features have a notable impact on the interest rate sensitivity of life insurers.

The statistics on the US and UK insurer samples, presented in table 2, report large sizes of the insurance industries in both regions. Especially in the United Kingdom, the life insurance industry plays an important role due to the compulsory use of annuities as retirement provisions[124]. In 2019, the profitability of the life insurance sectors in both regions was comparable. In the US, however, the life insurance industry showed a significantly lower performance than the non-life insurance industry. Hartley et al. report similar findings for US life insurers for the year 2014, and also the SPDR insurance exchange-traded fund ("ETF") in figure 2 shows a low performance of the US insurance sector, compared to the overall US economy. The UK insurance sector, on the other hand, shows a much better performance in recent years. Considering the comparably high interest rate levels in the US after the financial crisis, this situation seems surprising. An assessment of the characteristics of the US and the UK insurance sectors, however, reveals several reasons, which can explain the underperformance of US life insurers, compared to life insurers in other developed economies.

[122] Hartley et al. (2016), p. 4.

[123] Moody's (2015), p. 20. With-profit policies typically consist of a combination of a unit-linked policy with a guaranteed profit that changes every year. The guarantees, therefore, pose a much lower risk for issuing insurers.

[124] Cf. Cannon and Tonks (2010).

Moody's attests a moderate risk for the profitability of US life insurers due to changes in long-term interest rates. They base this classification on several factors: US life insurers show a relatively efficient asset liability management with duration gaps seldomly exceeding one year. They offer a wide range of products, with guaranteed products usually accounting for 60 to 80 percent of insurance liabilities. The average guaranteed rate on outstanding policies is estimated at 2 to 4 percent, which left US life insurers with portfolio yields, being one to two percentage points higher than promised returns in 2015. Moody's however also notes a decreasing ability of life insurers to lower crediting rates on outstanding contracts[125]. A prolonged low-yield environment could therefore impair the solvency situation of US life insurers.

In the United Kingdom, Moody's only notes a very low risk to the profitability of life insurers from interest rate changes. This classification is partly based on the traditionally low duration gaps of UK life insurers, in some cases even reaching asset durations, exceeding the durations of liabilities[126]. Guaranteed products make up 40 percent of UK life insurance reserves. The guaranteed products in the UK, however, typically provide very conservative guaranteed rates, and many guaranteed products adjust these rates during the contract term[127].

Regarding the use of contract designs, featuring some degree of policyholder optionality, Hartley et al. report a higher prevalence in the United States, compared to the United Kingdom[128]. As described in chapter 2.1, giving policyholders the ability to prolong or terminate their policies at will can expose life insurers to additional interest rate risk, especially if the options come in conjunction with products, featuring guaranteed rates of return. Since interest rates in the United States fell after the global financial crisis, it is likely that policyholders make use of their options to extend their contract terms in order to profit from high returns, which could not be earned on the capital markets[129]. Even if US life insurers show low duration gaps, their situation could deteriorate if policyholders prolong their contract terms, while the highly yielding assets, bought at contract issuance, successively run out.

[125] Moody's (2015), p. 16f.
[126] EIOPA (2014a, p. 17) reports a duration gap of -0.44 for the United Kingdom.
[127] Moody's (2015), p. 20.
[128] Cf. Oliver Wyman (2014); Geneva Association (2012b). Quoted according to Hartley et al. (2016), p. 3.
[129] Cf. Berends et al. (2013), p. 49.

The different situations in the life insurance sectors of the United States and the United Kingdom give rise to a number of hypotheses for the subsequent analysis. Hypotheses 1 to 3 are adopted from Hartley et al. (2016). The extended timeframe of the analysis enables an observation of interest rate sensitivities of life and non-life insurers in a prolonged low-rate environment. This gives rise to a fourth hypothesis, concerned with the influence of a sustained exposure to low interest rates on life insurers.

Hypothesis 1 is concerned with the situation of life insurers in the US and UK after the global financial crisis: Due to the characteristics of their outstanding policies, life insurers in the US should be more exposed to falling interest rates than UK life insurers. Under a low interest rate environment, insurers, which are engaged in insurance products, featuring guaranteed rates of return, should find it more difficult to meet their promised rates. Furthermore, policies, which allow policyholders to prolong their contracts, should raise the duration gap of affected insurers under these conditions. Accordingly, hypothesis 1 is defined as follows:

> Life insurance companies in the United States should become more sensitive to changes in long-term interest rates than life insurance companies in the United Kingdom under falling interest rates, following the 2007 global financial crisis.

As described in chapter 2.1, non-life insurers both in the US and UK typically have insurance liabilities with much lower durations than life insurers, and therefore place a lower share of their investments into long-term fixed-income securities. Furthermore, P&C insurance products do not grant guaranteed minimum rates of return or options to prolong contract terms in connection with these. The profitability of non-life insurers is therefore expected to be less sensitive to changes in long-term interest rates than the profitability of life insurers. Especially in the US, where life insurers should be particularly exposed to interest rate risk, the difference between the bond return coefficients of life and non-life insurers should become negative after the financial crisis[130]. Hypothesis 2, therefore, reads as follows:

[130] A negative bond return coefficient hints at a positive relationship between insurer profitability and changes in long-term interest rate levels. If insurers are exposed to interest rate risk, their profitability should deteriorate in an environment of decreasing interest rates, as described in chapter 2.1. In this work, a negative bond return coefficient, therefore, signals exposure to interest rate risk.

> The change in bond return coefficients between the normal-rate period and the low-rate period should be more negative for US life insurers than for US non-life insurers.

When the interest rate sensitivities of US and UK life insurers are compared, differences in bond return coefficients are attributed to the previously described characteristics of insurance products in the portfolios of both insurance sectors. As Hartley et al. point out, however, insurance companies in both regions are not only subject to different interest rate levels, but also to many other factors[131], including economic, regulatory, and demographical differences. While the market return variable captures a part of these variations, other factors, which only influence the insurance sector of the market, are not individually tracked. Thereby, the bond return variable could be influenced by other factors, which are not related to interest rate risk.

These deviations can be revealed when the whole insurance sector of a region is assessed. If factors, unrelated to interest rate risk, affect the US or UK insurance sectors, life and non-life insurers will likely be affected by them in a similar way. The bond return coefficients of both parts of the industry should therefore show similar movements. The following analysis introduces an additional bond return variable γ_2, which measures the difference in interest rate sensitivities of life and non-life insurers from the same region, based on the share of the life insurance business within the assessed insurance companies $Life\, share_{i,t}$. If factors, outside the regression model, influenced life and non-life insurers in the same way, these will not be reflected in γ_2. As non-life insurers are known to exhibit comparably low degrees of interest rate risk, the γ_2 variable is expected to yield bond return coefficients which describe the interest rate risk exposure of life insurance companies without significant biases through omitted variables.

Since the characteristics of life insurance products in the United States only affect the interest rate sensitivity of US life insurers, the resulting γ_2 variable should reflect their effects through a negative value, following the global financial crisis. The γ_2 variable for the insurance sector in the United Kingdom, on the other hand, should not show a decrease, which is as significant as in the US sample. This fact constitutes hypothesis 3:

[131] Hartley et al. (2016), p. 11.

> The change in γ_2 between the normal-rate period and the low-rate period should be more negative for the US insurance sector than for the UK insurance sector.

The extended timeframe of the analysis, compared to the study, conducted by Hartley et al. (2016), includes a significantly longer timeframe, in which insurers were exposed to low, and in the case of the United Kingdom, continuously falling interest rates. This allows the analysis to investigate the effects of sustained exposures to low interest rates on life and non-life insurers from the United States and the United Kingdom. As studies by Kablau and Wedow (2012), Serra and Harris (2013)[132], Kablau and Weiß (2014), and Berdin and Gründl (2015) concluded for the German insurance sector, prolonged exposures to low-yield environments can severely harm the solvency situation of life insurers, which are exposed to high levels of interest rate risk. The German situation is comparable to the US-American one, in that life insurers in both countries issued high amounts of contracts with guaranteed returns in the past. The literature, however, generally agrees that the German life insurance sector is particularly exposed to interest rate risk[133]. Therefore, it is uncertain, whether US life insurers are affected by a low-rate environment in the same way.

Following this premise, US life insurers should find it more difficult to recover their financial strength under a low-rate environment than UK life insurers. However, interest rates in the United Kingdom continued to fall in recent years, while interest rates in the United States stagnated. This fact could bias a comparison between both regions since UK life insurers are now subject to harsher conditions. If US life insurers, despite their more favorable interest rate environment, show a further decrease in the bond return coefficient, or a recovery, which is weaker than the recovery in the UK, this would confirm the stronger impact of the prolonged low-yield environment on US life insurers. If the previous hypotheses hold, hypothesis 4 therefore follows:

> After a long exposure to a low-yield environment, negative bond return coefficients of US life insurers should show weaker signs of recovery than bond return coefficients of UK life insurers.

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[132] Quoted according to Kablau and Weiß (2014), p. 3.

[133] Cf. Berdin and Gründl (2015); EIOPA (2014a); Möhlmann (2017); Moody's (2015); Swiss Re (2012). Quoted according to Berdin and Gründl (2015), p. 386.

To assess life and non-life insurers separately, all insurance samples are split into two subsamples. Since large insurance companies typically offer both life and non-life insurance products, insurers are allocated to the life insurer group, if at least 50 percent of their earned premiums come from life or health insurance products[134]. This share is measured through the variable $Life\ share_{i,t}$. While $Life\ share_{i,t}$ typically varies over time, the allocation of insurers to the life and non-life insurer samples is based on the average $Life\ share_{i,t}$ over the timeframe, in which an insurance company participates in regressions. The composition of both subsamples is therefore fixed over time[135]. Depending on the availability of premium and reserve data, different types of data were used to calculate $Life\ share_{i,t}$. Preferably, direct insurance premiums were used. If no or a comparably low amount of data was available for direct premiums, gross written premiums, reserves, and finally, net written premiums were used instead. Premium and reserve data was available either quarterly or yearly. For the intermediate dates, $Life\ share_{i,t}$ was linearly interpolated.

The $Life\ share_{i,t}$ variable is employed in the assessment of differences between the interest rate sensitivities of life and non-life insurers. The regression model, presented in term 9, is an extension of the basic regression model, presented in term 8:

$$R_{i,t} = \alpha + \beta_1 R_{m,t} + \beta_2 R_{m,t} * Life\ share_{i,t} + \gamma_1 R_{10,t} + \gamma_2 R_{10,t} * Life\ share_{i,t} + \varepsilon_{i,t}, \quad (9)$$

where

β_1	= Market return coefficient for non-life insurer sample,
β_2	= Market return coefficient for life to non-life difference,
γ_1	= Bond return coefficient for non-life insurer sample,
γ_2	= Bond return coefficient for life to non-life difference.

134 A similar approach is used by Pelizzon and Sottocornola (2018).

135 This method deviates from the method, Hartley et al. (2016) used for the group allocations in their samples: Hartley et al. use the $Life\ share_{i,t}$ of insurers from the end of 2014. Thereby, they run the risk of allocating insurers, which typically show life shares of more than 50 percent to the non-life insurer sample, if they temporarily show life shares below 50 percent in 2014 and vice versa. In general, using the latest available life share in an analysis over a 13.5-year timeframe can lead to misallocations. If insurers operated primarily in one of the two sectors over the major part of the timeframe but change their focus only in the last years of the assessment, the allocation would only be representative for a fraction of the investigated period. This problem is aggravated for the timeframe of almost 19 years in this work. For this reason, the method to determine allocations to the life and non-life samples was changed for this work.

This model is consistent with the model, applied by Hartley et al. (2016). Since a regression, based on the above formula, would not yield practical results due to multicollinearity, the regression approach is split into a two-step process: In a first step, a basic regression, based on term 8, is conducted for the non-life sample. In the second step, the β and γ coefficients from the regression of the non-life sample are implemented as fixed values for the β_1 and γ_1 coefficients of term 9. Thereby, a regression, based on term 9, only estimates the remaining coefficients β_2 and γ_2. This approach eliminates the collinearity within the model.

Since β_2 and γ_2 are designed to estimate the difference between life and non-life insurers, the second step is conducted, using the sample of life insurers. The model estimates the difference in the bond return coefficient based on the current value of $Life\ share_{i,t}$. For a given $R_{i,t}$, if $Life\ share_{i,t}$ is low, γ_2 will on tendency be higher in magnitude[136]. This is reasonable, considering that life insurers, which only earn parts of their premiums from life insurance products, are still subject to interest rate risk. If their $Life\ share_{i,t}$ would be higher, their interest rate sensitivity would likely rise accordingly. γ_2 thereby weights the coefficients of the life insurers in a way, that generates a result, which assumes an underlying sample of life insurers, which earn all of their premiums from life or health insurance products. The described two-step process is implemented for each two-year time window in the rolling regression.

The results for the US-American insurer sample are depicted in figures 3 to 8. Figures 3 and 4 show the results for the complete US sample based on data with weekly and daily frequency. Here, panel A depicts the development of the bond return coefficient, and panel B depicts a number of measures for the statistical significance of the results. Figures 5 and 7 show the results for the bond return coefficients of the life and non-life subsamples. Panels A and B show the results of the basic regression approach, presented in term 8. Panel C shows the results for the difference in the bond return coefficients of life and non-life insurers, as represented by the γ_2 coefficient, obtained from term 9. Figures 6 and 8 provide measures on the statistical significance of the results, depicted in figures 5 and 7.

[136] Note that the analysis, based on term 9, is conducted, using a sample of life insurance companies. In most cases, $Life\ share_{i,t}$ is, therefore, higher than 50 percent. If the same model was applied to non-life companies with life shares close to zero, γ_2 would be adjusted by a large degree, leading to unreasonable estimations.

The regression results and the related measures of statistical significance are presented, following a uniform scheme for all regional samples: Panel A of figure 3 depicts the estimated bond return coefficient γ as a black line from 2004 to 2020. Each point of the line represents a point estimate for γ, based on a time window, starting two years before the reporting date, and ending at the reporting date. The confidence interval for the coefficient is reported at a 95 percent confidence level as a grey area around the coefficient. Both the coefficient and the confidence intervals represent the weighted average results of all insurers in a sample. The grey line in the panel represents the average available interest rate on the related long-term bond over each time window.

Panel B shows measures of statistical significance for the results, presented in panel A. The p-value for the bond return coefficient is again depicted as a black line. The confidence interval for the coefficient is adopted from panel A. The coefficient of determination for the applied regression model is displayed as a grey line. At this point, it should be noted that the coefficient of determination always refers to the last regression, conducted to generate a bond return coefficient. For figures 6 and 8 this means that the coefficient of determination for the C panels refers to the second step to determine γ_2, using the sample of US-American life insurers. Chapters 4.2 and 4.3 will introduce additional variations of the γ coefficient. Also for these, the coefficient of determination always refers to the last conducted regression step.

Panel A of figure 5 shows the results for US life insurance companies based on data with a weekly frequency. In the normal-rate period, both the results of this study and by Hartley et al. show bond return coefficients close to zero, while interest rate levels were relatively stable at around 4.5 percent. During the financial crisis, the bond return coefficients show a clearly distinct and substantial increase to a value of almost 1, accompanied by a notable widening of confidence intervals, and falling interest rates from November 2008 onwards. In 2011, γ fell back to a value close to zero, until it began to decrease slowly in 2013. This development, however, is not mirrored by the results of Hartley et al.: They find an immediate decrease in the bond return coefficient after the global financial crisis to a value of about -0.7 in late 2011. After the initial decrease, bond coefficients in both analyses stayed negative for the complete low-rate period. Interest rates during that time remained at levels around 2.5 percent. Only with the impact of the COVID-19 pandemic, γ increased back to zero again.

A comparison of the weekly and daily results yields no significant deviations. As expected, the results in figure 7 yield narrower confidence intervals and a lower volatility due to the increased number of observations, underlying each 2-year time window. These results, however, indicate that the analysis by Hartley et al., relying on a lower number of companies, and using weekly, instead of daily data, is likely to have overestimated the swing of life insurers' bond return coefficients into the negative sphere in the low-rate period[137]. Overall, the coefficients, based on daily data, were closer to zero, especially during the financial crisis. Despite the narrower confidence intervals, figures 6 and 8 reveal that the results for both datasets are predominantly statistically insignificant.

The results for the UK sample are presented in figures 9 to 14. Panel A of figure 11 shows the results for UK life insurance companies based on weekly data. The results by Hartley et al. exhibit bond return coefficients with relatively high volatility and values close to zero over the complete timeframe of their analysis. Coefficients decrease along with available interest rates between 2011 and 2013 but show signs of recovery from 2013 until the end of their investigated period. The results in figure 11 are very similar to Hartley et al.'s results until 2015. After 2015, however, interest rates in the United Kingdom continued to fall. This was accompanied by a significant decrease in γ. Apart from a temporary recovery in 2018, γ decreased consistently until it reached its minimum at -1.6 in 2020[138]. Just as in the US-American sample, COVID-19 then had a notable positive impact on bond return coefficients of UK life insurers. Its long-term effects are however unclear at this point.

UK results, based on daily data, are presented in figure 13. Again, the daily results show narrower confidence intervals and values for γ closer to zero than the weekly results. The lowest value for γ, according to daily data, only amounts to -0.9 instead of -1.6. Furthermore, the daily results reveal a negative shift in γ for UK life insurers during the global financial crisis, as opposed to the positive shift in the United States. Following the financial crisis, the daily data yields statistically significant negative bond return coefficients. After its recovery in 2016, γ is significant both for the results, based on weekly data and daily data.

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[137] Hartley et al. (2016) present their US and UK results on pages 22 and 23.

[138] The value of the γ coefficient describes the change in insurers' stock returns, following a change in the associated bond return. A coefficient of -1.6 thereby indicates a decrease in insurers' stock returns of 1.6 percent, following an increase in the associated bond return of 1 percent.

The results for life insurers in the United States and the United Kingdom confirm hypothesis 1 for the timeframe between 2011 and 2016. While Hartley et al.'s results indicate a clear and consistent picture of higher interest rate sensitivities for US life insurers after the financial crisis, the results of this study reveal a more complicated situation, however: After the financial crisis, both US-American and UK life insurers exhibit a statistically significant decrease in γ. UK insurers then recover back to a sensitivity coefficient of zero until 2016. While interest rates in the United States then stabilize at around 2 to 2.5 percent, interest rates in the United Kingdom continue to decrease. From 2016 onwards, this decrease is accompanied by falling sensitivity coefficients for UK life insurers. After 2018, US life insurers seemed to be able to lower their interest rate sensitivities, while UK life insurers, under the pressure of historically low interest rates, have been more exposed to interest rate risk. In recent years, this analysis shows higher sensitivities to changes in long-term interest rates for UK instead of US life insurers, contrary to the expectation, indicated by hypothesis 1.

Regarding the interest rate sensitivity of non-life insurers in the United States, both panel B of figure 5 and figure 7 report bond return coefficients close to zero for the major part of the analyzed timeframe. Just as life insurance companies, US non-life insurers exhibit an increase in γ during the global financial crisis, however to a much smaller degree. Between 2017 and 2020, γ decreases for non-life insurers. This decrease is however statistically insignificant according to both weekly and daily data, and is again small, compared to the decrease in γ for life insurers after the financial crisis. In conclusion, the results of both the analysis, based on weekly data and on daily data, confirm hypothesis 2.

Panel C of figures 5 and 11 reports the γ_2 coefficients for the US and UK insurance sectors, based on data with a weekly frequency. Since bond return coefficients of non-life insurers did not show statistically significant results, with γ always close to zero, the γ_2 coefficients for the most part of the investigated timeframe resemble the results for life insurers in both regions. Compared to the situation of non-life insurers after the crisis, US life insurers still exhibit more negative bond return coefficients. Overall, panel C registers a decrease in interest sensitivity after the crisis, which is higher for life than for non-life insurers. Compared to panel A, panel C however reports wider confidence intervals and an earlier recovery of the γ_2 coefficient due to the negative γ of non-life insurers between 2017 and 2020.

In the United Kingdom, the situation is similar. In the years before and after the crisis, γ_2 is close to zero and even slightly positive. The decrease in γ for UK life insurers immediately after the crisis is not replicated by the γ_2 coefficient, as this decrease was also visible in the non-life insurer sample. After 2016 however, γ_2 fell to values up to -1.4 and remained negative until the end of the investigated timeframe. Therefore, only the second decrease in γ for UK life insurers was exclusive to the life insurer sample. This decrease was statistically significant, as reported in panel C of figure 12.

The results, based on daily data, are depicted in panel C of figures 7 and 13. For both regions, the daily results show narrower confidence intervals, as well as less volatile coefficients, which are generally closer to zero. Apart from these differences, the daily results confirm the observations, based on the weekly results. While Hartley et al. could not find statistically significant results for γ_2 coefficients in their UK sample[139], this analysis was able to detect statistically significant γ_2 coefficients for UK insurers between 2016 and 2020.

Regarding hypothesis 3, the daily results indicate a higher change in γ_2 coefficients between the normal-rate and the early low-rate period for the US insurance sector. These findings are consistent with the results of Hartley et al.[140]. In the late low-rate period, however, the UK insurance sector shows a substantial and statistically significant decrease in γ_2. Hypothesis 3 is therefore confirmed for the years 2011 to 2016. After 2016, however, UK life insurers become more exposed to interest rate risk, compared to UK non-life insurers, than US life insurers, compared to US non-life insurers.

Hypothesis 4 is evaluated based on γ_2 coefficients, as these report interest rate sensitivities for life insurers, which are free of effects, common to both life and non-life insurers in the same market. As mentioned earlier, life insurance companies in the United States and the United Kingdom are subject to interest rate risk in different periods of time. US life insurers show negative bond return coefficients between 2012 and 2019, while UK life insurers are particularly exposed between 2016 and 2020. US life insurers, therefore, seem to have suffered from falling interest rates earlier than UK life insurers. However, they were able to profit from relatively stable interest rates from 2013 onwards: The comparably high interest rates are likely to have had a positive influence on the

[139] Hartley et al. (2016), p. 23.
[140] Hartley et al. (2016), p. 15.

demand for life insurance products in the US. Furthermore, it is reasonable to assume that the combined negative effects of long-term guarantees and policyholder options in the portfolios of US life insurers would have been graver if interest rates declined further. For this reason, US life insurers were able to reduce their exposure to interest rate risk since 2018, raising their γ_2 coefficient back to zero in 2019.

In the United Kingdom, on the other hand, interest rates continued to fall during the low-rate period. Between 2011 and 2015, the γ_2 coefficients in the UK sample remained in the low positive domain, possibly due to low exposures to contracts with long-term guaranteed returns and policyholder options, as well as particularly low duration gaps. When interest rates on 10-year UK government bonds fell below 1.5 percent, however, the profitability of UK life insurers became increasingly sensitive to changes in interest rates. Therefore, contrary to the expectation due to hypothesis 4, γ_2 decreased for UK life insurers since 2016, while it increased for US life insurers in recent years. For this reason, hypothesis 4 is rejected.

The results for the US and UK insurer samples can be interpreted in several different ways. In addition to the previously discussed differences regarding characteristics of insurance products in both regions, Hartley et al. consider three possible causes: (1) the influence of the convexity problem, (2) incomplete hedges of US life insurers, and (3) varying demand for insurance products, due to changes in interest rate levels[141]. Since this analysis features an extended timeframe, a fourth cause is considered: (4) the influence of unconventional monetary policy measures, conducted by central banks in both regions. As mentioned in chapter 2.2, regulatory differences are not assumed to have been a major factor for the different performances of insurers in both regions.

Life insurers both in the US and UK show comparably low, or even negative duration gaps. As noted in chapter 2.1, duration matching is however only an approximate hedge against interest rate risk. The convexity problem could therefore have influenced the interest rate sensitivities of life insurers in both regions under falling interest rates, following the financial crisis. As Gründl et al. report, fixed income securities and loans accounted for approximately 90 percent of American and European insurer assets between 2012 and 2014[142]. Therefore, the severity of the convexity problem should be

[141] Hartley et al. (2016), p. 6, 15.
[142] Gründl et al. (2016), p. 11f.

similar in both regions. Yet, the interest rate sensitivities of US and UK life insurers reacted in different ways to falling interest rates. For this reason, the convexity problem is unlikely to be the main driver of the found results[143].

It is reasonable to assume that life insurers in the US understand their increased exposure to interest rate risk, arising from the design of their products. Consequently, they employ risk management techniques like duration matching. As discussed earlier, duration matching loses its accuracy, once changes in interest rates become too large. A risk management, based exclusively on duration matching, could therefore explain the results for US life insurers: In the normal-rate period, life insurers were able to manage their exposures to interest rate risk, using duration matching. When interest rates fell, they did not anticipate the combined effects of guaranteed products and policyholder options, however. Policyholders, prolonging their contracts, could have raised the duration of life insurers' liabilities, thereby increasing their duration gap, and making them more vulnerable to further decreases in interest rates[144].

When the situation of life insurers in the United States and the United Kingdom are compared, US life insurers show negative bond return coefficients much earlier than UK life insurers. These did not hold substantial risks through guaranteed products or policyholder options, which could have allowed them to withstand the low-yield environment much longer. Only when average interest rates fell below 1.5 percent, their bond return coefficients decreased significantly. The results of this chapter, therefore, support the assumption of higher interest rate sensitivities for US life insurers if these did not account for their increased exposure in the case of substantial decreases in available long-term interest rates.

Further, the decreased interest rates resulted in lower asset returns for insurers and forced them to cut benefits or increase prices for new policies. Especially guaranteed products were affected by this, as insurers need to be able to cover promised rates with their future investment income. This decreased the attractiveness of life insurance products for customers, and thereby lowered the demand for them. This is reflected by falling stock returns for insurers, occurring simultaneously with falling interest rates, causing γ to decrease[145].

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[143] Cf. Hartley et al. (2016), p. 6.
[144] Cf. Hartley et al. (2016), p. 6, 15.
[145] Cf. Hartley et al. (2016), p. 7.

This effect is likely to impact both US and UK insurers. Still, US life insurers see decreases in gamma much earlier than UK life insurers. Decreases in demand could have therefore been higher in the US, presumably due to the lower attractiveness of guaranteed products. In the UK, gamma fell much later, which could match the combined effects of decreasing asset returns and lower demand for life insurance products. It is questionable, however, whether these effects outweigh the influence of guaranteed products and policyholder options on insurers' interest rate sensitivities, discussed in chapter 2.1. Either way, the earlier decline in gamma for US life insurers could have been accelerated by a decrease in demand for guaranteed insurance products, as this decline was less pronounced in the UK insurer sample[146].

The extended timeframe of the analysis allows this study to consider a fourth possible explanation for the developments of bond return coefficients in the US and UK during and after the global financial crisis: In order to stimulate the markets, central banks in Europe and the United States supported their conventional monetary policy interventions with substantial purchases of government and corporate bonds, as well as mortgage-backed securities in the case of the FED. Papadamou and Siriopoulos argue that the way, in which monetary policy is conducted, could have a significant influence on the interest rate risk exposures of banks and insurance companies[147]. The timing and scope of quantitative easing programs in the US, UK, and EU during and after the crisis differed from each other substantially. The implementation of these programs could therefore be directly related to the interest rate risk exposures of insurers in the samples for the United States and the United Kingdom.

Gros, Alcidi, and Giovanni provide an overview of the assets, owned by the FED, the ECB and the Bank of England ("BoE") between 2008 and 2012[148]: While the BoE made the largest investments, relative to the previous size of its balance sheet, its investments were outclassed by the endeavors of the FED. Also, in comparison to the ECB, the FED engaged in quantitative easing to a much larger extent, investing around USD 1.25 tn. within the first months of the crisis, and inflating its balance sheet to USD 4.5 tn. until 2014. The ECB, on the other hand, started its large-scale QE program only in 2015[149].

[146] Hartley et al. (2016), p. 12f.
[147] Papadamou and Siriopoulos (2012), p. 46.
[148] Gros et al. (2012), p. 3.
[149] Reisenbichler (2020), p. 467. ECB (2021).

Pelizzon and Sottocornola (2018) argue that the effects of quantitative easing on the profitability of (re-)insurers is inconclusive: QE generally exerts positive effects on the stock markets, and thereby also on (re-)insurers. On the other hand, QE lowers the availability of low-risk long-term assets on the markets and intensifies the downturn of interest rates. For this reason, they investigate the effects of QE measures, conducted by the FED and the ECB, on (re-)insurers between 2002 and 2015. Their results show a positive influence of QE on the stock markets between 2008 and 2013, with (re-)insurers profiting more than other market sectors. For the period between 2013 and 2015, when the ECB started its QE program, the influence on insurer stock returns was not statistically significant, however[150].

These findings match the results of this study: Between 2008 and 2013, when the FED started its QE program, the bond return coefficients of US-American life insurers increased drastically. This could be the result of positive stock returns for US life insurers, while interest rate levels dropped. When the ECB engaged in their asset purchase programs in 2015, however, the impact on the insurance industry was not significant. If this trend continued over the following years, the ECB QE program could not support life insurers in the UK sufficiently to withstand historically low interest rates. The developments of the interest rate sensitivities of life insurers in both the US and UK could therefore be explained by the unconventional monetary policy measures, conducted by the FED and the ECB.

Overall, the results of this study coincide with findings by other researchers: Berends et al. find insignificant sensitivities of US-American life insurance companies' equity values to changes in long-term interest rates before the financial crisis. During the crisis, bond return coefficients increased, after the crisis, however, they turned negative, indicating a positive relationship between insurer profitability and long-term interest rate levels. In their sample, this exposure was particularly strong for larger insurance companies[151]. Regime switching in insurer interest rate sensitivities was also identified by Brewer et al. They, however, find a negative relationship between life insurers' stock prices and changes in interest rates in their analysis of earlier stock market data from 1975 to 2000[152].

[150] Pelizzon and Sottocornola (2018), p. 0.
[151] Berends et al. (2013), p. 49, 62. They attribute the change in sensitivity partly to policyholders, prolonging their contract terms in the low-rate environment. P&C coefficients were consistently insignificant.
[152] Brewer et al. (2007), p. 402, 407, 408, 411f. These results are consistent with other earlier works.

4.2 Interest Rate Risk in Continental Europe

Following the example of Hartley et al., this chapter presents a robustness check for the results of chapter 4.1, using a comprehensive sample of life and non-life insurers from continental Europe. The dataset, summarized in table 5, features insurance companies from 24 countries, including 20 member states of the European Union, as well as Russia, Serbia, Switzerland, and Turkey. Compared to the analysis, conducted by Hartley et al., the dataset includes more than twice as many companies[153] and also uses data with daily frequency, in addition to weekly data. For this reason, the analyses in this chapter are expected to produce meaningful results, which are suited to confirm or reject the previously presented hypotheses, regarding the influence of guaranteed minimum rates of return and options for policyholders on the interest rate risk exposures of life insurance companies.

This chapter first implements the regression approach, already used for the US and UK insurer samples. Since the continental European sample includes insurance sectors from countries with varying exposures to guaranteed products and policyholder options, however, this approach will then be extended to separate insurers with high and low exposures to these contract features into two different subsamples. The results for both subsamples are then compared to obtain an estimation for the influence of long-term guarantees and policyholder options on life insurers' exposures towards interest rate risk.

For the allocation of insurance companies to these subsamples, two variables are used: First, insurers with high or low exposures to the German and US-American insurance markets are allocated to different samples. This procedure makes use of publicly available information on the share of insurers' earned premiums from different countries and is consistent with the robustness check, conducted by Hartley et al.[154]. As a second robustness check, insurers are allocated based on the average exposure to insurance products with guaranteed rates of return within the life insurance sector of their home country. Information on the insurance sectors of the countries, included in the continental European sample, is primarily obtained from an analysis, conducted by Moody's in 2015[155].

[153] Hartley et al. (2016), p. 29.
[154] Hartley et al. (2016), p. 16f.
[155] Moody's (2015), p. 8.

The results for the regression approach, which was already implemented in chapter 4.1, are depicted in figures 15 to 20. The presentation of the European results follows the same scheme, as the US and UK results. Figures 17 and 19 report the bond return coefficients for continental European life and non-life insurers, as well as the coefficient for the difference between both groups. Panel A shows the coefficients for life insurers. Here, a very similar picture to the earlier results for UK life insurers, depicted in figures 11 and 13, presents itself: For the normal-rate period, γ is insignificant and stays close to zero. During the financial crisis, confidence intervals widen, however, no significant change in γ is observed in the weekly data. The results, using daily data, conversely report a decrease in γ, which is statistically significant for the continental European sample. After the financial crisis, γ is negative, but recovers to almost zero in 2016. It should be noted that the recovery in the UK sample is stronger and earlier than in the continental European sample. After 2016, γ decreases substantially and becomes highly significant, as shown in figures 18 and 20. In contrast to the UK life insurer sample, European life insurers exhibit a slow recovery in interest rate sensitivities from 2018 onwards, which was boosted by the impact of COVID-19 on the European stock markets.

As in the UK sample, γ coefficients for non-life insurers were predominantly very close to zero and statistically insignificant. Panel C of figures 17 and 19 show the γ_2 coefficients for the continental European sample. In comparison to UK life insurers, life insurers in the rest of Europe overall seem to have been affected more strongly by the impact of the global financial crisis. Both during the crisis and in the low-rate period, γ_2 was more negative for continental European insurers. Especially in the early low-rate period, continental European life insurers were significantly more exposed to changes in long-term interest rates.

These increases in sensitivities could be related to the European sovereign debt crisis: In the years, following the crisis, government bonds for several member states of the European Union exhibited substantial credit risk. Accordingly, insurers and other investors showed a higher demand for secure investment opportunities, like German government bonds[156]. This decreased the yields on these bonds, and thereby put insurers under increased pressure[157].

[156] Bijlsma and Vermeulen (2016), p. 153.
[157] Lane (2012), p. 57.

From 2015 onwards, the ECB amplified the decline in interest rates with their expansionary monetary policy measures. European insurance companies were therefore exposed to a particularly sharp decline in interest rates since the advent of the global financial crisis. In fact, interest rates on the German 10-year government bond continued to decline almost constantly over the complete low-rate period. Since March 2019, the bond even offers negative interest rates. As Pelizzon and Sottocornola note, the quantitative easing activities of the ECB did, however, not have a significant positive impact on stock returns of insurance companies between 2013 and 2015[158]. These difficult conditions for life insurers in continental Europe are directly captured by the model, which uses the German DAX 30 index and the German 10-year bond for the estimation of the market and bond return factors.

The model consequently attests a comparably high sensitivity of life insurer stock returns to changes in long-term interest rates since these started to decrease. The results of this basic model can however not identify the sources of interest rate risk within the life insurer subsample. Reports by Moody's and EIOPA suggest that life insurers from different European countries should exhibit very heterogeneous levels of interest rate risk, based on the average duration gaps and exposures to insurance products with guaranteed returns in their home countries[159]. Therefore, a separation of insurers into two subsamples with presumably high and low exposures to interest rate risk, based on their home countries, seems useful. As Hartley et al. note, however, this approach ignores the substantial amount of cross-national activities of insurance companies in Europe. A company, which is based in a country with a relatively well-hedged insurance industry, might primarily operate in a market that makes heavy use of products with guaranteed returns or policyholder options, and vice versa[160].

For this reason, Hartley et al. propose to allocate insurers to the presumably more or less risky samples based on the share of the business, they conduct in countries with insurance sectors, which should be exposed to significant degrees of interest rate risk. For many European countries, it is difficult to make a definite statement on the prevalence of insurance products with guaranteed rates of return or policyholder options[161]. For Germany, however, researchers and supervisors agree that the life insurance sector is

[158] Pelizzon and Sottocornola (2018), p. 0.
[159] EIOPA (2014a), p. 17; Moody's (2015), p. 8.
[160] Hartley et al. (2016), p. 15f.
[161] Hartley et al. (2016), p. 5.

particularly exposed to interest rate risk. This assessment is based on multiple characteristics of the German life insurance industry: EIOPA and Moody's estimate an average duration gap of 11 years in the German life insurance sector. Among 27 countries, which participated in EIOPA's stress test, Germany thereby had the second-largest duration gap[162]. These estimations also match a more recent analysis by Möhlmann, who found a median gap in the modified duration of German life insurers' portfolios of 6.1. This result indicates that a 1 percentage point decrease in interest rates should cause an increase in the value of insurers' liabilities, which is approximately 6 percent larger than the simultaneous increase in their value of assets[163].

Möhlmann also notes that German life insurers primarily sell long-term endowment and annuity policies, usually involving guaranteed minimum rates of return[164]. Accordingly, Moody's estimates around 90 percent of German life insurers' liabilities to come from guaranteed insurance products, whereby the average guaranteed rate on these was 3.1 percent in 2015[165]. Furthermore, the German generally accepted accounting principles ("GAAP") exert additional pressure on the insurance sector: Life insurers are obliged to pay 90 percent of their investment profits on assets, which are tied to insurance policies, back to their policyholders. Similar rules exist for other sources of income[166]. This makes it more difficult for life insurers to balance out losses from periods with low returns with profits from periods with higher returns. Considering the substantial decline in the offered interest rate on the German 10-year government bond, this fact aggravates the situation for German life insurers. Due to these circumstances, the German financial supervisor Bundesanstalt für Finanzdienstleistungsaufsicht ("BaFin") recognizes interest rate risk as one of the most pressing issues in the German insurance industry[167]. This view is shared by many researchers, studying interest rate risk in the German market, as, for example, Swiss Re (2012)[168], Kablau and Weiß (2014), Berdin and Gründl (2015), Moody's (2015), and Möhlmann (2017).

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[162] EIOPA (2014a), p. 17; Moody's (2015), p. 10.
[163] Möhlmann (2017), p. 2f.
[164] Möhlmann (2017), p. 2.
[165] Moody's (2015), p. 10.
[166] Berdin and Gründl (2015), p. 394. Berdin and Gründl report further requirements of the German GAAP, including a forced disbursement of a part of life insurers' hidden reserves at contract liquidations, and the creation of an additional precautionary reserve in the case of a too strong decrease in a reference interest rate. These further increase the pressure on life insurers in Germany.
[167] BaFin (2018).
[168] Quoted according to Berdin and Gründl (2015), p. 386.

Based on this assessment, the following analysis will employ the variable $German_i$ as a measure of insurers' activities in markets with substantial exposures to interest rate risk. Insurance companies are assigned either to a high or low exposure group, based on the share of premiums, they earn from Germany. This approach is consistent with the regression design, implemented in the robustness check by Hartley et al.[169].

The separation of insurers into samples, which make use of guaranteed products to different degrees, creates a similar situation as in chapter 4.1: The high German exposure group takes the role of the US-American dataset, and the low exposure group replaces the UK dataset. Hartley et al. note that the situation regarding the prevalence of guaranteed insurance products is similar in the United States and Germany. Since life insurers, operating in both countries, should show higher sensitivities to changes in interest rates, Hartley et al. also include the share of premiums earned from the United States in the $German_i$ variable[170].

The extended regression model, taking account of insurers' exposures to the German and US-American markets, is presented in term 10. Here, $German_i$ has a value of 1 if an insurance company earns at least 25 percent of its premiums from Germany and the United States, and 0 otherwise[171]. Information regarding the origin of insurers' premiums is obtained from their most recent annual report as of March 2021. Most insurers do not report detailed information on this matter, however. $German_i$ therefore only represents an estimation of insurers' business activities, which also considers other publicly available information, for example from their websites. The shares, obtained in this way, are reported in table 5[172].

$$R_{i,t} = \alpha + \beta_1 R_{m,t} + \beta_2 R_{m,t} * Life\ share_{i,t} + \beta_3 R_{m,t} * German_i + \beta_4 R_{m,t} * Life\ share_{i,t} * German_i + \gamma_1 R_{10,t} + \gamma_2 R_{10,t} * Life\ share_{i,t} + \gamma_3 R_{10,t} * German_i + \gamma_4 R_{10,t} * Life\ share_{i,t} * German_i + \varepsilon_{i,t}, \tag{10}$$

[169] Hartley et al. (2016), p. 15f.
[170] Hartley et al. (2016), p. 5.
[171] Hartley et al. (2016, p. 16) only consider the share of life insurance premiums for the allocation to the high or low exposure groups. Some non-life insurers show very low shares of life insurance business overall. Basing their allocation to the high or low exposure samples on this small part of their business, is therefore likely to produce arbitrary allocations. This analysis, therefore, considers both life and non-life premiums for $German_i$. Non-life insurers in both samples should show comparable bond return coefficients. This will be checked by comparing the results of this approach to another approach, using one combined non-life sample.
[172] For four companies, no conclusive information regarding the origin of their premiums was found. These companies are excluded from this analysis.

where

β_3	= Market return coefficient for high German exposure to low German exposure difference,
β_4	= Market return coefficient for high German exposure to low German exposure × life to non-life difference,
γ_3	= Bond return coefficient for high German exposure to low German exposure difference,
γ_4	= Bond return coefficient for high German exposure to low German exposure × life to non-life difference.

As in the calculation of β_2 and γ_2 in term 9, the approach is dissected into multiple steps in order to avoid multicollinearity. Since the approach now features four bond return coefficients and four samples of insurance companies, the process to determine γ_4 relies on six steps: In the first step, β_1 and γ_1 are calculated for the high German exposure non-life insurer sample. Since only one market return coefficient and one bond return coefficient are involved, the underlying regression term is equal to the basic regression model, depicted in term 8. The coefficients, obtained in this way, are then used as fixed values for the calculation of β_2 and γ_2 in step two. For this step, the high German exposure life insurer sample is used. This approach is consistent with the calculation of β_2 and γ_2 in chapter 4.1.

Steps three and four repeat the first two steps for the low German exposure insurer sample. The resulting γ_2 coefficients for the samples with high and low exposures are presented in panels A and B of figures 21 and 23. The associated measures of statistical significance are presented in figures 22 and 24. For the calculation of γ_4, however, two further steps are necessary: Step five calculates β_3 and γ_3 to measure the influence of the allocation to the high and low exposure samples on the sensitivities of non-life insurance companies. Since these coefficients measure the difference between high and low exposure non-life insurers, the β_1 and γ_1 coefficients of the low exposure non-life insurer sample are used as a baseline. These coefficients are taken from the results of step three. β_3 and γ_3 are then calculated based on the high exposure non-life insurer sample, employing the β_1 and γ_1 results of the low exposure non-life insurer sample as fixed values. The β_2 and γ_2 coefficients are ignored in this step.

Step six calculates the β_4 and γ_4 coefficients based on the high exposure life insurer sample. These coefficients represent the difference in sensitivities of high exposure life insurers to high exposure non-life insurers and to low exposure life insurers[173]. Accordingly, β_1 to β_3 and γ_1 to γ_3, obtained in steps three to five, are inserted as fixed values in the complete regression term, presented in term 10. The resulting γ_4 coefficients are reported in panel C of figures 21 and 23.

Figure 21 presents the results of the described regression approach, based on weekly data. As expected, life insurers in the high German exposure sample become more sensitive to changes in interest rates during the low-yield environment, compared to non-life insurers from the same sample. This effect is less pronounced in the low exposure sample. This difference is also reflected in the γ_4 coefficient: From 2014 onwards, the difference between life insurers and non-life insurers from the high German exposure sample became increasingly negative, compared to a lower difference between life and non-life insurers from the low German exposure sample. These findings are consistent with the results by Hartley et al.[174]. They find a negative γ_4 coefficient from 2012 onwards. The coefficient is, however, only significant for a short amount of time and shows a recovery from 2014 onwards. In Hartley et al.'s sample, γ_4 was unusually low in 2014 and exhibited wide confidence intervals. The results in this study, on the other hand, exhibit narrower confidence intervals and a lower volatility of γ coefficients in panel A and panel C. This could be related to the size of the high German exposure sample in Hartley et al.'s analysis: Instead of 7 companies[175], this study allocates 11 companies to this sample.

Hartley et al. further find a decrease in γ_2 during the financial crisis both for the high German exposure and low German exposure samples. As for the results of the complete European sample, presented in figures 17 and 19, this development is not observed in the weekly dataset but becomes visible in the daily dataset, depicted in figure 23. In this study, this effect was limited to the high German exposure sample, however.

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[173] The model already captures the effect of being a low exposure life insurer and being a high exposure non-life insurer separately. β_4 and γ_4 measure the difference in sensitivities of these insurers to insurers, which are both life insurers and part of the high German exposure sample. Hartley et al. (2016, p. 17) comment on the γ_4 coefficient as follows: "This coefficient measures the effect of life insurance exposure to bond returns over and above the effect of non-life insurance exposure for firms more exposed to Germany relative to those less exposed to Germany. We interpret this coefficient as measuring how interest rate sensitivity for a pure life insurance firm highly exposed to German products changed relative to a pure life insurance firm with low exposure to German products."

[174] Hartley et al. (2016) present their EU results on page 24.

[175] Hartley et al. (2016), p. 17f.

The daily results further reveal a different picture for the γ_4 coefficient than the weekly results: While the coefficient is still statistically significant after the financial crisis, the difference between the high German exposure sample and the low German exposure sample is much smaller in this case. On the other hand, the daily results report statistically significant negative γ_4 coefficients also for the period between 2007 and 2009.

Based on the daily results, the difference between the high and low German exposure samples is much smaller than it was originally estimated by Hartley et al. For this reason, a further robustness check for the model appears useful: So far, the model has worked with two separate samples of non-life insurers in the high and low German exposure samples. Considering their typical business activities, non-life insurers' exposures to interest rate risk should be low and not significantly influenced by the share of premiums, generated in countries with a strong focus on guaranteed insurance products. Therefore, the decision to separate non-life insurers into a presumably high and low risk category based on this characteristic seems unnecessary and could bias the results.

For this reason, an additional analysis, using only one combined sample of non-life insurers, is conducted. Here, life insurers from the high and low German exposure samples are compared against the same non-life insurance companies. This change in design makes the β_3 and γ_3 coefficients obsolete. The reduced regression model is presented in term 11.

$$R_{i,t} = \alpha + \beta_1 R_{m,t} + \beta_2 R_{m,t} * Life\ share_{i,t} + \beta_4 R_{m,t} * Life\ share_{i,t} * German_i + \gamma_1 R_{10,t} + \gamma_2 R_{10,t} * Life\ share_{i,t} + \gamma_4 R_{10,t} * Life\ share_{i,t} * German_i + \varepsilon_{i,t} \quad (11)$$

The new results are presented in figures 25 to 28. If the previous regression approach produced reliable results, the findings of the new model should turn out very similar. Considering the daily results, reported in figure 27, the new results indeed closely resemble the results of the previous model. The new results are not as consistently statistically significant, the γ_4 coefficient however behaves similarly: The difference in life to non-life insurer interest rate sensitivities is slightly higher for the high German exposure sample almost over the complete timeframe of the analysis. The main finding of the new model is that the downturn in γ_2 during the crisis is now present in both samples. This indicates that the shift in γ_2 is caused by the non-life insurer sample, rather than the life insurer samples.

Overall, the results of both models suggest that life insurers, which operate in the German and US-American markets, are typically more exposed to interest rate risk than other life insurers. Life insurers with lower exposures to these markets were still more sensitive to changes in long-term interest rates than non-life insurers. The difference in sensitivity for them was, however, lower than for the high exposure life insurers, as shown by the γ_4 coefficient. It is likely that insurers with higher exposures to Germany and the United States offer considerable amounts of insurance products with guaranteed minimum rates of return and options for policyholders, as these are popular in the mentioned markets. The results, based on a single sample of non-life insurers, therefore support the hypotheses, put forward in chapter 4.1, and are consistent with the results, found for the US-American and UK insurer samples.

Remarkably, the new results, based on daily data, show negative γ_4 coefficients already since 2006. This indicates that stock market investors took into account the increased interest risk for life insurers, exposed to guaranteed products and policyholder optionality, already long before the global financial crisis[176]. Since the γ_4 coefficients were statistically significant only for a part of this period, however, the results are not conclusive enough to make a definitive statement on this finding.

The low statistical significance of the results could potentially be explained by an imprecise estimation of life insurers' exposures to interest rate risk through the $German_i$ variable. While life insurers, operating in Germany and the United States, are likely to hold larger amounts of liabilities from guaranteed insurance products, other factors, like the duration mismatch or differences in regulatory treatment, might not be covered by this variable. Hartley et al. mention the extensive amount of European insurers' cross-border activities as one of their main arguments to assess insurers' interest rate sensitivities based on the source of their premiums, instead of a country-level. Considering the substantial differences in duration gaps between European countries, found by Moody's in 2015[177], insurers' exposures to interest rate risk seem to be substantially related to their home country, however.

[176] In most datasets, the crisis had its strongest influence between 2009 and 2011, as indicated by substantial swings in bond return coefficients during this period of time.

[177] Moody's (2015), p. 8. EIOPA (2014a, p. 17) also reports duration gaps per member state of the European Union. This assessment was however conducted on an undertaking-level, instead of a country-level (see Hartley et al., 2016, p. 19).

For this reason, a third analysis is conducted, using an alternative variable, which assesses insurers' interest rate risk from guaranteed products on a country-level. The variable, labelled LTG_i, replaces $German_i$ in the previous model. It is assigned a value of 1 if an insurer comes from a country, which is particularly exposed to insurance products with long-term guarantees, and a value of 0 otherwise. Countries' exposures to long-term guarantees are evaluated based on the assessment by Moody's, which ranks countries into five risk categories. Moody's uses four criteria for this classification: the share of overall insurance reserves from guaranteed products, the average guaranteed rate, insurers' abilities to reduce credited rates, and the average duration gap[178].

Since the goal of the analysis is to measure the influence of differences in the use of guaranteed products, the average duration gap in each country is disregarded for the determination of LTG_i. Nonetheless, for most countries, the allocated LTG_i value follows the classification by Moody's: "Moderate risk" to "very high risk" countries were allocated a value of 1, and "very low risk" to "low risk" countries a value of 0. Only two exceptions were made: France was classified as a country with "moderate risk to profitability" due to its medium-sized duration gap, while the measures regarding guaranteed products generally showed a better performance. Companies from France, therefore, received an LTG_i value of 0. Spain on the other hand received a "low risk" classification despite its comparably dire situation regarding the use of guaranteed products. Spanish companies, therefore, were allocated a value of 1.

Companies from the countries, which were not included in Moody's assessment, were allocated a value for LTG_i based on an analysis by EIOPA from 2019[179]: EIOPA reports the average influence of long-term guarantees on SCR ratios in EU member states. Countries, in which SCR ratios were strongly connected to long-term guarantees, were allocated a value of 1. The resulting LTG_i value for every company in the continental European dataset is reported in table 5. Effectively, 27 companies from 10 out of the 24 countries, represented in the dataset, were allocated to the high exposure sample[180].

[178] Moody's (2015), p. 5-8.
[179] EIOPA (2019), p. 25.
[180] Germany, Italy, the Netherlands, Norway, Spain, and Switzerland were allocated due to the classifications by Moody's. Belgium, Denmark, Finland, and Greece were allocated due to the assessment by EIOPA. EIOPA's findings confirm Moody's classifications. For Russia, Serbia, and Turkey, no information regarding the use of long-term guarantees was found. Companies from these countries were assigned an LTG_i value of 0.

The investigations by Moody's and EIOPA reveal that many more European countries besides Germany are heavily exposed to insurance products with guaranteed minimum rates of return. This further supports the introduction of an alternative variable, which also measures insurers' exposures to guaranteed products based on their activities in other European markets. The new analysis replaces $German_i$ with LTG_i, but does not change the regression approach. The first results, based on two separate samples of non-life insurers, are depicted in figures 29 to 32.

Figure 29 shows the results for the weekly dataset. As in previous results, life insurers became more sensitive to changes in interest rates after the financial crisis, compared to non-life insurers. This development is observed both in the high and low exposure samples. The results also show a drop in γ_2 in the high exposure sample during the financial crisis. This drop was already observed in the UK sample and in figure 23. Previously, it was only visible in results, based on daily data, however.

In contrast to the results, based on the $German_i$ variable, the new results indicate a higher difference between life and non-life insurer sensitivities in the low exposure sample. This finding is confirmed by the γ_4 coefficient in panel C: Here, the coefficient was almost constantly positive apart from the crisis period between 2009 and 2011. This observation stands in opposition to the expectation that the profitability of life insurers with higher exposures to guaranteed products should be more sensitive to changes in interest rates than the profitability of less exposed life insurers. These findings are however not statistically significant, as reported in panel C of figure 30.

The daily results, presented in figure 31, largely confirm the findings of the weekly results. Here, the drop in γ_2 during the crisis is recorded in both the high and low exposure samples. The γ_4 coefficient, therefore, does not register a notable difference between both samples for this period. Overall, both the sensitivities in panels A and B, as well as the resulting difference between both samples in panel C, are less volatile and show a lower magnitude than the coefficients in the weekly dataset. Especially between 2006 and 2011, γ_4 was close to zero. In the periods from 2012 to 2014 and 2018 to 2020, however, the coefficient was positive. Over the complete timeframe of the analysis, the daily dataset shows statistically significant γ_4 coefficients only for 6.4 percent of the considered two-year regression samples.

As for the analysis, using the $German_i$ variable, a second investigation with only one combined sample for non-life insurance companies is conducted. This approach should yield γ_4 coefficients, which are unbiased from differences between non-life insurer bond return coefficients in the high and low exposure samples. The resulting coefficients and measures of statistical significance are presented in figures 33 to 36.

For both the results, based on weekly and daily data, the γ_2 coefficients in the high and low exposure samples were more similar in this approach. Accordingly, the γ_4 coefficients in panel C are less volatile and closer to zero overall. The results, based on daily data, were only statistically significant in 0.5 percent of the investigated two-year regression samples.

In conclusion, the analysis, based on the LTG_i variable, did not produce statistically significant results to a degree, which would allow the model to verify or reject the hypotheses, formulated in chapter 4.1. Insurance sectors in the countries, included in the continental European dataset, exhibit substantial differences in the prevalence of insurance products with guaranteed rates of return. Nonetheless, an allocation of insurers to samples with presumably high or low exposures to guaranteed products, based on their home countries, did not yield significant differences in their sensitivities to changes in long-term interest rates. This result is consistent with the assumption by Hartley et al. that the extent, to which insurers offer products with guaranteed returns and policyholder options, is determined by the countries, they operate in, rather than the country, they are based in.

Accordingly, the results of the approach, employing the $German_i$ variable, yielded more significant results and confirmed the expectations, based on the hypotheses, formulated in chapter 4.1: From 2006 onwards, life insurers from the high German exposure sample were considerably more sensitive to changes in long-term interest rate levels than insurers from the low German exposure sample. Since 2018, the difference between the bond return coefficients of both samples was almost consistently statistically significant at the 95 percent confidence level. These results were also robust to an analysis, employing a changed sample allocation of non-life insurers. Concluding, the analyses in this chapter confirm the hypothesis that life insurers, which are more exposed to insurance products with guaranteed rates of return, are subject to an increased level of interest rate risk. Moreover, the $German_i$ variable discovers that this relationship existed already before the 2007 global financial crisis.

4.3 Comparison to a Bottom-Up Assessment of Interest Rate Risk

The analyses in this work measure the interest rate risk exposures of insurance companies with a top-down approach. Usually, bottom-up approaches are likely to produce more reliable results through the use of detailed company-level data. This type of data, however, is not available to the public in most cases, which makes bottom-up assessments of interest rate risk exposures unfeasible for most scientific investigations.

The European supervisory authority EIOPA provides a bottom-up measure of interest rate risk in the form of average life insurer duration gaps in its 2014 insurance stress test. The results are publicly available at the country-level[181]. In particular, it conducted a test based on a "Japanese-like scenario", simulating a "persistent low interest rate environment" for life insurers[182]. Following the example of Hartley et al.[183], this chapter compares EIOPA's bottom-up results with the changes in interest rate sensitivities of insurers in the continental European sample between the normal-rate and the low-rate period.

In their regression model, Hartley et al. implement an indicator variable to distinguish the bond return coefficients from the normal-rate period and the difference to these in the low-rate period[184]. This study employs the same concept, for the sake of consistency with the earlier regression models however, the approach, depicted in term 12, avoids the use of an indicator variable, and splits the approach into two consecutive steps again.

$$R_{i,t} = \alpha + \beta_{normal} R_{m,t} + \beta_{low} R_{m,t} + \gamma_{normal} R_{10,t} + \gamma_{low} R_{10,t} + \varepsilon_{i,t}, \qquad (12)$$

where

β_{normal} = Market return coefficient for normal-rate period,

β_{low} = Market return coefficient for low-rate period to normal-rate period difference,

γ_{normal} = Bond return coefficient for normal-rate period,

γ_{low} = Bond return coefficient for low-rate period to normal-rate period difference.

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181 EIOPA (2014a), p. 17.
182 EIOPA (2014a), p. 16.
183 See Hartley et al. (2016), p. 18f.
184 Hartley et al. (2016), p. 18.

As for the calculation of the β_2 and γ_2 coefficients in chapter 4.1, β_{low} and γ_{low} are calculated based on the β_{normal} and γ_{normal} coefficients: In a first step, β_{normal} and γ_{normal} are determined individually for every insurer in the continental European dataset. As indicated by their index, β_{normal} and γ_{normal} are calculated only for the normal-rate period from January 2002 to June 2007. In a second step, the same process is repeated for the low-rate period, starting in July 2010, and ending in October 2020. The thereby obtained coefficients constitute the sensitivities of insurers during the low-rate period. To obtain β_{low} and γ_{low}, the average of each insurer's β_{normal} and γ_{normal} coefficients over the complete normal-rate period is subtracted from its low-rate period coefficients. The β_{low} and γ_{low} coefficients thereby reflect each insurer's change in sensitivities between the normal-rate and low-rate period. The individual coefficients are then aggregated for each sample.

Like in the previous analyses, insurers are again allocated to life and non-life samples, and all reported coefficients represent the weighted average over the coefficients of the included insurers. The resulting bond return coefficients for the years 2012 to 2020 are reported on a country-level, separate for the underlying life and non-life insurer samples, in appendices A to D[185].

Hartley et al. allocate insurers to the countries in their continental European sample based on their share of earned premiums per country at the end of 2014. This decision is consistent with their design of the $German_i$ variable, discussed in the previous chapter. Appendices A and B report bond return coefficients, following the same allocation method, considering the most recent publicly available data. Appendix A thereby shows the results for the weekly dataset, and appendix B for the daily dataset. Since the previous chapter also introduced the LTG_i variable, using a country allocation, based on insurers' home countries, this chapter provides results, following this allocation method, as well. The corresponding findings are presented in appendices C and D for weekly and daily data, respectively[186].

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[185] Since regressions are reported on the last date of their underlying two-year time windows, the first month for which γ_{low} coefficients are available is July 2012.

[186] For some samples in several countries, γ_{low} is not reported. In each case, this is due to one of two reasons: (1) No insurer was allocated to the sample, e.g. if one country is only represented by one insurer; (2) The allocated insurers were not active either in the normal or low-rate period, preventing the calculation of γ_{low}.

The average γ_{low} coefficients over the complete low-rate period are then compared to the estimated average duration gaps, obtained from EIOPA. Each sample of life and non-life insurers is assessed separately for every country in the continental European sample. EIOPA does not provide duration gaps for Iceland, Norway, Russia, Serbia, Switzerland, and Turkey. The scope of the comparison is therefore limited to a maximum of 18 out of the 24 featured countries. The results of the comparison are reported in tables 13 to 16.

In the results, life insurers are expected to exhibit strong decreases in bond return coefficients due to the historically low interest rates after the financial crisis. Furthermore, the change should be higher for life insurers with high duration gaps since these were not appropriately hedged against the falling rates. Therefore, life insurers, which were allocated to countries, for which EIOPA reports high average duration gaps, should on average show lower γ_{low} coefficients. At the same time, non-life insurers should on average show much more stable bond return coefficients between the normal-rate and the low-rate period.

Table 13 reports the correlation between γ_{low} and the duration mismatch measures over all countries in the weekly dataset, following a country allocation based on the source of earned premiums. The life insurer sample exhibits a correlation of -0.20, indicating a weak negative relationship between the change in their bond return coefficients and average duration gaps. A negative correlation generally confirms the expectations of higher decreases in coefficients for life insurers, which had higher average duration gaps.

The non-life insurer sample, on the other hand, only shows a correlation of -0.06. This indicates that non-life insurers' changes in sensitivities were less related to the average duration gaps in the countries, they operate in. These findings confirm the expectations for both subsamples and are consistent with the outcomes of Hartley et al.'s analysis. Hartley et al. find a statistically non-significant correlation of -0.40 for life insurers, but do not report the correlation for non-life insurers due to the low significance of the γ_{low} coefficients in these samples[187]. While they find highly significant changes in interest rate coefficients for the life insurer samples in five out of six countries in their analysis, this study does not reveal any correlations or changes in sensitivity coefficients, which are significantly different from zero.

[187] Hartley et al. (2016), p. 19, 30. Hartley et al. label this coefficient γ_1.

Table 14 reports the results for the daily dataset. In this analysis, the negative γ_{low} coefficients for the French, Icelandic, and Russian life insurer samples were significant at significance levels of one to five percent. At the same time, the positive coefficients for the Finnish, Hungarian and Dutch non-life insurer samples were significant at the five percent level. The correlations of both samples with EIOPA's duration mismatch estimates were almost identical at -0.28 and -0.27[188]. Again, these results were not significant, however.

The results for the analyses of weekly and daily data, following a country allocation, based on insurers' home countries, are depicted in tables 15 and 16. Since some countries are only represented by a small number of insurers in the dataset, not all countries feature both life and non-life insurer subsamples. The number of reported γ_{low} coefficients is, therefore, lower than in the results for the analysis, using a premium share-based country allocation method. In contrast to this method, the second allocation method yields positive correlations for the life and non-life insurer subsamples, both in the weekly and the daily dataset. As in the previous results, most coefficients are not statistically significant again.

While the first findings confirm the expectations for life insurance companies, they show different outcomes for non-life insurers in the weekly and daily datasets. The second findings are more consistent between both datasets but do not reflect the expectations for life insurance companies. Hartley et al. note that EIOPA's stress tests were conducted at an undertaking-level[189], consistent with the country allocation in the earlier results. This could explain why these results were closer to the expectations, while the results, based on the allocation method, which already produced insignificant results in chapter 4.1, again could not deliver an outcome, which corresponds to the expectations, or which would be consistent with the findings of other analyses. The results of the first allocation method are therefore assumed to be more representative. Nonetheless, the findings in tables 13 to 16 could not identify a significant relationship between this works' top-down measure of interest rate risk, and EIOPA's bottom-up measure. For this reason, a second comparison is established, comparing the earlier obtained γ_{low} coefficients with results from EIOPA's 2016 stress test.

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[188] While the correlations were similar, the average change in sensitivities between the normal and the low-rate periods was different in both samples: The life insurer samples on average show a change of -0.40, while the non-life insurer samples on average show an increase of 0.22.

[189] Hartley et al. (2016), p. 19.

As in their 2014 stress test, EIOPA's 2016 insurance stress test again includes a "low-for-long" scenario[190], suited to analyze the impact of a prolonged low interest rate environment on life and non-life insurers' solvency situations. Among other results, EIOPA presents the relative change in the value of insurers' assets over liabilities ("AoL") under the low-for-long scenario for each member state[191]. If a decrease in interest rates lowers the value of an insurer's assets by a larger degree than the value of its liabilities, the insurer shows a sensitivity towards changes in interest rates, consistent with a negative γ_{low} coefficient, or an exposure to a positive duration gap. Insurers, which are subject to lower γ_{low} coefficients should therefore on average show a larger decrease in AoL than insurers with higher γ_{low} coefficients. Accordingly, a comparison of the results, presented earlier in this chapter, with EIOPA's estimates for changes in AoL in the low-for-long scenario is expected to yield a positive correlation between both measures. This effect is likely to be stronger in the life than in the non-life insurer sample since life insurers on average exhibited larger declines in bond return coefficients between the normal- and the low-rate period.

Tables 17 to 20 present the results for the findings, depicted in tables 13 to 16, with the average change in AoL per country replacing the average duration mismatch. As expected, tables 17 and 18 report comparably high positive correlations for the life insurer samples. The non-life insurer samples, on the other hand, showed remarkably high negative correlations, especially in the weekly results. Both the correlations of life and non-life insurers' γ_{low} coefficients with EIOPA'S change in AoL estimates were almost significant in table 17. With average p-values of 0.057 and 0.066, they are the closest to achieve statistical significance over all correlations in tables 13 to 20. The results, based on the home country allocation method, report negative correlations for both the life and non-life insurer samples, however with comparably lower significance.

In conclusion, the comparisons, discussed in this chapter, could not identify a statistically significant relationship between the results of this work and EIOPA's estimates. However, the new findings support the presumption that results, following a premium share-based allocation method, are more promising than results, following a home country allocation.

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190 EIOPA (2016), p. 9, 51-53.
191 EIOPA (2016), p. 30.

4.4 Interest Rate Risk in International Regions

As an extension of the analyses, conducted in chapter 4.1, this chapter applies the same regression approach to seven further samples of insurance companies from different regions around the world. The samples cover insurance companies from North America, Africa, Asia, and Australia[192]. Company data was acquired from a combination of SNL Financial, Datastream, and Bloomberg. Out of all the companies, included in their datasets, only those were selected for the international insurer samples, which complied with the data quality requirements, set out in chapter 3. Each of the new sets of insurers thereby includes between 8 and 31 companies, which are reported in tables 6 to 12.

As opposed to the analyses for the three main samples, the international samples do not make use of a uniform currency for all involved insurers. Instead, stock returns are calculated based on the local currency for each country. Only for the weighting of the results, using stock market capitalizations, a common currency is used in every dataset. Furthermore, a different stock market index and different government bond rates are used per country[193]. This stands in contrast to the continental European sample, which makes use of the DAX 30 stock index and the German 10-year government bond rate for all countries in the sample. The reasoning behind this is that in some regions, substantial economic differences exist between the included countries. Thus, the developments of stock markets, bond interest rates, and currency exchange rates differ notably, and a comparison of stock returns with market developments in other countries would not be justifiable.

It should be noted that the results of the international samples are likely to be less representative than the results of the three main samples: In most regions, a substantial number of companies had to be excluded from the analysis due to the poor quality of their available time series data. All seven samples therefore only report coefficients for a part of the covered insurance sectors, and the applicability of the findings to real-world use cases is limited.

[192] The data coverage for South American insurers was not sufficient to create a separate sample for insurers from this region.

[193] As for the company data, the stock market and bond yield data was not always available in perfect quality. Especially in the African and Middle Eastern samples, this limits the timeframe for which regressions are possible in many countries. In some cases, long-term government bond data was not available either. For these countries, interest rates for lower maturities were chosen. For an overview, see table 1.

The reduced coverage in the samples also restricts the interpretability of their results. For the evaluation of the findings, primarily information, provided by Moody's (2015), is consulted. However, since the average number of insurers per country, included in the international samples, is low, it is not guaranteed that Moody's country-level assessments match the characteristics of the international samples. This chapter therefore only provides comparisons between the found interest rate sensitivities with Moody's background information on the insurance sectors of the involved countries. It does not, however, make statements whether the match or mismatch between both sources of information can confirm or reject the hypotheses, formulated in chapter 4.1.

The results for the international samples are presented in figures 37 to 78. For each sample, a set of six figures is reported, following the same scheme, which was already applied for the three main samples in figures 3 to 20. The first set of results relates to the Canadian sample: Figure 39 shows the results for the weekly dataset: Life insurers in Canada exhibit bond return coefficients close to zero in the normal-rate period, and show a positive jump in γ and wider confidence intervals during the financial crisis. After the crisis, however, the bond return coefficients decrease substantially to values up to -1.26 and stay statistically significant between 2012 and 2018. Out of the three main samples, this development is most comparable to the continental European sample, as shown in figure 17. In Canada, the initial decrease in γ was stronger, however, and the coefficient did not recover as well between 2014 and 2016.

Canadian non-life insurers at the same time show comparably wide confidence intervals and γ coefficients close to zero for the complete timeframe of the analysis. Also, the coefficients of determination, reported in figure 40, are comparably low for this sample. These results indicate a particularly low dependence of Canadian non-life insurers' profits on changes in long-term interest rates. Panel C reports the γ_2 coefficients for the weekly dataset. The coefficients confirm the findings of the first two panels and report a constantly high and statistically significant dependence of Canadian life insurers' profitabilities to changes in long-term interest rates between 2012 and 2019. Figures 41 and 42 confirm these findings with results from the daily dataset as well. Overall, Canadian life insurers appear to have been more sensitive to changes in long-term interest rates after the global financial crisis than life insurers from the United States, the United Kingdom, and continental Europe.

These findings match the information for Canada's life insurance industry, provided by Moody's: Despite its low average duration gaps of one to three years, Canada is classified as a country with moderate risk to life insurers' profitabilities from prolonged exposures to low-yield environments. With this categorization, Canada matches the risk level of the United States in Moody's assessment. Moody's further identifies long-term guarantees as an important source of risk for the Canadian insurance sector: With guaranteed products making up 60 to 80 percent of life insurers' liabilities, and average guaranteed rates amounting to two to four percent, Canadian life insurers run the risk of falling short behind their promised rates, if interest rates decrease by a high degree. Furthermore, the impact of falling interest rates on life insurers is likely to be visible to stock investors much earlier in Canada than in the United States, since the Canadian International Financial Reporting Standards force insurers to recognize losses from falling rates immediately, unlike in the United States[194].

Considering that the offered rates on Canadian 10-year bonds fell to levels as low as 0.5 percent in 2020, the identified declines in γ and γ_2 coefficients match the expectations, raised by Moody's assessment. At the same time, the representativeness of the results for Canada is questionable, taking into account the low sample size of only 6 life and 4 non-life insurers.

Figures 43 to 48 depict the results for the African insurer sample. Figure 45 thereby shows the results for the weekly dataset: As opposed to the results from the Canadian sample and the three main samples, life insurers in Africa on average showed positive as opposed to negative bond return coefficients after the financial crisis. This result is confirmed by statistically significant p-values since 2016, reported in figure 46.

This finding also applies to the non-life sample, which shows less constant γ coefficients before the crisis, but similar positive values thereafter. The γ_2 coefficients in panel C report a statistically significant difference between life and non-life insurers' coefficients in 2008, which was caused by a high positive coefficient in the non-life sample. After the financial crisis, life insurers on average were exposed to interest rate risk to a slightly larger degree. Apart from a short period from 2014 to 2015, this difference is mostly insignificant, however. In general, these results are confirmed by the daily dataset, as shown in figures 47 and 48.

[194] Moody's (2015), p. 14f.

Between 2009 and 2011, life insurers in previous samples had mostly shown either positive or negative reactions in their γ coefficients. In the African sample, the sensitivity of life insurers did not seem to be immediately affected by the crisis, however. Non-life insurers, on the other hand, show a slow decline in γ in the mentioned years.

The low dependence of life insurers' financial conditions on changes in interest rates during the crisis, as well as the reverse interest rate sensitivity after the crisis, could be related to the comparably high interest rate level in most African countries. In each of the included countries, long-term rates did not decrease significantly after the crisis. As table 7 shows, the African sample is dominated by South African insurers, judging by their market capitalizations at the end of 2019. Accordingly, the results mostly reflect the situation in South Africa, where interest rates were not notably affected by the global financial crisis and stayed at a level of around eight percent throughout the post-crisis period. Consequently, life insurers in the African sample, in contrast to the western samples, were not exposed to a low-yield environment in their home countries.

Out of the five countries, included in the African sample, Moody's only provides information on the South African life insurance sector: Despite a comparably high level of guaranteed interest rates, South African life insurers are classified with a low risk, emanating from a low-yield environment. Moody's justifies this decision with high investment returns in the portfolios of South African life insurers and higher amounts of profit-sharing and unit-linked products than in other countries[195]. The coefficients, depicted in figures 45 and 47, therefore confirm the assessment by Moody's with a low exposure to interest rate risk in the African life insurer sample, which even exhibited a reverse sensitivity after 2013.

Furthermore, taking into account the lower economic development of the countries in the African sample, it is conceivable that the performance of life insurers in these countries was less bound to the developments of interest rates, and more to factors outside the model. This assumption was, however, not confirmed by the coefficients of determination, depicted in figures 46 and 48: With values around 0.4, the coefficients indicate a similar fit of the regression model for the South African sample, compared to the previous western samples.

[195] Moody's (2015), p. 18.

Figures 49 to 54 report the results for the Middle Eastern sample of insurance companies. Out of all the samples, discussed in this chapter, the Middle Eastern sample features the highest number of insurers with 31 companies. The distribution of these to the life and non-life subsamples is uneven, however, with 29 non-life but only 2 life insurers. This fact is directly visible in the results: Panel A of figure 51 shows the weekly results for the life insurer sample. For the two life insurance companies, total return index data was only available with sufficient quality since 2008. Accordingly, figures 51 to 54 only report results for the life insurer sample from 2010 onwards. Its bond return coefficients stay close to zero both in the weekly and daily results. The non-life insurer sample shows similar findings but features wider confidence intervals in the weekly results and a jump in γ in the daily results, which occurs simultaneously with a collapse in the associated coefficient of determination. Both the bond return coefficients in the weekly and daily results are insignificant for the life as well as the non-life sample. Considering the small life insurer sample size, these findings are not representative for the life insurance sectors in the Middle East, however.

The two featured life insurers come from Saudi Arabia and the United Arab Emirates. Also in the non-life insurance sample, most companies come from these two countries. Moody's does not provide a classification on the risk level of their insurance sectors, however, and also from other sources, information on the interest rate risk in Middle Eastern insurance sectors is limited[196]. Considering the widespread use of sharia-compliant insurance products in these countries, life insurers should be subject to a lower amount of insurance products with guaranteed rates of return than insurers from most other countries[197]. Movements in long-term interest rate levels are therefore expected to be less relevant for the profitability of Middle Eastern life insurers. This assumption is also supported by the comparably low coefficients of determination for the employed regression model, shown in figures 52 and 54.

The results for the South Asian set of insurance companies are reported in figures 55 to 60. Due to data quality constraints, only insurers from Thailand and Vietnam are included in this dataset. The results for the weekly and daily samples are depicted in figures 57 and 59: As in the previous region, the timeframe for which γ coefficients are available for life

[196] The Saudi Arabian Monetary Agency (2016, p. 40f) attests a high resilience of the Saudi Arabian insurance sector. This statement is not verified through statistics on the interest rate sensitivity of the industry, however.

[197] See Institute of Islamic Banking and Insurance (n.d.).

insurers is limited due to the small size of the subsample. In this case, only two insurers from Thailand were included. Both the results for the weekly and daily data show mostly insignificant γ coefficients for the covered period after the financial crisis. The general development of the coefficient is similar to that of the coefficients of life insurers in the previous western samples, with lower values between 2011 and 2013, an increase between 2014 and 2016, and another low phase until the end of the low-rate period. Overall, neither the coefficients of the life, nor the non-life sample, are significant for a considerable amount of time during the 19-year timeframe, and also the coefficients of determination, shown in figures 58 and 60, report a worse fit of the regression model for stock returns in South Asia than in the western samples. This is especially evident for the non-life sample.

As in the Middle Eastern sample, the profitability of South Asian life insurers depends less on changes in long-term interest rate levels than it was the case in the previously discussed western samples. In contrast to these, the bond return coefficients of South Asian life insurers showed similar developments to those from the western samples after the global financial crisis, however. This fact is likely related to the declining interest rate levels in Thailand and Vietnam: The Thai 10-year government bond fell from levels around 5 percent p.a. before the crisis to 1.5 percent in 2020, and also the Vietnamese government bond fell from 12 percent in 2011 to 3 percent in 2020. These developments exert a pressure on the insurance sectors of these countries, which was not observed in the African or Middle Eastern samples before.

While information on the interest rate risk in the Thai and Vietnamese insurance sectors is again limited[198], both the γ and γ_2 coefficients in the South Asian sample show a mostly statistically insignificant sensitivity of life insurers towards changes in interest rates. Taking into account the coefficients of determination in figures 58 and 60, the stock returns in the South Asian life insurer sample were less strongly related to changes in interest rates than stock returns in western life insurer samples and showed a similar dependence like life insurers from the Middle Eastern sample.

[198] Cf. IMF (2019, p. 20): Thai life insurers show notable duration gaps and hold substantial amounts of liabilities from guaranteed products. The guaranteed rates on these were set with a more favorable development of interest rates in mind. Cf. KPMG (2020): Vietnamese life insurers are likely to be affected by falling interest rates both in terms of investment profits and their solvency outlook.

Figures 61 to 66 report the results for the East Asian sample. Figures 63 and 65 thereby depict the developments of the γ and γ_2 coefficients for life and non-life insurers in the weekly and daily datasets. In both datasets, life, as well as non-life insurers, showed relatively volatile coefficients, which however stayed close to zero throughout most of the investigated timeframe. Apart from a statistically significant decrease in γ in 2006 to 2007 for non-life insurers, the coefficients were predominantly statistically insignificant at the 95 percent confidence level. The same applies for the γ_2 coefficients: These only found a statistically significant difference between life and non-life insurers' interest rate sensitivities for a short time in 2007 and 2006 in the weekly and the daily dataset.

While the bond return coefficients do not indicate a strong relationship between the profitability of East Asian insurers and long-term interest rates, the coefficient of determination, reported in figures 64 and 66, shows a value for the life insurer sample, which is similar to those of western samples. The model can therefore explain an adequate amount of the volatility in East Asian life insurers' stock returns.

Moody's assigns different risk levels to the life insurance sectors of the countries, included in the sample. Life insurers from Taiwan are assumed to be exposed to a very high risk to their profitability under a prolonged low-yield environment. This assessment is based on a duration gap of five to eight years, a share of guaranteed products in life insurers' liabilities of around 90 percent, and an average guaranteed rate of four to five percent in 2015[199]. Since the global financial crisis, the long-term interest rate level in Taiwan has decreased to values below one percent. This development was even stronger in Hong Kong. Only in China, interest rates were relatively stable at levels between 3 and 4.5 percent.

Accordingly, Moody's assigns lower risk levels to the other two markets: Hong Kong is classified with a moderate risk to profitability, given an average share of guaranteed products in the liabilities of life insurers and an average guaranteed rate, compared to other assessed countries[200]. China is only classified with a low risk level due to a conservative maximum allowed guaranteed rate of 2.5 percent since 1999 and a strong growth in its life insurance sector, which helps to offset higher promised rates, active in older contracts[201].

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199 Moody's (2015), p. 8, 12.
200 Moody's (2015), p. 8, 15f.
201 Moody's (2015), p. 8, 17.

Based on the market capitalizations of the life insurers in the East Asian sample, reported in table 10, the stated results for their bond return coefficients are mostly based on insurers from China. At the year-end of 2019, Chinese life insurers had a weight of 73 percent in the group, followed by 24 percent for insurers from Hong Kong. The life insurance sectors from Singapore and Taiwan only had a negligible influence on the results for the region. Accordingly, the reported coefficients mostly reflect the Chinese situation, which shows a relatively low risk level. While the inclusion of Taiwanese life insurers into the sample raises expectations for significantly negative bond return coefficients after the global financial crisis, the low weight of Taiwan in the sample conceals this effect. Overall, the close to zero coefficients are consistent with Moody's assessment of the risk level in the Chinese life insurance sector.

The results for insurers from Japan and South Korea are depicted in figures 67 to 72. Both the results from the weekly dataset in figure 69 and from the daily dataset in figure 71 show a very similar development of γ for life insurers: In the normal-rate and crisis periods, it stays close to zero with comparably low volatility. In 2008, interest rates in Japan and South Korea started to decrease. In the following years, they fell continuously until the end of the investigated timeframe and even reached negative values in Japan in 2016 and 2019. Accordingly, γ starts to decrease in the life insurer sample in 2016 and shows levels up to -5.9 and -3.4 in 2018 in the weekly and daily samples. The Japanese and South Korean life insurer sample thereby is the sample with the highest sensitivity to changes in long-term interest rates, following the financial crisis, out of all samples, assessed in this work.

The interest rate sensitivity in the non-life insurer sample showed a similar behavior to the sensitivity in the life insurer sample: Bond return coefficients stay slightly negative throughout the normal-rate and crisis periods and fall for a short amount of time in 2018. Also the γ_2 coefficients, reported in panel C, show values close to zero during the normal-rate and crisis periods but decrease significantly from 2016 onwards. Compared to previous results, the difference in interest sensitivities between life and non-life insurance companies is particularly large in the Japanese and South Korean sample with γ_2 coefficients up to -3.9 and -2.2 in the weekly and daily datasets. This difference has increased almost constantly since 2016.

The pronounced interest rate sensitivity in Japan's and South Korea's life insurance sectors matches Moody's risk assessment for these markets: Both countries are classified with a high risk to the profitability of life insurers in a prolonged low-yield environment. For South Korea, Moody's justifies this classification with the high exposure of its life insurance sector to guaranteed products with particularly high guaranteed minimum rates of return. On average, around 80 percent of South Korean life insurers' liabilities are related to guaranteed products. While the duration gaps in the sector are usually low, the average guaranteed rate lies at five to six percent, which leaves many life insurers with a negative spread between earned investment returns and promised credited rates[202].

The Japanese life insurance sector is exposed to long-term guarantees to a similar degree but shows lower guaranteed rates on average. On the other hand, average duration gaps are longer at two to five years. Furthermore, Japan has been subject to low interest rates for a longer time than most other economies: After the burst of the Japanese asset price bubble in 1991, life insurers had to operate under difficult conditions for over a decade before the global financial crisis. Accordingly, the industry had already adjusted to the low interest rates before the crisis hit the markets[203]. This could explain why γ did not decrease substantially before 2016. When the long-term interest rates became negative, however, also life insurers in the Japanese and South Korean sample became more sensitive to further changes in interest rates.

Figures 73 to 78 present the results for the sample, containing insurance companies from Australia, Indonesia, and Malaysia. Figures 75 and 77 report the γ and γ_2 coefficients for the life and non-life insurer subsamples, based on data with weekly and daily frequency: Figure 75 describes a similar development of bond return coefficients for both subsamples. In the normal-rate and crisis period, γ is close to zero. Between 2011 and 2014, γ decreases substantially, indicating a high exposure to interest rate risk both for life and non-life insurers. After this phase, γ recovers again and stays slightly negative until the end of the assessed timeframe. Figure 76 reports statistical significance for the mentioned period in both samples but does not find significant γ_2 coefficients for an extended amount of time.

[202] Moody's (2015), p. 8, 13

[203] Moody's (2015), p. 8, 9, 12f. See Nakaso (2001) for detailed information on Japan's financial crisis in the 1990s.

The daily results reveal statistically significant bond return coefficients in both subsamples from 2007 and confirm the peak in interest rate sensitivity in 2012. Figure 78 reports a high significance both for the results in the life and non-life insurer subsamples. Due to the similar development of the bond return coefficients in both samples, the γ_2 coefficients stay close to zero throughout the complete timeframe of the analysis, however. Panel C describes a slightly higher interest rate sensitivity for life insurers than for non-life insurers in the normal-rate and crisis periods, but a slightly lower sensitivity in the low-rate period. Statistical significance for these results is only achieved for short and incoherent periods of time.

As table 12 shows, both the life and non-life samples are dominated by Australian insurance companies. According to Moody's, Australia's life insurance sector is well prepared for a prolonged low-yield environment. This assessment is based on the high share of unit-linked products without guarantees in the market. Guaranteed products only account for around 15 percent of life insurers' liabilities, with guaranteed rates typically lying between zero and one percent. For this reason, Moody's sees a very low risk for the profitability of Australian life insurers emanating from a low-yield environment[204].

From this point of view, the negative bond return coefficients in the life insurer sample between 2005 and 2014 seem surprising. Considering the similar development of the coefficients in the non-life sample, however, the interest rate risk exposure in both samples appears to be related to factors, which both affect life and non-life insurers simultaneously. This fact is underlined by the γ_2 coefficients, which stay close to zero throughout the complete timeframe of the analysis. Moreover, both life and non-life insurers showed higher values for γ in the late low-rate period when interest rates were lower than in the normal-rate and crisis periods. Therefore, the results of this study do not contradict the assessment by Moody's.

Overall, the findings for the international samples in this chapter were consistent with the expectations, based on the country-level assessment by Moody's (2015). According to the presented measures of statistical significance, the results of several samples were significant and consistent with expectations. Nonetheless, the small sample sizes and the fact that each region comprises multiple countries call for a prudent interpretation of the results.

[204] Moody's (2015), p. 8, 18f.

5 Conclusion

This work assesses the interest rate sensitivities of stock returns in international insurance sectors based on a two-factor regression model. The approach for the covered analyses follows the example by Hartley et al. (2016), who investigate the interest rate sensitivities of insurers from the United States, the United Kingdom, and continental Europe for the timeframe of 2002 to 2015. The analyses in this work extend their approach by using additional and more comprehensive samples of insurance companies, a longer investigated timeframe, additional regression variables, and a second dataset based on daily data.

Overall, the findings of this work are consistent with the results by Hartley et al. and confirm their hypotheses: Before the 2007 global financial crisis, stock returns of life and non-life insurers did not exhibit statistically significant sensitivities to changes in long-term interest rates. During the crisis, when interest rates started to fall, sensitivity coefficients for most life insurance samples changed considerably. However, this reaction did not always point in the same direction: Life insurers from the United States showed an increase in bond return coefficients, while insurers from the United Kingdom and continental Europe showed a decrease instead.

After the crisis, interest rates in many of the covered regions continued to decline. At the same time, bond return coefficients of most life insurer samples, as well as several non-life insurer samples, decreased significantly. This result describes a positive relationship between insurer profitability and long-term interest rate levels and is consistent with higher liability durations than asset durations of life insurers, as well as lower investment returns and lower demand for life insurance products in a low-rate environment. These findings also match the results of other studies, such as Berends et al. (2013). In regions, in which interest rates did not decrease to a high degree, interest rate sensitivities were lower. In the African sample, stock returns increased when long-term interest rates fell.

Furthermore, a comparison of life insurer bond return coefficients from the United States and the United Kingdom yielded higher interest rate sensitivities for US-American insurers in the years after the crisis. This result is again consistent with the findings by Hartley et al. and indicates a higher exposure to interest rate risk for life insurers, which are strongly engaged in insurance contracts with guaranteed minimum rates of return and policyholder options. These findings are supported by results from other countries, which are particularly exposed to these contract features, like Canada, Japan, or South Korea.

While the results of this work confirm the findings by Hartley et al. for their assessed timeframe until 2015, the developments of bond return coefficients after 2015 contradict the expectation of continuously rising interest rate sensitivities of particularly exposed life insurers in a prolonged low-yield environment: Since 2018, bond return coefficients in most samples recovered back to zero. This development was accelerated through the stock market impact of the COVID-19 pandemic. Beyond this observation, the comparison of the US and UK datasets reveals a faster recovery of sensitivity coefficients in the US-American sample, despite its high exposure to guaranteed insurance products and policyholder options. This fact could however be related to higher interest rate levels in the US than in the UK since 2014. It is, therefore, questionable, whether the results of a direct comparison between both markets after 2014 are suited to reject the hypothesis regarding the effects of guaranteed products and policyholder options on insurers' sensitivities to changes in interest rates.

The findings for the US and UK samples are verified through a robustness check, involving insurers from continental Europe: Insurers from this sample are separated into two groups, based on their exposure to guaranteed products. To assess this exposure, insurers are first separated based on their share of earned premiums from Germany and the United States. The sensitivities of both groups are then compared against each other. The results for this assessment are consistent with the findings by Hartley et al., however with inconsistent significance levels for different approaches. For this reason, insurance companies are separated again, based on the assumed exposure of their home countries' life insurance sectors to long-term guarantees. The results for this assessment were predominantly insignificant, however.

In a second robustness check, the results of the employed top-down regression approach are compared with two bottom-up measures of interest rate risk, provided on a country-level by EIOPA (2014a, 2016). The findings for a premium share-based country allocation method again yielded results, which support the hypothesis of higher interest rate sensitivities for life insurers with high exposures to guaranteed products and policyholder options. The findings are thereby consistent with the results by Hartley et al. but are not significant at a 95 percent confidence level. The results for the home country-based allocation method are again insignificant and do not coincide with the stated hypotheses.

Overall, the results of this work indicate a positive effect of contract designs, using guaranteed minimum rates of return or policyholder options, on the interest rate risk exposure of life insurance companies. Life insurers, in general, showed higher sensitivities to changes in long-term interest rates than non-life insurers. The approach, employed by this work, however, cannot clearly identify the reasons for the observed differences in sensitivities. In addition to the mentioned contract features, other possible causes include incomplete hedges against substantial declines in interest rates, optimistically set guaranteed rates in the time before the global financial crisis, lower demand for life insurance products in a low-yield environment, and different timings of unconventional monetary policy interventions, conducted by central banks. Ultimately, changes in stock returns, and thereby also sensitivity coefficients, are dependent on the value, stock investors attach to insurance companies. Therefore, also changes in investor sentiment regarding the financial health of insurance companies could have had a large influence on the findings of this work. Evaluating the influence of these factors on the found results is, however, beyond the scope of this study and is left open for further research.

The decreasing interest rate sensitivities in recent years indicate that life insurers are slowly adapting to the low-yield situation. In addition to improvements in their asset liability management, life insurers are reducing guaranteed interest rates and keep looking for alternatives to guaranteed products. Nonetheless, regulators and supervisors hold the responsibility to monitor trends like decreasing solvency ratios or increased risk-taking behavior. Especially in particularly vulnerable markets like Germany or Japan, a persisting environment of low interest rates could eventually harm financial stability.

Table 1: Country Allocation for International Samples

Country	# Companies	Region	Stock Index	Government Bond
Canada	10	Canada	S&P/TSX Composite	Canada 10-year
Kenya	4	Africa	FTSE NSE Kenya 15	Kenya 10-year
Morocco	3	Africa	FTSE CSE Morocco 15	Morocco 10-year
Nigeria	8	Africa	MSCI Nigeria	Nigeria 10-year
South Africa	6	Africa	FTSE/JSE All-Share	S. Africa 10-year
Tunisia	1	Africa	Tunindex	Tunisia 3-month deposit
Jordan	2	Middle East	Amman SE General	Jordan 10-year
Kuwait	5	Middle East	KSX 15	Kuwait 2-year deposit
Oman	1	Middle East	MSCI Oman	Oman 9-month deposit
Qatar	5	Middle East	QE All-Share - TRI	Qatar 5-year
Saudi Arabia	12	Middle East	TASI	Saudi Arabia 10-year
United Arab Emirates	6	Middle East	ADX General	United Arab Emirates 1-year
Thailand	3	South Asia	Bangkok SET	Thailand 10-year
Vietnam	5	South Asia	FTSE Vietnam All-Share L	Vietnam 10-year
China	7	East Asia	SSEA	China 10-year
Hong Kong	2	East Asia	Hang Seng	Hong Kong 10-year
Singapore	2	East Asia	MSCI Singapore	Singapore 10-year
Taiwan	7	East Asia	MSCI Taiwan	Taiwan 10-year
Japan	6	Japan & South Korea	NIKKEI 225	Japan 10-year
South Korea	11	Japan & South Korea	KOSPI	South Korea 10-year
Australia	7	Australia & Oceania	ASX	Australia 10-year
Indonesia	2	Australia & Oceania	IDX Composite	Indonesia 10-year
Malaysia	1	Australia & Oceania	FTSE Bursa Malaysia KLCI	Malaysia 10-year

Table 2: Insurer Sample Statistics

Region	United States		United Kingdom		Europe		Canada		Africa	
Insurer Type	Life	N.-Life	Life	N.-Life	Life	N.-Life	Life	N.-Life	Life	N.-Life
Combined Size - Total Assets (year-end 2019) [USD bil.]	3,628	1,537	2,338	62	3,502	2,414	1,643	93	151	75
Average Size - Total Assets (year-end 2019) [USD bil.]	106.7	23.3	292.2	8.9	166.8	63.5	273.8	23.1	18.9	5.4
Financial Leverage - Assets to Equity Ratio (year-end 2019, value-weighted)	5.6	3.2	39.4	6.0	14.2	8.5	19.2	8.3	12.1	9.3
Profitability - Net Income before Taxes to Equity Ratio (year-end 2019, value-weighted)	9%	15%	10%	8%	12%	10%	13%	10%	11%	14%
Number of Companies	34	66	8	7	21	38	6	4	8	14

Region	Middle East		South Asia		East Asia		Japan & S. Korea		Australia & Oceania	
Insurer Type	Life	N.-Life	Life	N.-Life	Life	N.-Life	Life	N.-Life	Life	N.-Life
Combined Size - Total Assets (year-end 2019) [USD bil.]	3	32	17	5	2,232	229	1,270	602	110	120
Average Size - Total Assets (year-end 2019) [USD bil.]	1.5	1.1	8.4	0.8	223.2	28.7	127.0	86.0	27.6	20.0
Financial Leverage - Assets to Equity Ratio (year-end 2019, value-weighted)	40.0	17.0	32.2	8.2	7.6	6.9	11.4	7.1	1.9	6.0
Profitability - Net Income before Taxes to Equity Ratio (year-end 2019, value-weighted)	6%	6%	7%	11%	7%	9%	12%	10%	-5%	7%
Number of Companies	2	29	2	6	10	8	10	7	4	6

Table 3: United States Insurer Sample

Company Name	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
ACMAT Corporation	0%	984	4916	34
Aetna Inc.	66%	984	4916	69,638*
Affirmative Insurance Holdings,	0%	717	3581	0*
Aflac Incorporated	96%	984	4916	38,830
Alleghany Corporation	0%	984	4916	11,486
American Equity Investment Life Holding Company	100%	883	4413	2,725
American Financial Group, Inc.	0%	984	4916	9,888
American Independence Corp.	100%	984	4916	201*
American National Group, Inc.	88%	984	4916	3,164
American Physicians Service Group, Inc.	0%	984	4916	222*
AMERISAFE, Inc.	0%	781	3902	1,274
AmTrust Financial Services, Inc.	0%	729	3645	2,916*
Anthem, Inc.	28%	984	4916	76,584
AssuranceAmerica Corporation	0%	785	3921	4*
Assurant, Inc.	1%	874	4368	7,948
Atlantic American Corporation	47%	984	4916	40
Atlas Financial Holdings, Inc.	0%	403	2015	5
Berkshire Hathaway Inc.	9%	984	4916	553,690
Cigna Corporation	97%	984	4916	76,362
Cincinnati Financial Corporation	25%	984	4916	17,179
Citizens, Inc.	85%	984	4916	360
CNO Financial Group, Inc.	99%	895	4473	2,740
Conifer Holdings, Inc.	0%	273	1363	38
Donegal Group Inc.	0%	984	4916	414
Employers Holdings, Inc.	0%	718	3589	1,328
FBL Financial Group, Inc.	100%	984	4916	1,453
FedNat Holding Company	0%	984	4916	249
FG Financial Group, Inc.	0%	344	1720	12*
Fidelity National Financial, Inc.	0%	787	3934	12,475
First Acceptance Corporation	0%	984	4916	33
First American Financial	0%	545	2725	6,551
GAINSCO, INC.	0%	984	4916	161
Genworth Financial, Inc.	97%	858	4290	2,215
Global Indemnity Group, LLC	0%	881	4405	301

Globe Life Inc.	100%	984	4916	11,397
Hallmark Financial Services, Inc.	0%	984	4916	318
Hanover Insurance Group, Inc.	0%	984	4916	5,384
Hartford Financial Services Group, Inc.	22%	984	4916	21,903
HCC Insurance Holdings, Inc.	1%	984	4916	7,442*
HCI Group, Inc.	0%	640	3197	366
Heritage Insurance Holdings, Inc.	0%	337	1682	391
Horace Mann Educators Corporation	91%	984	4916	1,800
Independence Holding Company	100%	984	4916	625
Infinity Property and Casualty Corporation	0%	925	4624	1,563*
Investors Title Company	0%	984	4916	301
Kansas City Life Insurance Company	100%	984	4916	355
Kemper Corporation	52%	984	4916	5,165
Kingstone Companies, Inc.	0%	984	4916	84
Kingsway Financial Services Inc.	0%	984	4916	41
Lincoln National Corporation	100%	984	4916	11,703
Loews Corporation	32%	984	4916	15,613
Markel Corporation	0%	984	4916	15,790
Mercury General Corporation	0%	984	4916	2,697
MetLife, Inc.	100%	984	4916	46,874
Midwest Holding Inc.	100%	270	1348	67
Molina Healthcare, Inc.	0%	905	4524	8,508
National General Holdings Corporation	0%	350	1747	2,505
National Security Group, Inc.	5%	984	4916	39
National Western Life Group, Inc.	100%	984	4916	1,058
Navigators Group, Inc.	0%	984	4916	2,097*
NMI Holdings, Inc.	0%	365	1822	2,256
Old Republic International Corporation	0%	984	4916	6,791
PICO Holdings, Inc.	0%	984	4916	221
Primerica, Inc.	100%	553	2762	3,363*
Principal Financial Group, Inc.	100%	984	4916	15,272
ProAssurance Corporation	0%	984	4916	1,944
Progressive Corporation	0%	984	4916	42,319
Protective Insurance Corporation	0%	984	4916	230
Prudential Financial, Inc.	100%	984	4916	37,683
Radian Group Inc.	0%	984	4916	5,061

RLI Corp.	0%	984	4916	4,036
Safety Insurance Group, Inc.	0%	937	4682	1,423
Security National Financial Corporation	100%	984	4916	91
Seibels Bruce Group, Inc.	0%	984	4916	41
Selective Insurance Group, Inc.	0%	984	4916	3,872
StanCorp Financial Group, Inc.	100%	984	4916	4,890*
State Auto Financial Corporation	0%	984	4916	1,351
Stewart Information Services Corporation	0%	984	4916	967
Symetra Financial Corporation	100%	563	2812	3,719*
Syncora Holdings Ltd.	0%	744	3719	432
The Allstate Corp.	41%	984	4916	36,429
Tiptree Inc.	3%	698	3487	281
Travelers Companies, Inc.	0%	984	4916	35,349
Triad Guaranty Inc.	0%	984	4916	3
Triple-S Management Corporation	97%	674	3367	450
Trupanion, Inc.	0%	329	1642	1,309
Unico American Corporation	0%	984	4916	33
United American Healthcare Corporation	0%	984	4916	2
United Fire Group, Inc.	0%	984	4916	1,095
United Insurance Holdings Corp.	0%	678	3388	545
UnitedHealth Group Incorporated	100%	984	4916	278,521
Universal American Corp.	99%	984	4916	625*
Universal Insurance Holdings, Inc.	0%	984	4916	930
Unum Group	99%	984	4916	6,015
UTG, Inc.	100%	984	4916	116
Voya Financial, Inc.	100%	392	1958	8,220
W. R. Berkley Corporation	0%	984	4916	12,692
WellCare Health Plans, Inc.	0%	853	4263	16,619
White Mountains Insurance Group, Ltd.	0%	984	4916	3,553
Yadkin Valley Company	100%	984	4916	43*

* No data available for year-end 2019 - most recently available value is displayed

Table 4: United Kingdom Insurer Sample

Company Name	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
Admiral Group Plc	0%	841	4203	8,960
Aviva Plc	65%	984	4916	21,693
Beazley Plc	4%	938	4690	2,945
Chesnara Plc	100%	859	4293	627
Direct Line Insurance Group Plc	0%	421	2103	5,678
esure Group Plc	0%	398	1987	1,556*
Just Group Plc	100%	364	3624	1,080
Legal & General Group Plc	100%	984	4916	23,883
Personal Group Holdings Plc	0%	984	4916	105
Phoenix Group Holdings Plc	100%	572	2859	7,141
Prudential Plc	100%	984	4916	37,688
RSA Insurance Group Plc	0%	984	4916	7,710
Saga Plc	0%	337	3932	386
St. James's Place Plc	100%	984	4916	8,223
Standard Life Aberdeen Plc	100%	748	3736	9,275

* No data available for year-end 2019 - most recently available value is displayed

Table 5: Continental European Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Premium Income from Germany and US (2019)	Risk from Long-Term Guarantees in Home Country	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
UNIQA Insurance Group AG	Austria	44%	- **	low	984	4916	3,095
Vienna Insurance Group AG	Austria	40%	4%	low	984	4916	3,580
Ageas SA/NV	Belgium	55%	- **	high	984	4916	11,662
ADRIATIC osiguranje d.d.	Croatia	0%	0%	low	707	3533	77
CROATIA osiguranje d.d.	Croatia	20%	0%	low	984	4916	441
Atlantic Insurance Company Public Ltd.	Cyprus	0%	0%	low	984	4916	58
Cosmos Insurance Company Public Ltd.	Cyprus	0%	0%	low	984	4916	2
Liberty Life Insurance PCL	Cyprus	100%	- **	low	984	4916	1
Alm. Brand A/S	Denmark	26%	< 25%	high	984	4916	1,372
Tryg A/S	Denmark	6%	0%	high	786	3927	8,600
Sampo Oyj	Finland	34%	0%	high	984	4916	23,563
April SA	France	64%	< 25%	low	984	4916	996
AXA SA	France	48%	26%	low	984	4916	65,434
CNP Assurances SA	France	92%	0%	low	984	4916	13,126
Coface SA	France	0%	< 25%	low	332	1657	1,798
SCOR SE	France	56%	- **	low	984	4916	7,541
Allianz SE	Germany	31%	37%	high	984	4916	103,892
NÜRNBERGER Beteiligungs-AG	Germany	77%	> 25%	high	984	4916	887
Talanx AG	Germany	35%	42%	high	422	2110	12,735
Wüstenrot & Württembergische AG	Germany	55%	100%	high	984	4916	2,070

European Reliance General Insurance Company SA	Greece	30%	0%	high	984	4916	157
CIG Pannónia Életbiztosító Nyrt.	Hungary	100%	0%	low	522	2606	60
Sjóvá-Almennar tryggingar hf.	Iceland	20%	0%	low	343	1711	213
TM hf.	Iceland	8%	0%	low	984	4916	225
Vátryggingafélag Íslands hf.	Iceland	10%	0%	low	956	4776	174
Aon plc	Ireland	4%	> 25%	low	984	4916	48,344
FBD Holdings Plc	Ireland	0%	0%	low	984	4916	340
Assicurazioni Generali SpA	Italy	68%	22%	high	984	4916	31,986
Società Cattolica di Assicurazione - SC	Italy	69%	0%	high	984	4916	1,404
Unipol Gruppo SpA	Italy	39%	0%	high	984	4916	4,063
Vittoria Assicurazioni SpA	Italy	16%	0%	high	984	4916	1058*
Foyer SA	Luxembourg	72%	0%	low	984	4916	762*
LifeStar Holding Plc	Malta	100%	< 25%	low	984	4916	9
AEGON N.V.	Netherlands	87%	57%	high	984	4916	9,657
NN Group NV	Netherlands	78%	0%	high	331	1654	13,016
Gjensidige Forsikring ASA	Norway	9%	0%	high	517	2582	10,170
Insr Insurance Group ASA	Norway	0%	0%	high	343	1715	114
Protector Forsikring ASA	Norway	0%	0%	high	746	3730	499
Storebrand ASA	Norway	100%	0%	high	984	4916	3,565
Powszechny Zakład Ubezpieczeń SA	Poland	36%	0%	low	547	2734	9,017
Ingosstrakh Joint-Stock Insurance Company Ltd.	Russia	8%	0%	low	705	3521	824*
Globos osiguranje a.d.o. Beograd	Serbia	0%	0%	low	770	3786	6
Kompanija Dunav Osiguranje a.d.o.	Serbia	15%	0%	low	791	3825	134
KD Group, finančna družba, d.d.	Slovenia	20%	< 25%	low	984	4916	263
Pozavarovalnica Sava, d.d.	Slovenia	15%	< 25%	low	647	3232	344

Zavarovalnica Triglav, d.d.	Slovenia	20%	0%	low	634	3169	840
Grupo Catalana Occidente, SA	Spain	18%	< 25%	high	984	4916	4,042
MAPFRE SA	Spain	24%	41%	high	984	4916	7,859
Bâloise Holding AG	Switzerland	53%	18%	high	984	4916	8,545
Chubb Limited	Switzerland	3%	66%	high	984	4916	70,584
Helvetia Holding AG	Switzerland	49%	11%	high	984	4916	6,806
Swiss Life Holding AG	Switzerland	98%	6%	high	984	4916	16,329
Vaudoise Assurances Holding SA	Switzerland	17%	0%	high	984	4916	1,717
Zurich Insurance Group AG	Switzerland	29%	39%	high	984	4916	59,442
Aksigorta AŞ	Turkey	0%	0%	low	984	4916	418
Anadolu Anonim Türk Sigorta Şirketi	Turkey	0%	0%	low	984	4916	494
Anadolu Hayat Emeklilik AŞ	Turkey	100%	0%	low	984	4916	660
Halk Sigorta AŞ	Turkey	0%	0%	low	440	2199	155
Türkiye Sigorta AŞ	Turkey	0%	0%	low	984	4916	264

* No data available for year-end 2019 - most recently available value is displayed

** Premium income for Germany and United States not publicly available

Table 6: Canadian Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
Echelon Financial Holdings Inc.	Canada	0%	778	3887	56
E-L Financial Corporation Limited	Canada	30%	984	4916	2,567
Fairfax Financial Holdings Limited	Canada	0%	984	4916	12,613
Great-West Lifeco Inc.	Canada	100%	984	4916	23,784
iA Financial Corporation Inc.	Canada	100%	984	4916	5,875
Intact Financial Corporation	Canada	0%	830	4146	15,060
Manulife Financial	Canada	100%	984	4916	39,584
Power Corporation of Canada	Canada	100%	984	4916	10,986
Sun Life Financial Inc.	Canada	100%	984	4916	26,809
Till Capital Corporation	Canada	0%	601	3002	5

Table 7: African Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
Britam Holdings Plc	Kenya	32%	478	2387	224
CIC Insurance Group Ltd.	Kenya	29%	433	2163	69
Jubilee Holdings Ltd.	Kenya	57%	984	4916	251
Liberty Kenya Holdings Plc	Kenya	39%	498	2484	55
Compagnie d'Assurances et de Reassurance Atlanta	Morocco	22%	681	3400	469
Saham Assurance SA	Morocco	20%	520	2596	587
Wafa Assurance SA	Morocco	100%	984	4916	1,428
AIICO Insurance Plc	Nigeria	76%	984	4916	14
Custodian Investment Plc	Nigeria	46%	699	3494	97
Mutual Benefits Assurance Plc	Nigeria	47%	898	4489	6
NEM Insurance Plc	Nigeria	0%	984	4916	35
Niger Insurance Plc	Nigeria	55%	984	4916	4
Royal Exchange Plc	Nigeria	61%	984	4916	4
Sovereign Trust Insurance Plc	Nigeria	0%	727	3633	6
Standard Alliance Insurance Plc	Nigeria	60%	872	4359	7*
Discovery Ltd.	South Africa	90%	984	4916	5,682
Liberty Holdings Ltd.	South Africa	96%	984	4916	2,266
Momentum Metropolitan Holdings Ltd.	South Africa	71%	984	4916	2,340
Old Mutual Ltd.	South Africa	40%	984	4916	6,165
Rand Merchant Investment Holdings Ltd.	South Africa	3%	504	2520	3,678
Sanlam Ltd.	South Africa	67%	984	4916	11,697
Société Tunisienne d'Assurances et de Réassurances	Tunisia	18%	984	4916	112

* No data available for year-end 2019 - most recently available value is displayed

Table 8: Middle Eastern Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
Islamic Insurance Co. (PSC)	Jordan	22%	984	4916	22
Jordan Insurance Company	Jordan	30%	984	4916	140
Al Ahleia Insurance Company S.A.K.P.	Kuwait	15%	984	4916	277
First Takaful Insurance Company - KPSC	Kuwait	33%	829	4144	13
Gulf Insurance Group K.S.C.P.	Kuwait	55%	984	4916	390
Kuwait Insurance Company S.A.K.P	Kuwait	37%	984	4916	201
Wethaq Takaful Insurance Company K.S.C.P.	Kuwait	5%	829	4144	9
Al Madina Insurance Company SAOG	Oman	6%	360	1799	36
Al Khaleej Takaful Insurance Company Q.P.S.C.	Qatar	30%	936	4679	140
Doha Insurance Group Q.P.S.C.	Qatar	0%	908	4538	165
Qatar General Insurance & Reinsurance Company Q.P.S.C.	Qatar	7%	936	4679	591
Qatar Insurance Company Q.S.P.C.	Qatar	10%	984	4916	2,835
Qatar Islamic Insurance Group (Q.P.S.C.)	Qatar	30%	927	4634	275
Al Rajhi Company for Cooperative Insurance	Saudi Arabia	4%	590	2950	677
Al-Etihad Cooperative Insurance Company	Saudi Arabia	0%	665	3321	157
Allianz Saudi Fransi Cooperative Insurance Company	Saudi Arabia	12%	693	3465	149
Arabia Insurance Cooperative Company	Saudi Arabia	0%	665	3325	125

Arabian Shield Cooperative Insurance Company	Saudi Arabia	0%	697	3485	139
Bupa Arabia For Cooperative Insurance Company	Saudi Arabia	100%	650	3250	3,276
Company for Cooperative Insurance	Saudi Arabia	0%	822	4110	2,556
Malath Cooperative Insurance Company	Saudi Arabia	0%	704	3635	134
Mediterranean and Gulf Cooperative Insurance and Reinsurance Company	Saudi Arabia	0%	704	3520	341
Saudi Arabian Cooperative Insurance Company	Saudi Arabia	0%	687	3435	96
United Cooperative Assurance Company	Saudi Arabia	0%	646	3227	97
Walaa Cooperative Insurance Company	Saudi Arabia	0%	694	3469	235
Dubai Islamic Insurance & Reinsurance Company (Aman) (PJSC)	United Arab Emirates	17%	850	4249	26
Islamic Arab Insurance Co. (Salama) PJSC	United Arab Emirates	41%	789	3945	198
Methaq Takaful Insurance Company PSC	United Arab Emirates	0%	627	3134	33
National General Insurance Co. (PJSC)	United Arab Emirates	9%	890	4399	90
Orient Insurance PJSC	United Arab	10%	676	3380	90
Ras Al Khaimah National Insurance Company PSC	United Arab Emirates	76%	791	3955	72

Table 9: South Asian Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
Bangkok Insurance PCL	Thailand	0%	984	4916	1.1
Bangkok Life Assurance PCL	Thailand	100%	580	2897	1.2
Dhipaya Insurance PCL	Thailand	0%	984	4916	0.5
Bank for Investment and Development of Vietnam	Vietnam	4%	478	2389	0.1
Bao Minh Insurance Corporation	Vietnam	0%	716	3581	0.1
Bao Viet Holdings	Vietnam	71%	593	2963	2.2
Petrolimex Insurance Corporation	Vietnam	0%	484	2416	0.1
PVI Holdings	Vietnam	0%	691	3451	0.3

Table 10: East Asian Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
China Life Insurance Company Ltd.	China	100%	881	4403	124,959
China Pacific Insurance (Group) Co., Ltd.	China	61%	671	3355	45,101
New China Life Insurance Company Ltd.	China	100%	464	2317	19,167
People's Insurance Company (Group) of China Ltd.	China	22%	413	2062	42,322
PICC Property and Casualty Company Ltd.	China	0%	887	4433	26,814
Ping An Insurance (Group) Company of China, Ltd.	China	66%	854	4268	221,007
ZhongAn Online P & C Insurance Co., Ltd.	China	0%	662	3175	5,302
AIA Group Ltd.	Hong Kong	100%	523	2612	126,953
China Taiping Insurance Holdings Company Ltd.	Hong Kong	80%	984	4916	8,914
Great Eastern Holdings Ltd.	Singapore	98%	984	4916	7,656
United Overseas Insurance Ltd.	Singapore	0%	984	4916	314
China Life Insurance Co., Ltd.	Taiwan	100%	984	4916	3,820
Farglory Life Insurance Co., Ltd.	Taiwan	100%	290	1447	304
First Insurance Co. Ltd.	Taiwan	0%	984	4916	146
Mercuries Life Insurance Co., Ltd.	Taiwan	100%	456	2277	920
Shinkong Insurance Co. Ltd.	Taiwan	0%	984	4916	408
Taiwan Fire & Marine Insurance Co., Ltd.	Taiwan	0%	984	4916	254
Union Insurance Co. Ltd.	Taiwan	0%	984	4916	161

Table 11: Japanese & South Korean Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
Anicom Holdings, Inc.	Japan	4%	557	2784	686
Dai-ichi Life Holdings, Inc.	Japan	100%	553	2763	20,049
MS&AD Insurance Group Holdings, Inc.	Japan	25%	984	4916	19,731
Sompo Holdings, Inc.	Japan	14%	553	2762	14,785
T&D Holdings Inc.	Japan	100%	866	4327	8,133
Tokio Marine Holdings, Inc.	Japan	24%	970	4850	40,012
DB Insurance Co., Ltd.	South Korea	68%	984	4916	3,207
Hanwha General Insurance Co.,Ltd.	South Korea	0%	984	4916	286
Hanwha Life Insurance Co., Ltd.	South Korea	62%	555	2774	1,738
Heungkuk Fire & Marine Insurance Co., Ltd.	South Korea	90%	984	4916	171
Hyundai Marine & Fire Insurance Co., Ltd.	South Korea	0%	984	4916	2,087
Lotte Insurance Co., Ltd.	South Korea	0%	979	4895	558
Meritz Fire & Marine Insurance Co., Ltd.	South Korea	85%	984	4916	1,758
Mirae Asset Life Insurance Co., Ltd.	South Korea	100%	278	1389	634
Samsung Fire & Marine Insurance Co., Ltd.	South Korea	63%	984	4916	9,992
Samsung Life Insurance Co., Ltd.	South Korea	100%	547	2734	12,906
TONGYANG Life Insurance Co., Ltd.	South Korea	100%	578	2888	559

Table 12: Australian & Oceanian Insurer Sample

Company Name	Country	Premium Income from Life and Health Insurance (2019)	Obser-vations (Weekly)	Obser-vations (Daily)	Market Capitalization (year-end 2019) [USD mio.]
AMP Ltd.	Australia	100%	984	4916	4,584
ClearView Wealth Ltd.	Australia	100%	882	4408	226
Insurance Australia Group Ltd.	Australia	0%	984	4916	12,434
Medibank Private Ltd.	Australia	100%	310	1550	6,113
Nib Holdings Ltd.	Australia	0%	678	3390	2,445
QBE Insurance Group Ltd.	Australia	0%	984	4916	11,837
Suncorp Group Ltd.	Australia	2%	984	4916	11,479
PT Paninvest Tbk	Indonesia	100%	984	4916	322
PT Victoria Insurance Tbk	Indonesia	0%	267	1331	13
Syarikat Takaful Malaysia Keluarga Bhd.	Malaysia	0%	984	4916	1,152

Table 13: Comparison of Bond Return Coefficients to EIOPA Duration Gap Estimates (Country Allocation by Premium Shares – Weekly Data)

Country	Average change in bond return coefficient (γ)		EIOPA duration mismatch, years
	Life insurers	Non-life insurers	
Austria	-0.79	0.11	11.33
Belgium	-0.56	0.12	1.78
Croatia	-0.47	0.06	5.88
Cyprus	-0.81	0.03	7.07
Denmark	-0.33	-0.03	5.42
Finland	-0.34	0.34	5.24
France	-0.67	0.07	5.58
Germany	-0.70	0.25	11.32
Greece	-0.79	0.06	2.47
Hungary	-0.32	0.35	3.08
Iceland	-1.46	0.04	--
Ireland	-0.62	0.27	-0.80
Italy	-0.76	0.06	1.16
Luxembourg	0.11	0.06	5.20
Malta	-0.73	-0.70	7.39
Netherlands	-0.84	0.35	6.16
Norway	-0.34	-0.09	--
Poland	-0.57	0.35	4.55
Russia	-1.23	0.65	--
Serbia	-0.34	0.37	--
Slovenia	-0.80	0.41	8.98
Spain	-0.58	0.06	0.89
Switzerland	-0.56	0.05	--
Turkey	-0.74	-0.26	--
Correlation with EIOPA duration mismatch	-0.20	-0.06	

Table 14: Comparison of Bond Return Coefficients to EIOPA Duration Gap Estimates (Country Allocation by Premium Shares – Daily Data)

Country	Average change in bond return coefficient (γ)		EIOPA duration mismatch, years
	Life insurers	Non-life insurers	
Austria	-0.49	0.30	11.33
Belgium	-0.30	0.33	1.78
Croatia	-0.51	0.25	5.88
Cyprus	-0.47	0.24	7.07
Denmark	-0.54	-0.03	5.42
Finland	-0.54	0.62*	5.24
France	-0.62*	0.26	5.58
Germany	-0.41	0.14	11.32
Greece	-0.46	0.25	2.47
Hungary	-0.18	0.62*	3.08
Iceland	-0.76**	-0.15	--
Ireland	-0.36	0.56	-0.80
Italy	-0.39	0.24	1.16
Luxembourg	0.05	0.26	5.20
Malta	-0.51	-0.48	7.39
Netherlands	-0.42	0.63*	6.16
Norway	-0.54	-0.07	--
Poland	-0.33	0.60	4.55
Russia	-0.75**	0.06	--
Serbia	-0.54	0.60	--
Slovenia	-0.42	0.42	8.98
Spain	-0.37	0.26	0.89
Switzerland	-0.29	0.28	--
Turkey	-0.28	0.20	--
Correlation with EIOPA duration mismatch	-0.28	-0.27	

Table 15: Comparison of Bond Return Coefficients to EIOPA Duration Gap Estimates (Country Allocation by Home Country – Weekly Data)

Country	Average change in bond return coefficient (γ)		EIOPA duration mismatch, years
	Life insurers	Non-life insurers	
Austria	-0.46	-0.01	11.33
Belgium	-0.16	--	1.78
Croatia	--	-0.01	5.88
Cyprus	-0.43	-0.41	7.07
Denmark	--	-0.07	5.42
Finland	--	-0.01	5.24
France	-0.41	-0.13	5.58
Germany	0.01	-0.07	11.32
Greece	--	-0.32	2.47
Hungary	0.02	--	3.08
Iceland	--	-0.01	--
Ireland	--	0.24	-0.80
Italy	-0.60*	-0.64*	1.16
Luxembourg	-0.15	--	5.20
Malta	-0.14	--	7.39
Netherlands	-0.36	--	6.16
Norway	-0.73*	0.11	--
Poland	--	-0.05	4.55
Russia	--	0.32	--
Serbia	--	0.09	--
Slovenia	--	0.05	8.98
Spain	--	-0.30	0.89
Switzerland	-0.08	0.09	--
Turkey	-0.21	-0.17	--
Correlation with EIOPA duration mismatch	0.11	0.23	

Table 16: Comparison of Bond Return Coefficients to EIOPA Duration Gap Estimates (Country Allocation by Home Country – Daily Data)

Country	Average change in bond return coefficient (γ)		EIOPA duration mismatch, years
	Life insurers	Non-life insurers	
Austria	-0.15	-0.13	11.33
Belgium	-0.14	--	1.78
Croatia	--	-0.04	5.88
Cyprus	-0.67***	-0.03	7.07
Denmark	--	-0.06	5.42
Finland	--	-0.03	5.24
France	-0.29*	-0.07*	5.58
Germany	-0.01	0.00	11.32
Greece	--	-0.23	2.47
Hungary	-0.01	--	3.08
Iceland	--	0.00	--
Ireland	--	0.21*	-0.80
Italy	-0.37**	-0.31	1.16
Luxembourg	0.03	--	5.20
Malta	0.11	--	7.39
Netherlands	-0.17	--	6.16
Norway	-0.38**	0.02	--
Poland	--	-0.04	4.55
Russia	--	0.03	--
Serbia	--	-0.10	--
Slovenia	--	0.15	8.98
Spain	--	-0.27*	0.89
Switzerland	-0.07	0.19*	--
Turkey	0.11	0.20	--
Correlation with EIOPA duration mismatch	0.15	0.23	

Table 17: Comparison of Bond Return Coefficients to EIOPA Net Worth Estimates (Country Allocation by Premium Shares – Weekly Data)

Country	Average change in bond return coefficient (γ)		EIOPA low-for-long impact on AoL
	Life insurers	Non-life insurers	
Austria	-0.79	0.11	-5.7%
Belgium	-0.56	0.12	-1.8%
Croatia	-0.47	0.06	-2.0%
Cyprus	-0.81	0.03	-1.1%
Denmark	-0.33	-0.03	-0.3%
Finland	-0.34	0.34	-3.7%
France	-0.67	0.07	-1.2%
Germany	-0.70	0.25	-5.8%
Greece	-0.79	0.06	-3.1%
Hungary	-0.32	0.35	-0.5%
Iceland	-1.46	0.04	--
Ireland	-0.62	0.27	-2.2%
Italy	-0.76	0.06	-0.8%
Luxembourg	0.11	0.06	-0.1%
Malta	-0.73	-0.70	--
Netherlands	-0.84	0.35	-3.0%
Norway	-0.34	-0.09	-2.2%
Poland	-0.57	0.35	-3.7%
Russia	-1.23	0.65	--
Serbia	-0.34	0.37	--
Slovenia	-0.80	0.41	-3.9%
Spain	-0.58	0.06	-0.4%
Switzerland	-0.56	0.05	--
Turkey	-0.74	-0.26	--
Correlation with EIOPA duration mismatch	0.46	-0.44	

Table 18: Comparison of Bond Return Coefficients to EIOPA Net Worth Estimates (Country Allocation by Premium Shares – Daily Data)

Country	Average change in bond return coefficient (γ)		EIOPA low-for-long impact on AoL
	Life insurers	Non-life insurers	
Austria	-0.49	0.30	-5.7%
Belgium	-0.30	0.33	-1.8%
Croatia	-0.51	0.25	-2.0%
Cyprus	-0.47	0.24	-1.1%
Denmark	-0.54	-0.03	-0.3%
Finland	-0.54	0.62*	-3.7%
France	-0.62*	0.26	-1.2%
Germany	-0.41	0.14	-5.8%
Greece	-0.46	0.25	-3.1%
Hungary	-0.18	0.62*	-0.5%
Iceland	-0.76**	-0.15	--
Ireland	-0.36	0.56	-2.2%
Italy	-0.39	0.24	-0.8%
Luxembourg	0.05	0.26	-0.1%
Malta	-0.51	-0.48	--
Netherlands	-0.42	0.63*	-3.0%
Norway	-0.54	-0.07	-2.2%
Poland	-0.33	0.60	-3.7%
Russia	-0.75**	0.06	--
Serbia	-0.54	0.60	--
Slovenia	-0.42	0.42	-3.9%
Spain	-0.37	0.26	-0.4%
Switzerland	-0.29	0.28	--
Turkey	-0.28	0.20	--
Correlation with EIOPA duration mismatch	0.31	-0.18	

Table 19: Comparison of Bond Return Coefficients to EIOPA Net Worth Estimates (Country Allocation by Home Country – Weekly Data)

Country	Average change in bond return coefficient (γ)		EIOPA low-for-long impact on AoL
	Life insurers	Non-life insurers	
Austria	-0.46	-0.01	-5.7%
Belgium	-0.16	--	-1.8%
Croatia	--	-0.01	-2.0%
Cyprus	-0.43	-0.41	-1.1%
Denmark	--	-0.07	-0.3%
Finland	--	-0.01	-3.7%
France	-0.41	-0.13	-1.2%
Germany	0.01	-0.07	-5.8%
Greece	--	-0.32	-3.1%
Hungary	0.02	--	-0.5%
Iceland	--	-0.01	--
Ireland	--	0.24	-2.2%
Italy	-0.60*	-0.64*	-0.8%
Luxembourg	-0.15	--	-0.1%
Malta	-0.14	--	--
Netherlands	-0.36	--	-3.0%
Norway	-0.73*	0.11	-2.2%
Poland	--	-0.05	-3.7%
Russia	--	0.32	--
Serbia	--	0.09	--
Slovenia	--	0.05	-3.9%
Spain	--	-0.30	-0.4%
Switzerland	-0.08	0.09	--
Turkey	-0.21	-0.17	--
Correlation with EIOPA duration mismatch	-0.06	-0.41	

Table 20: Comparison of Bond Return Coefficients to EIOPA Net Worth Estimates (Country Allocation by Home Country – Daily Data)

Country	Average change in bond return coefficient (γ)		EIOPA low-for-long impact on AoL
	Life insurers	Non-life insurers	
Austria	-0.15	-0.13	-5.7%
Belgium	-0.14	--	-1.8%
Croatia	--	-0.04	-2.0%
Cyprus	-0.67***	-0.03	-1.1%
Denmark	--	-0.06	-0.3%
Finland	--	-0.03	-3.7%
France	-0.29*	-0.07*	-1.2%
Germany	-0.01	0.00	-5.8%
Greece	--	-0.23	-3.1%
Hungary	-0.01	--	-0.5%
Iceland	--	0.00	--
Ireland	--	0.21*	-2.2%
Italy	-0.37**	-0.31	-0.8%
Luxembourg	0.03	--	-0.1%
Malta	0.11	--	--
Netherlands	-0.17	--	-3.0%
Norway	-0.38**	0.02	-2.2%
Poland	--	-0.04	-3.7%
Russia	--	0.03	--
Serbia	--	-0.10	--
Slovenia	--	0.15	-3.9%
Spain	--	-0.27*	-0.4%
Switzerland	-0.07	0.19*	--
Turkey	0.11	0.20	--
Correlation with EIOPA duration mismatch	-0.22	-0.28	

Fig. 1: Estimation Error for Bond Price Approximation Via Modified Duration

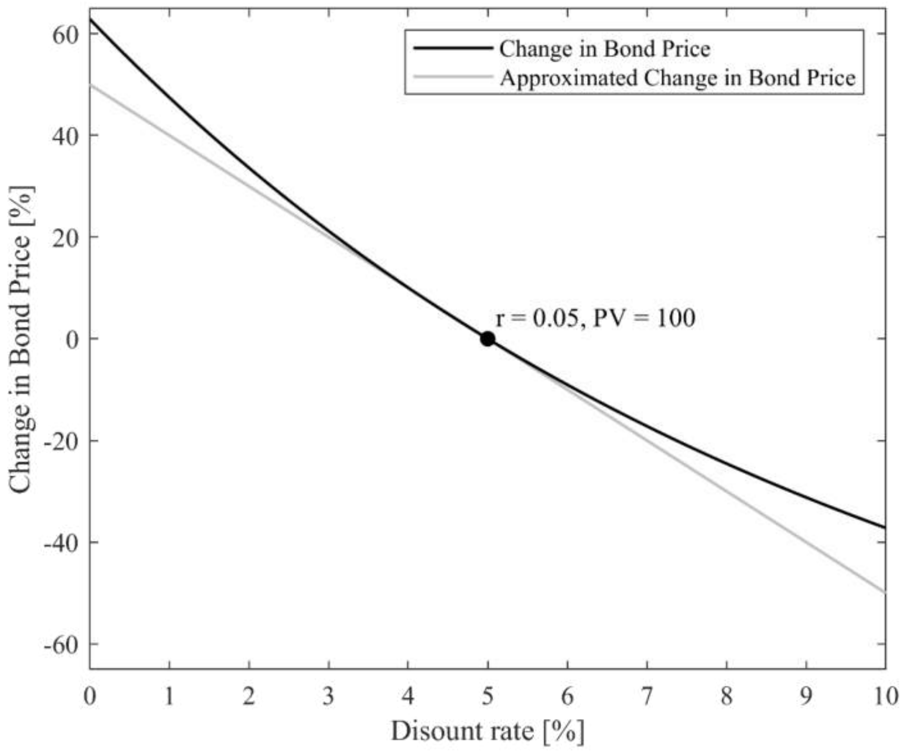
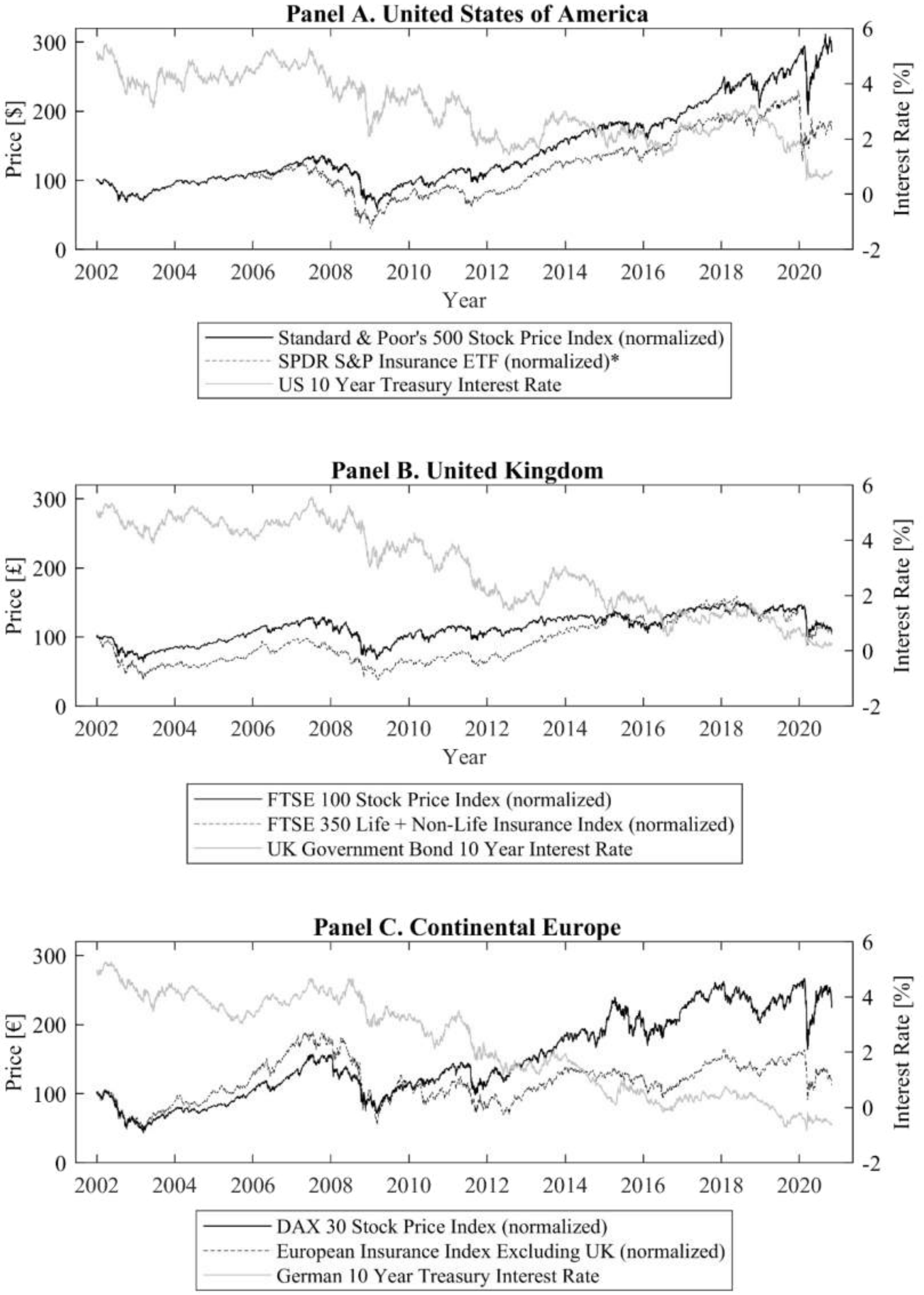


Fig. 2: Economic Developments in the United States, United Kingdom and Continental Europe



* Data available since November 2005. Retrieved from https://www.investing.com/etfs/spdr-kbw-insurance, visited on: 28.04.2021.

Fig. 3: Interest Rate Sensitivity Coefficients for US Insurance Industry - Weekly Data

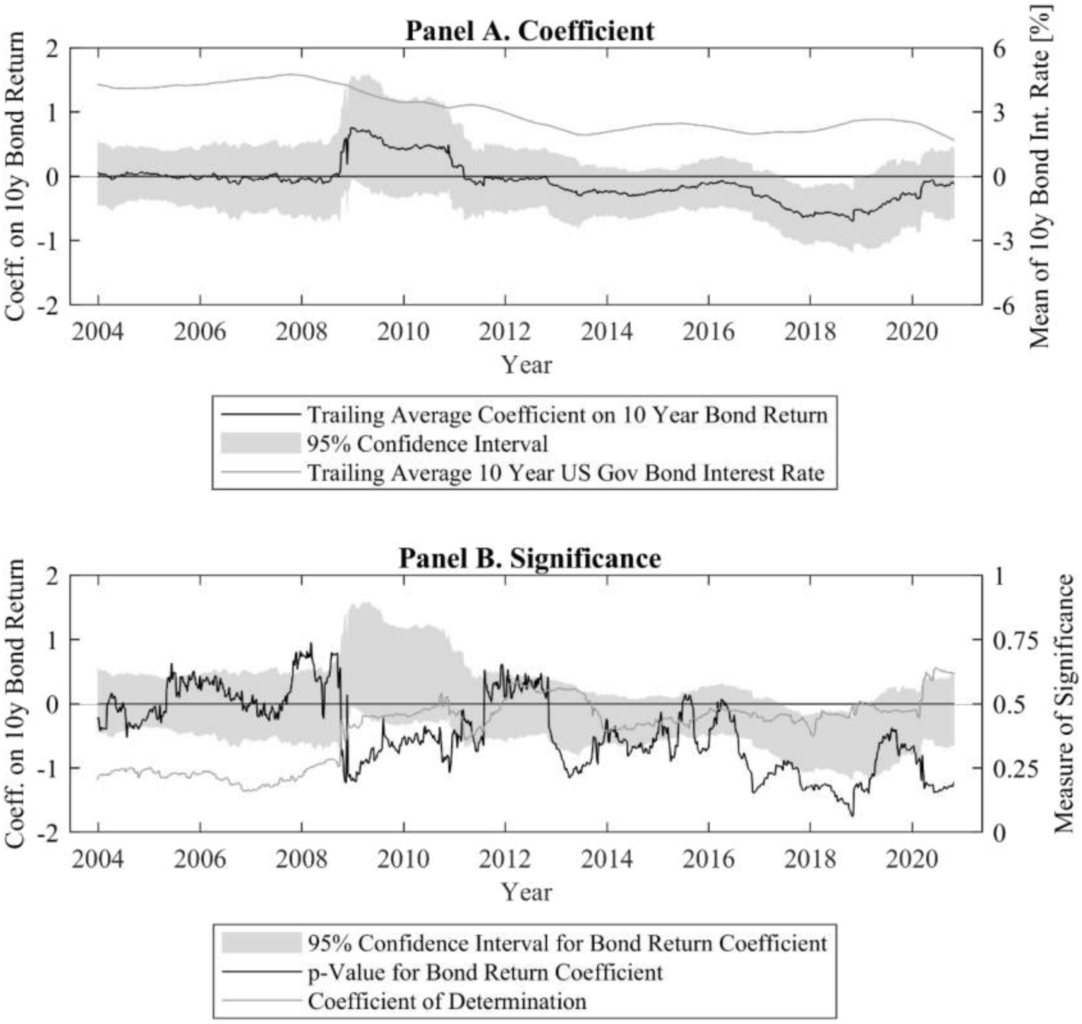


Fig. 4: Interest Rate Sensitivity Coefficients for US Insurance Industry - Daily Data

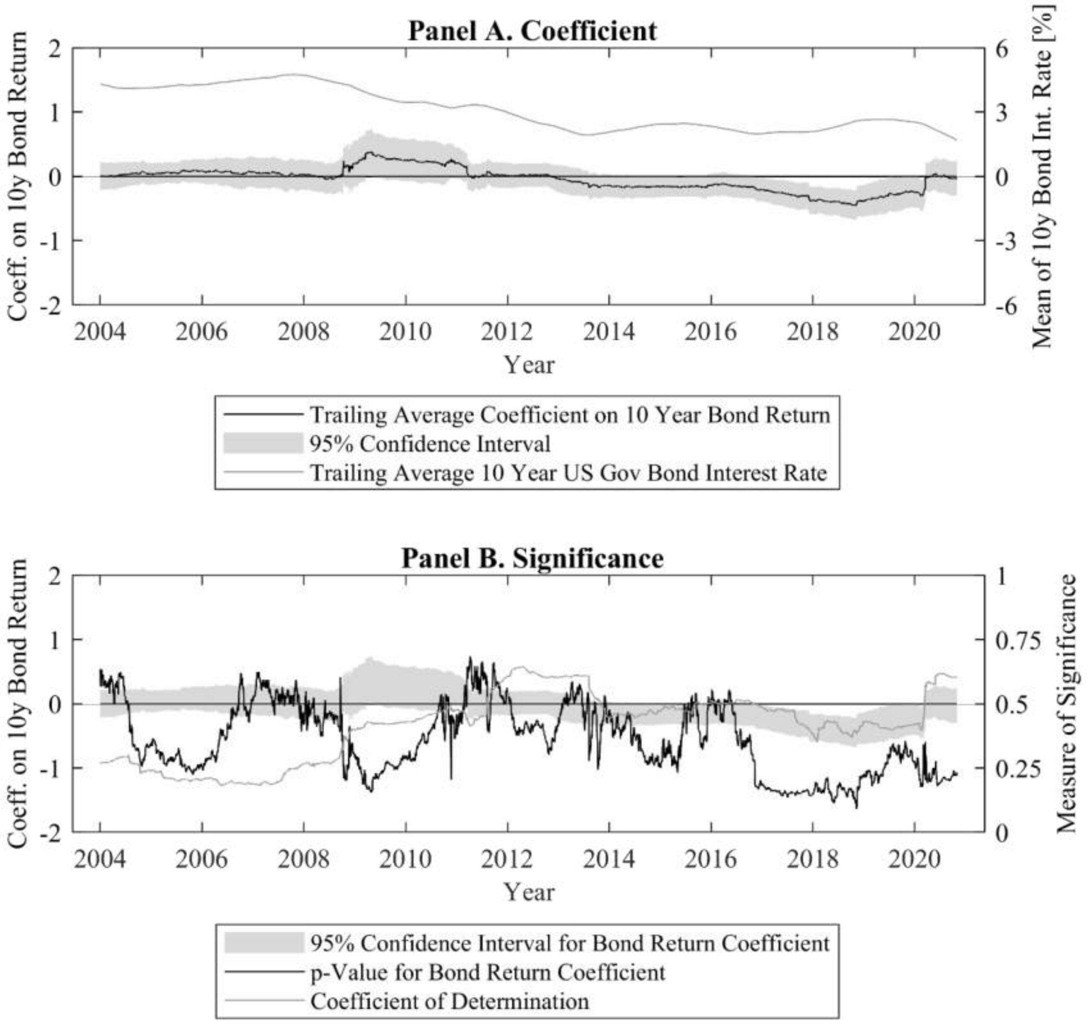


Fig. 5: Interest Rate Sensitivity Coefficients for US Insurers - Weekly Data

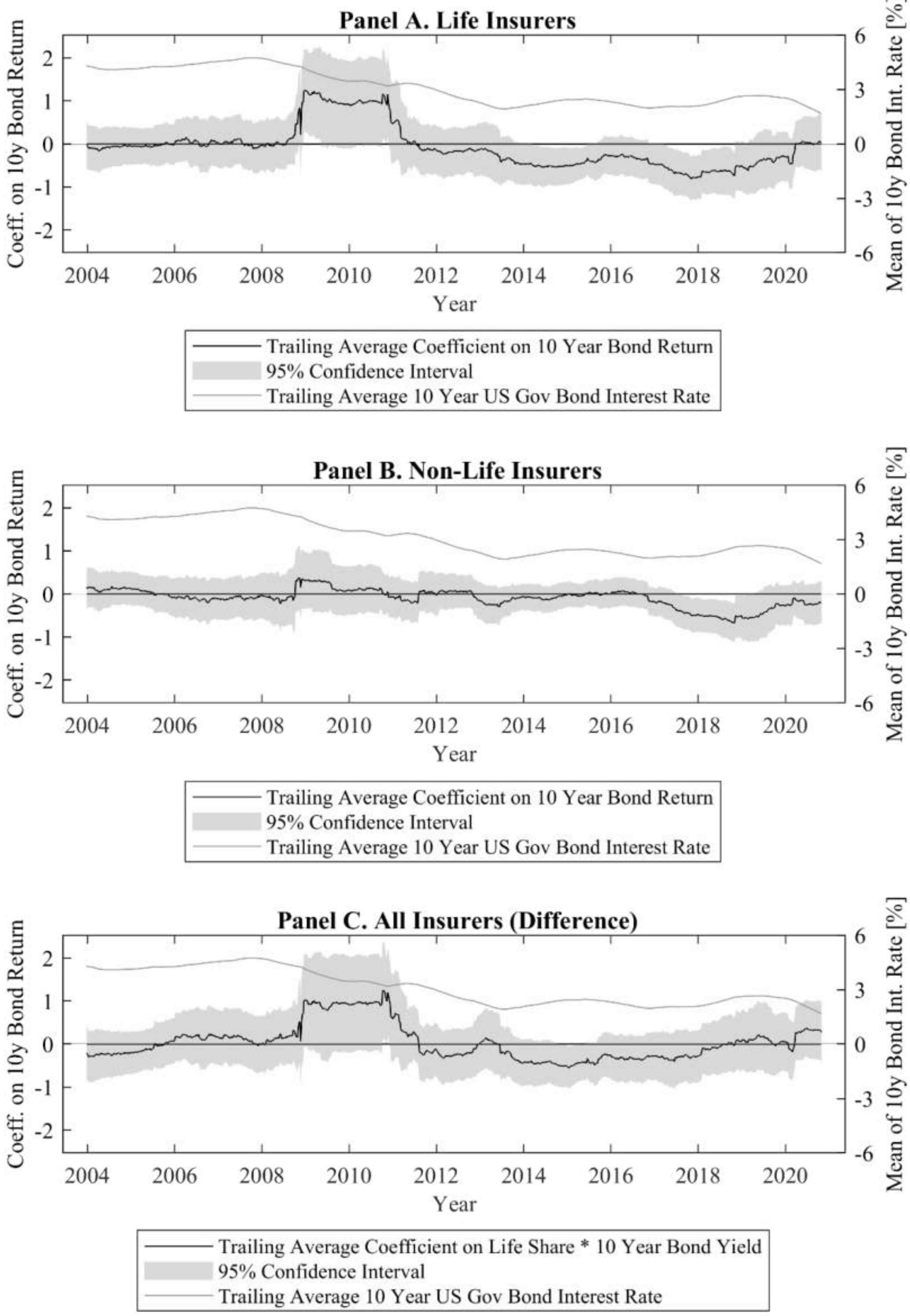


Fig. 6: Statistical Significance of Regression Model for US Insurers - Weekly Data

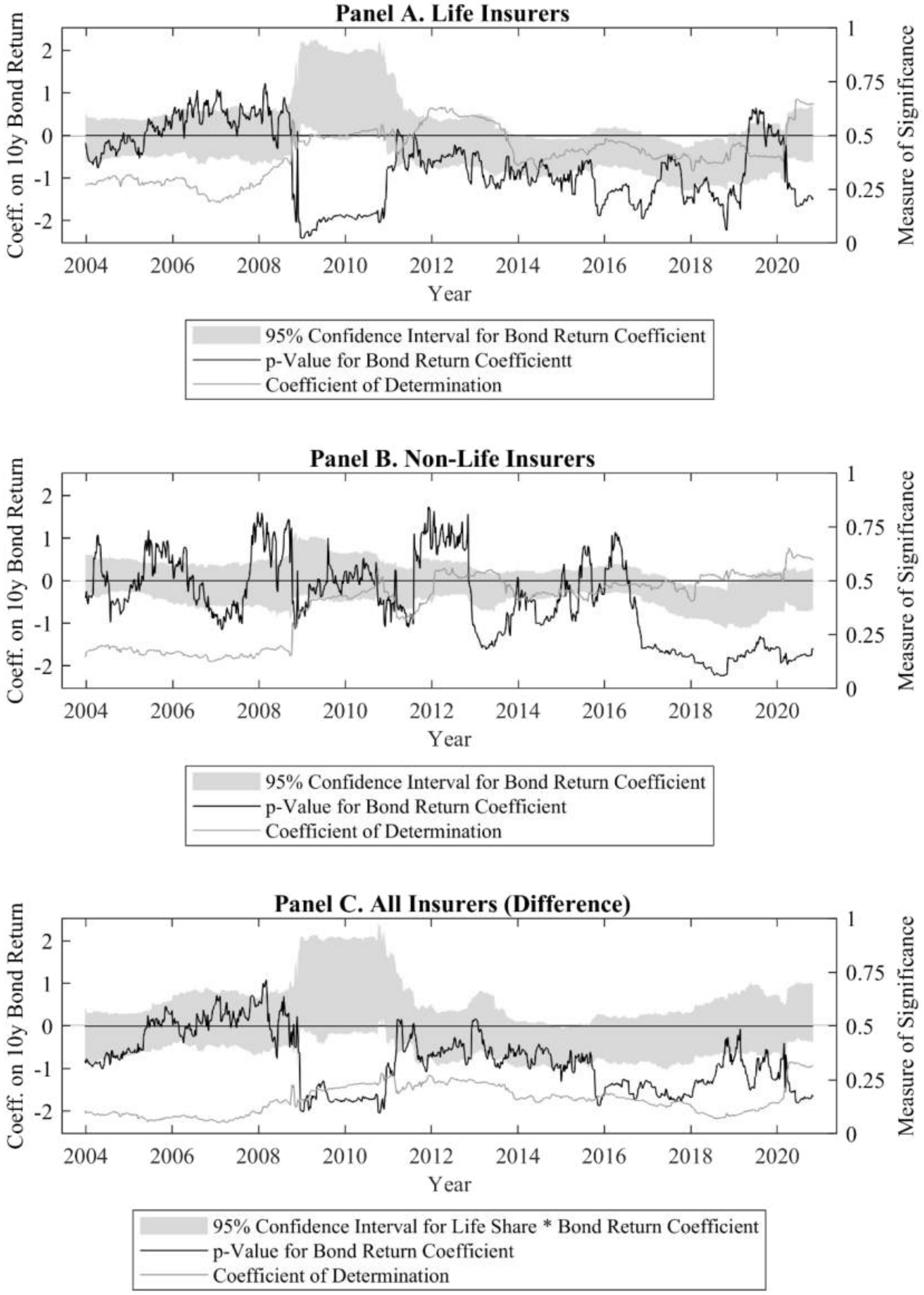


Fig. 7: Interest Rate Sensitivity Coefficients for US Insurers - Daily Data

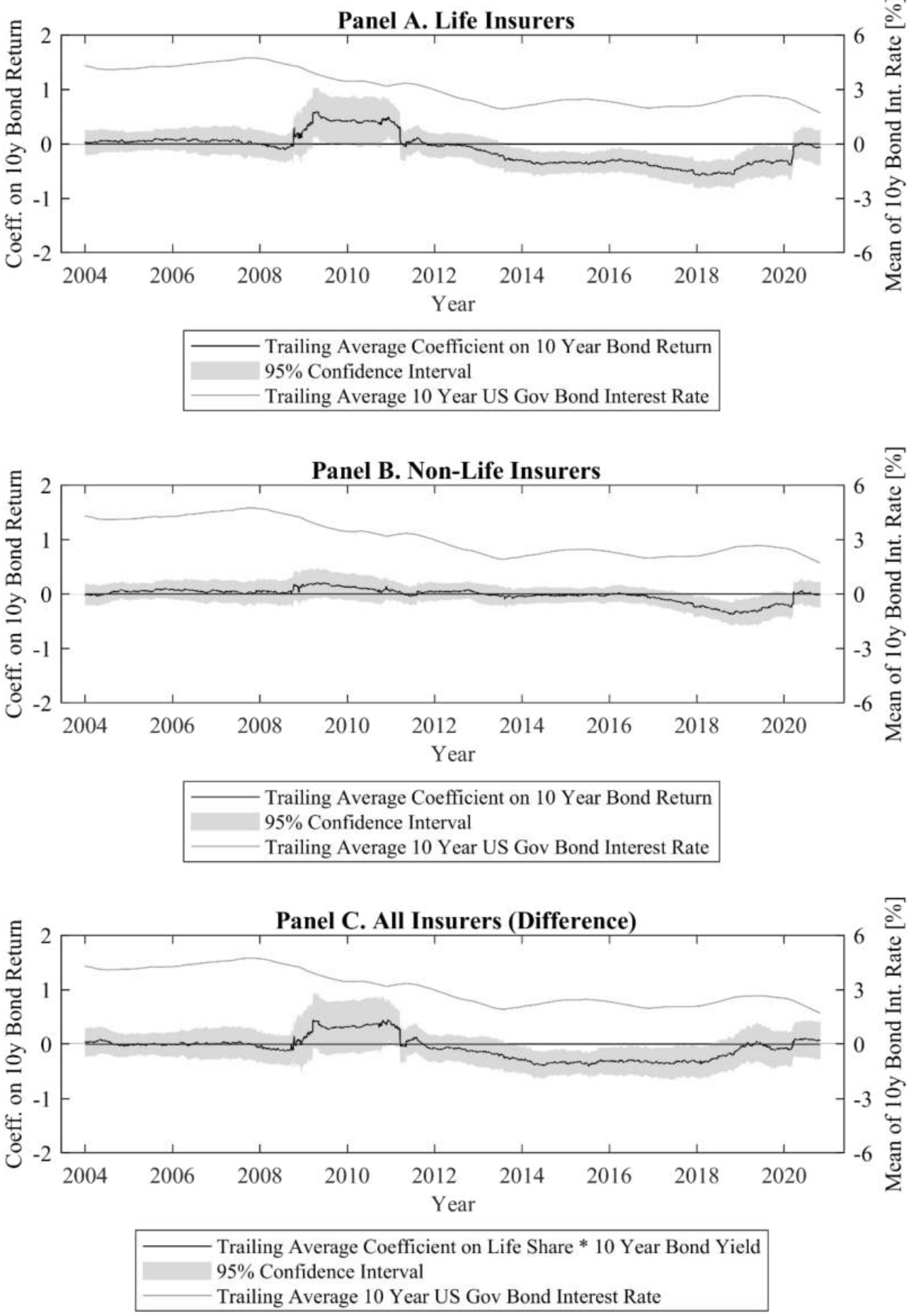
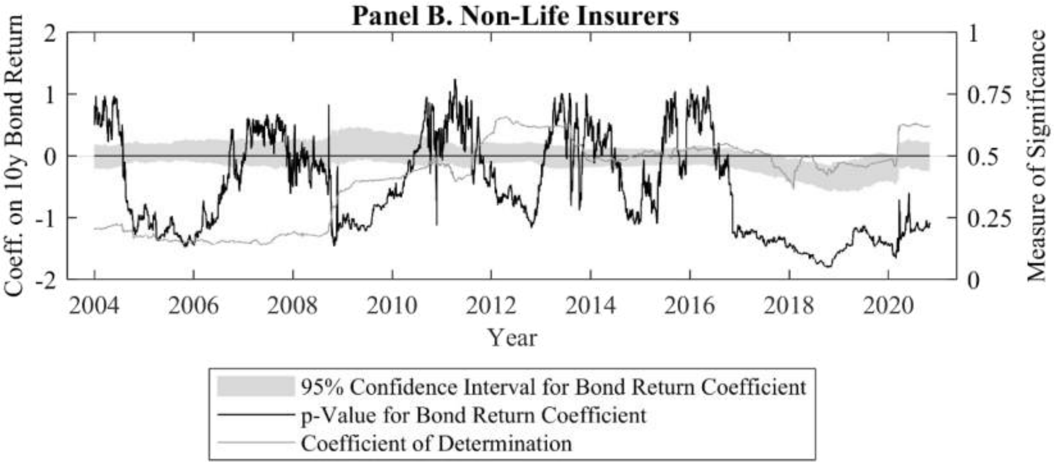


Fig. 8: Statistical Significance of Regression Model for US Insurers - Daily Data

Panel A. Life Insurers

Panel B. Non-Life Insurers



Panel C. All Insurers (Difference)

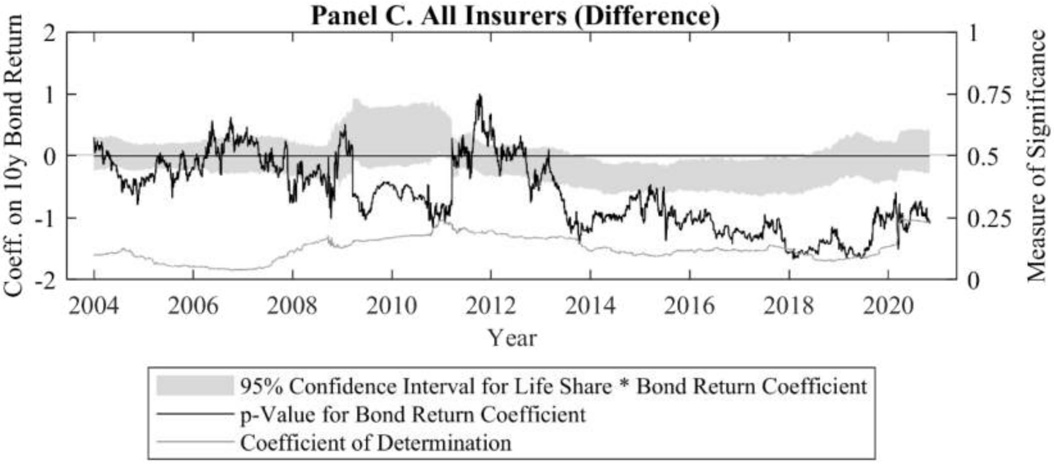


Fig. 9: Interest Rate Sensitivity Coefficients for UK Insurance Industry - Weekly Data

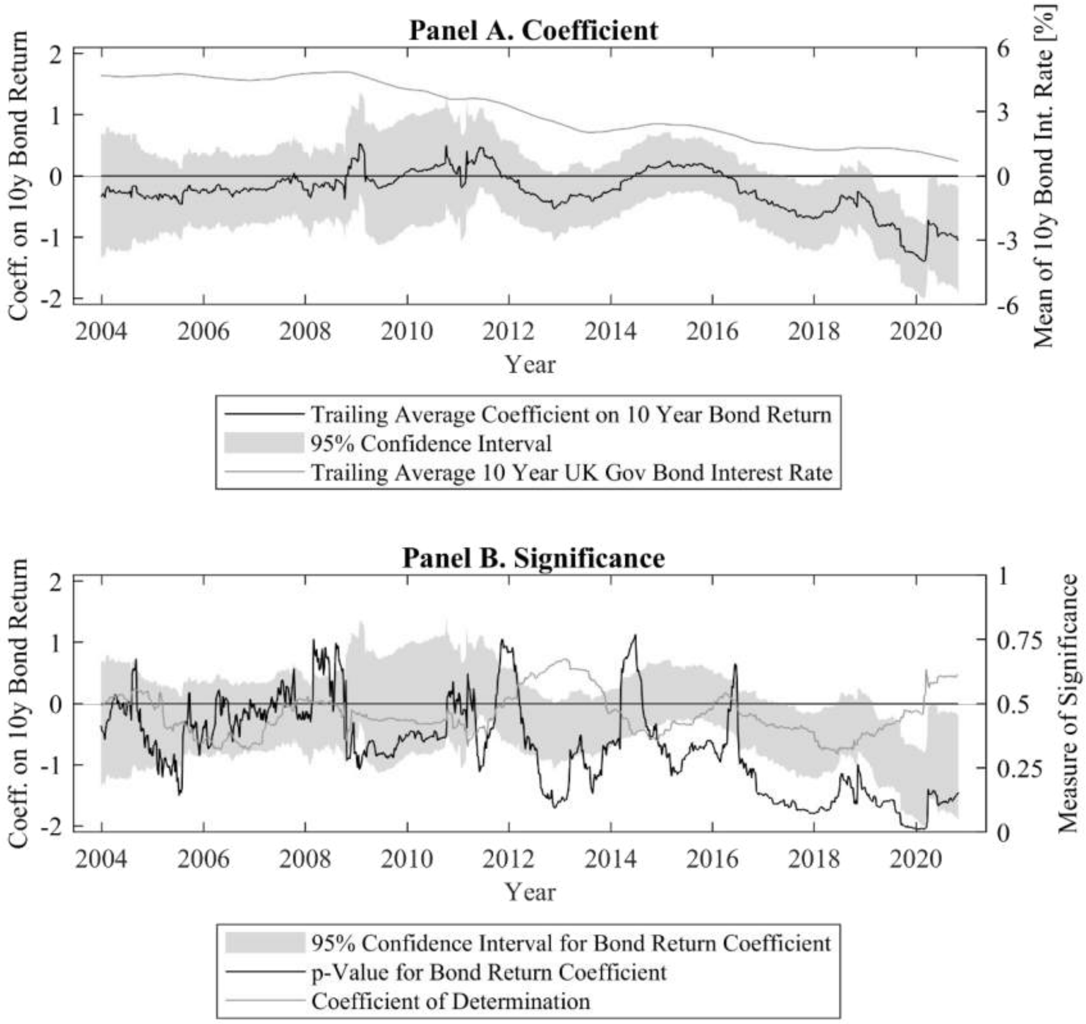


Fig. 10: Interest Rate Sensitivity Coefficients for UK Insurance Industry - Daily Data

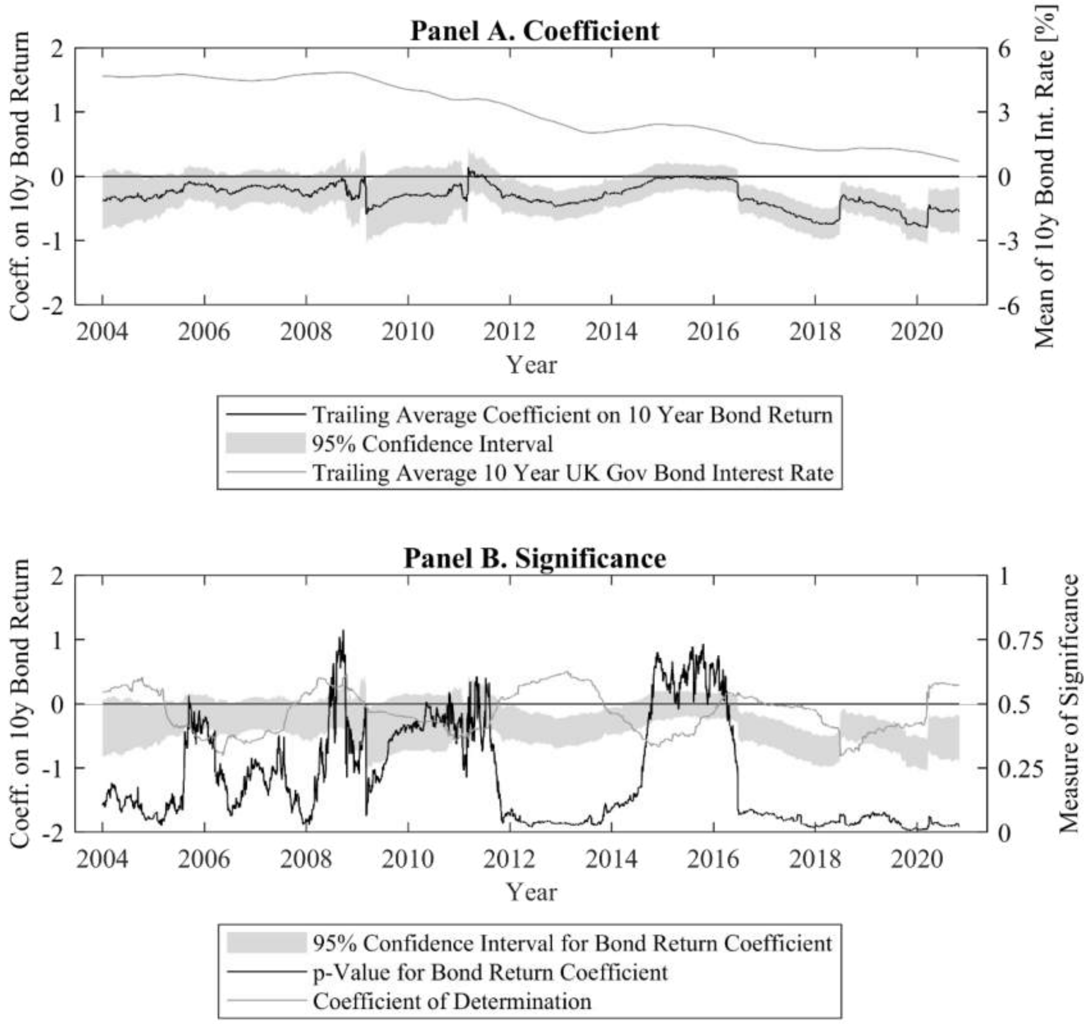


Fig. 11: Interest Rate Sensitivity Coefficients for UK Insurers - Weekly Data

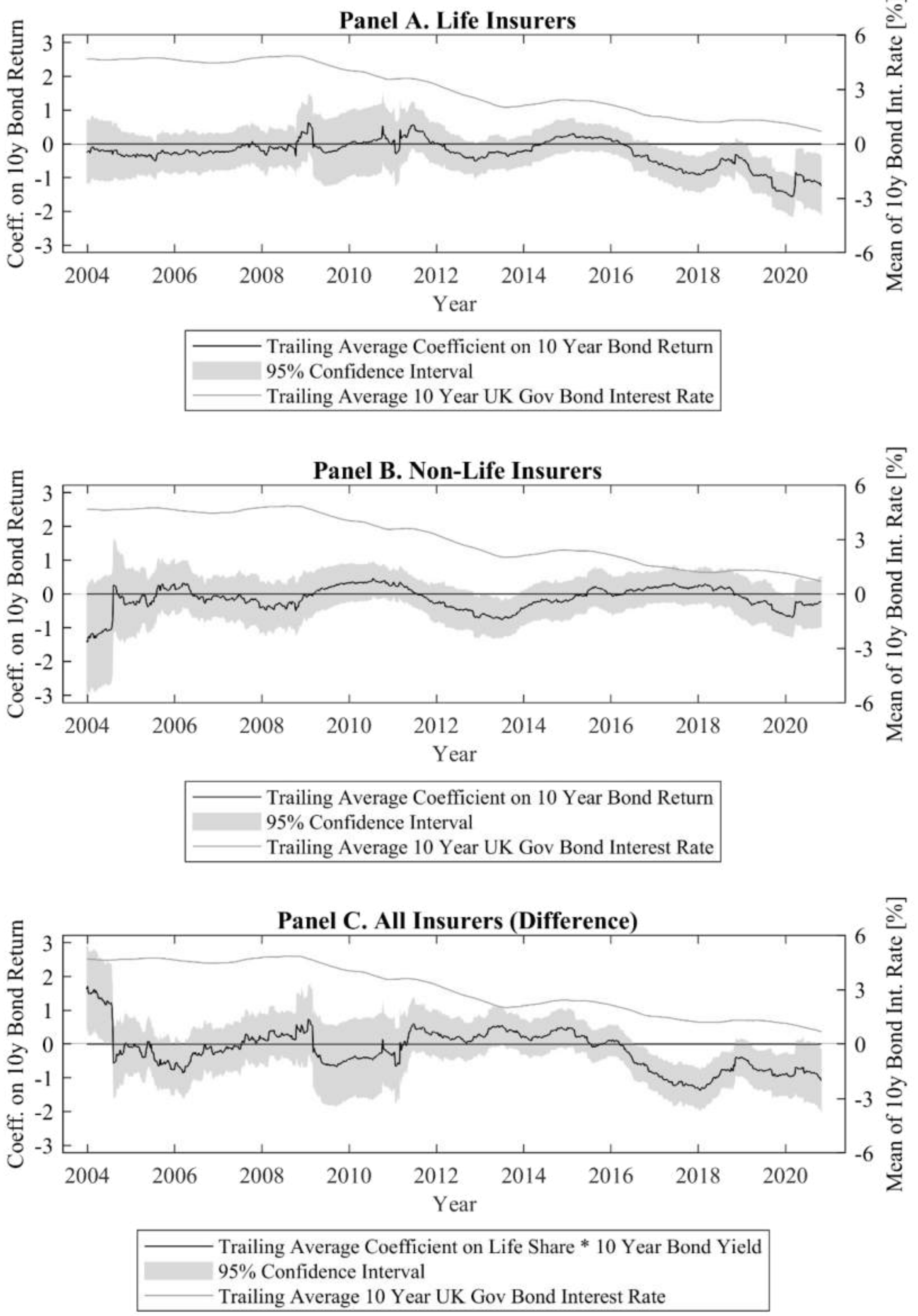


Fig. 12: Statistical Significance of Regression Model for UK Insurers - Weekly Data

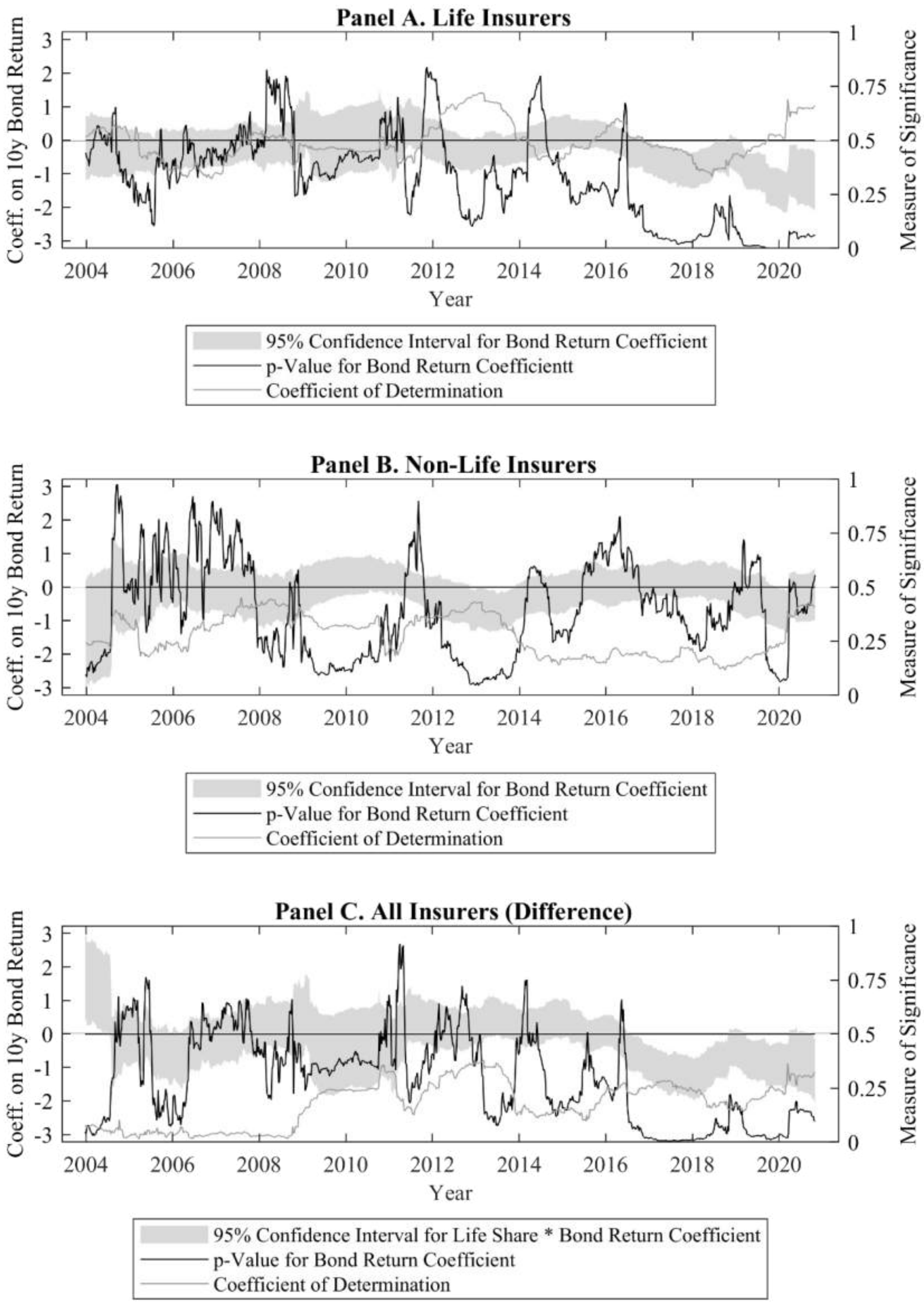


Fig. 13: Interest Rate Sensitivity Coefficients for UK Insurers - Daily Data

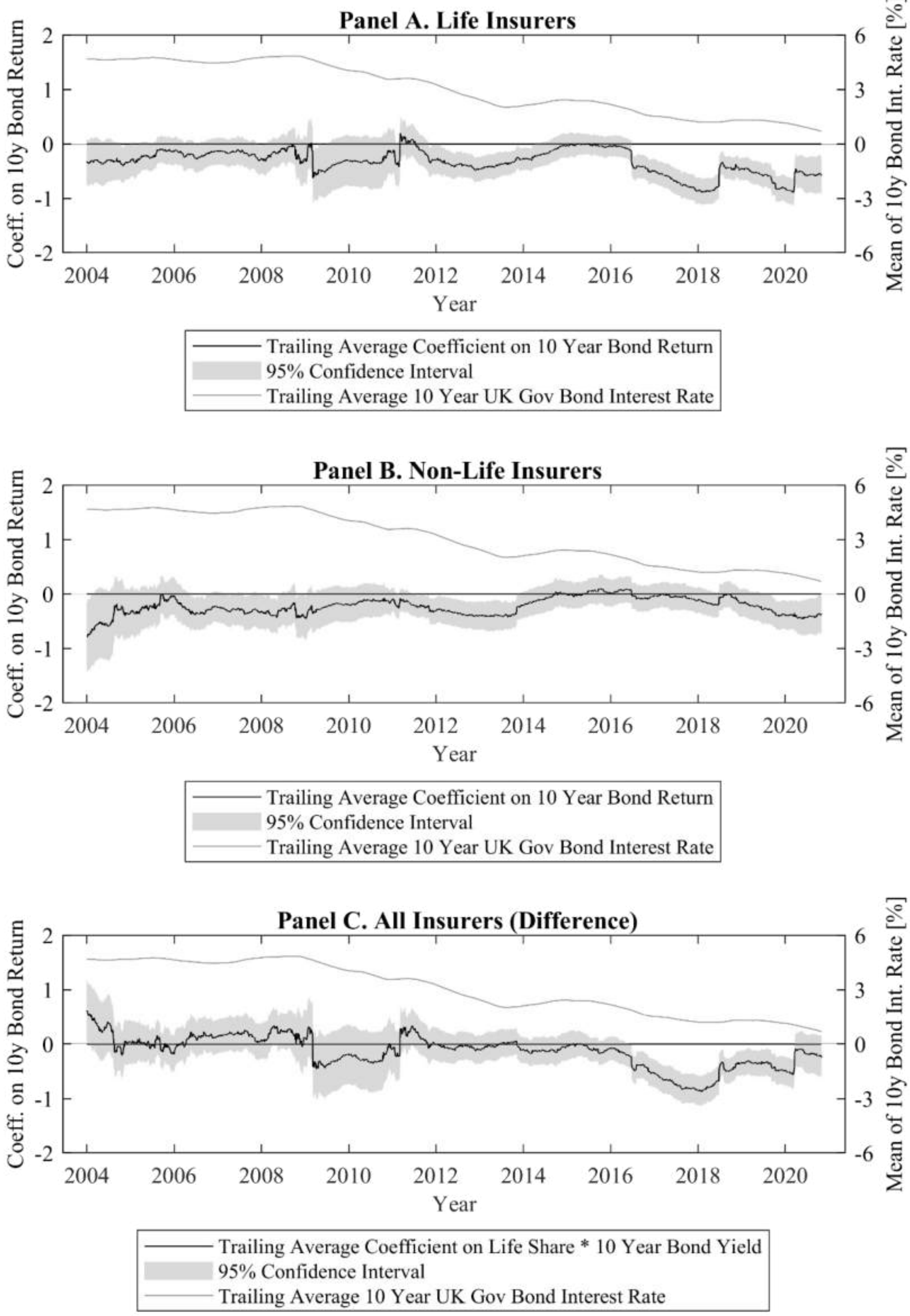


Fig. 14: Statistical Significance of Regression Model for UK Insurers - Daily Data

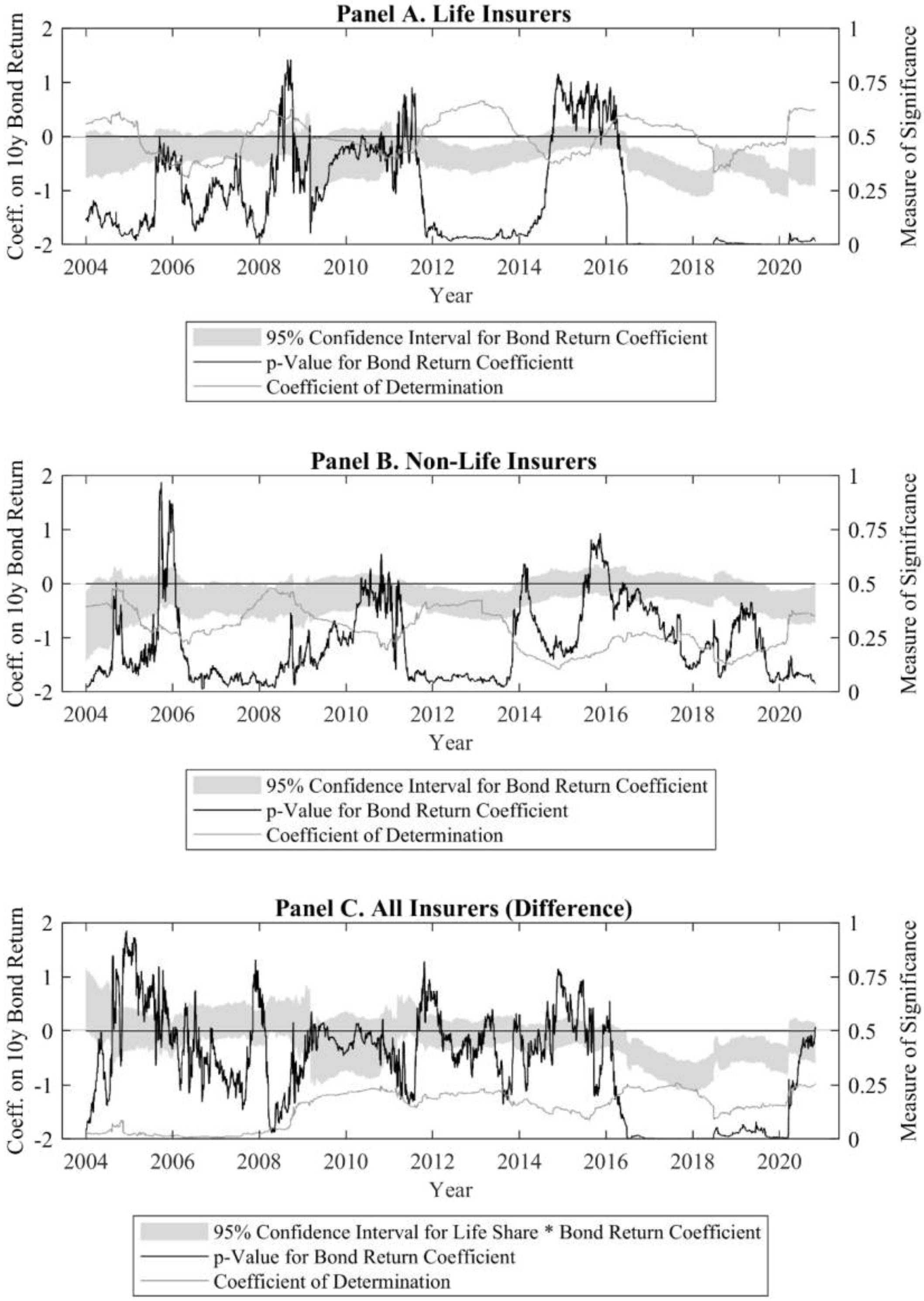


Fig. 15: Interest Rate Sensitivity Coefficients for EU Insurance Industry - Weekly Data

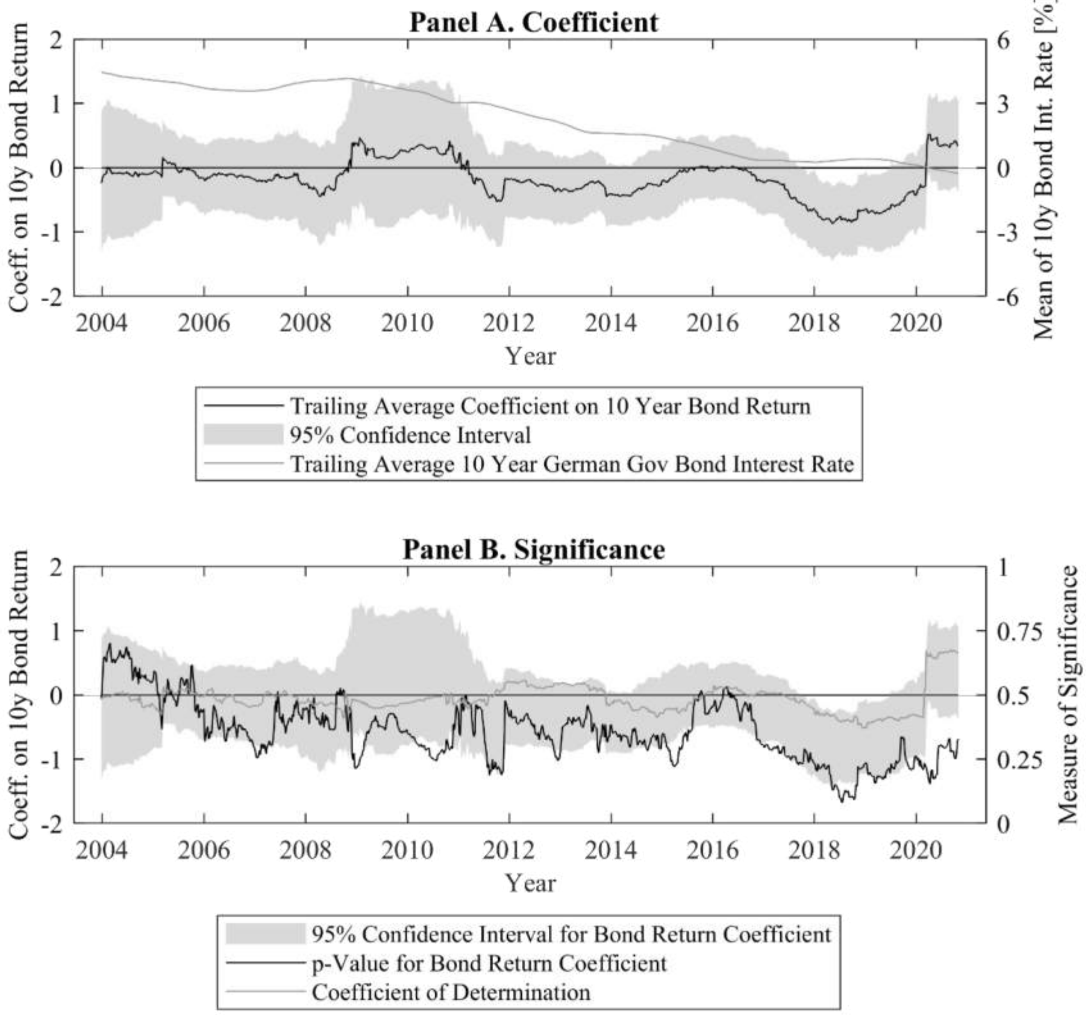
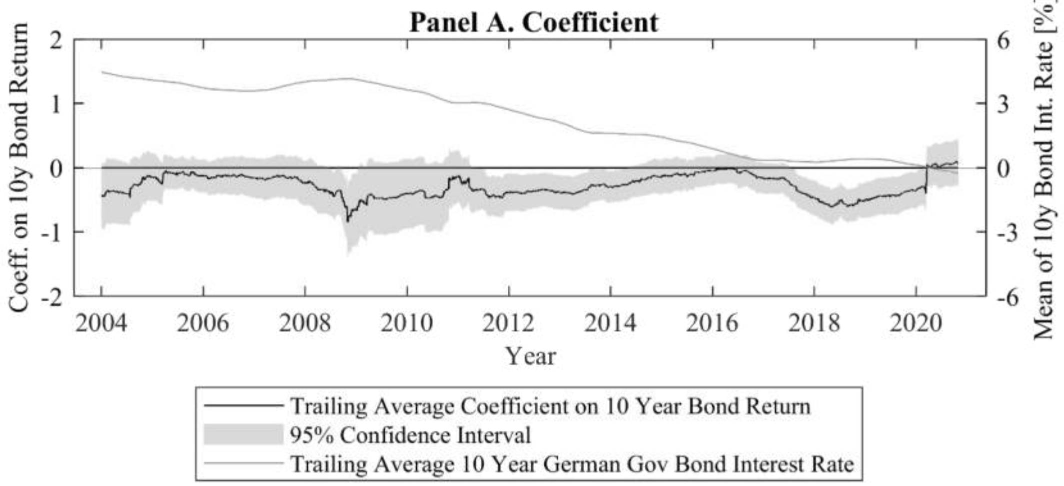


Fig. 16: Interest Rate Sensitivity Coefficients for EU Insurance Industry - Daily Data



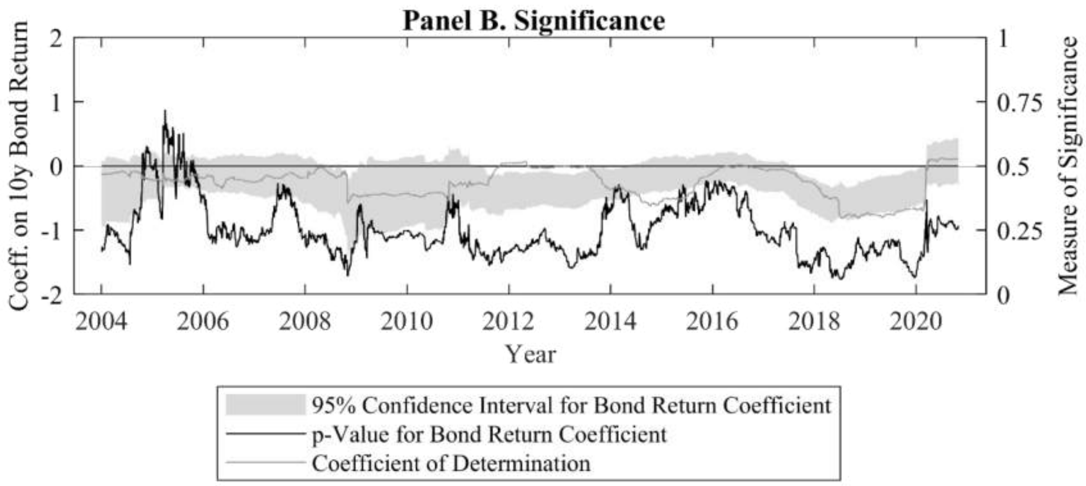


Fig. 17: Interest Rate Sensitivity Coefficients for EU Insurers - Weekly Data

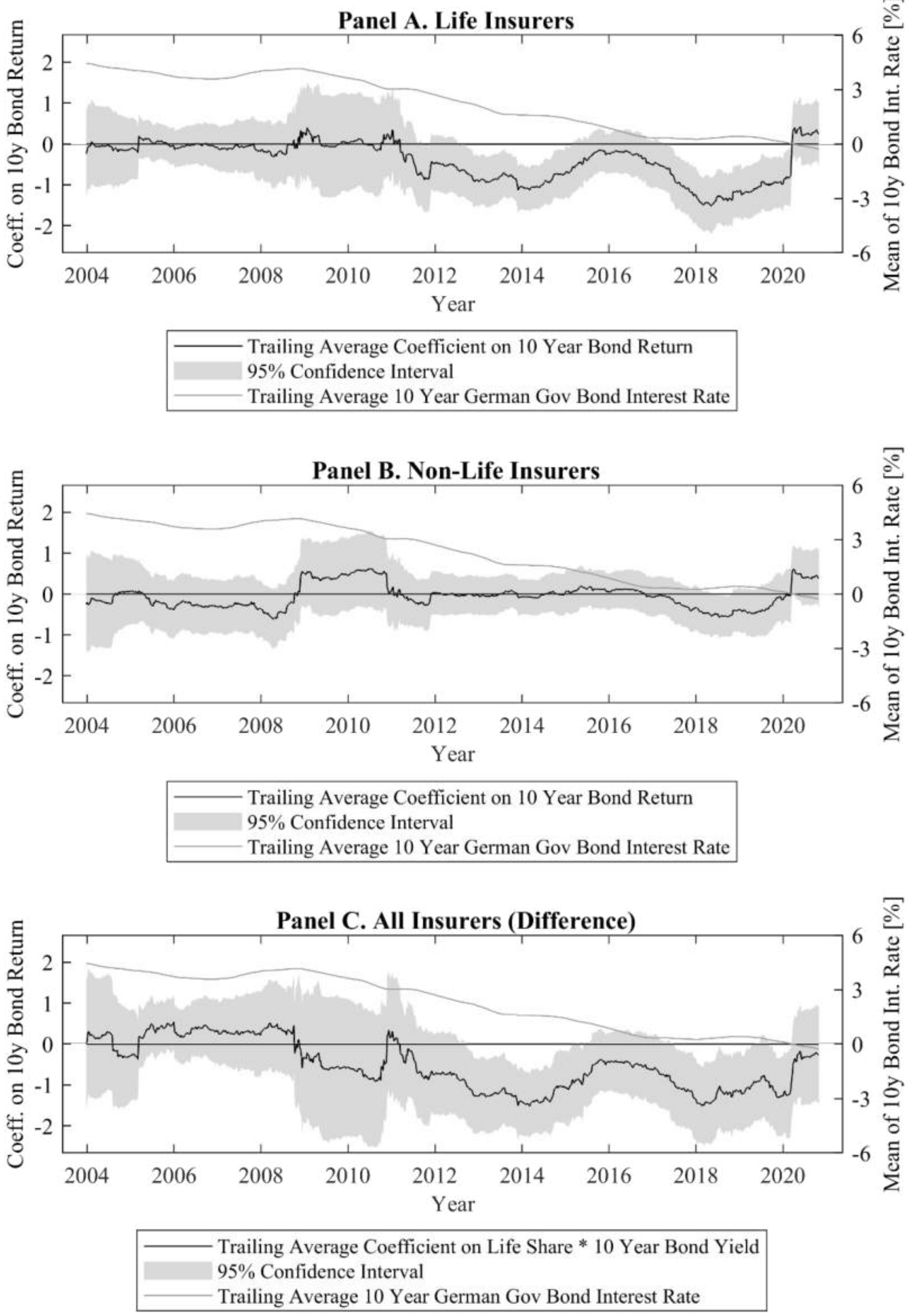


Fig. 18: Statistical Significance of Regression Model for EU Insurers - Weekly Data

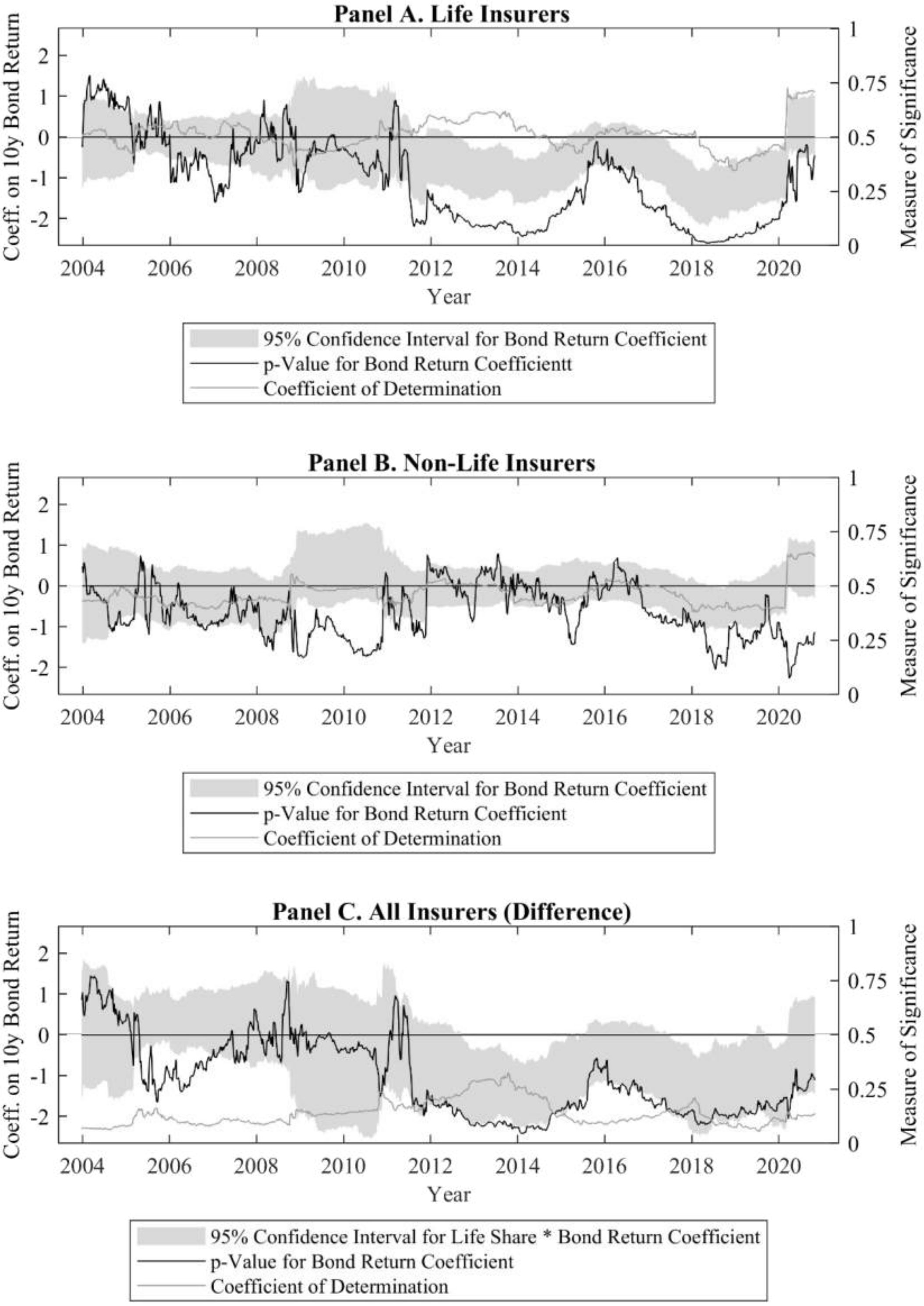


Fig. 19: Interest Rate Sensitivity Coefficients for EU Insurers - Daily Data

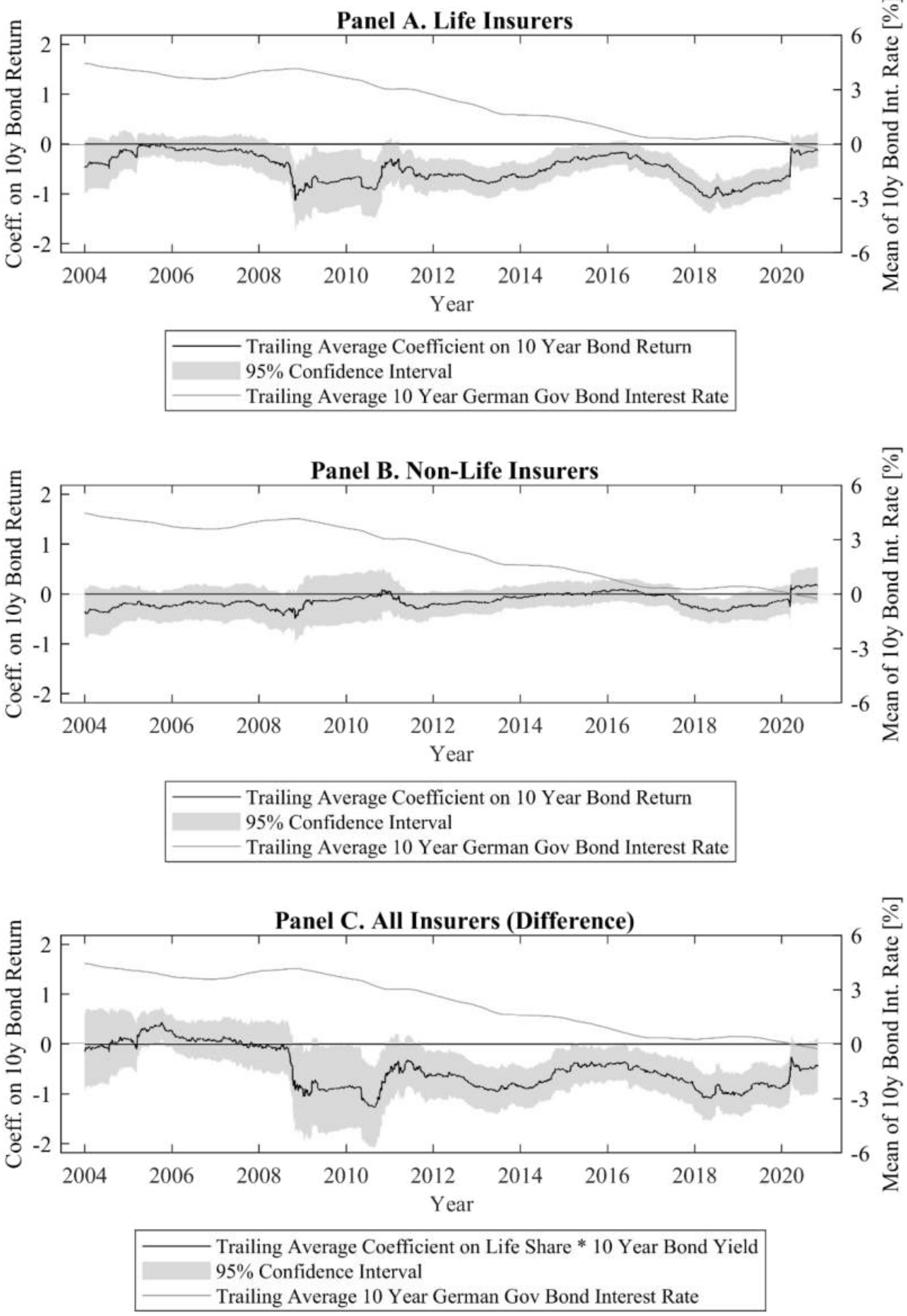


Fig. 20: Statistical Significance of Regression Model for EU Insurers - Daily Data

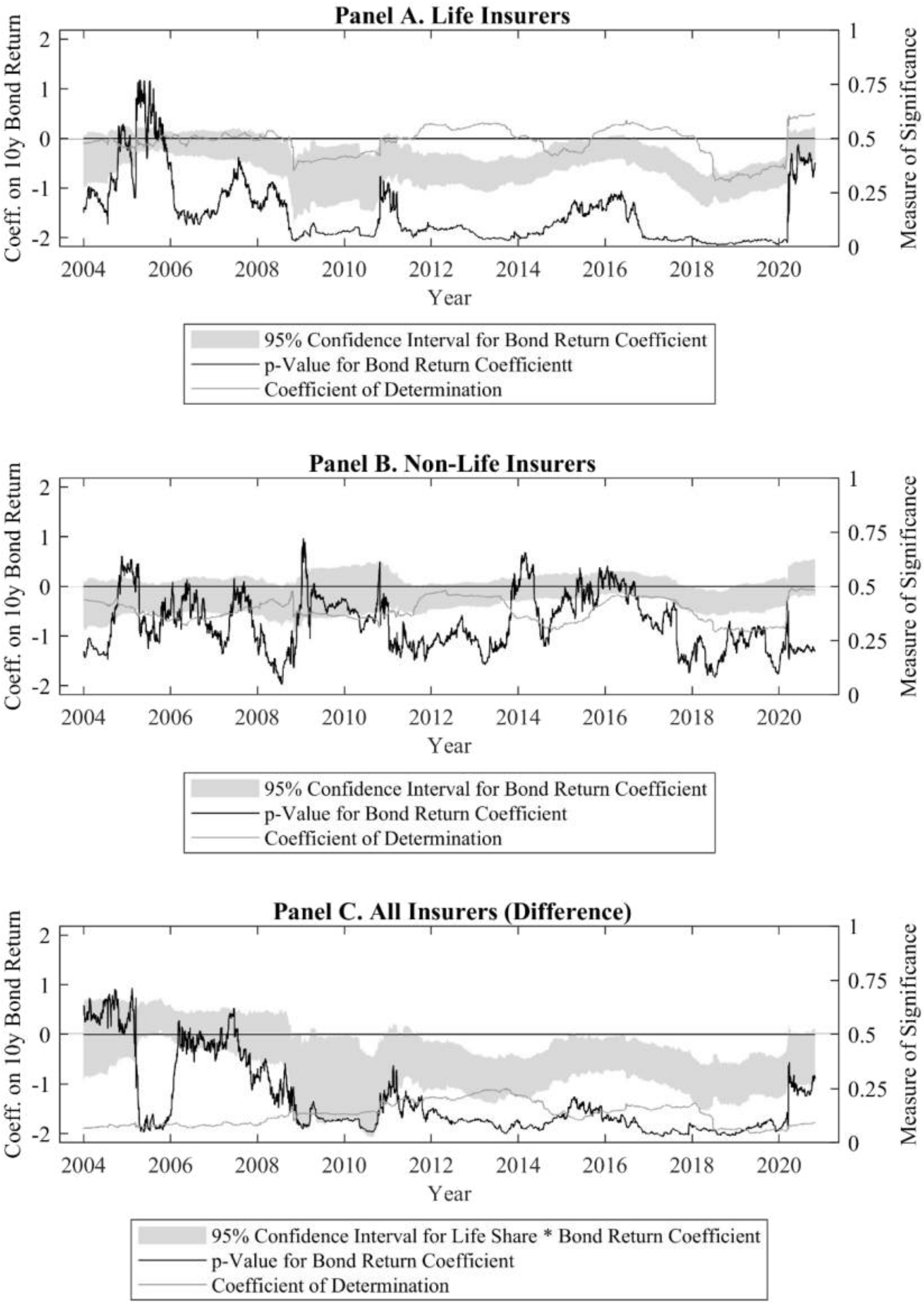
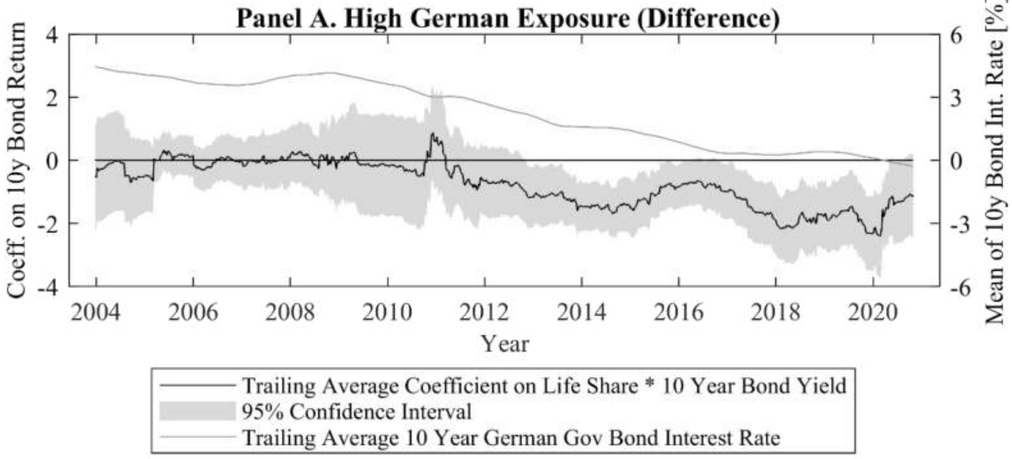
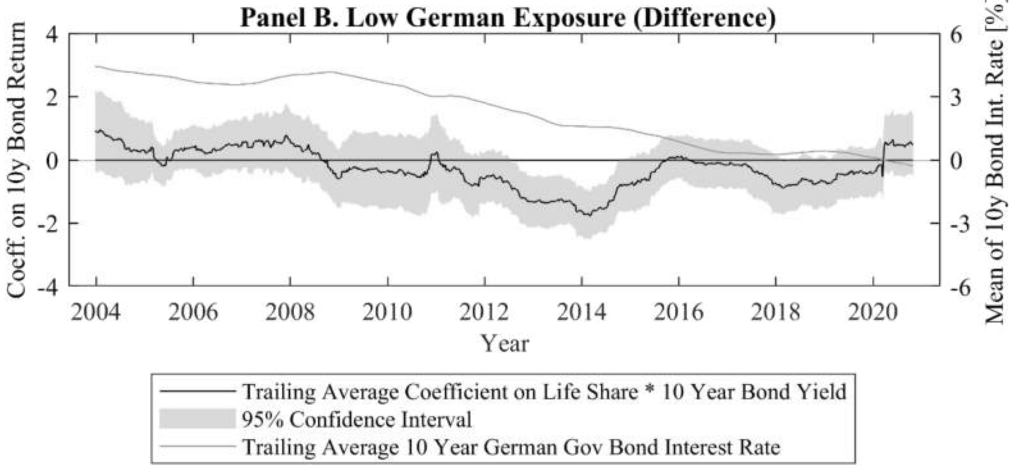


Fig. 21: Interest Rate Sensitivity Differences for Continental European Insurers German Exposure - Weekly Data

Panel A. High German Exposure (Difference)



Panel B. Low German Exposure (Difference)



Panel C. All Insurers (Difference in Differences)

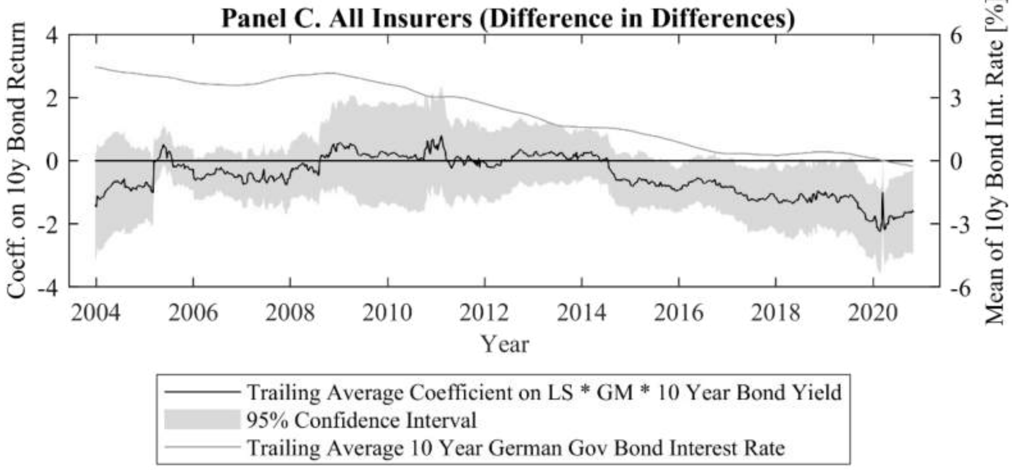


Fig. 22: Statistical Significance of Regression Model for Differences in Continental Europe German Exposure - Weekly Data

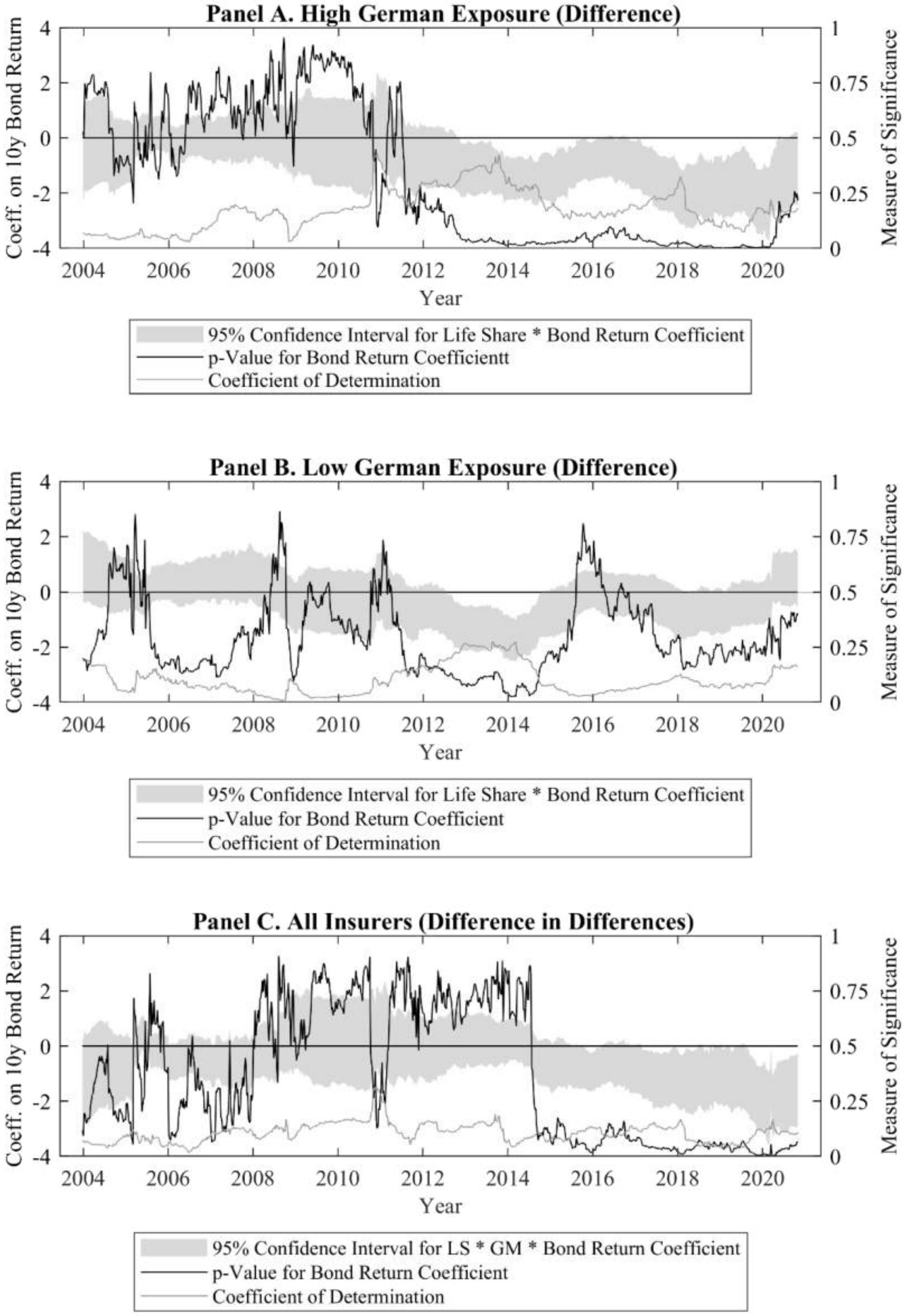


Fig. 23: Interest Rate Sensitivity Differences for Continental European Insurers German Exposure - Daily Data

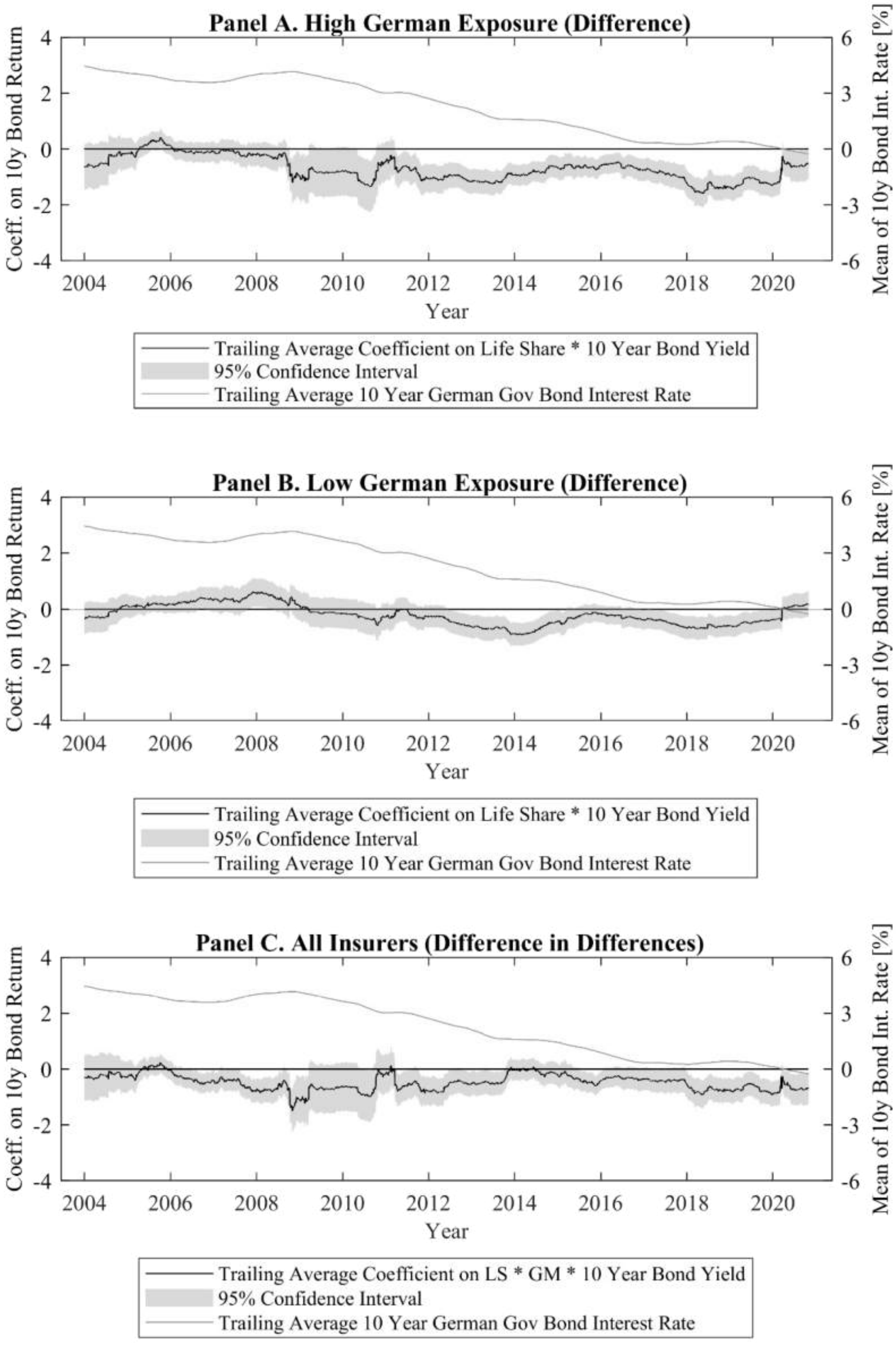


Fig. 24: Statistical Significance of Regression Model for Differences in Continental Europe German Exposure - Daily Data

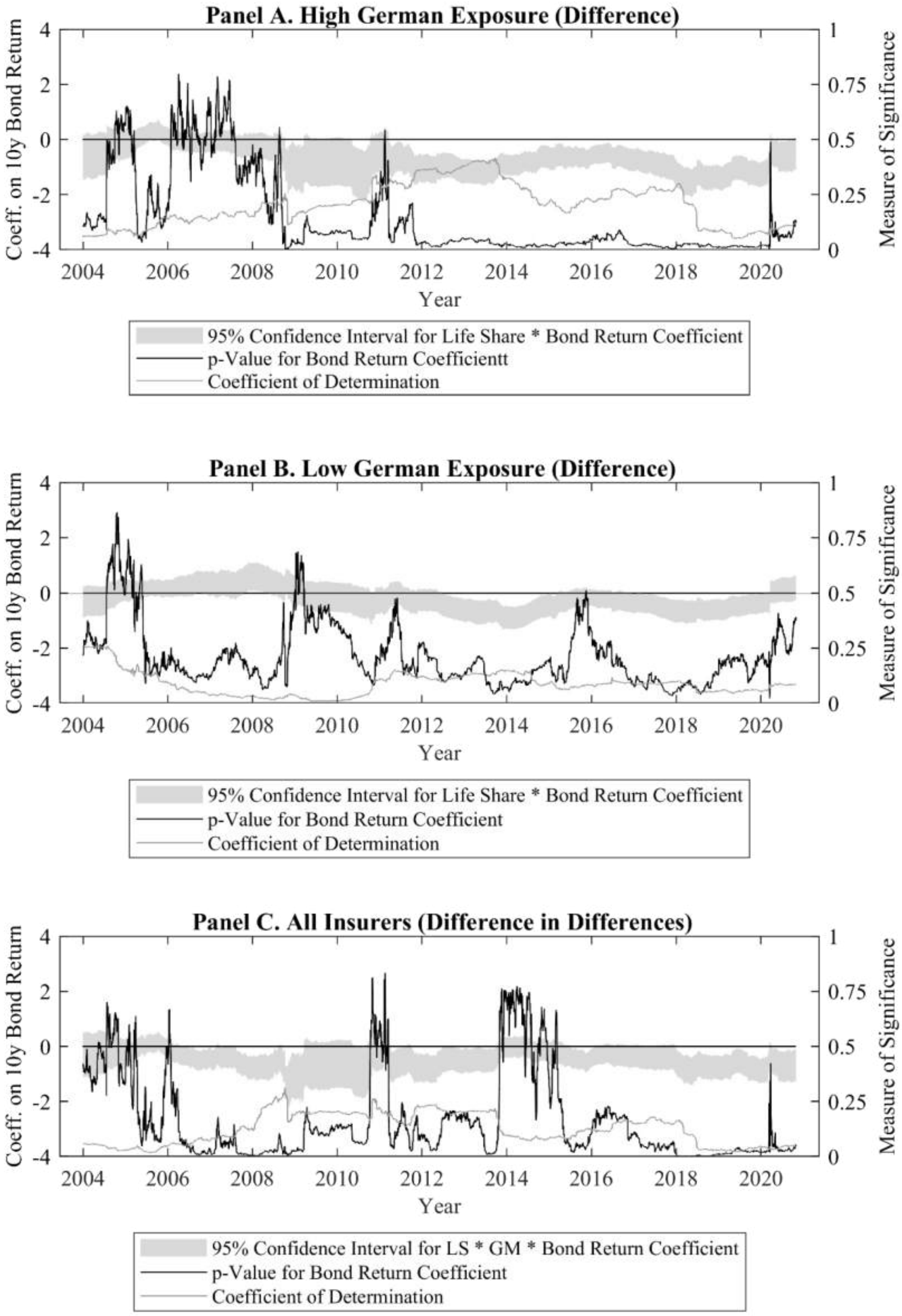
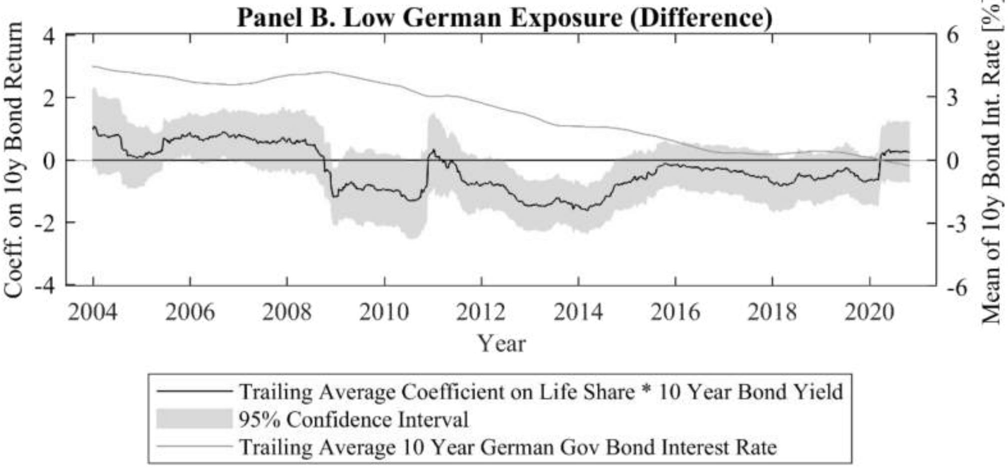


Fig. 25: Interest Rate Sensitivity Differences for Continental European Insurers One Non-Life Sample - German Exposure - Weekly Data

Panel A. High German Exposure (Difference)

Panel B. Low German Exposure (Difference)



Panel C. All Insurers (Difference in Differences)

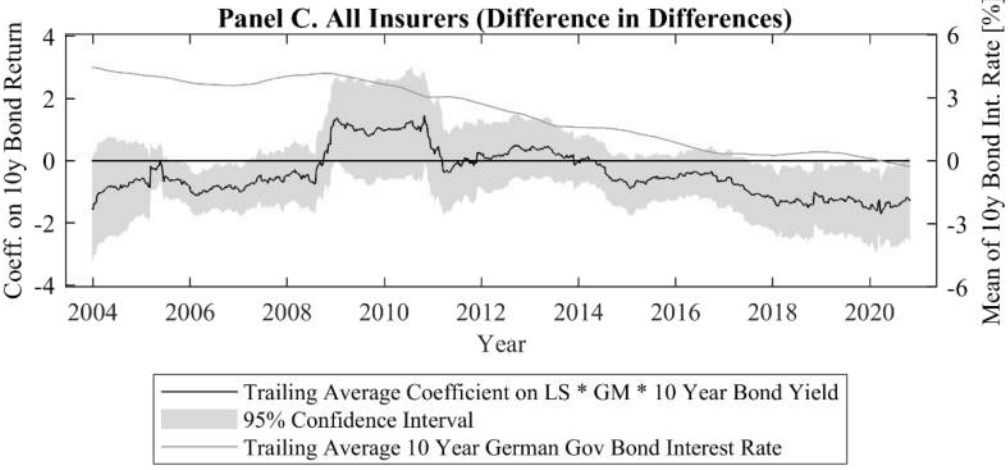


Fig. 26: Statistical Significance of Regression Model for Differences in Continental Europe One Non-Life Sample - German Exposure- Weekly Data

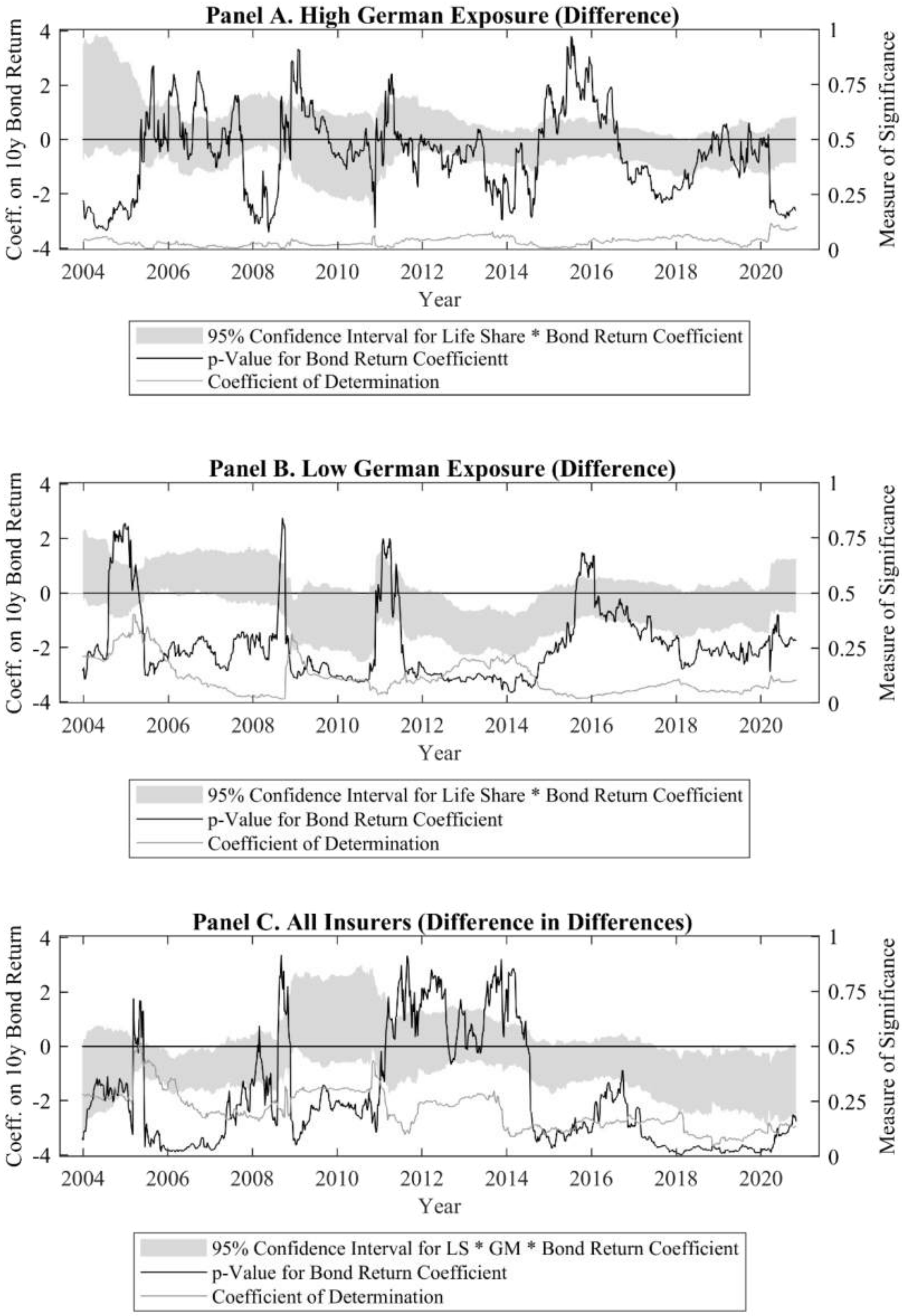


Fig. 27: Interest Rate Sensitivity Differences for Continental European Insurers One Non-Life Sample - German Exposure - Daily Data

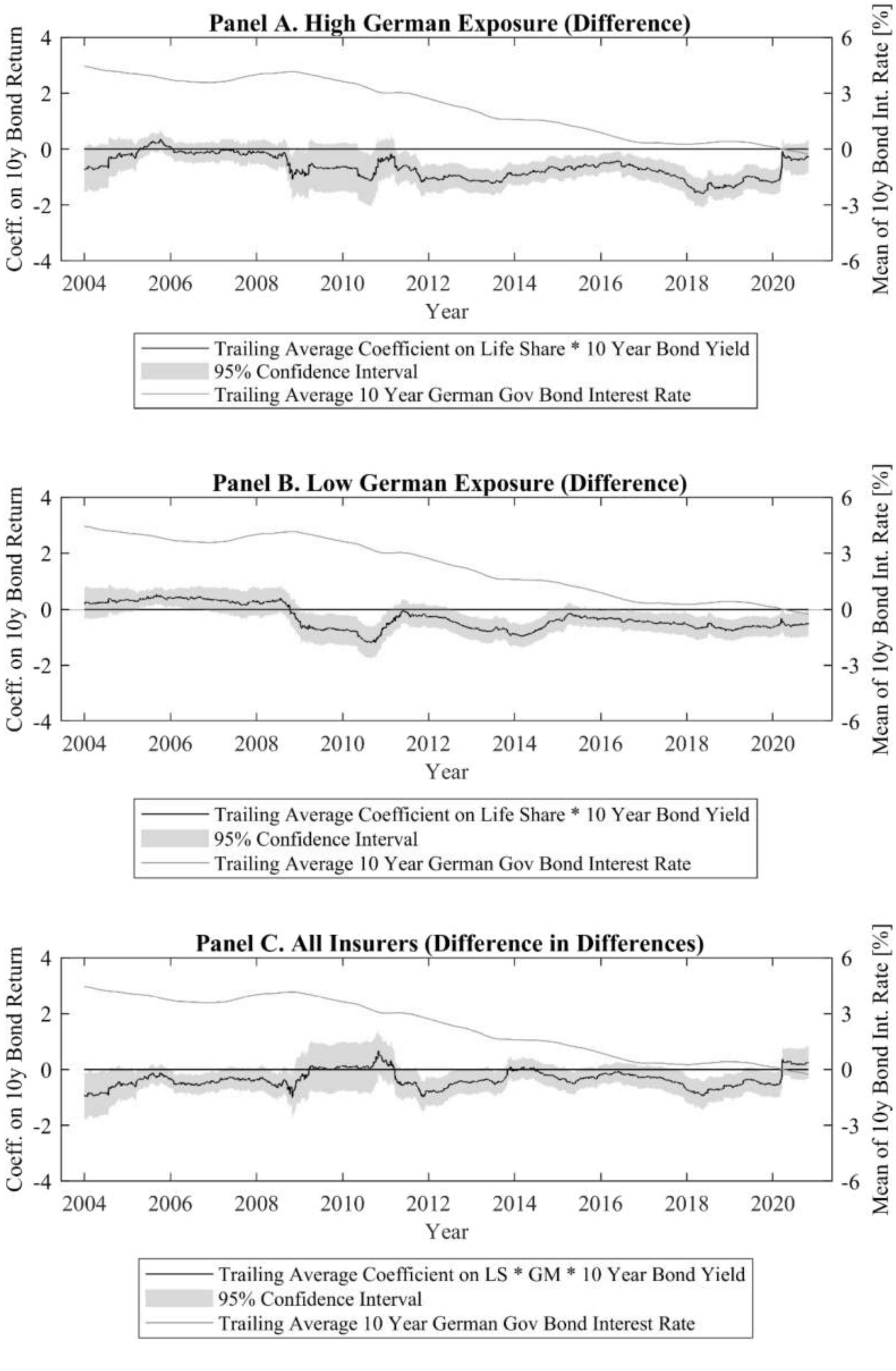


Fig. 28: Statistical Significance of Regression Model for Differences in Continental Europe One Non-Life Sample - German Exposure - Daily Data

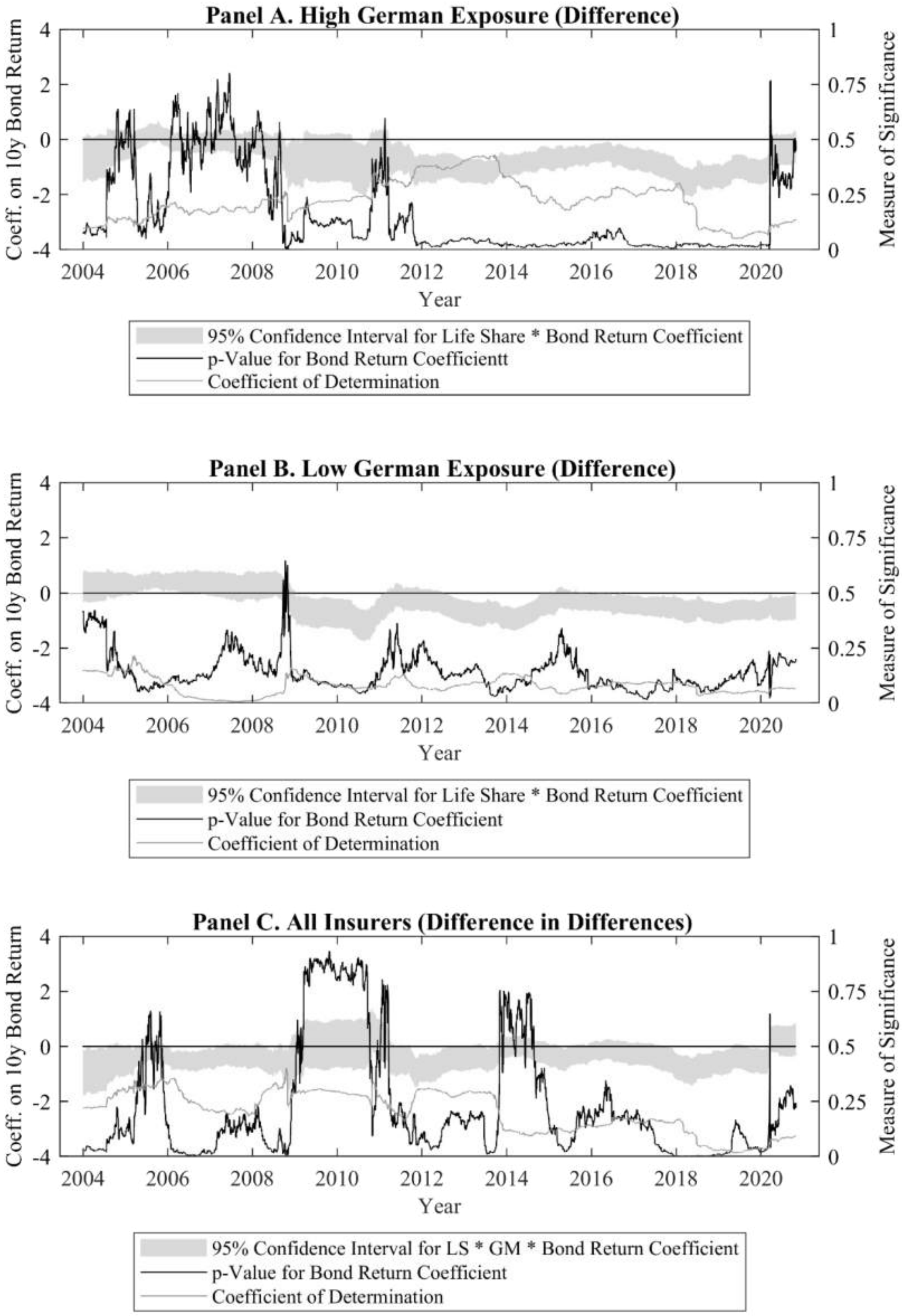


Fig. 29: Interest Rate Sensitivity Differences for Continental European Insurers LTG Exposure - Weekly Data

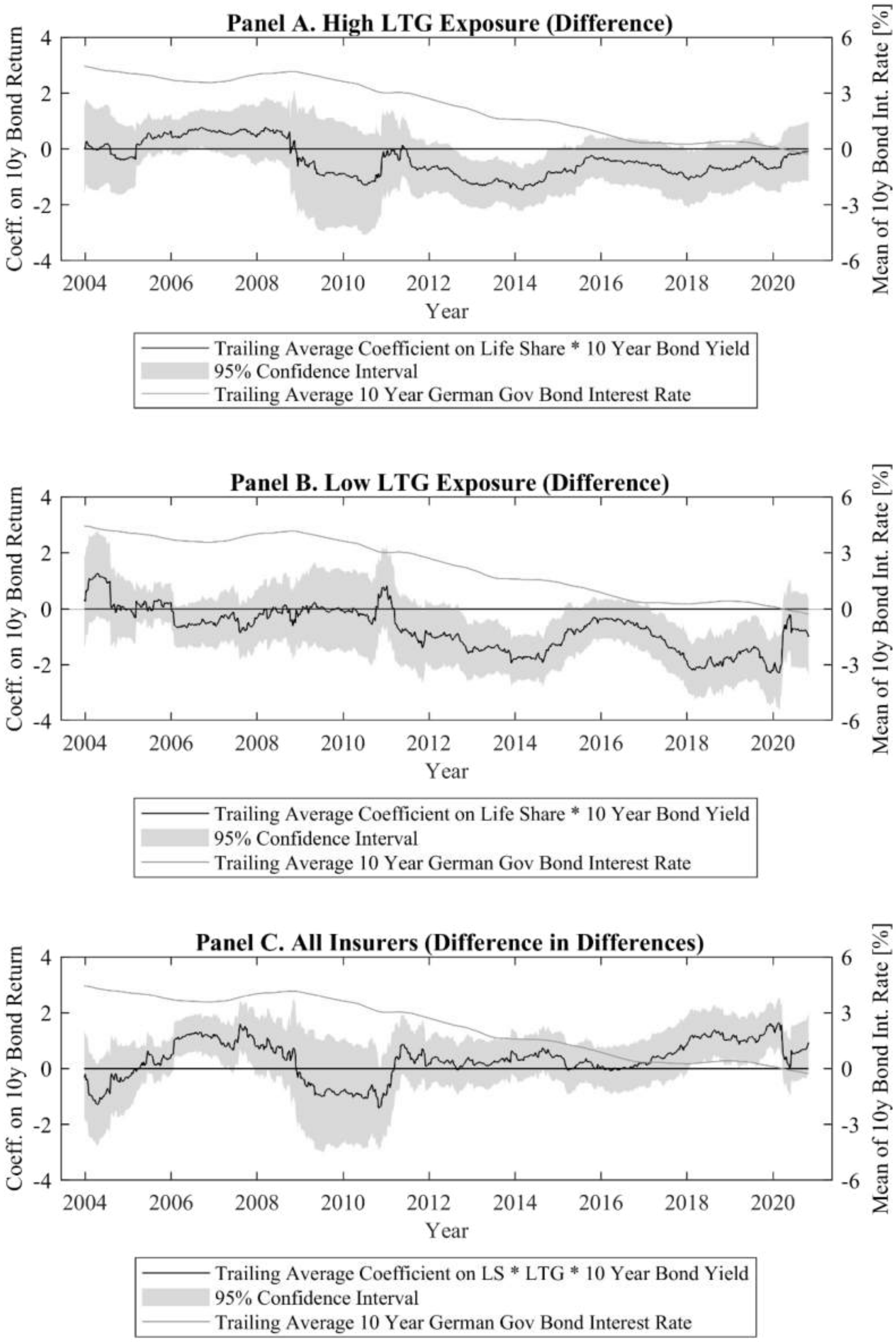


Fig. 30: Statistical Significance of Regression Model for Differences in Continental Europe LTG Exposure - Weekly Data

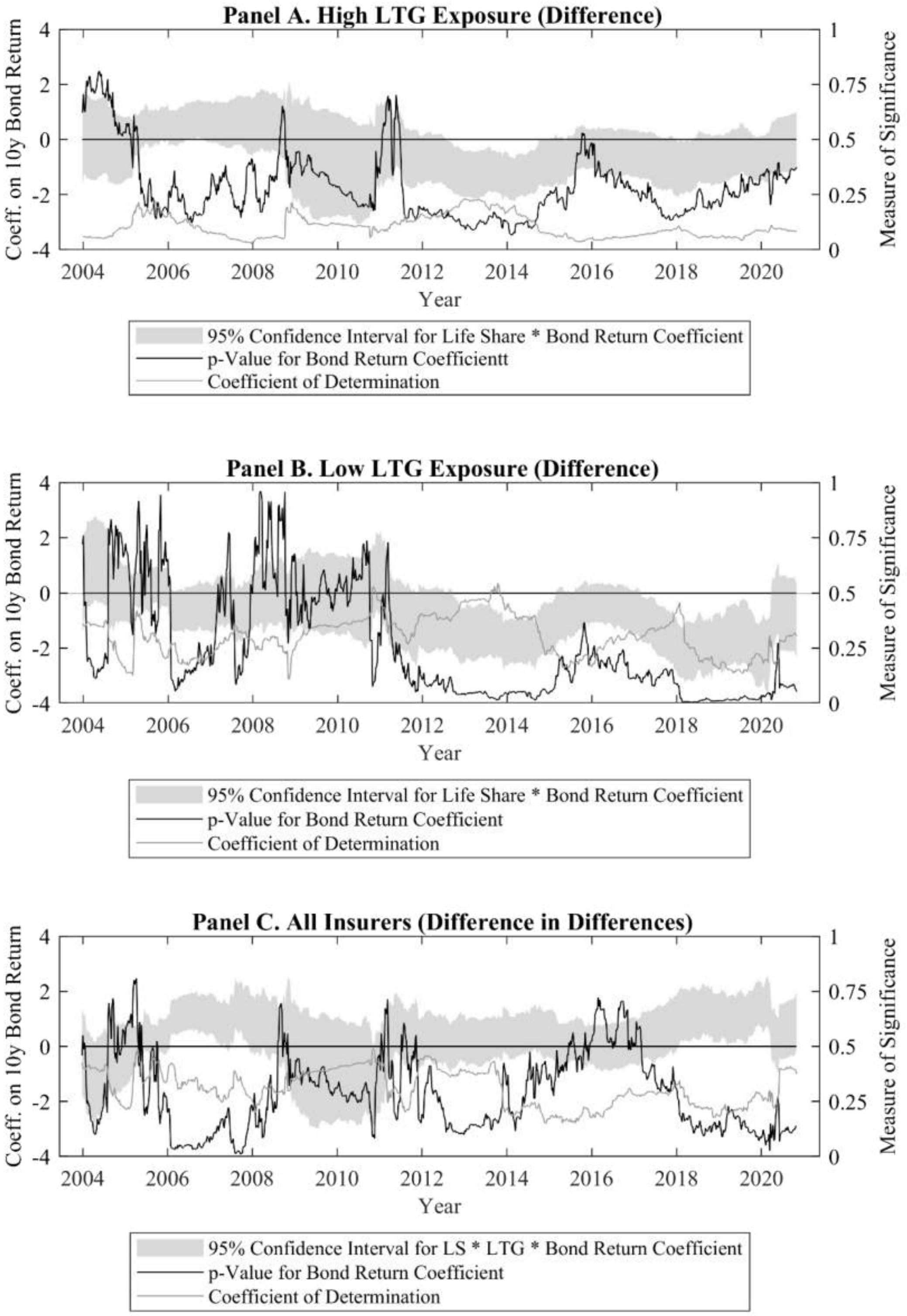


Fig. 31: Interest Rate Sensitivity Differences for Continental European Insurers LTG Exposure - Daily Data

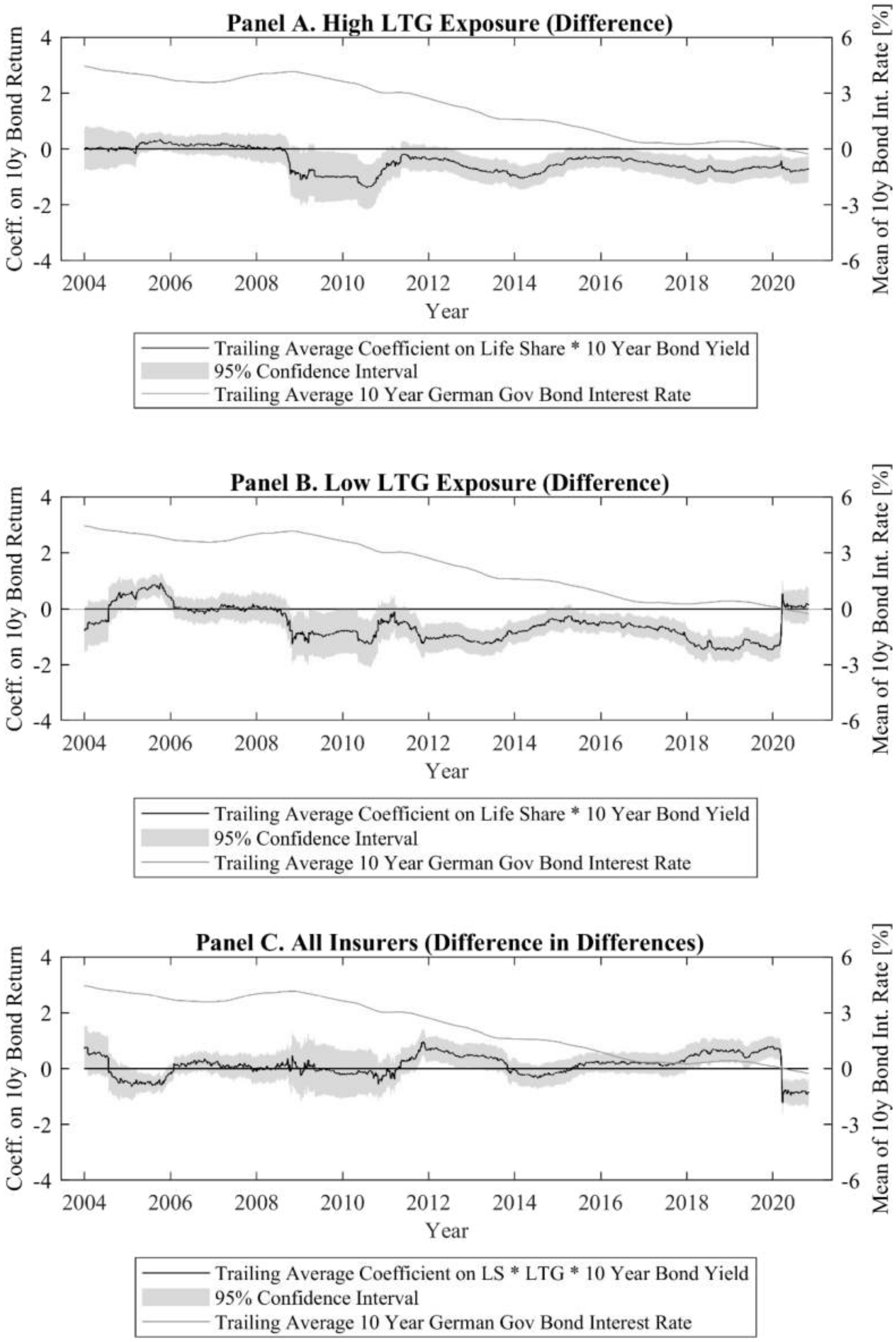


Fig. 32: Statistical Significance of Regression Model for Differences in Continental Europe LTG Exposure - Daily Data

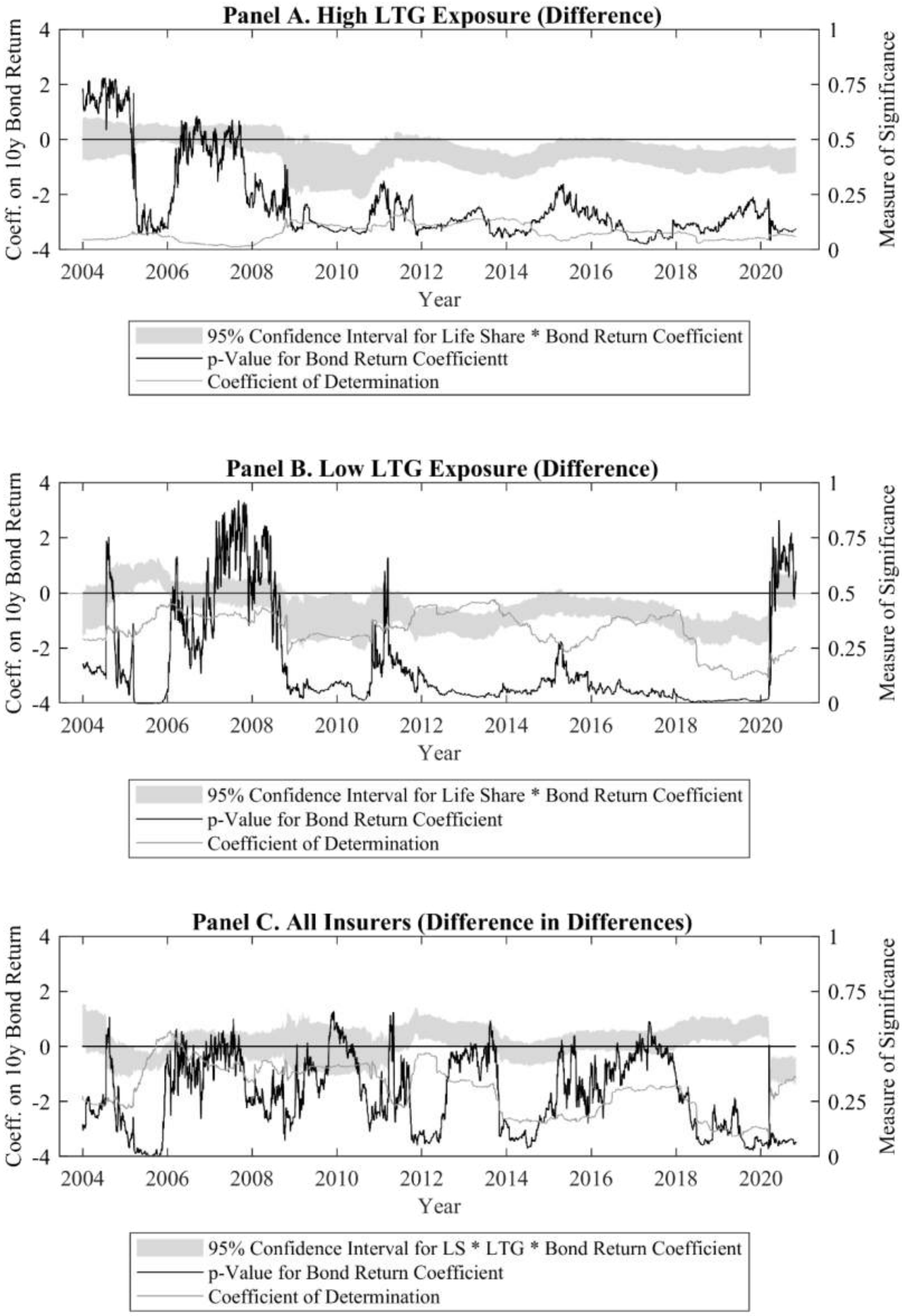


Fig. 33: Interest Rate Sensitivity Differences for Continental European Insurers One Non-Life Sample - LTG Exposure - Weekly Data

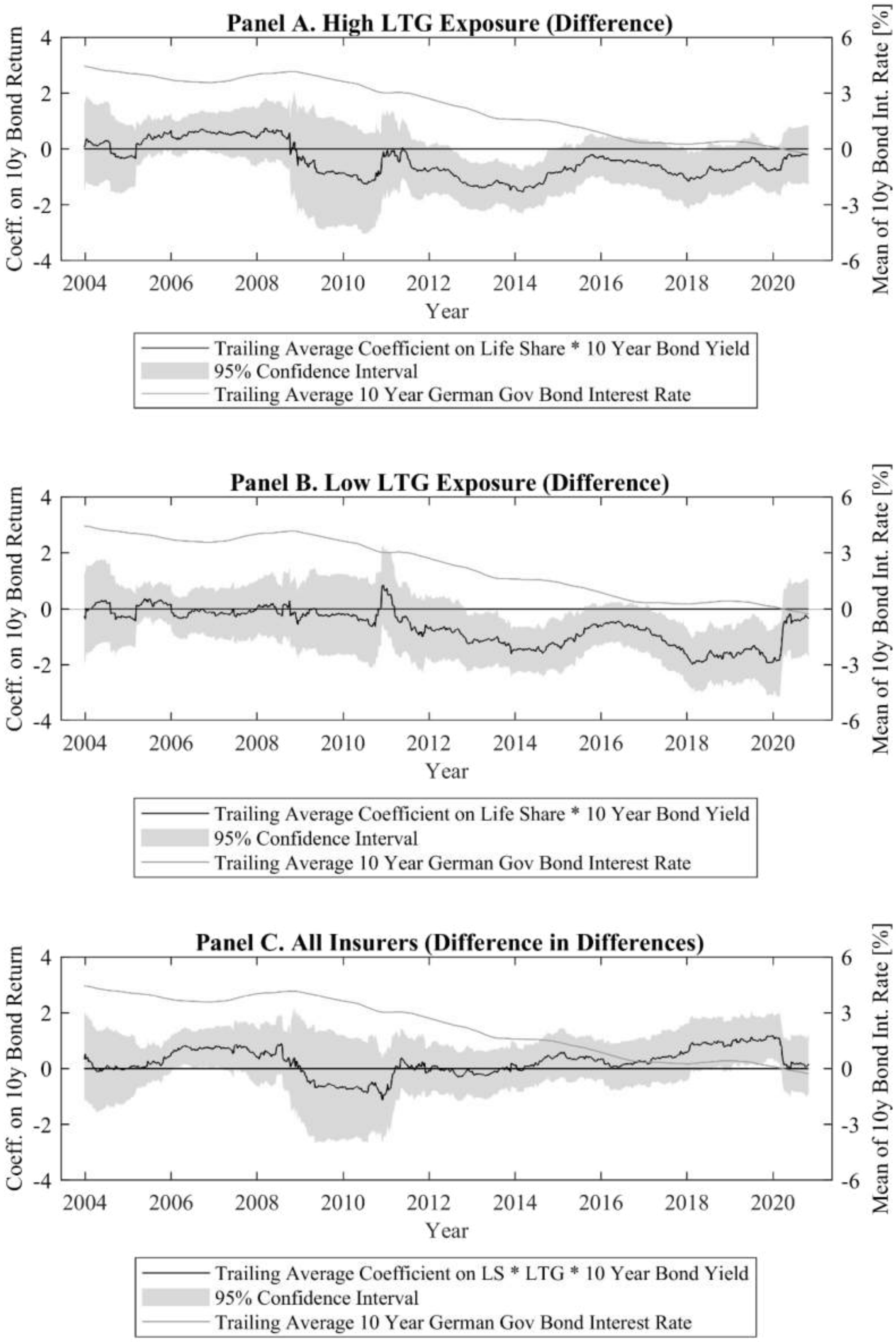


Fig. 34: Statistical Significance of Regression Model for Differences in Continental Europe One Non-Life Sample - LTG Exposure - Weekly Data

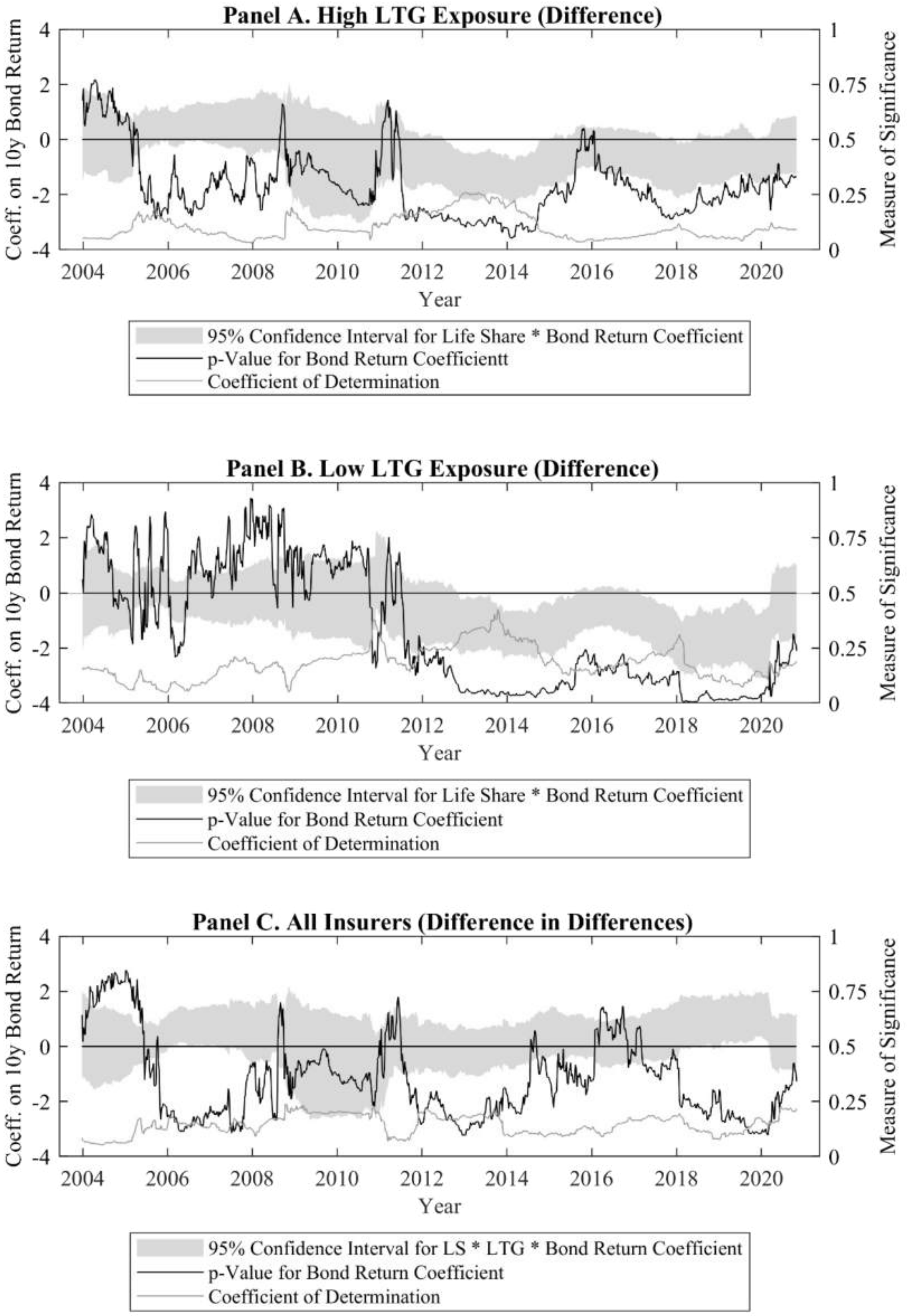


Fig. 35: Interest Rate Sensitivity Differences for Continental European Insurers LTG Exposure - One Non-Life Sample - Daily Data

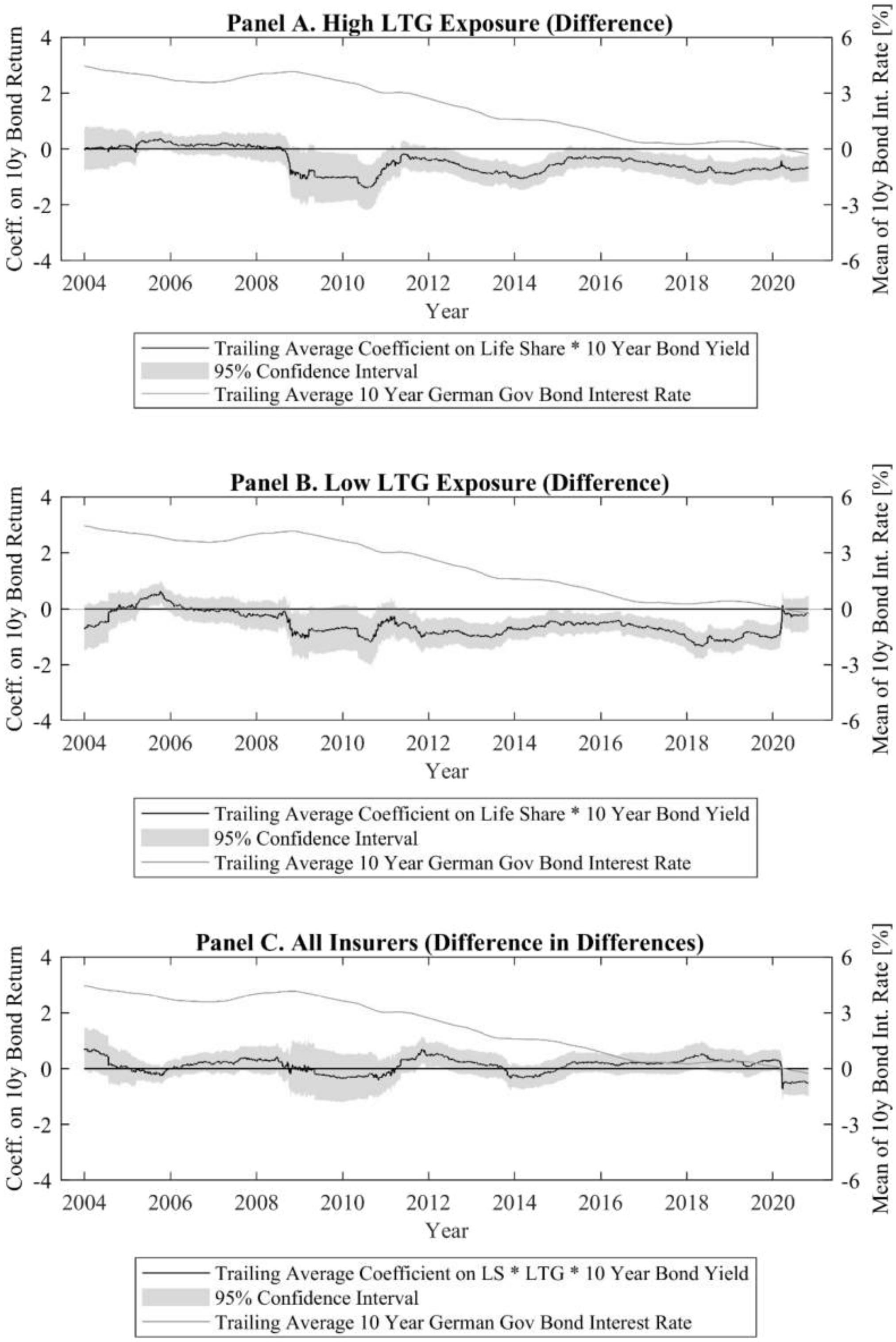


Fig. 36: Statistical Significance of Regression Model for Differences in Continental Europe One Non-Life Sample - LTG - Daily Data

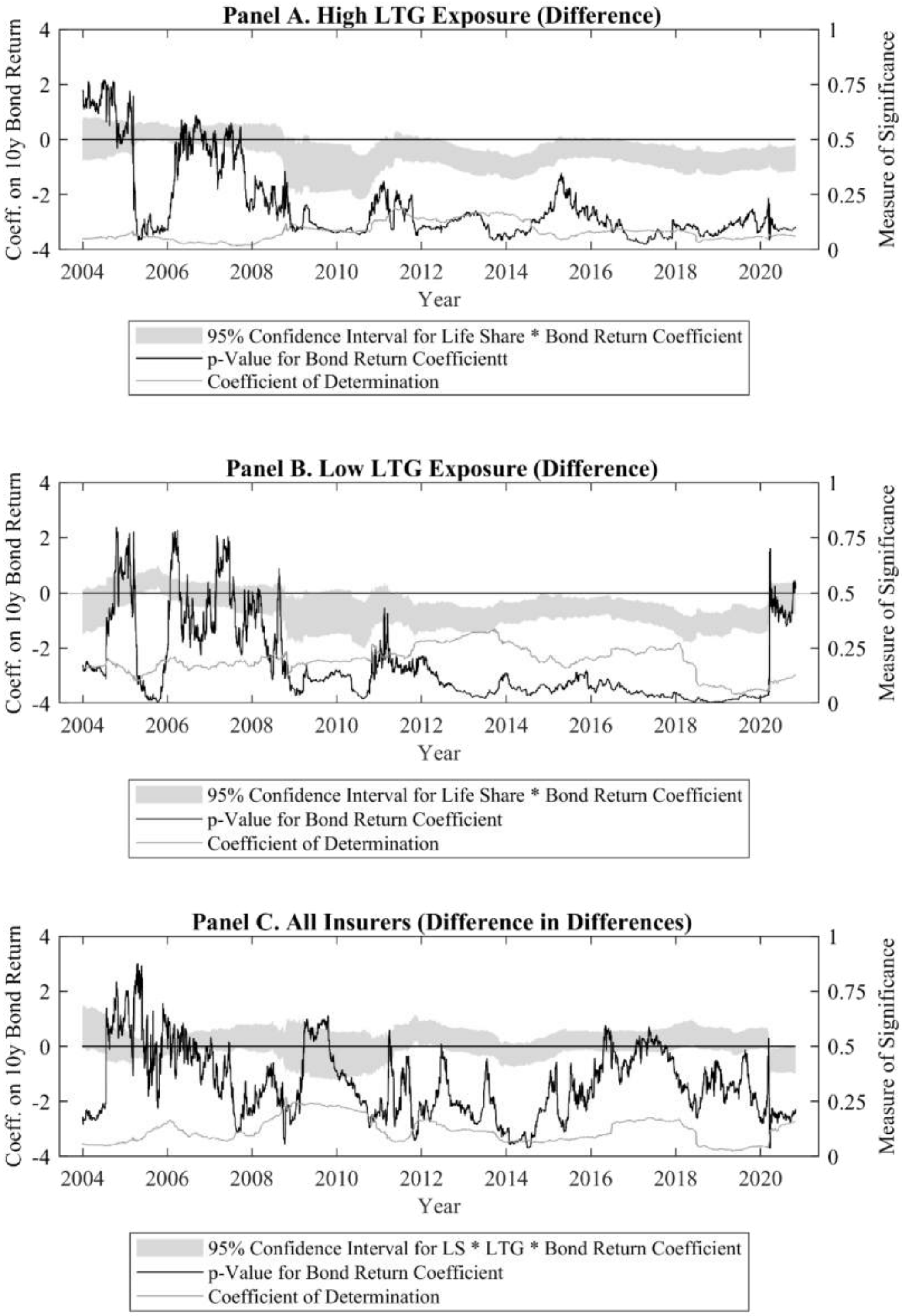


Fig. 37: Interest Rate Sensitivity Coefficients for Canadian Insurance Industry - Weekly Data

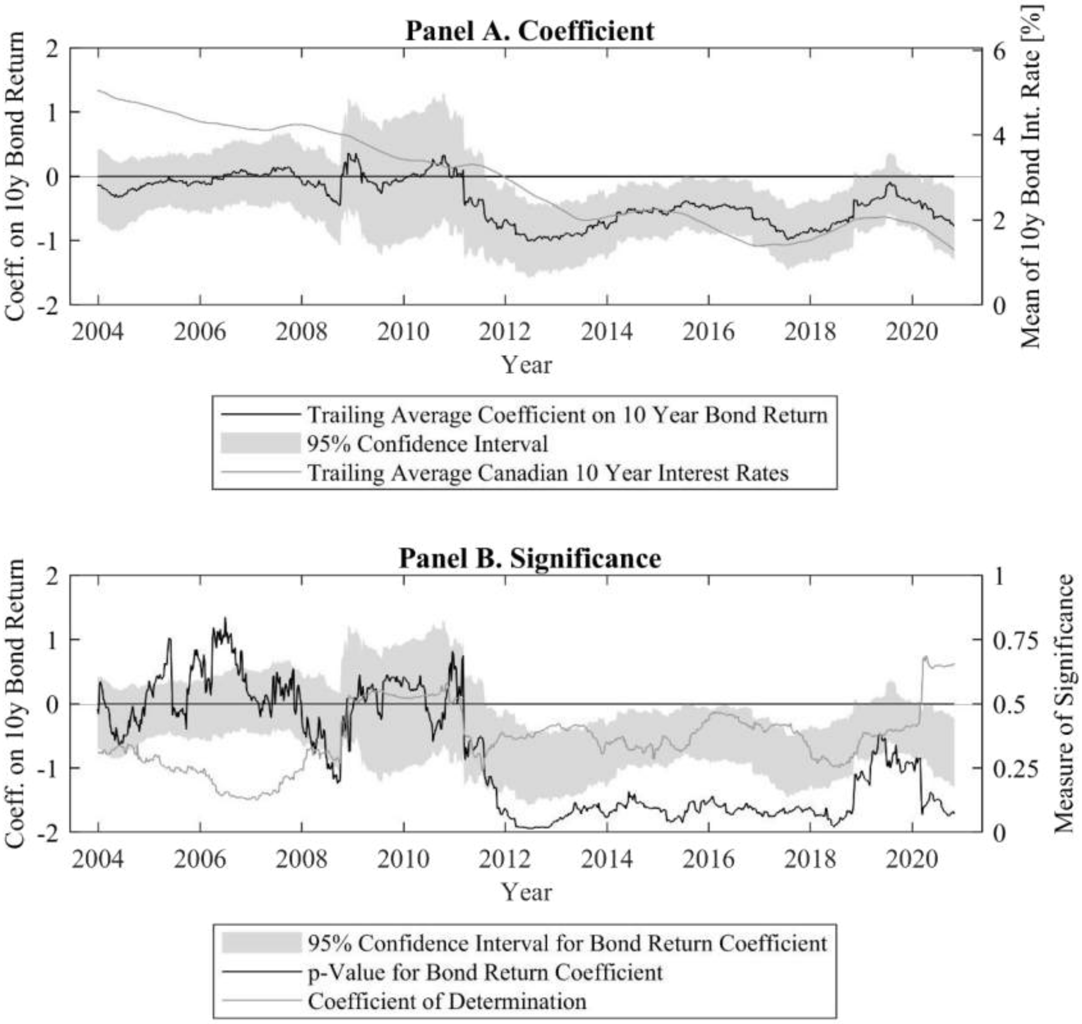


Fig. 38: Interest Rate Sensitivity Coefficients for Canadian Insurance Industry - Daily Data

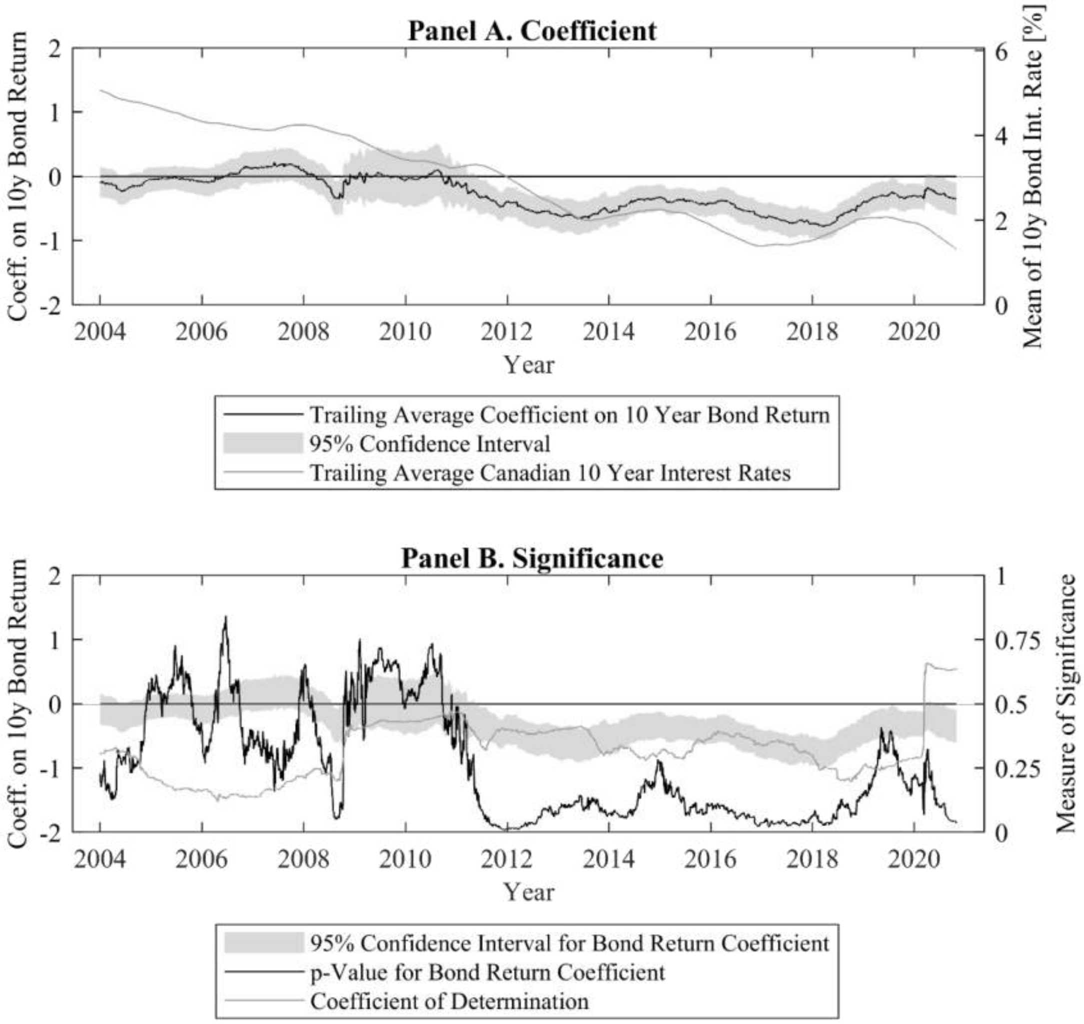


Fig. 39: Interest Rate Sensitivity Coefficients for Canadian Insurers - Weekly Data

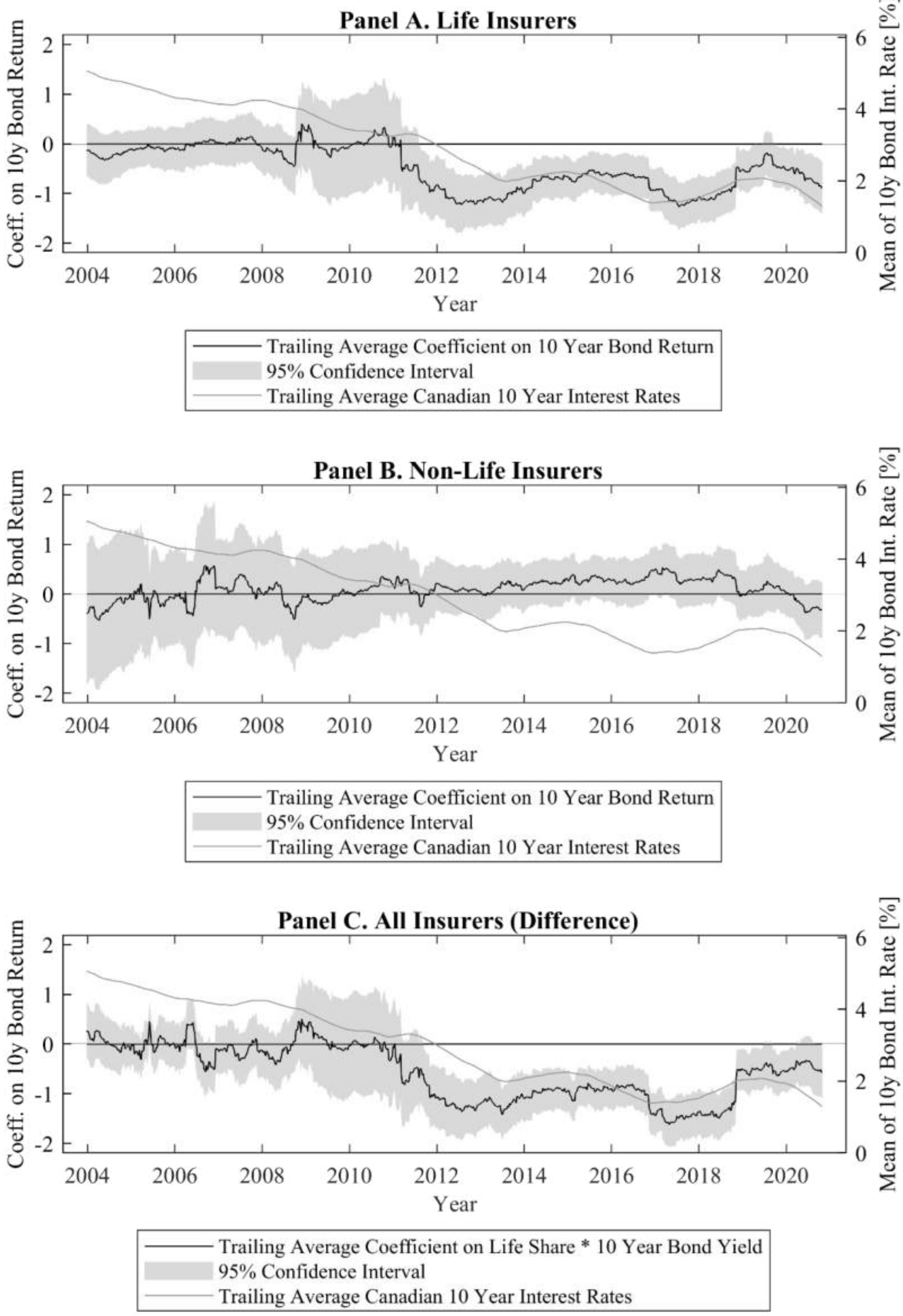


Fig. 40: Statistical Significance of Regression Model for Canadian Insurers - Weekly Data

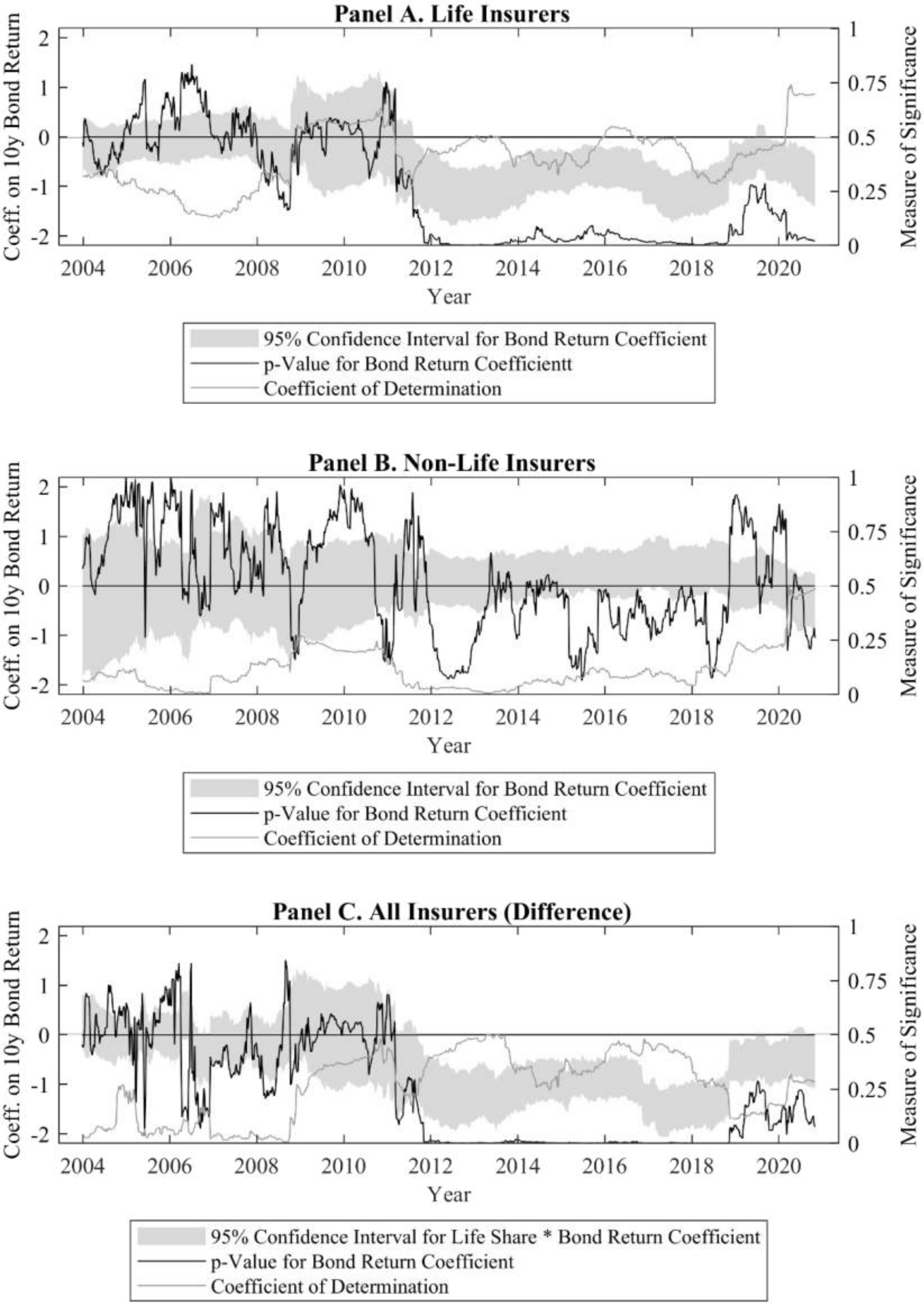


Fig. 41: Interest Rate Sensitivity Coefficients for Canadian Insurers - Daily Data

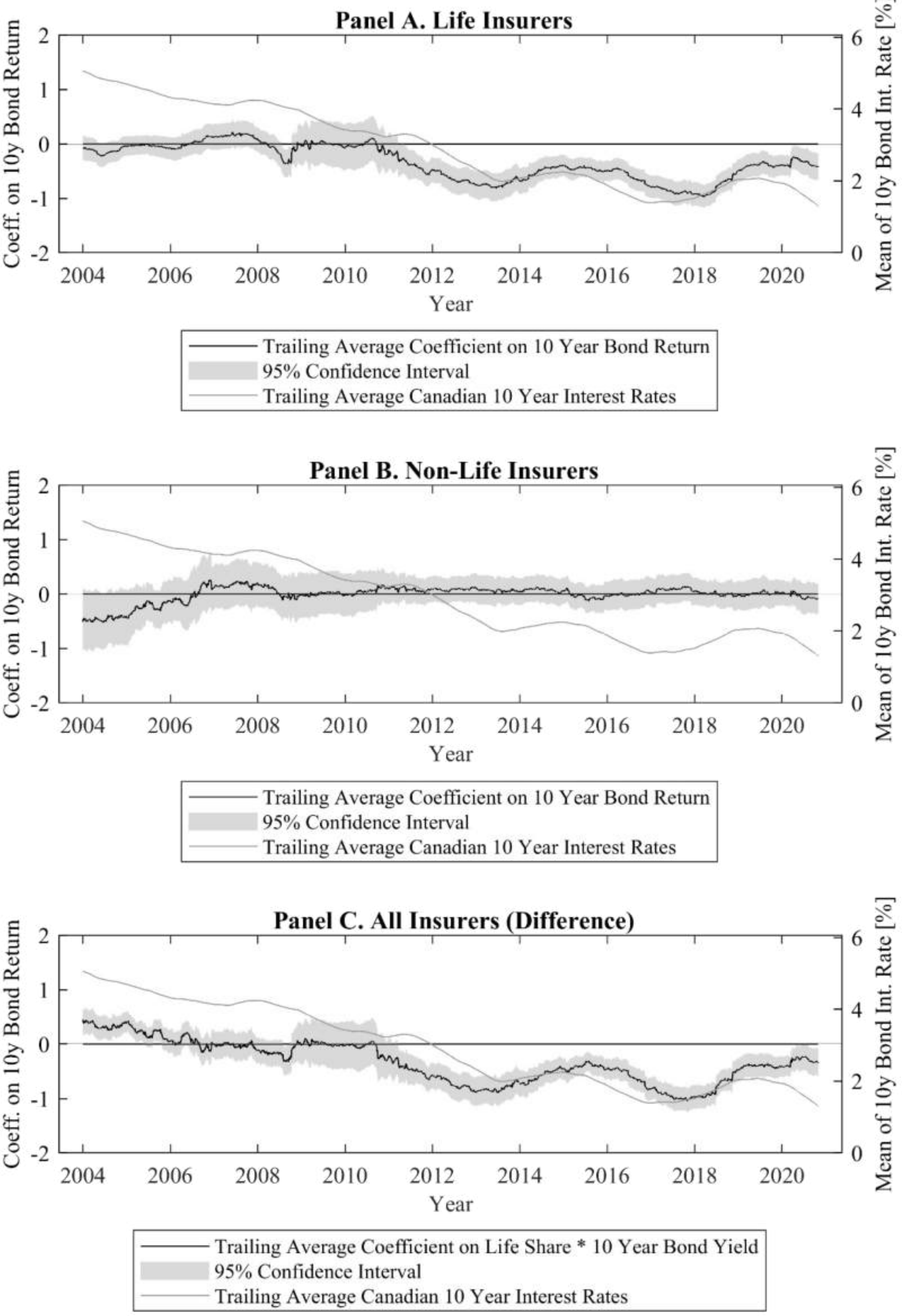


Fig. 42: Statistical Significance of Regression Model for Canadian Insurers - Daily Data

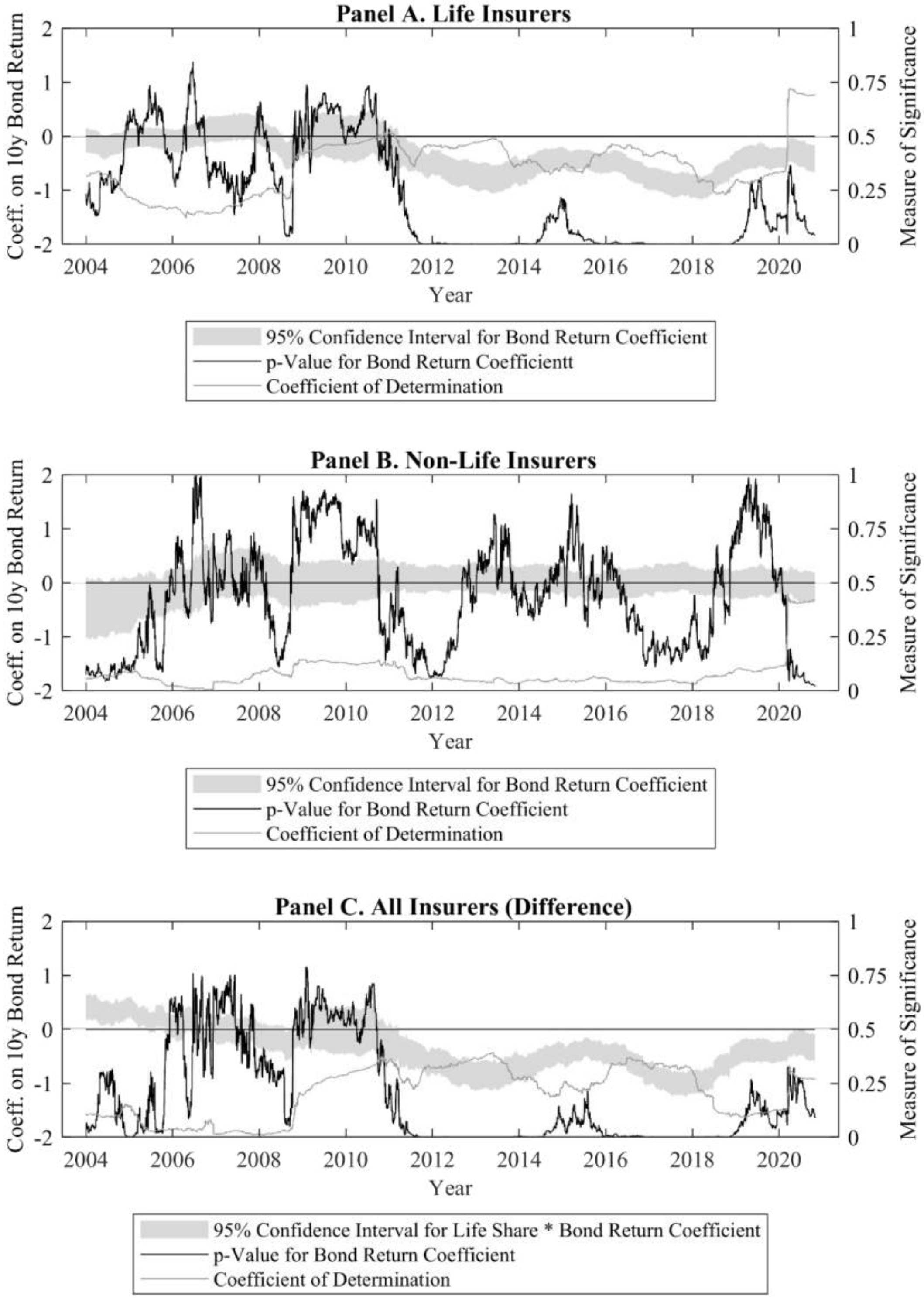


Fig. 43: Interest Rate Sensitivity Coefficients for African Insurance Industry - Weekly Data

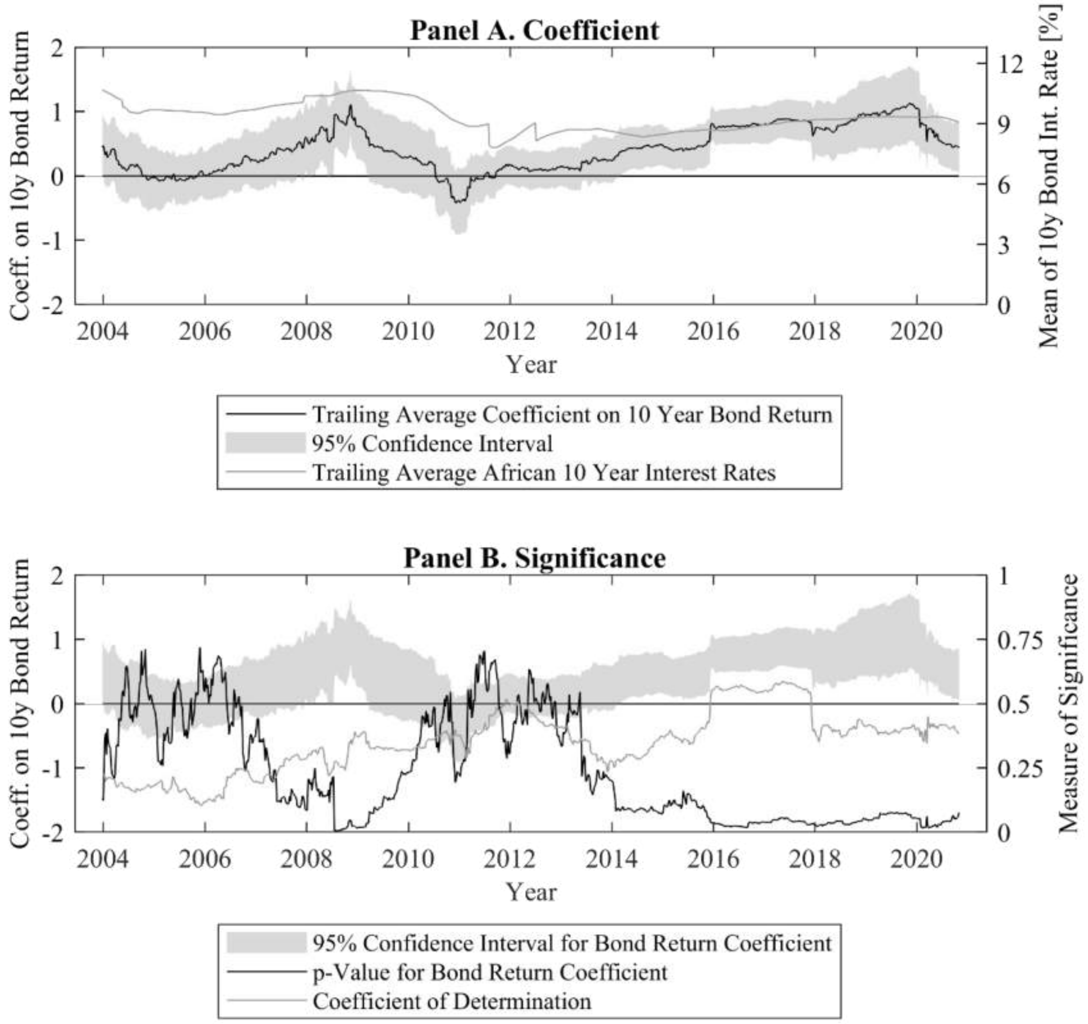


Fig. 44: Interest Rate Sensitivity Coefficients for African Insurance Industry - Daily Data

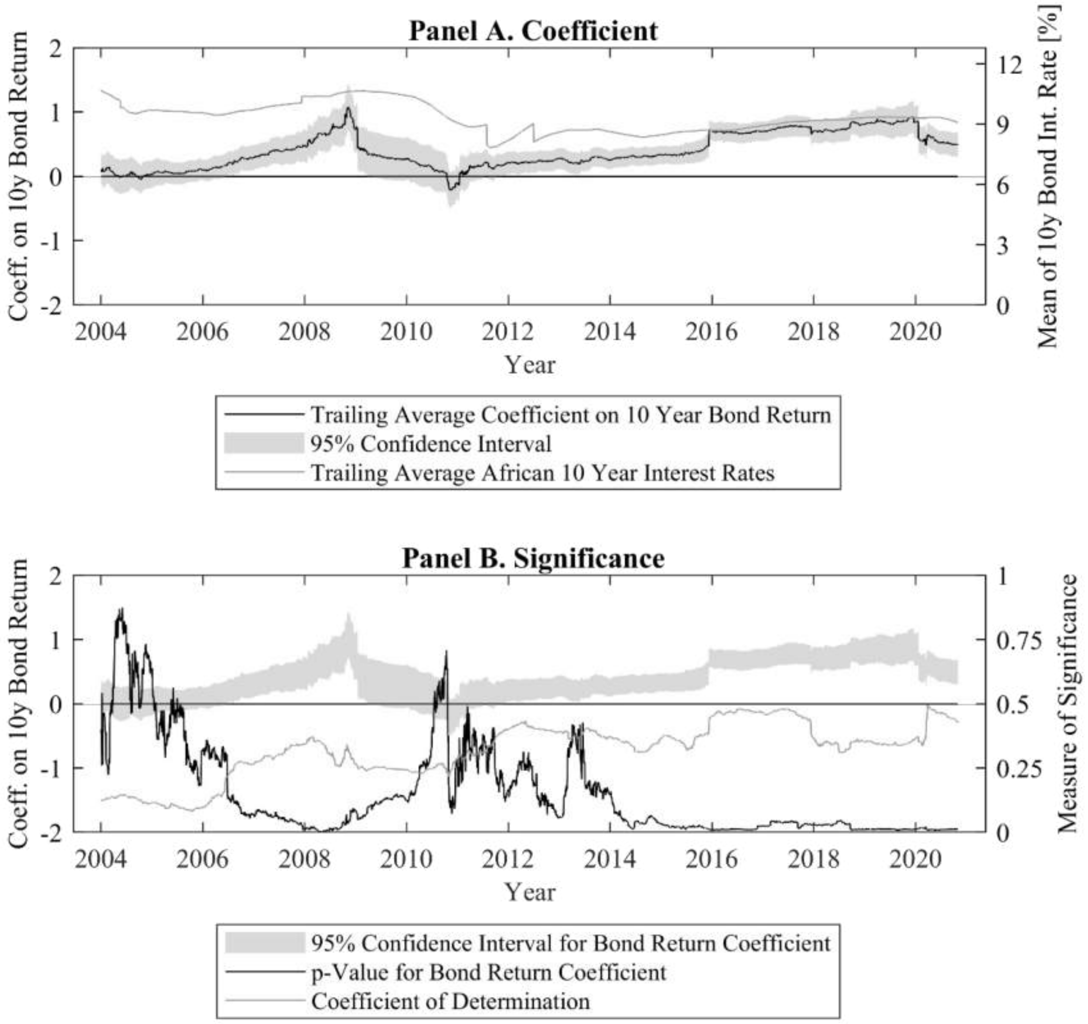


Fig. 45: Interest Rate Sensitivity Coefficients for African Insurers - Weekly Data

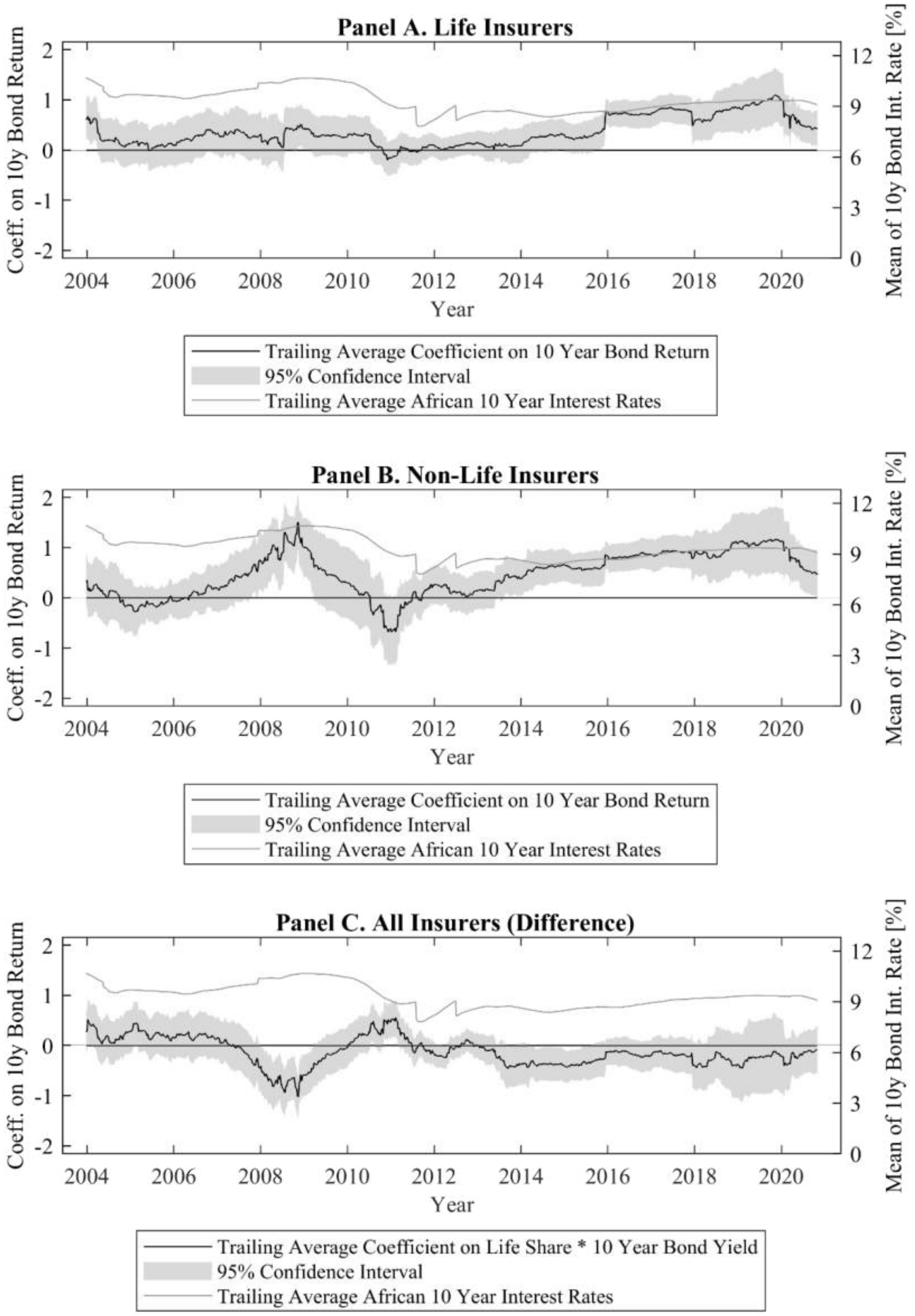


Fig. 46: Statistical Significance of Regression Model for African Insurers - Weekly Data

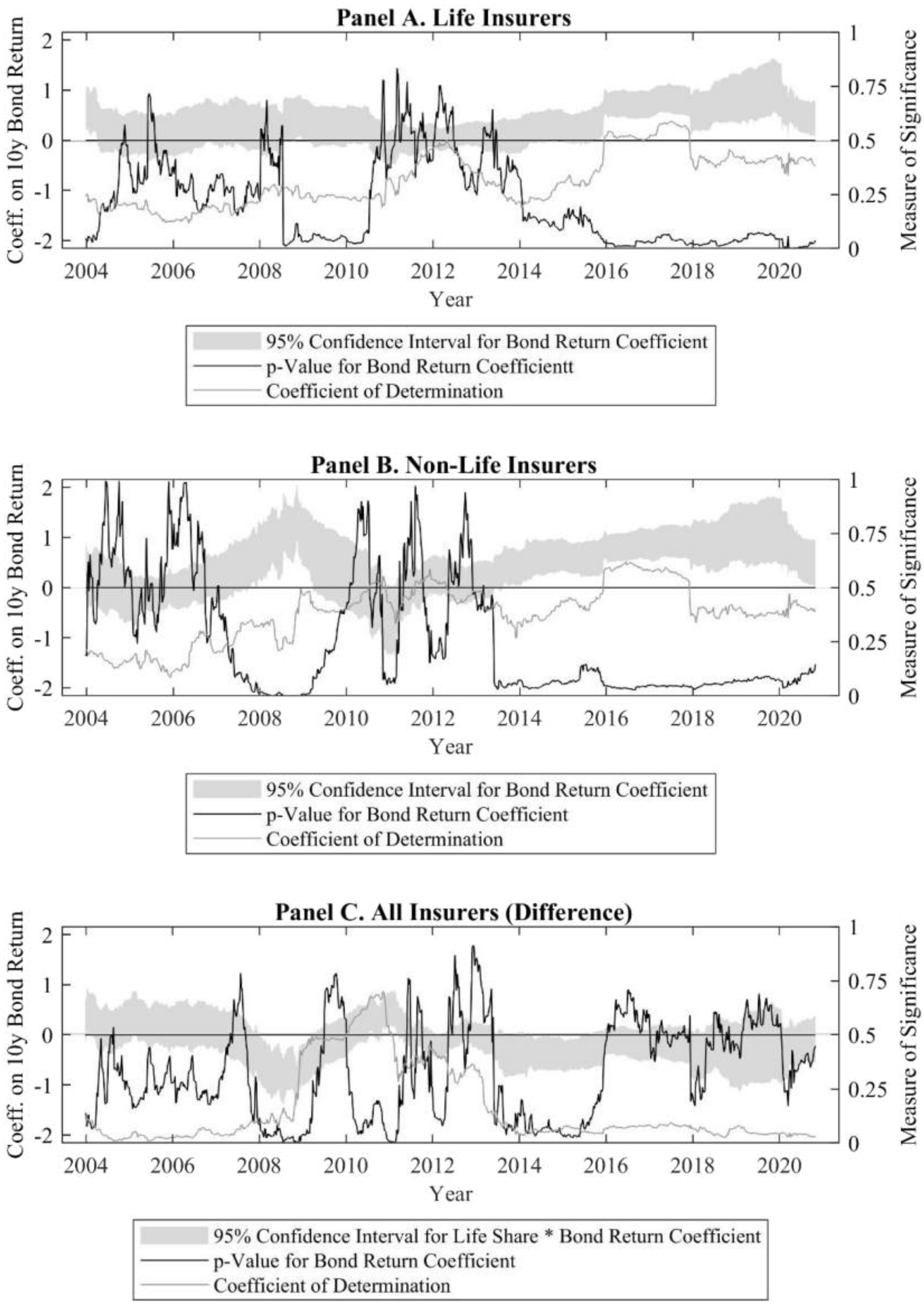


Fig. 47: Interest Rate Sensitivity Coefficients for African Insurers - Daily Data

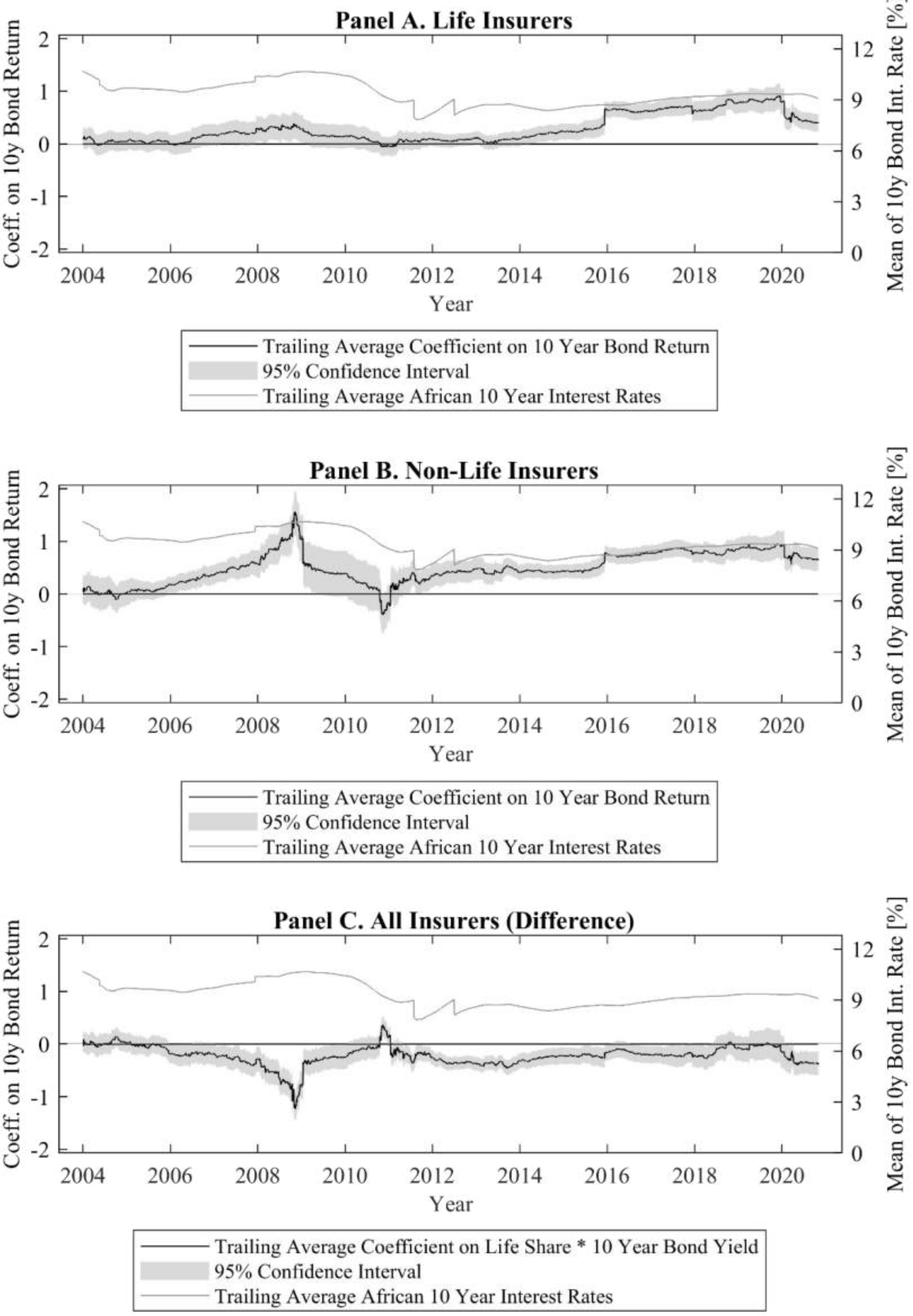


Fig. 48: Statistical Significance of Regression Model for African Insurers - Daily Data

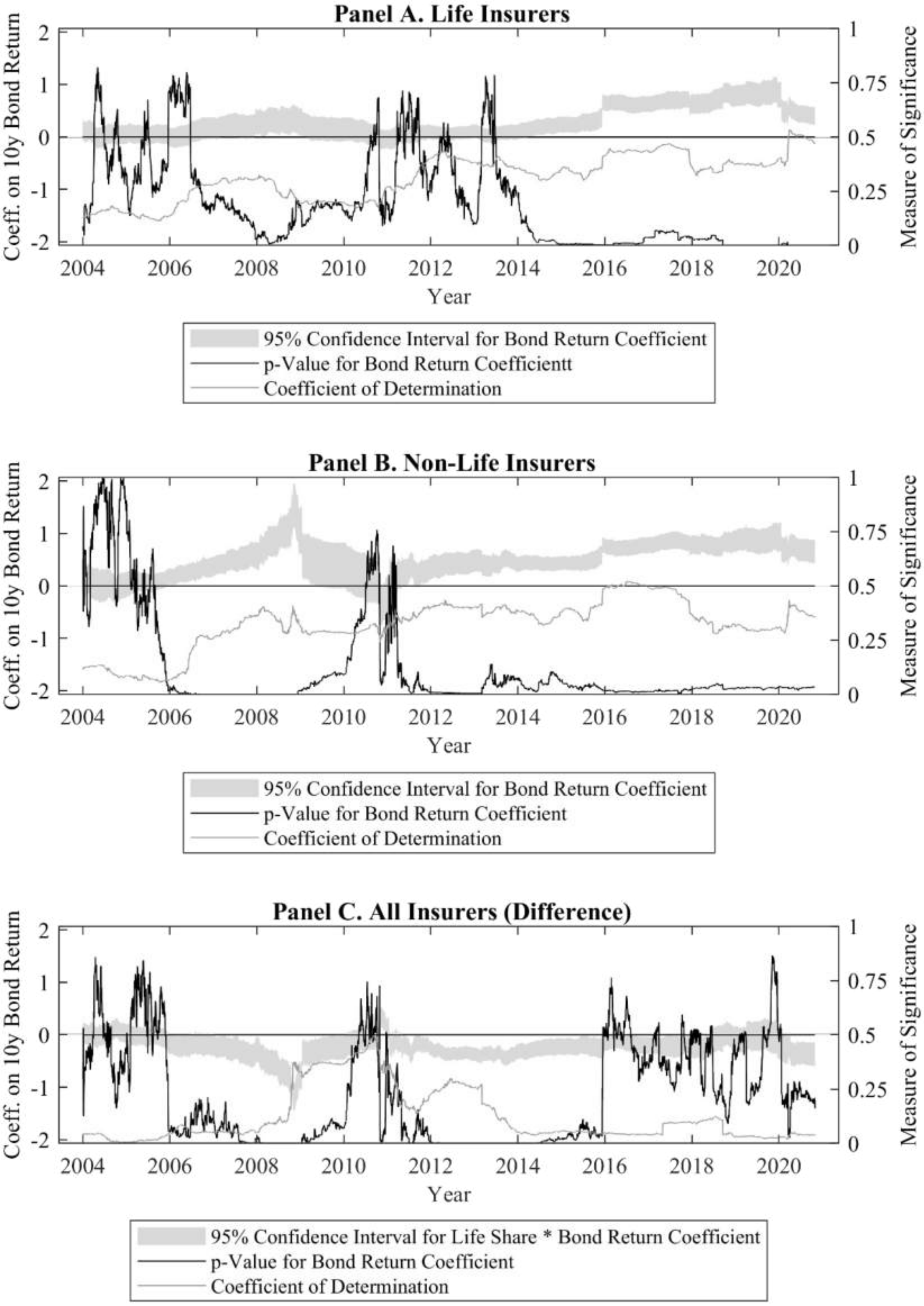


Fig. 49: Interest Rate Sensitivity Coefficients for Middle Eastern Insurance Industry - Weekly Data

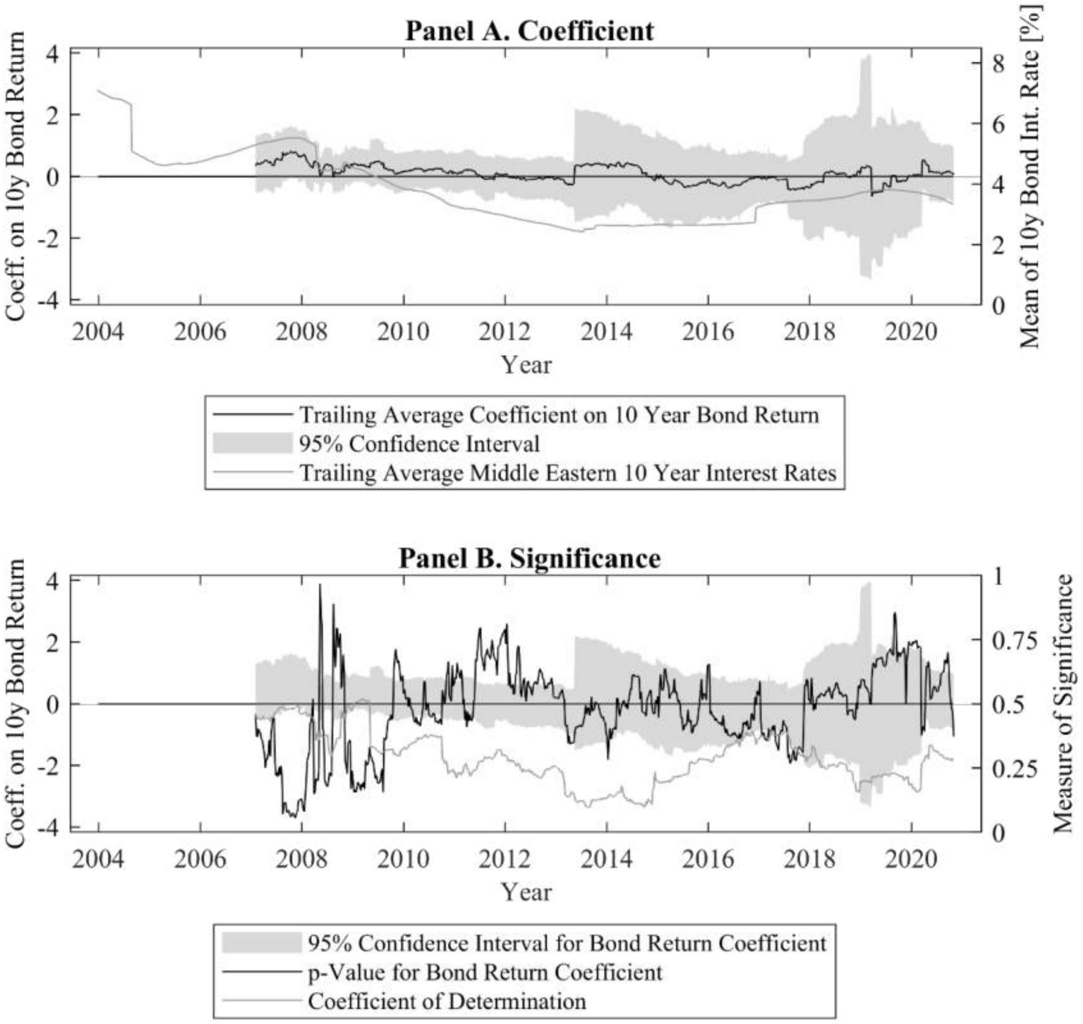
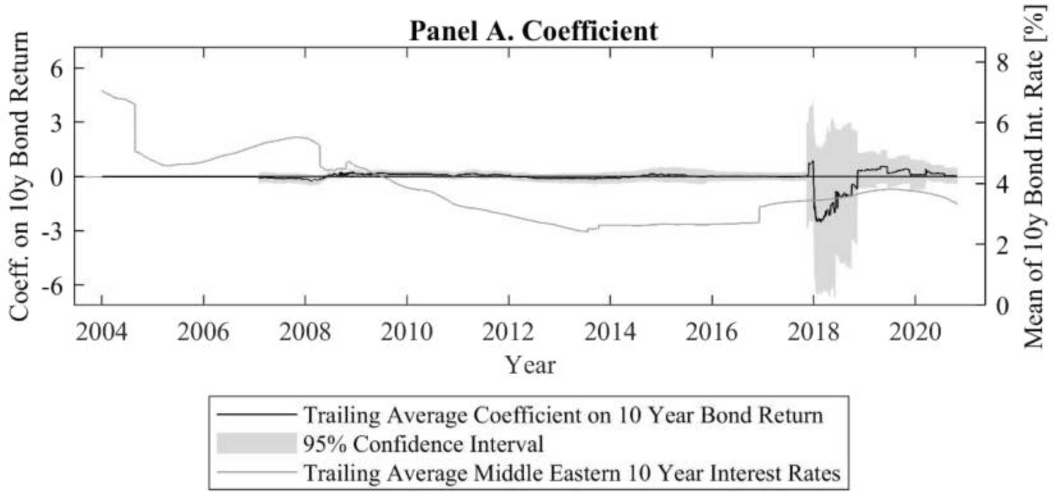


Fig. 50: Interest Rate Sensitivity Coefficients for Middle Eastern Insurance Industry - Daily Data



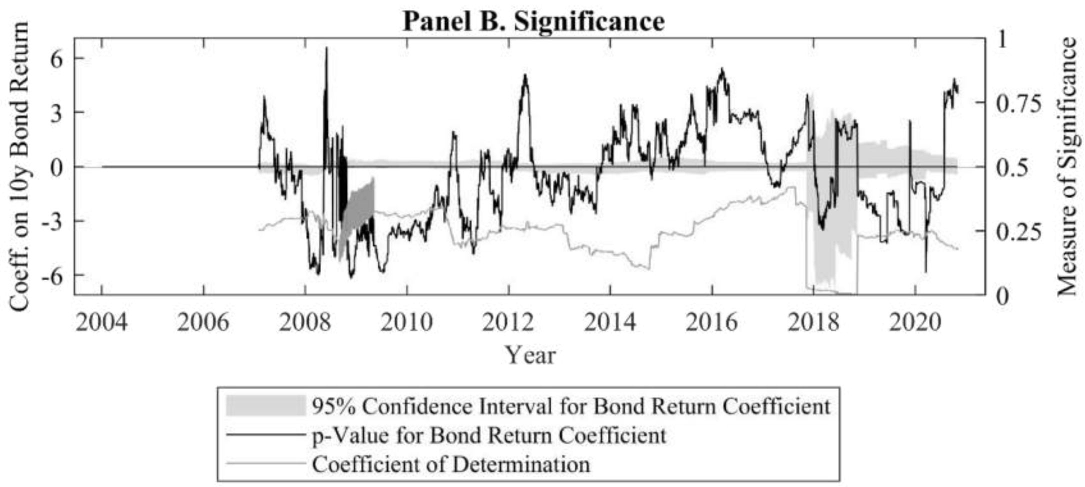


Fig. 51: Interest Rate Sensitivity Coefficients for Middle Eastern Insurers - Weekly Data

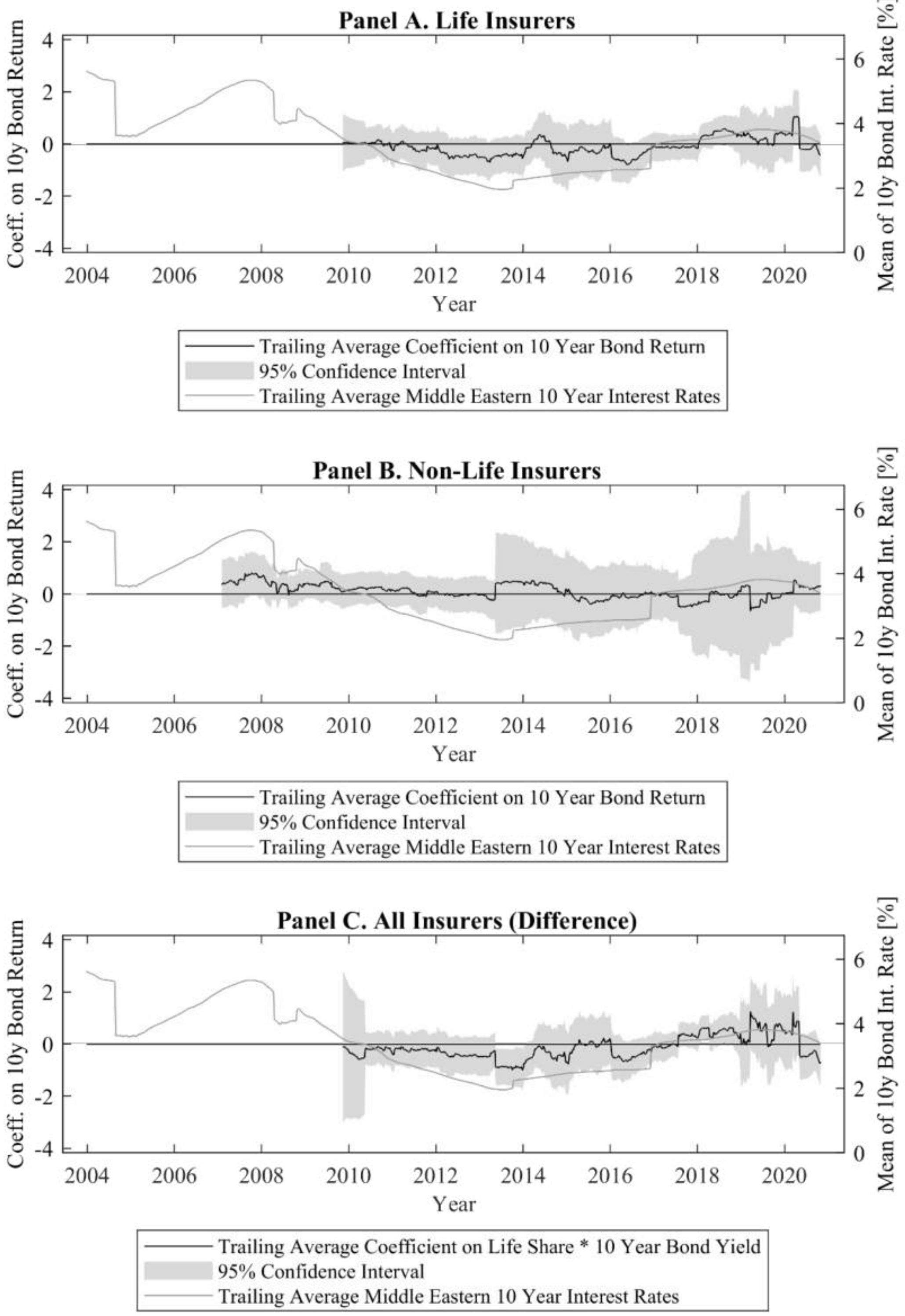


Fig. 52: Statistical Significance of Regression Model for Middle Eastern Insurers - Weekly Data

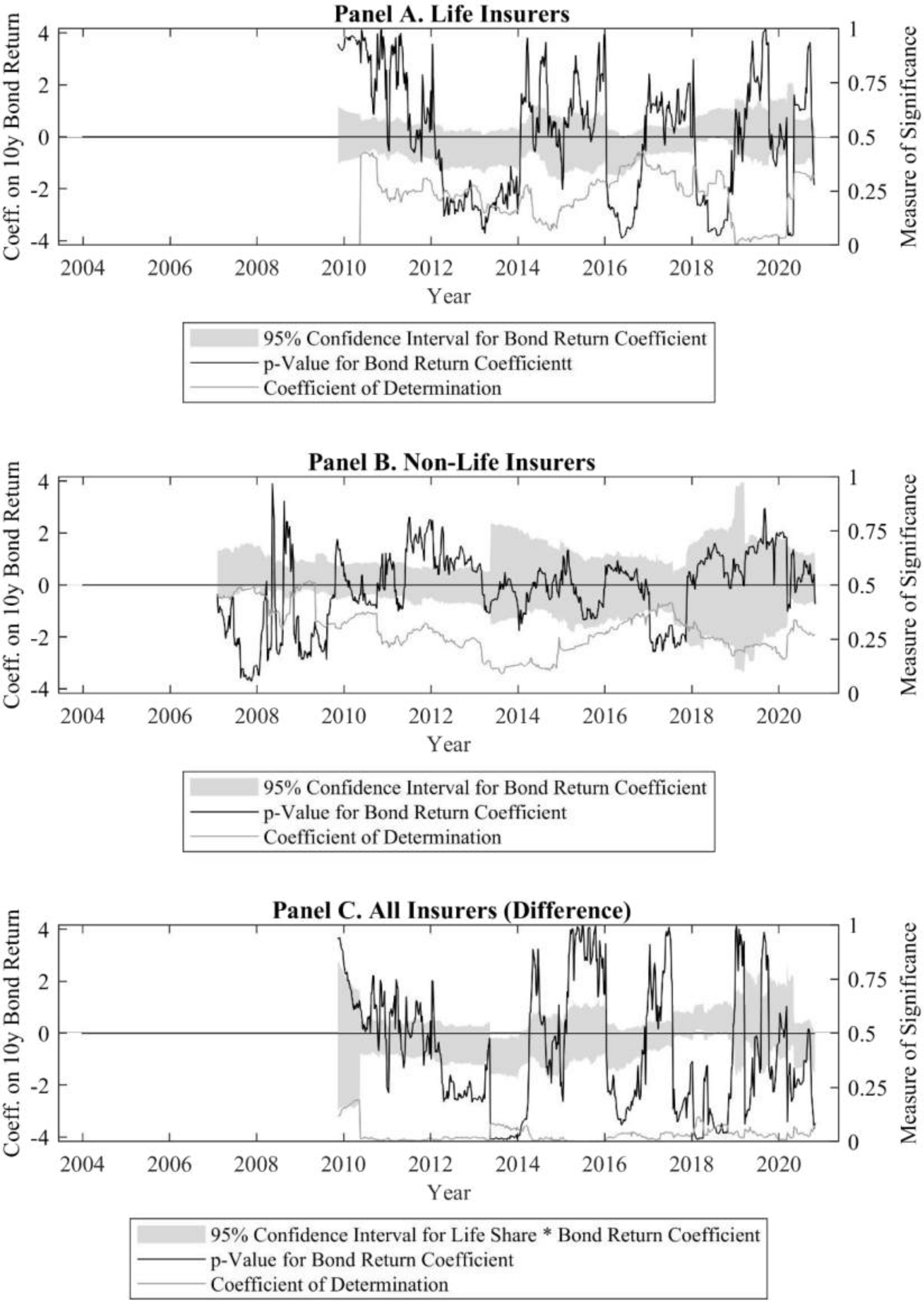
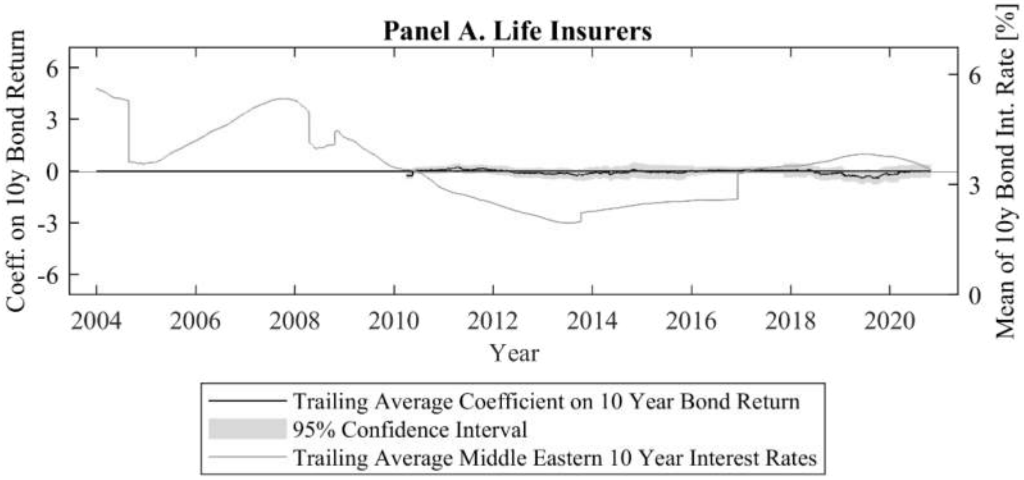
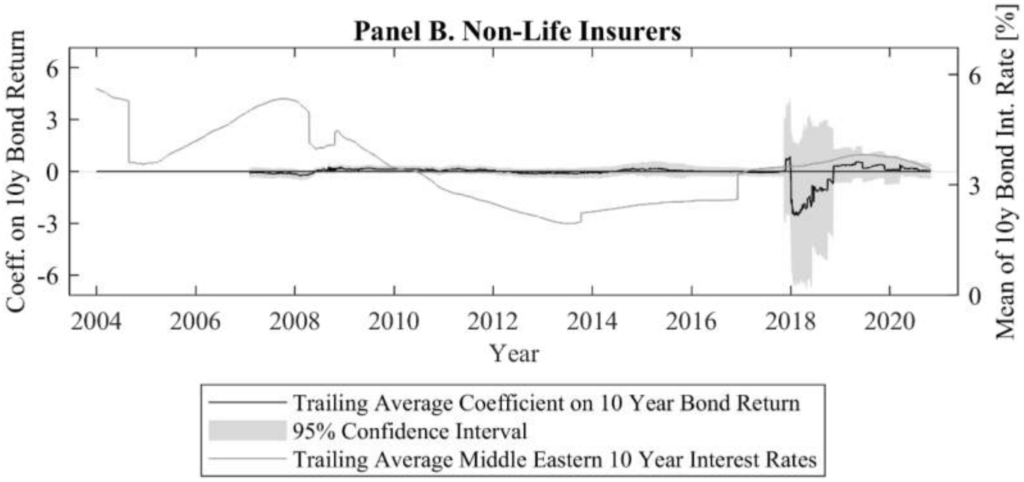


Fig. 53: Interest Rate Sensitivity Coefficients for Middle Eastern Insurers - Daily Data

Panel A. Life Insurers



Panel B. Non-Life Insurers



Panel C. All Insurers (Difference)

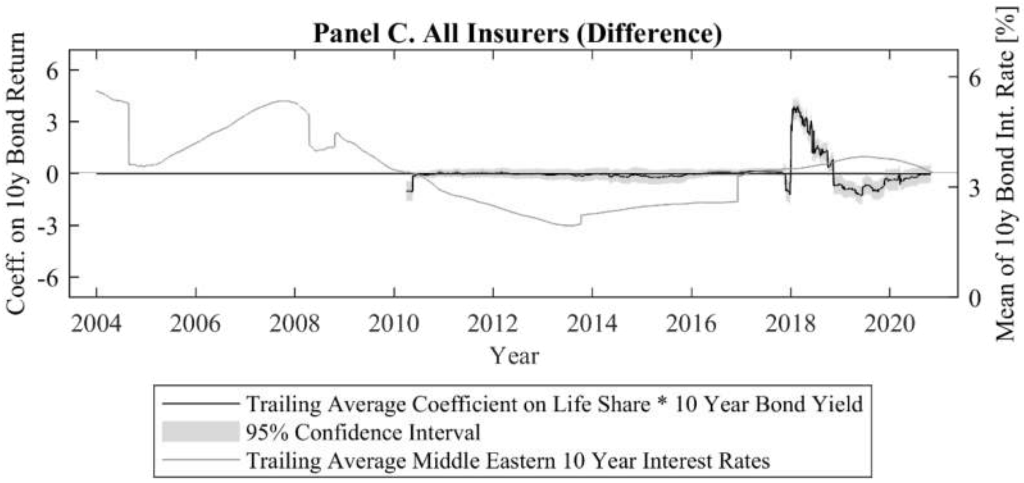


Fig. 54: Statistical Significance of Regression Model for Middle Eastern Insurers - Daily Data

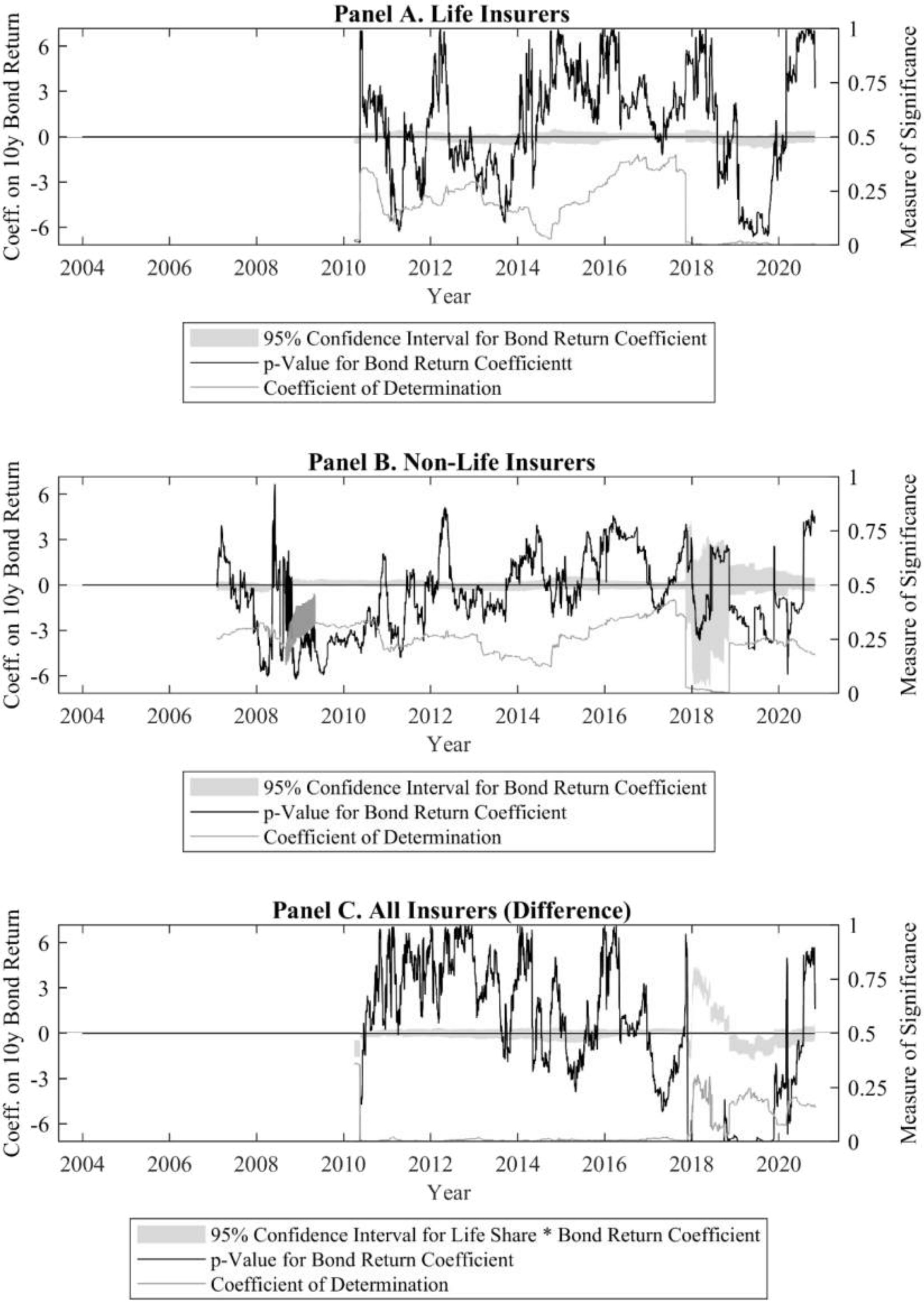


Fig. 55: Interest Rate Sensitivity Coefficients for South Asian Insurance Industry - Weekly Data

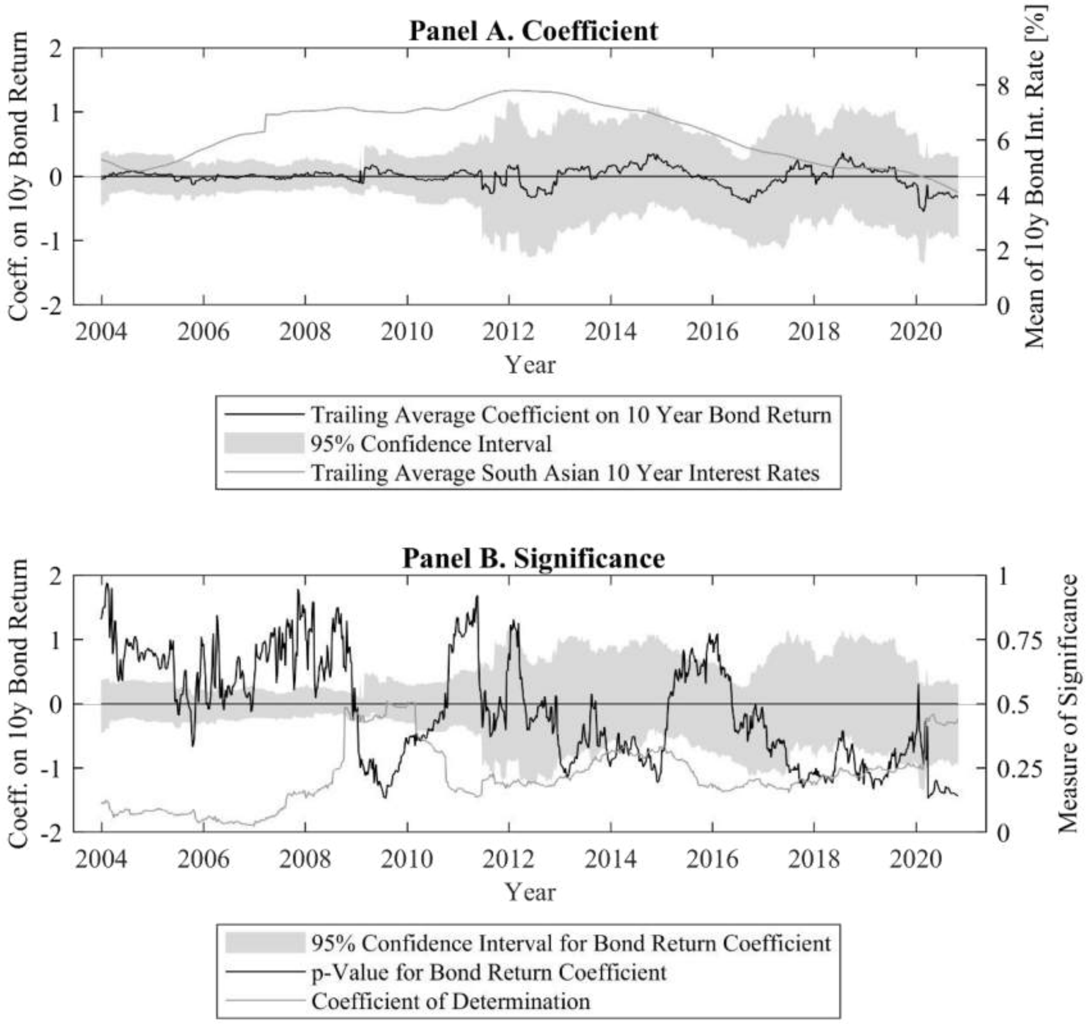
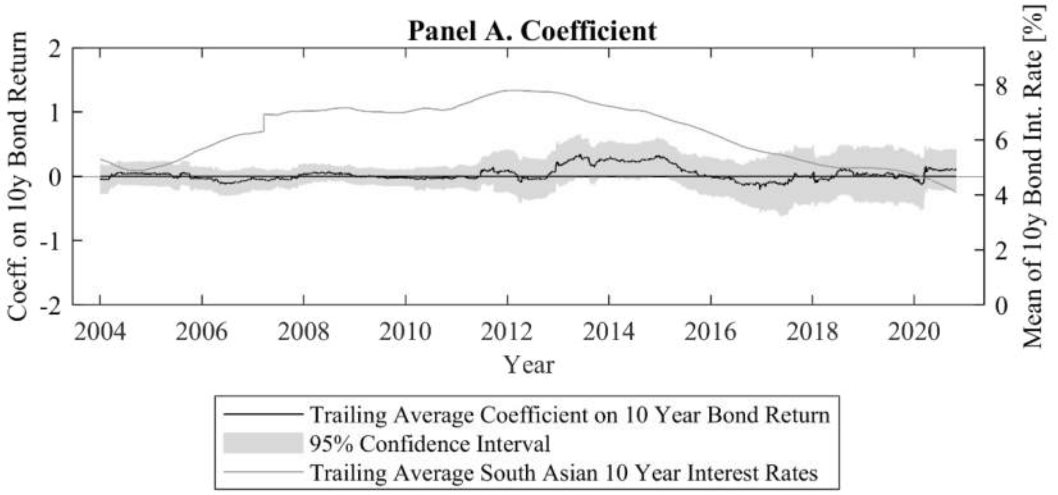


Fig. 56: Interest Rate Sensitivity Coefficients for South Asian Insurance Industry - Daily Data



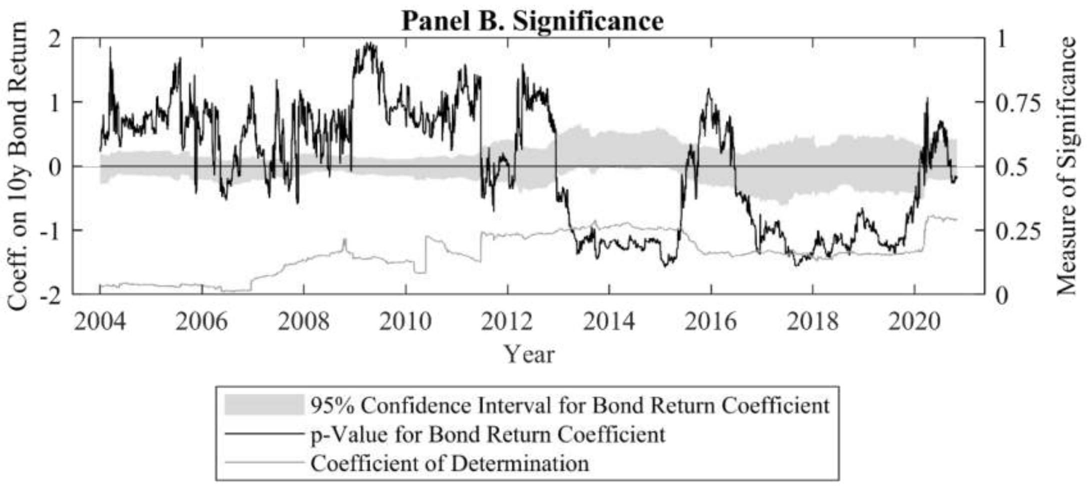


Fig. 57: Interest Rate Sensitivity Coefficients for South Asian Insurers - Weekly Data

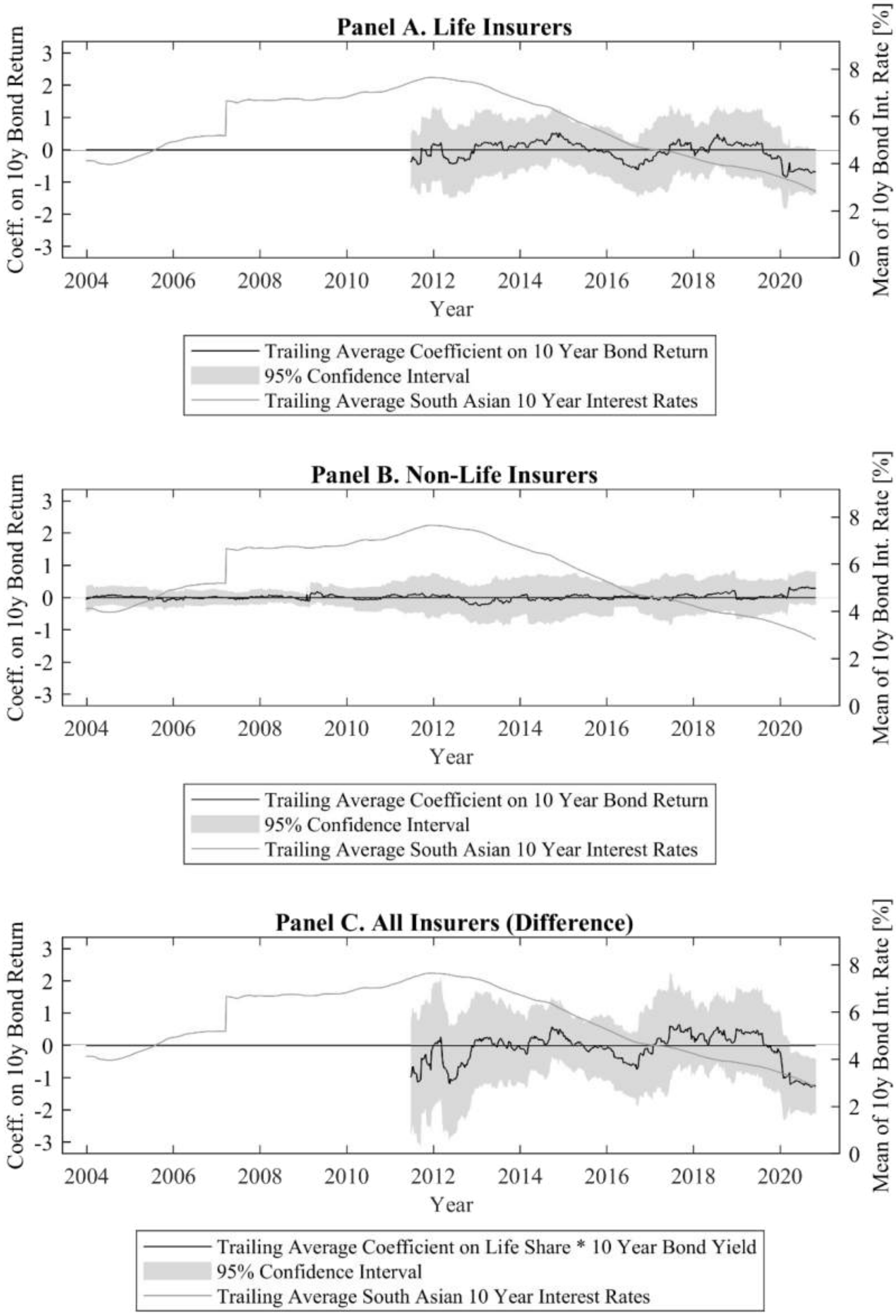


Fig. 58: Statistical Significance of Regression Model for South Asian Insurers - Weekly Data

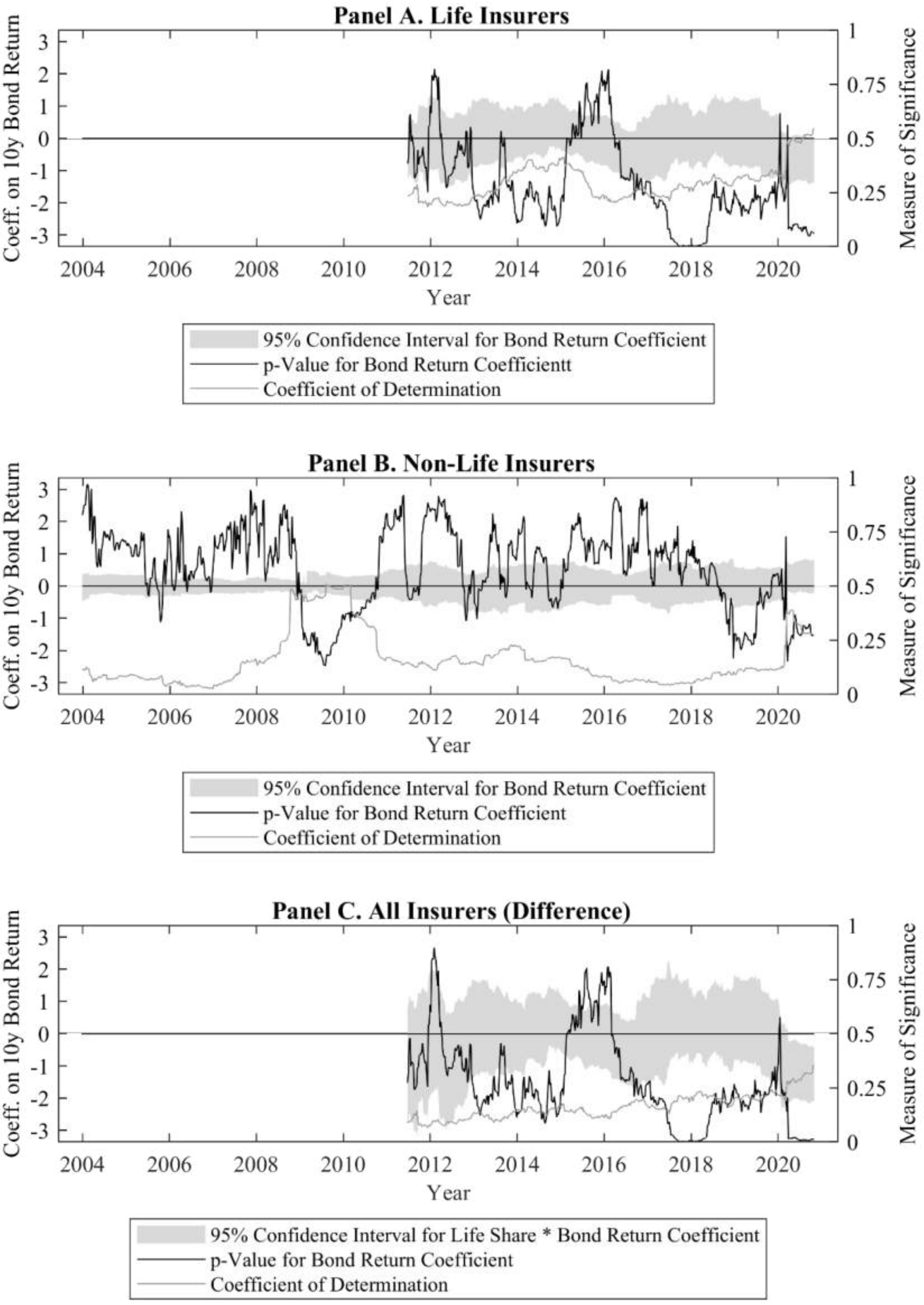


Fig. 59: Interest Rate Sensitivity Coefficients for South Asian Insurers - Daily Data

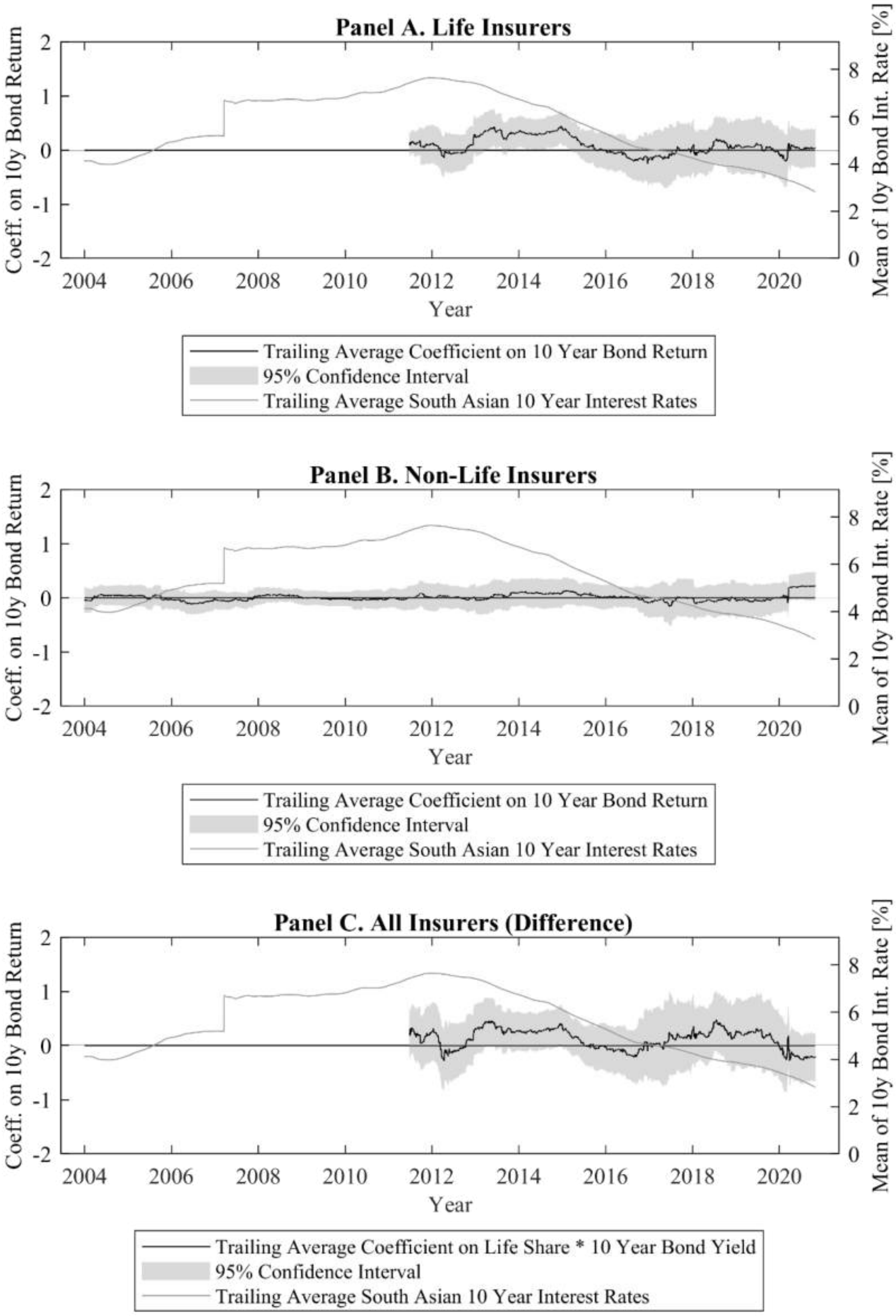


Fig. 60: Statistical Significance of Regression Model for South Asian Insurers - Daily Data

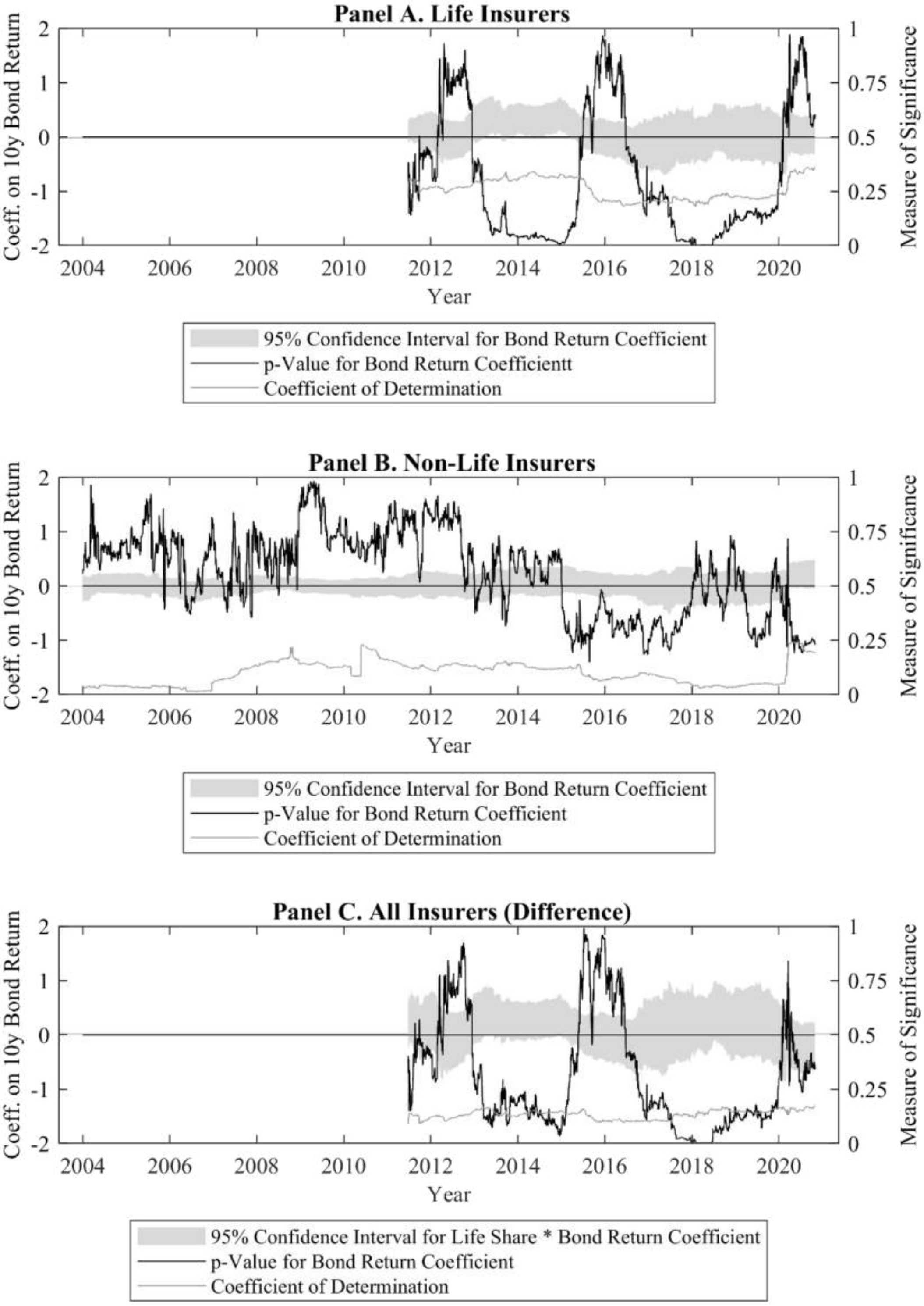


Fig. 61: Interest Rate Sensitivity Coefficients for East Asian Insurance Industry - Weekly Data

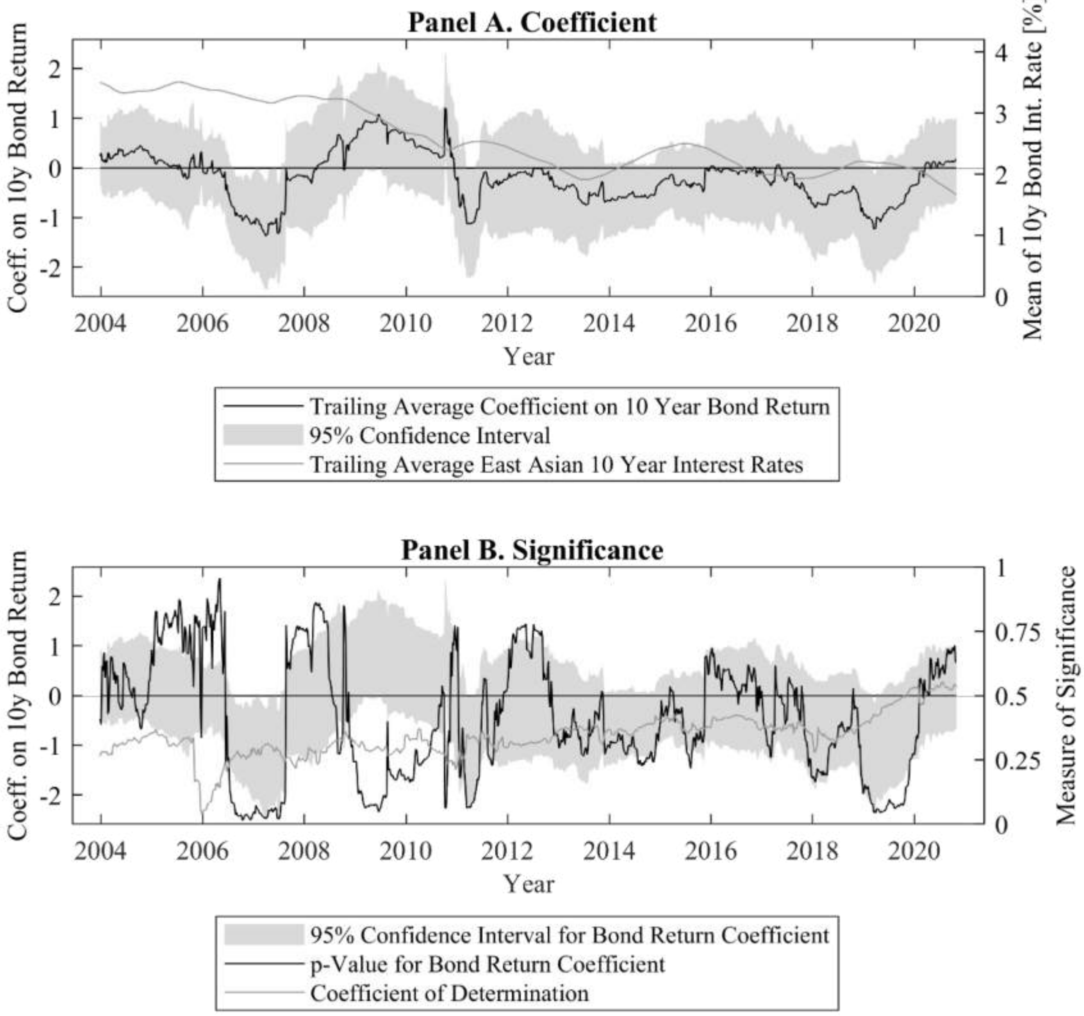
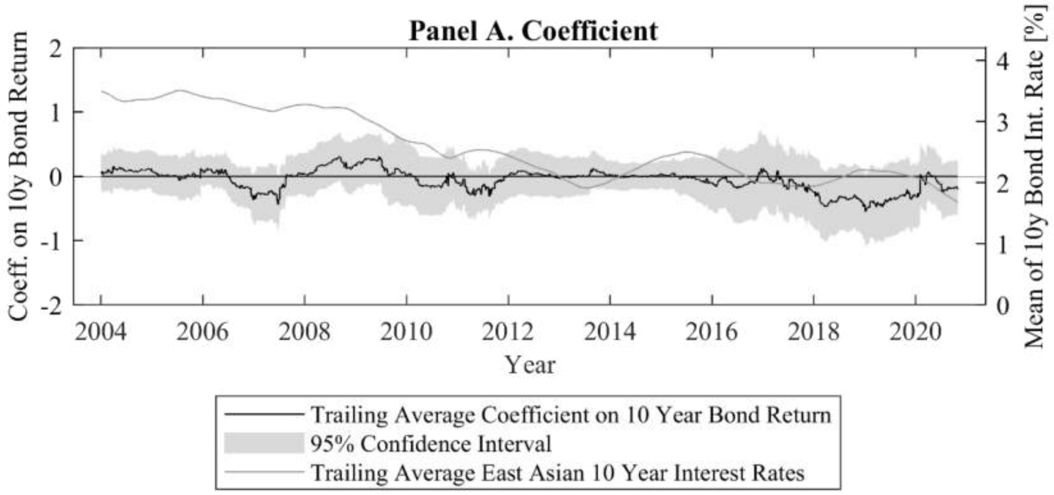


Fig. 62: Interest Rate Sensitivity Coefficients for East Asian Insurance Industry - Daily Data



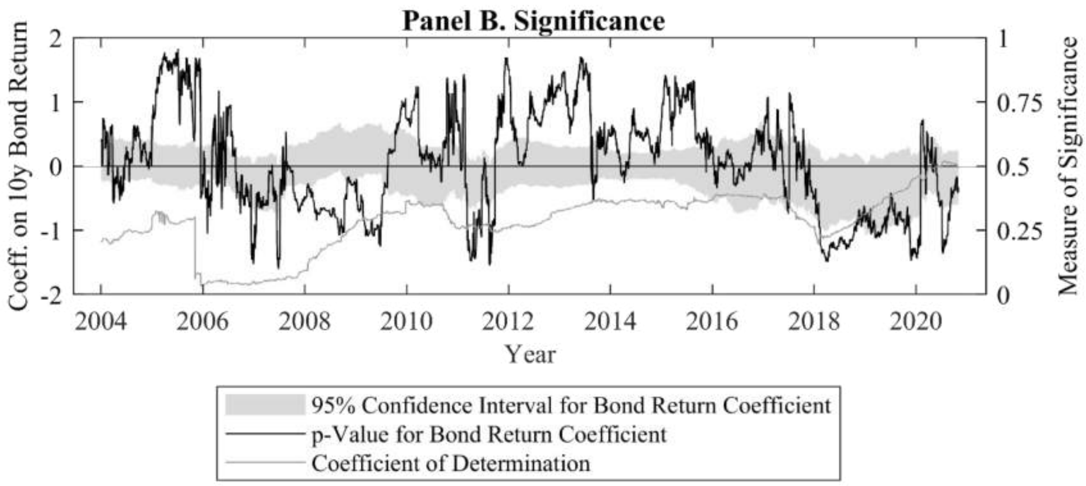


Fig. 63: Interest Rate Sensitivity Coefficients for East Asian Insurers - Weekly Data

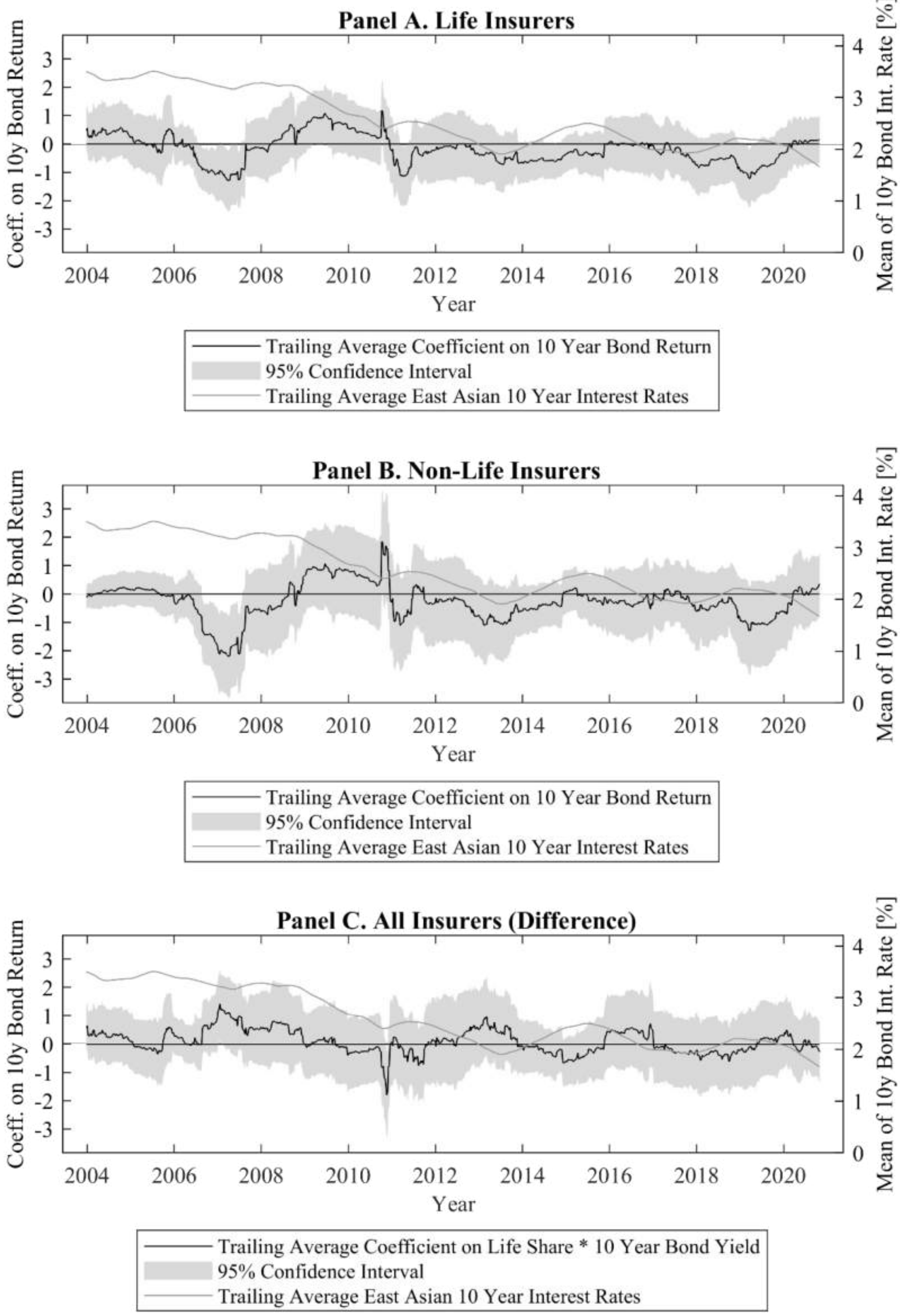


Fig. 64: Statistical Significance of Regression Model for East Asian Insurers - Weekly Data

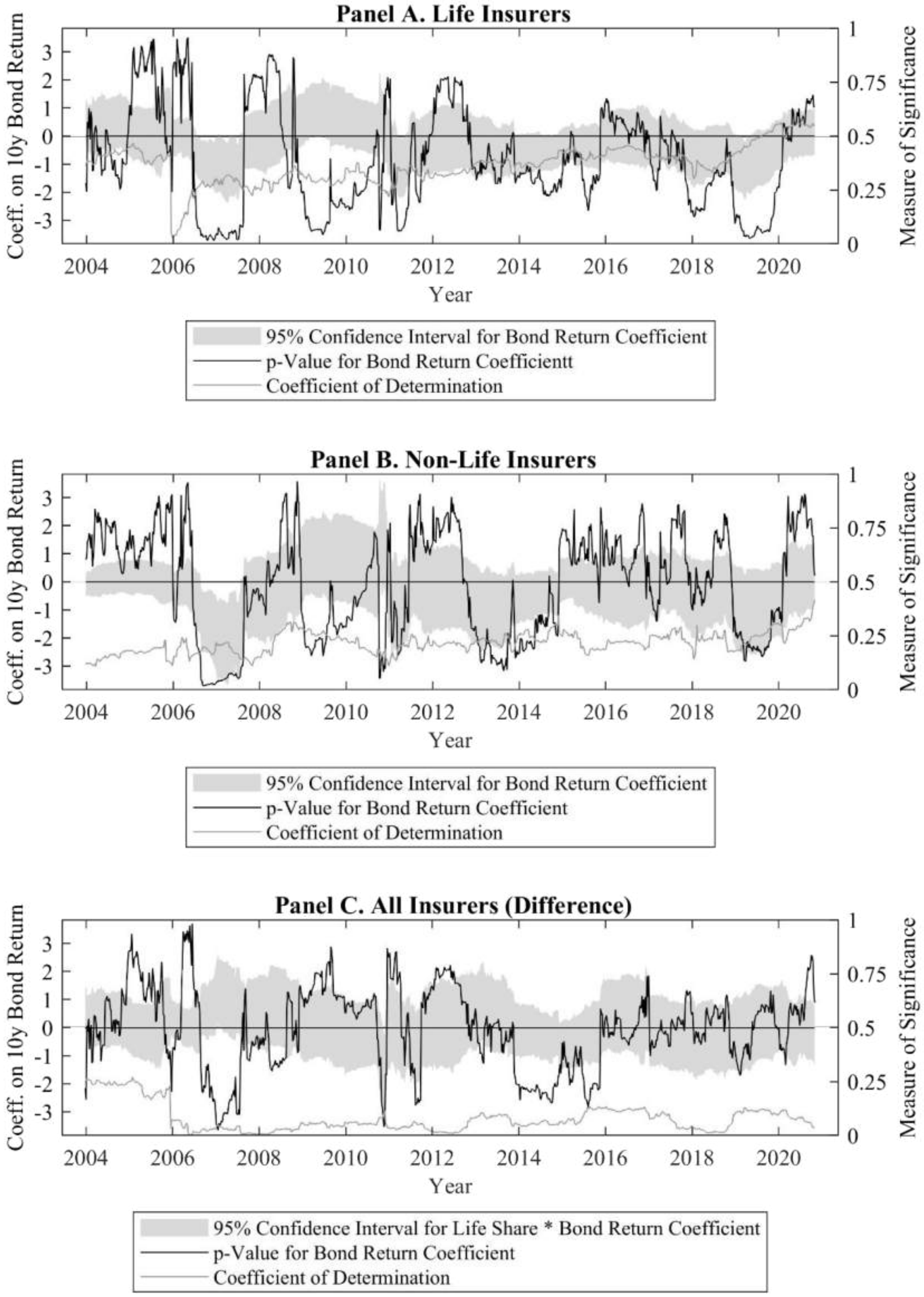


Fig. 65: Interest Rate Sensitivity Coefficients for East Asian Insurers - Daily Data

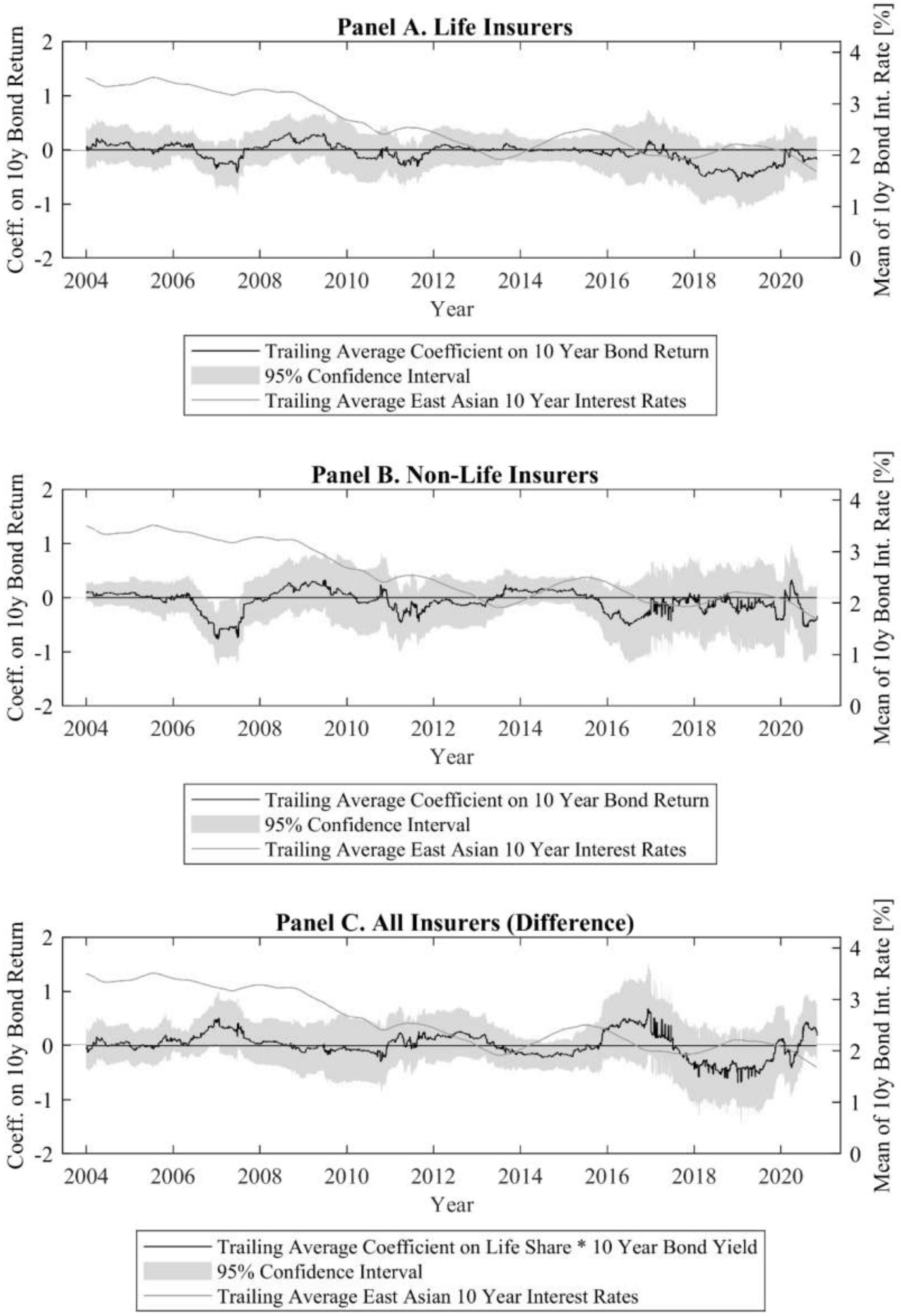


Fig. 66: Statistical Significance of Regression Model for East Asian Insurers - Daily Data

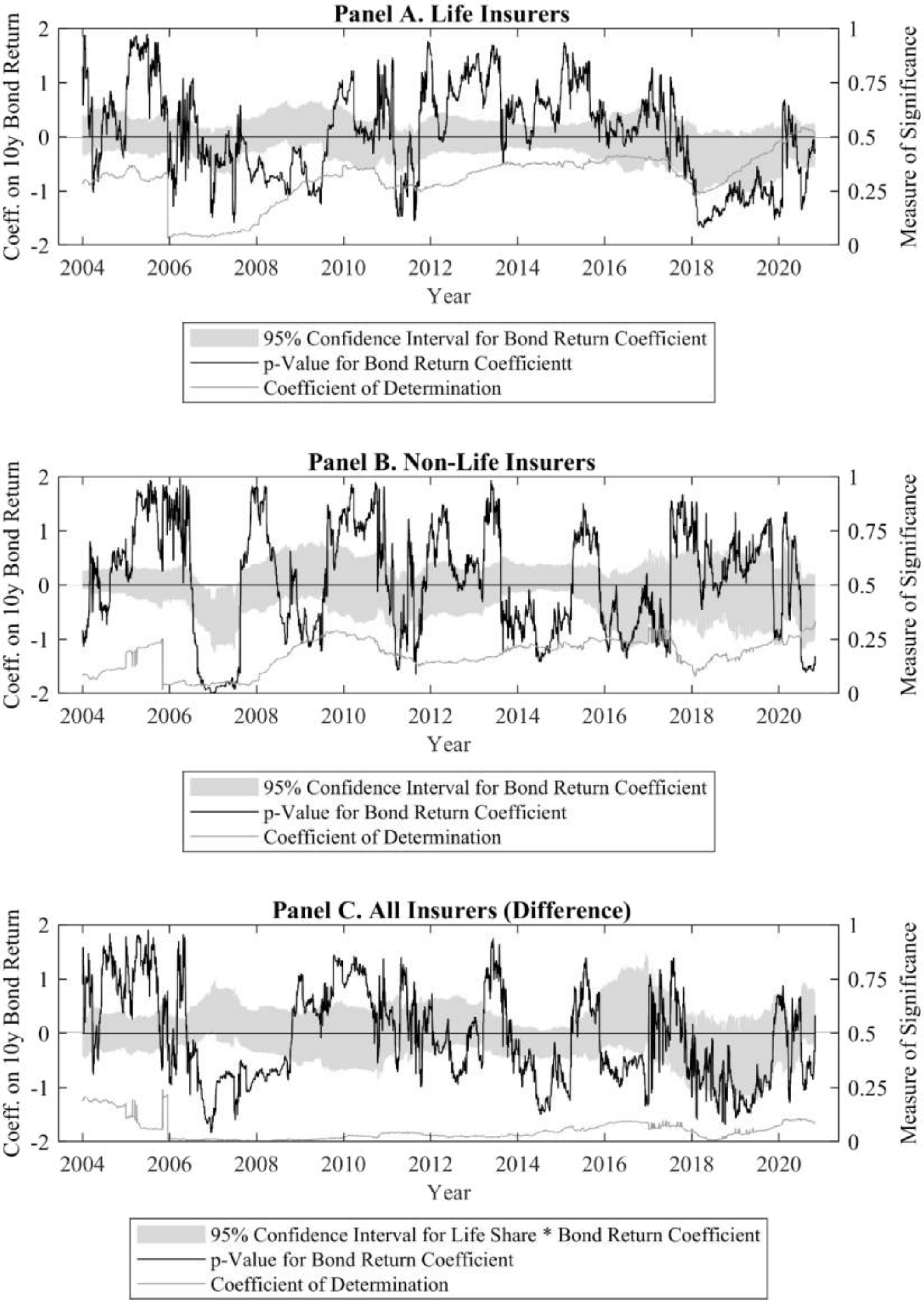
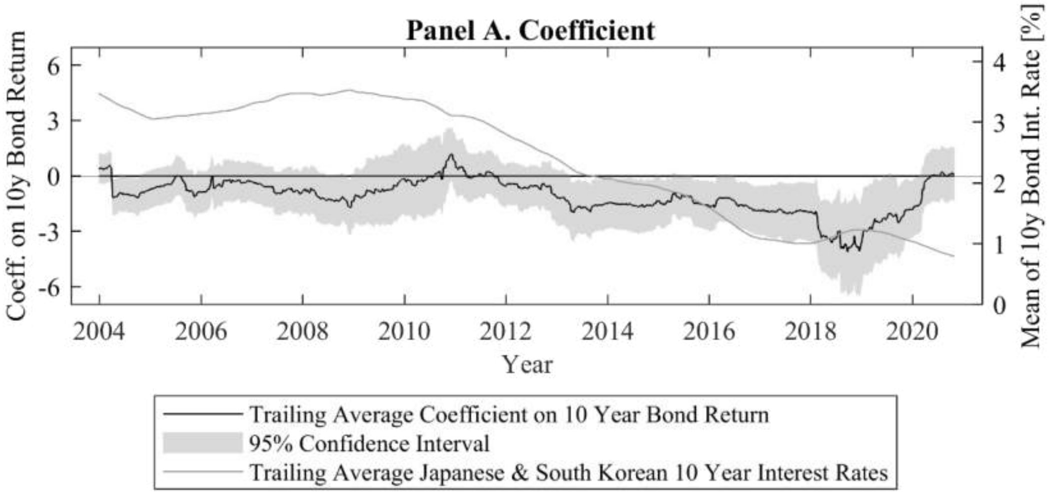


Fig. 67: Interest Rate Sensitivity Coefficients for Japanese & South Korean Insurance Industry - Weekly Data



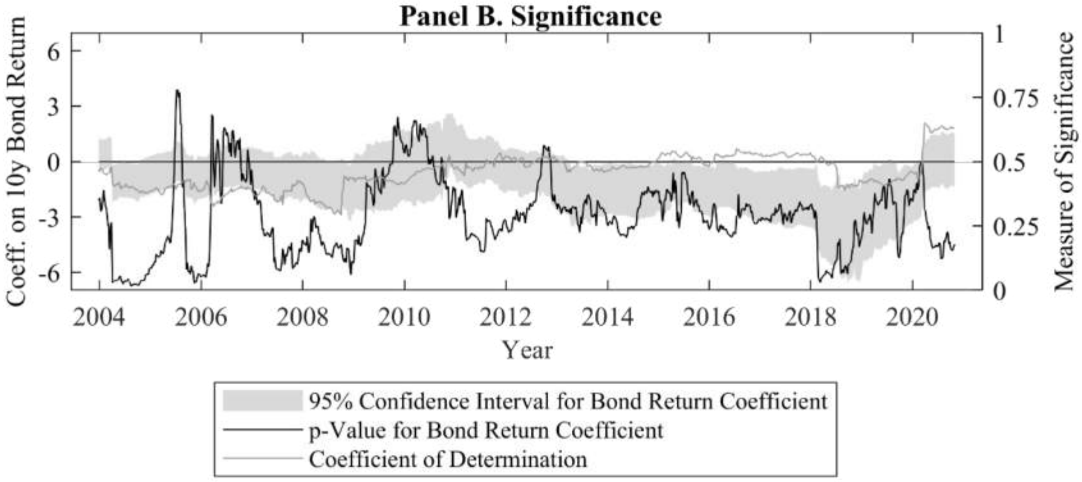


Fig. 68: Interest Rate Sensitivity Coefficients for Japanese & South Korean Insurance Industry - Daily Data

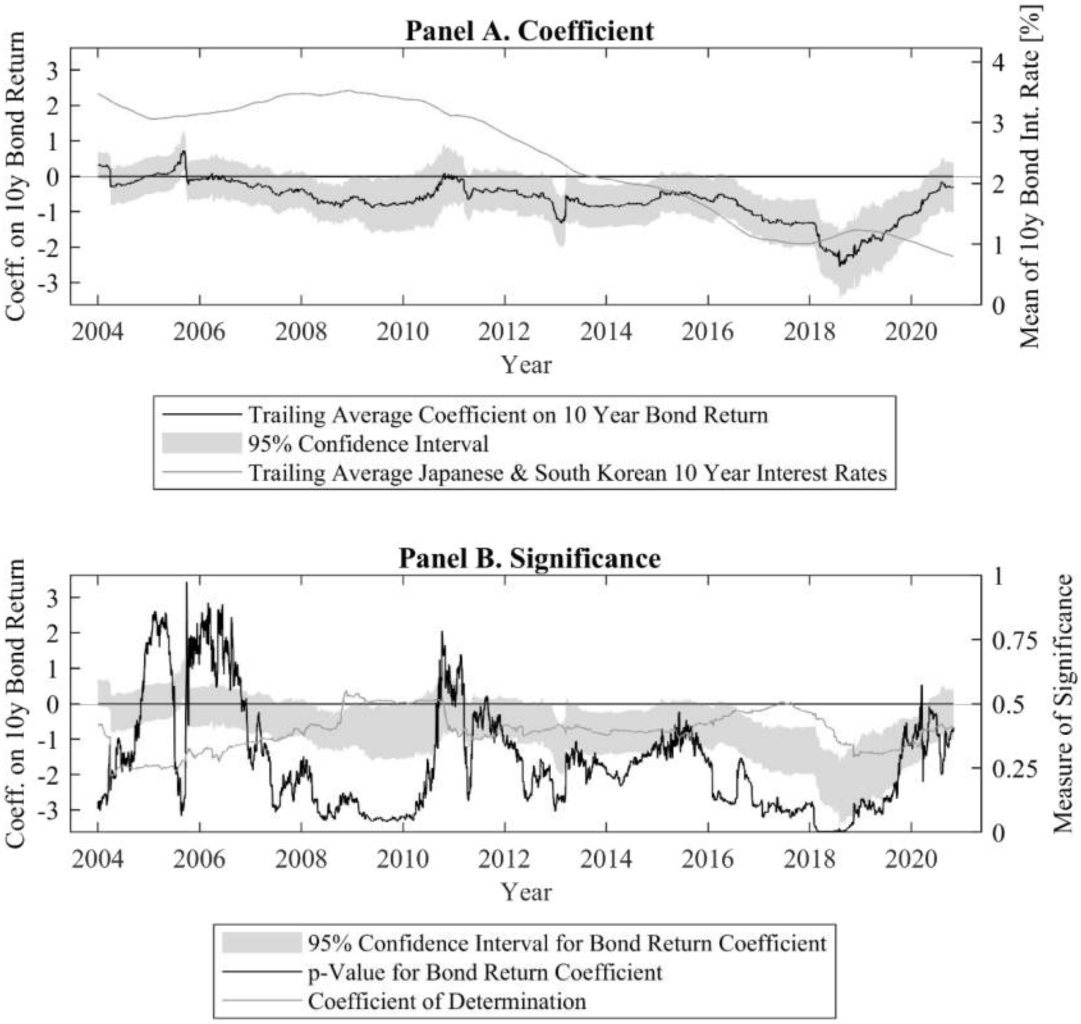


Fig. 69: Interest Rate Sensitivity Coefficients for Japanese & South Korean Insurers - Weekly Data

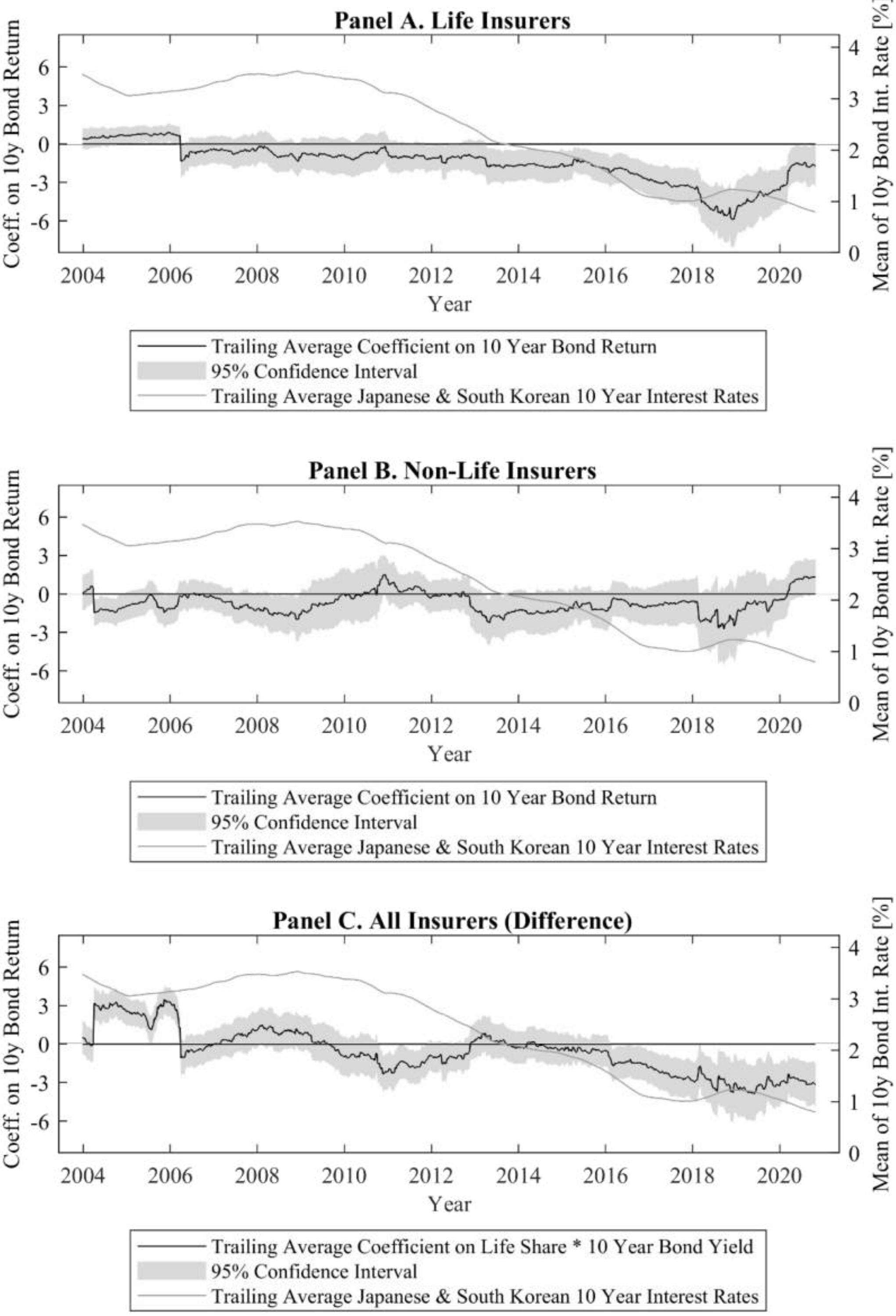


Fig. 70: Statistical Significance of Regression Model for Japanese & South Korean Insurers - Weekly Data

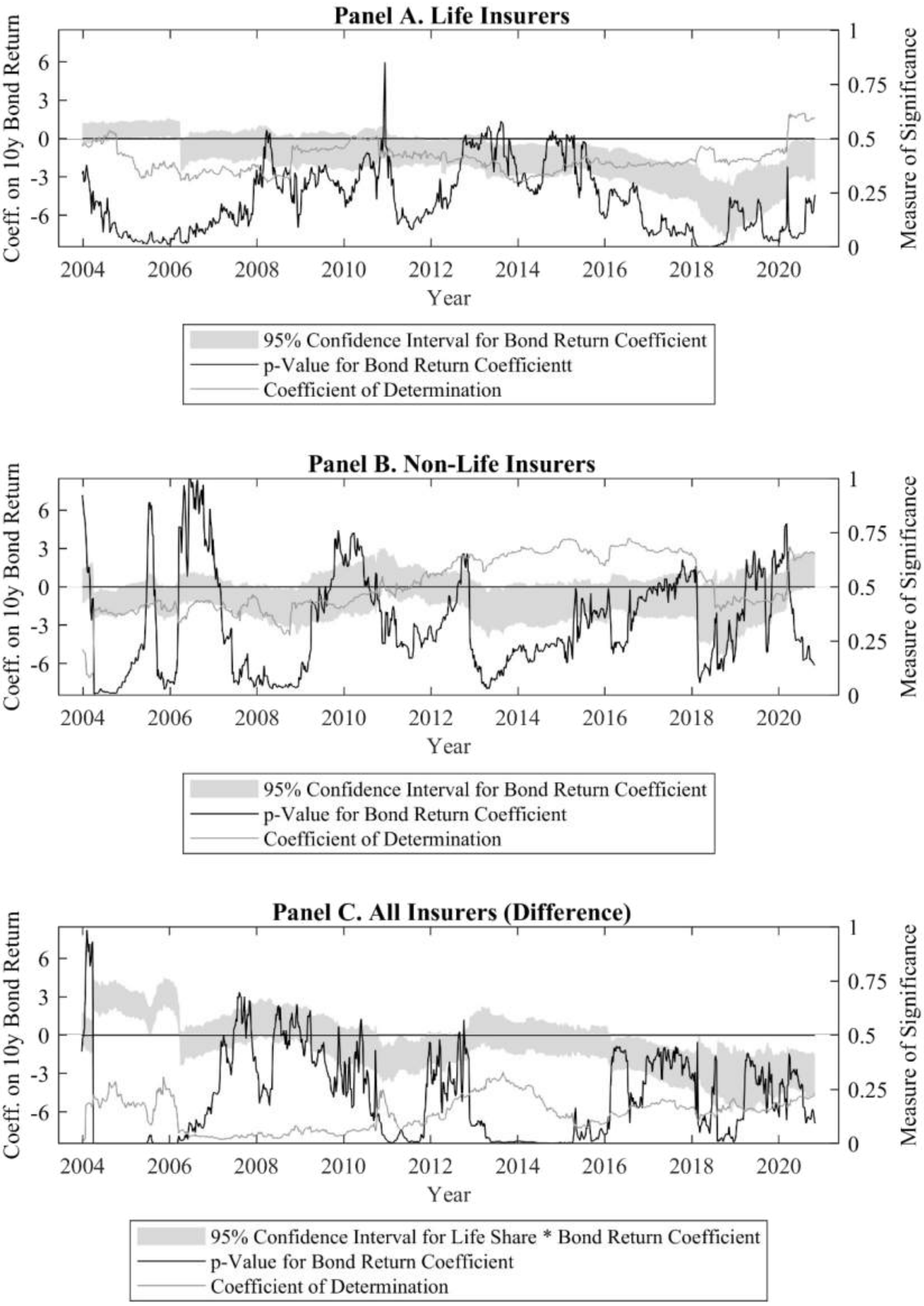


Fig. 71: Interest Rate Sensitivity Coefficients for Japanese & South Korean Insurers - Daily Data

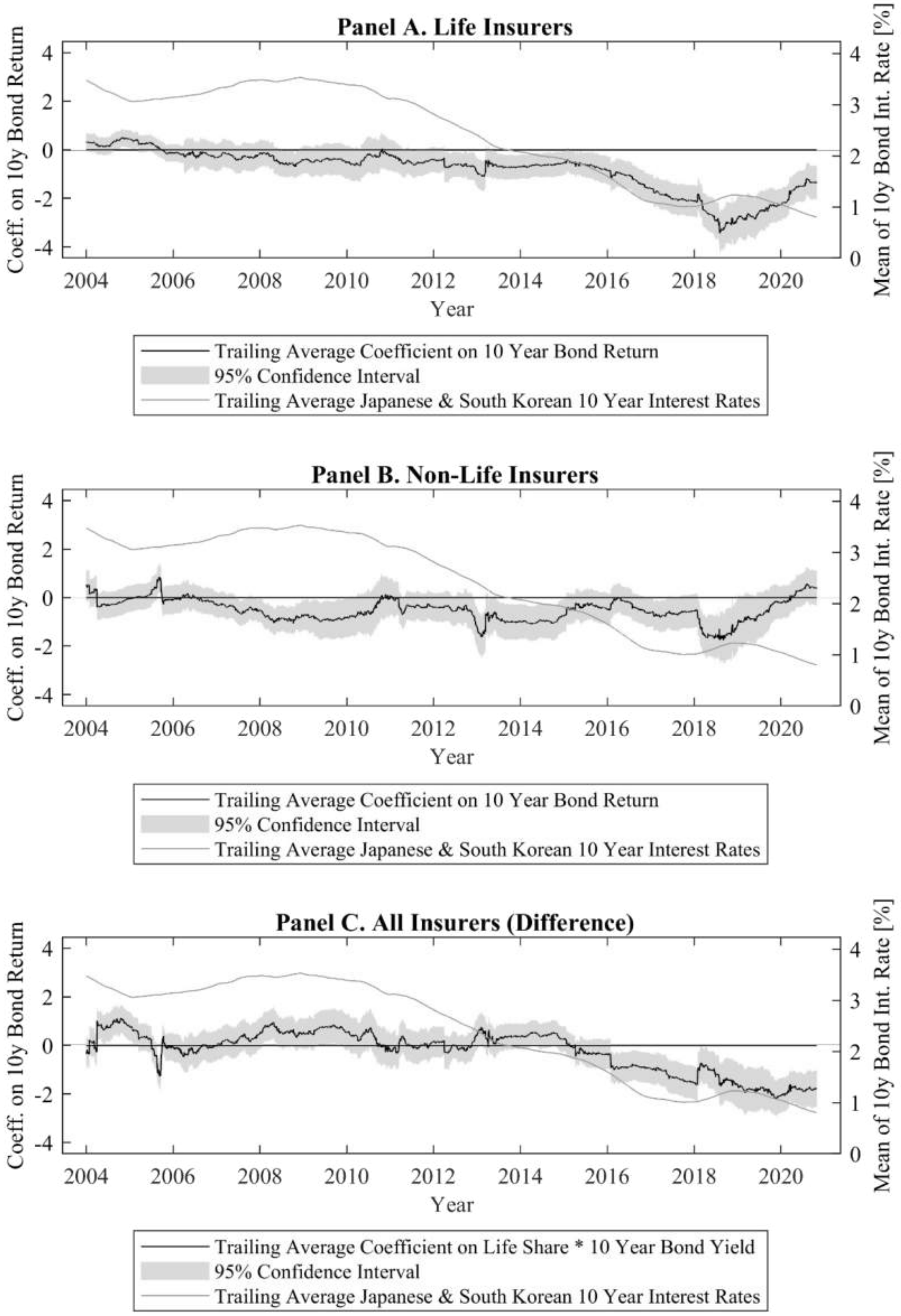


Fig. 72: Statistical Significance of Regression Model for Japanese & South Korean Insurers - Daily Data

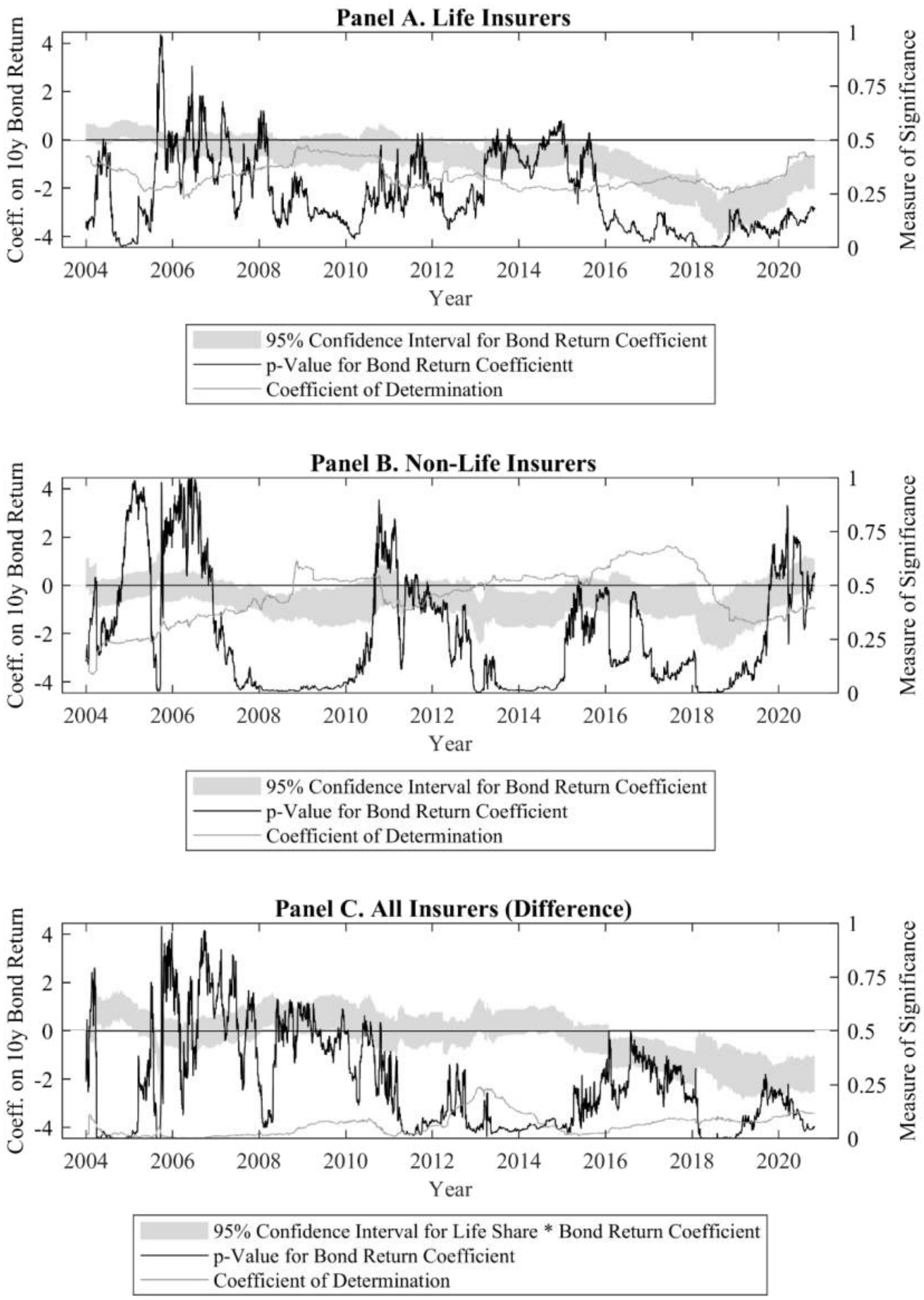


Fig. 73: Interest Rate Sensitivity Coefficients for Australian & Oceanian Insurance Industry - Weekly Data

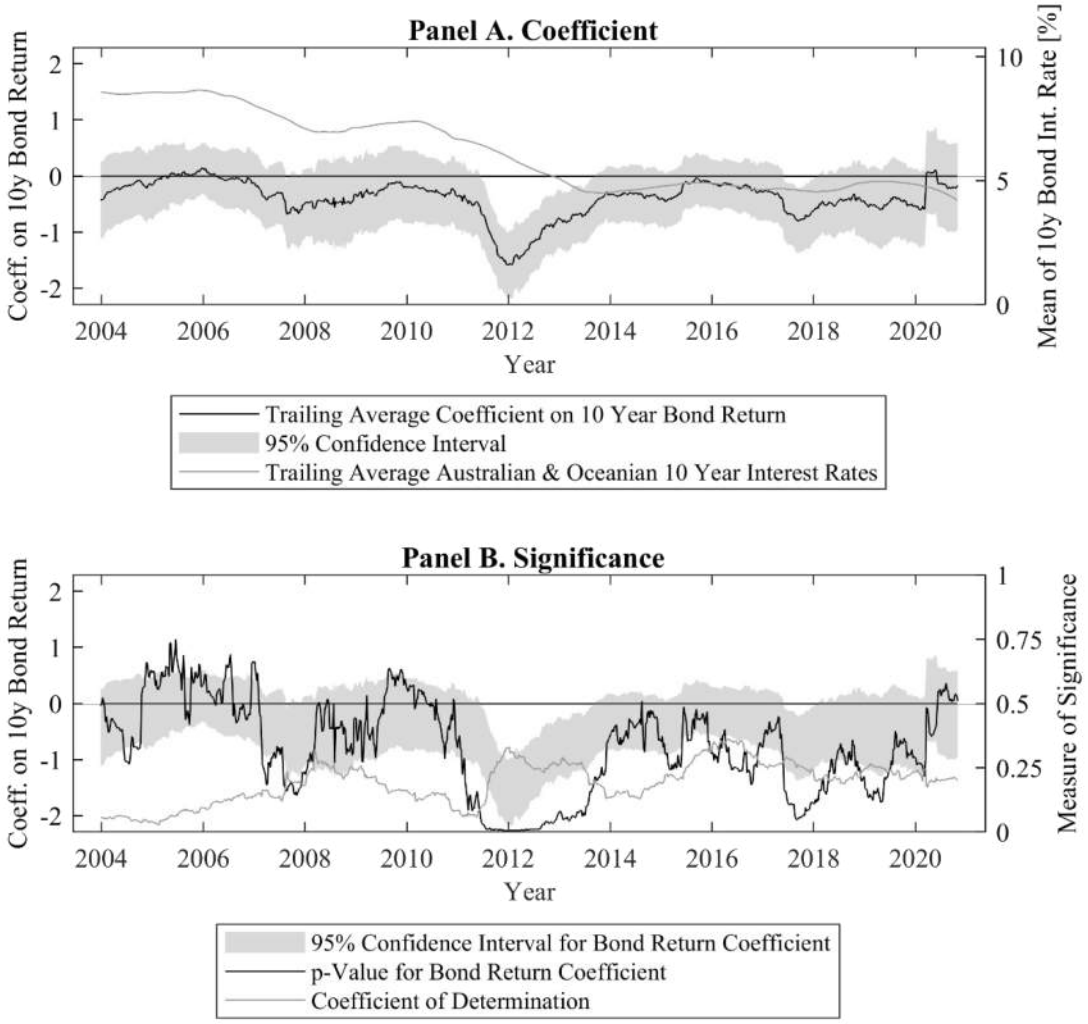


Fig. 74: Interest Rate Sensitivity Coefficients for Australian & Oceanian Insurance Industry - Daily Data

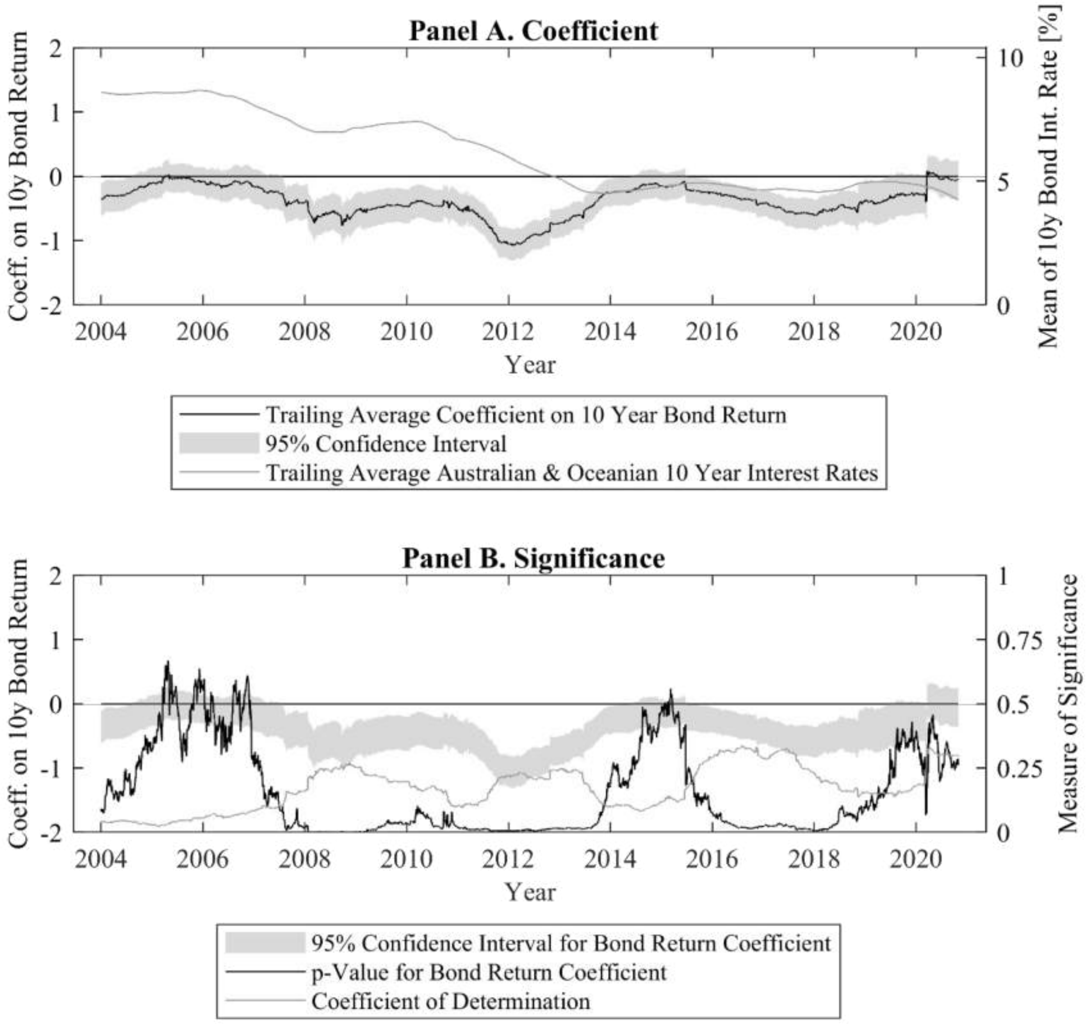


Fig. 75: Interest Rate Sensitivity Coefficients for Austrialian & Oceanian Insurers - Weekly Data

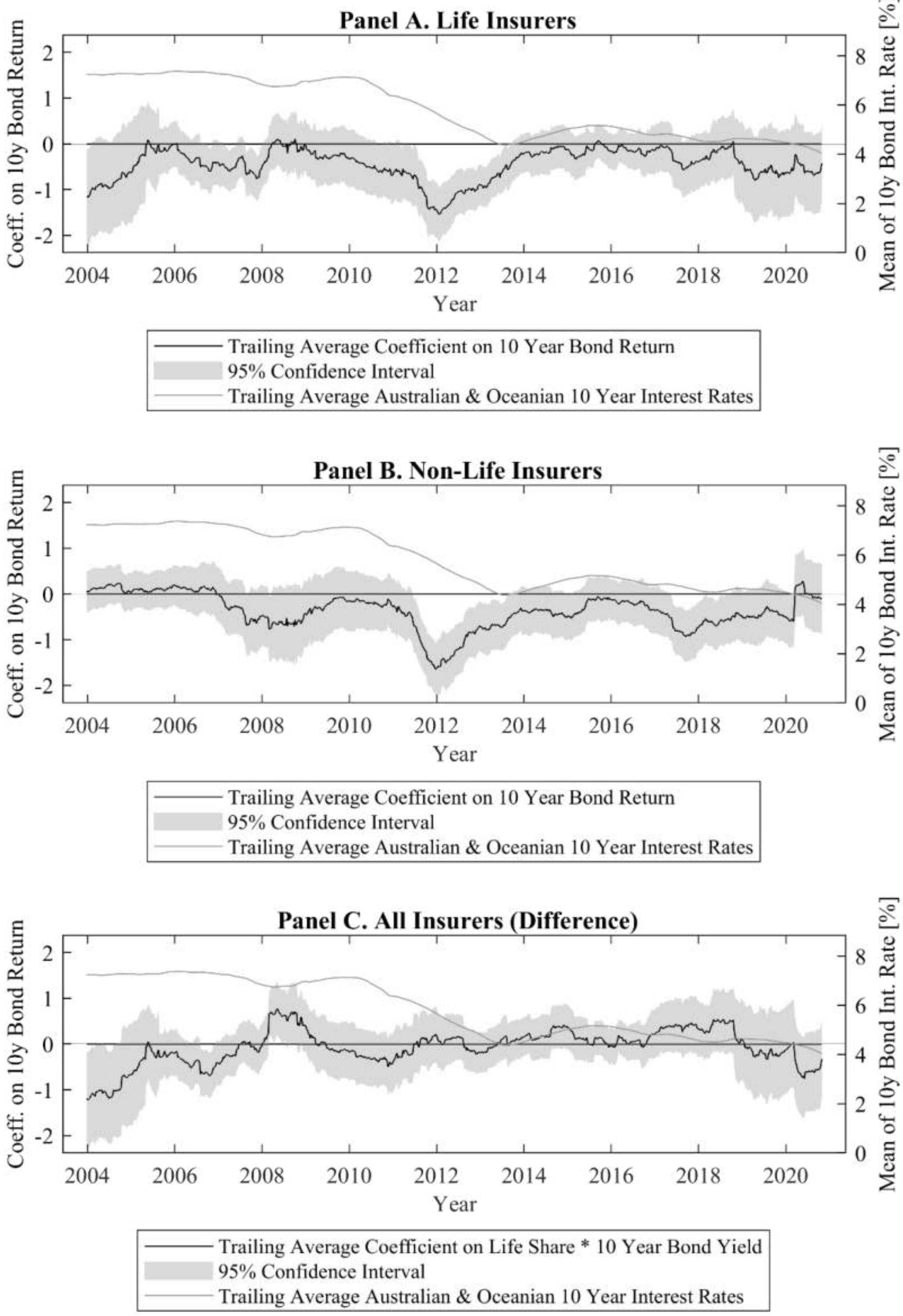


Fig. 76: Statistical Significance of Regression Model for Austrialian & Oceanian Insurers - Weekly Data

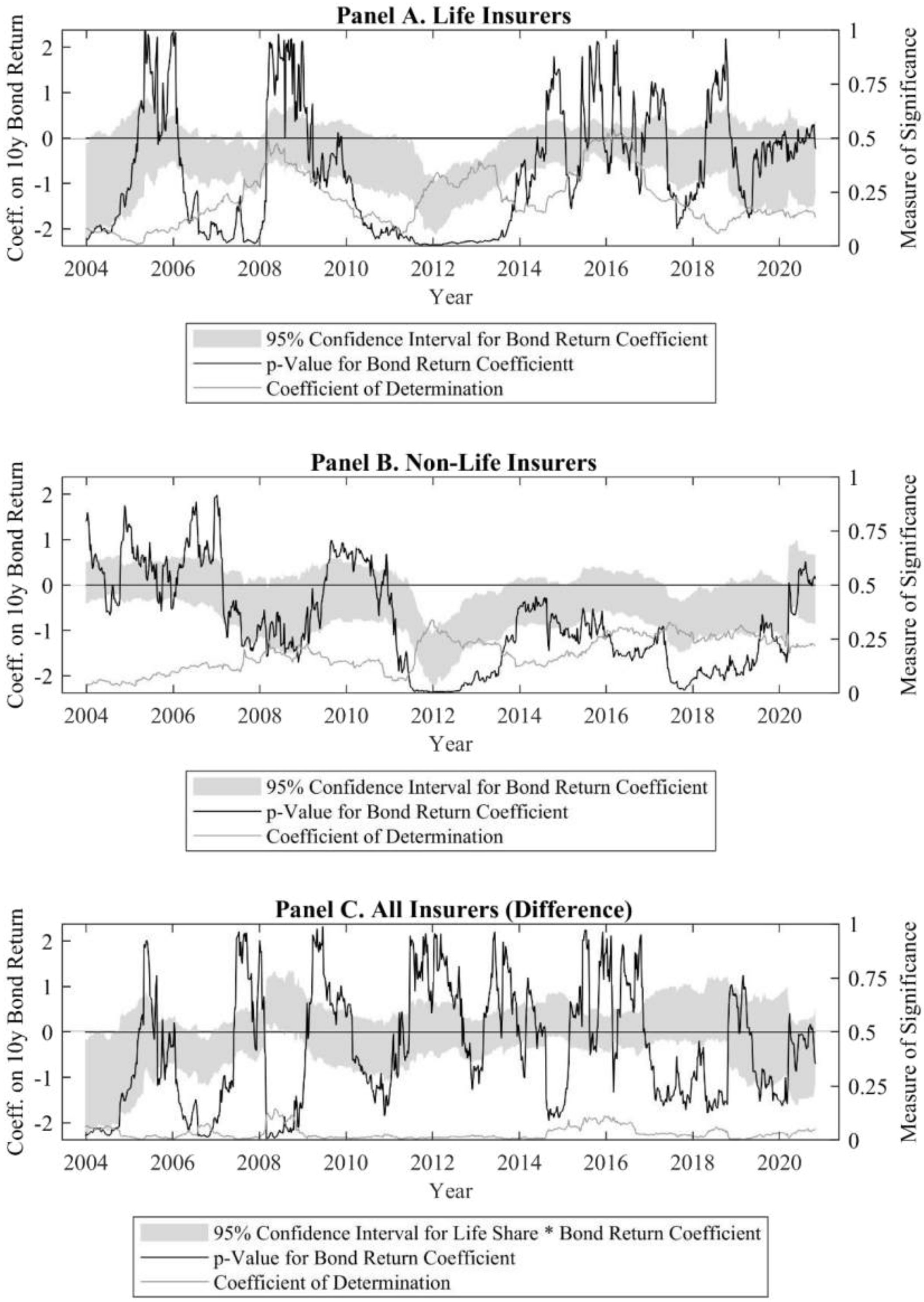
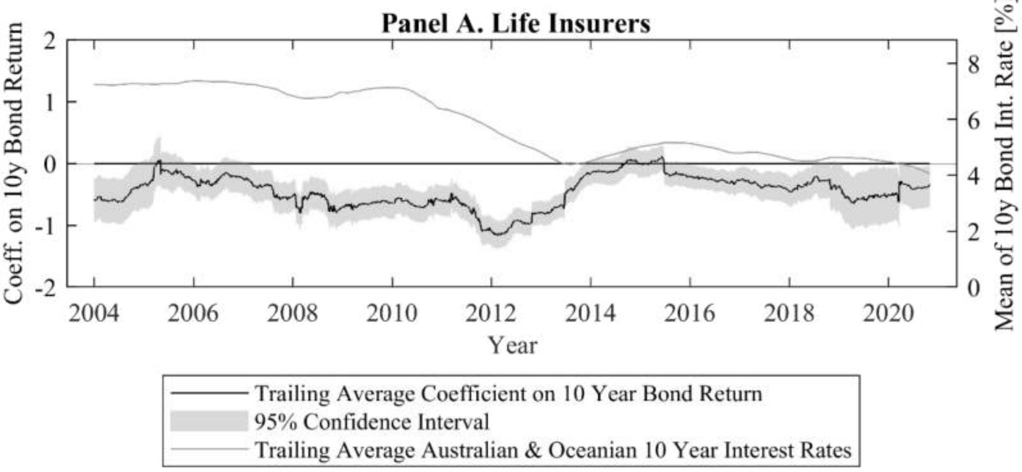
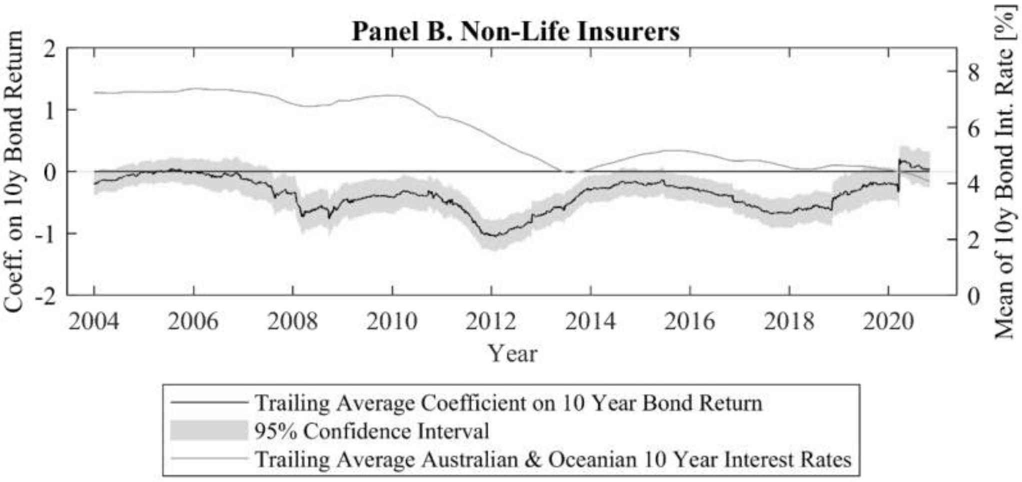


Fig. 77: Interest Rate Sensitivity Coefficients for Austrialian & Oceanian Insurers - Daily Data





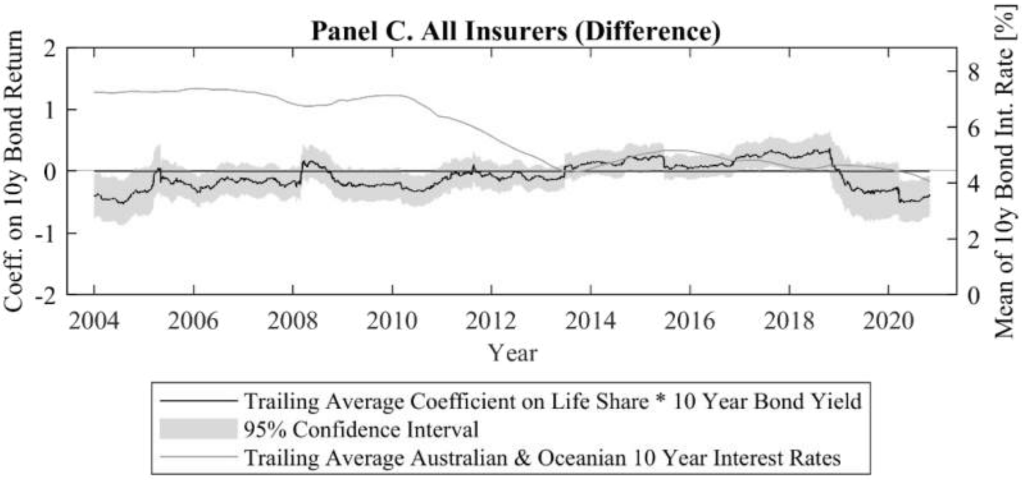
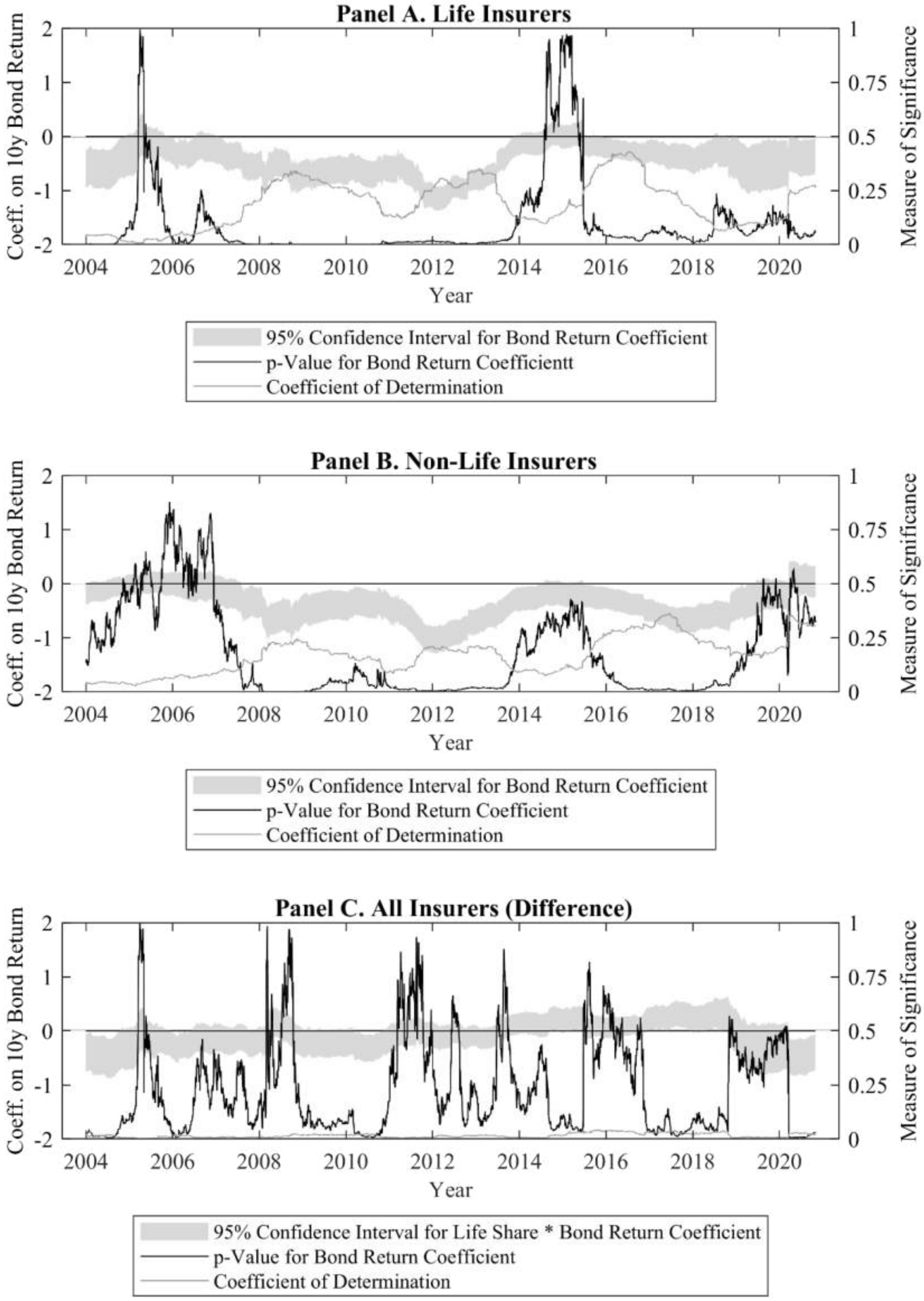


Fig. 78: Statistical Significance of Regression Model for Austrialian & Oceanian Insurers - Daily Data



Appendix A: Change in European Interest Rate Sensitivities by Country (Premium Share Allocation – Weekly Data)

Fig. A1: Changes in Austrian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

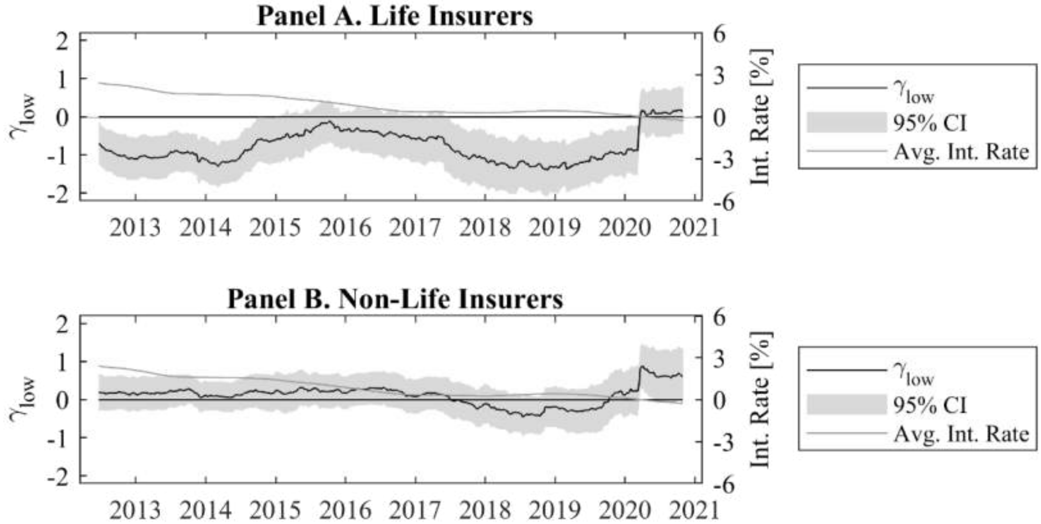


Fig. A2: Statistical Significance of Regression Model for Austrian Insurers - Premium Shares - Weekly Data

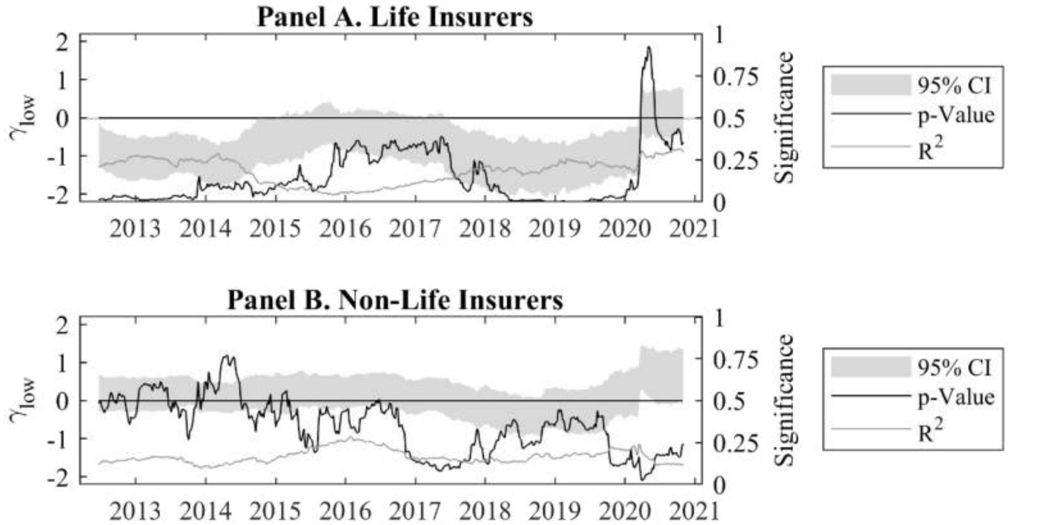


Fig. A3: Changes in Belgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

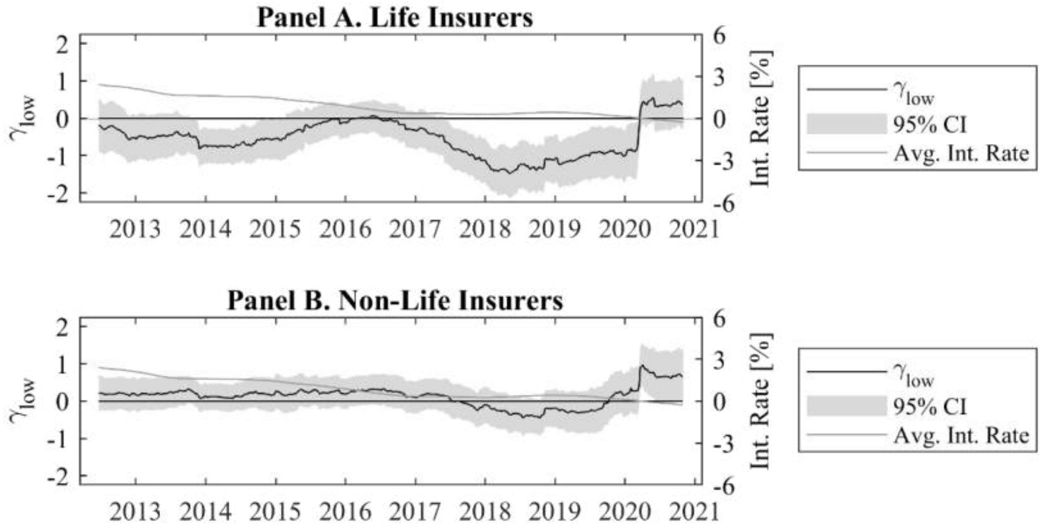


Fig. A4: Statistical Significance of Regression Model for Belgian Insurers - Premium Shares - Weekly Data

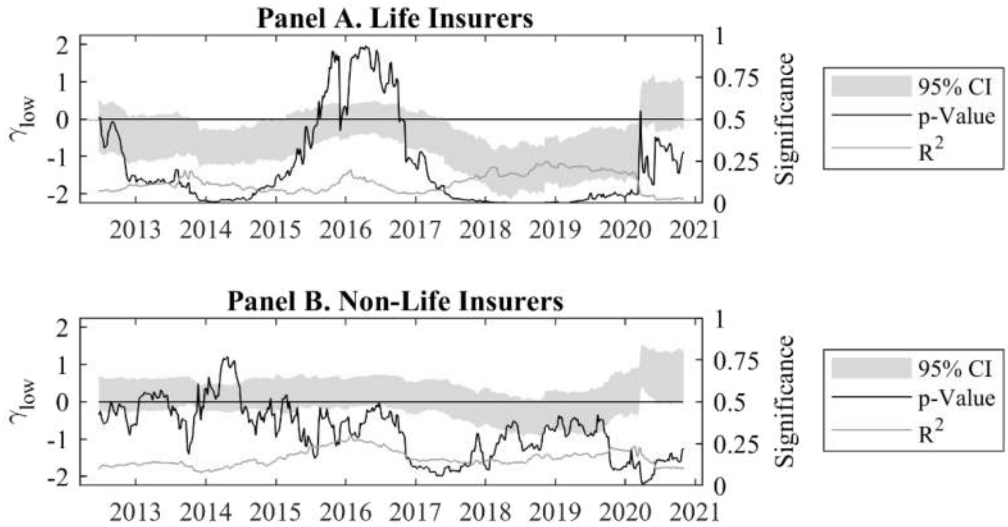


Fig. A5: Changes in Croatian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

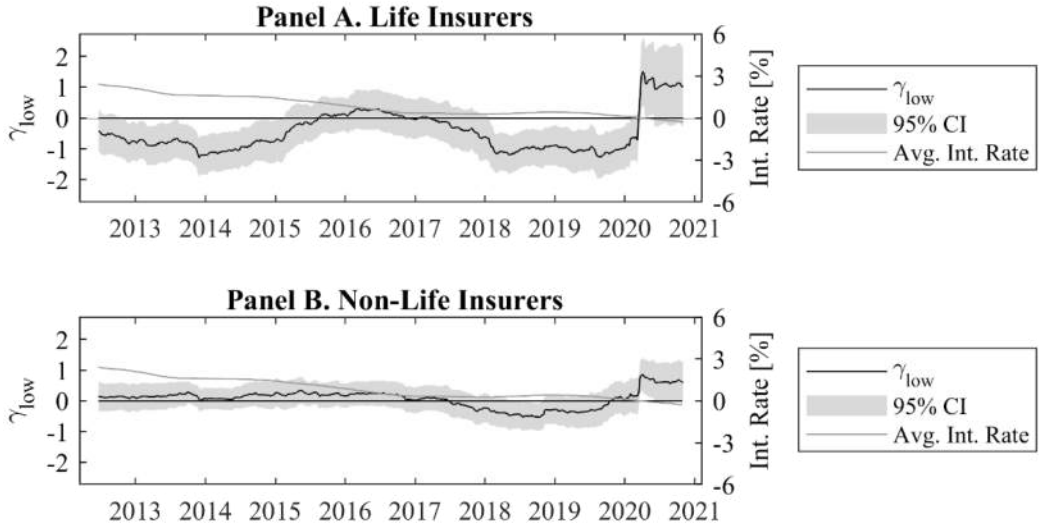


Fig. A6: Statistical Significance of Regression Model for Croatian Insurers - Premium Shares - Weekly Data

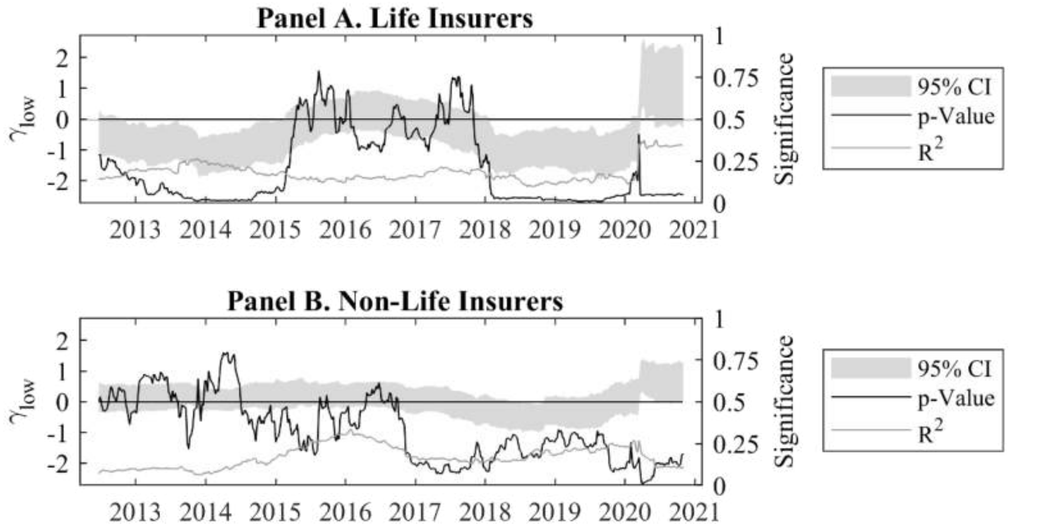


Fig. A7: Changes in Cyprian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

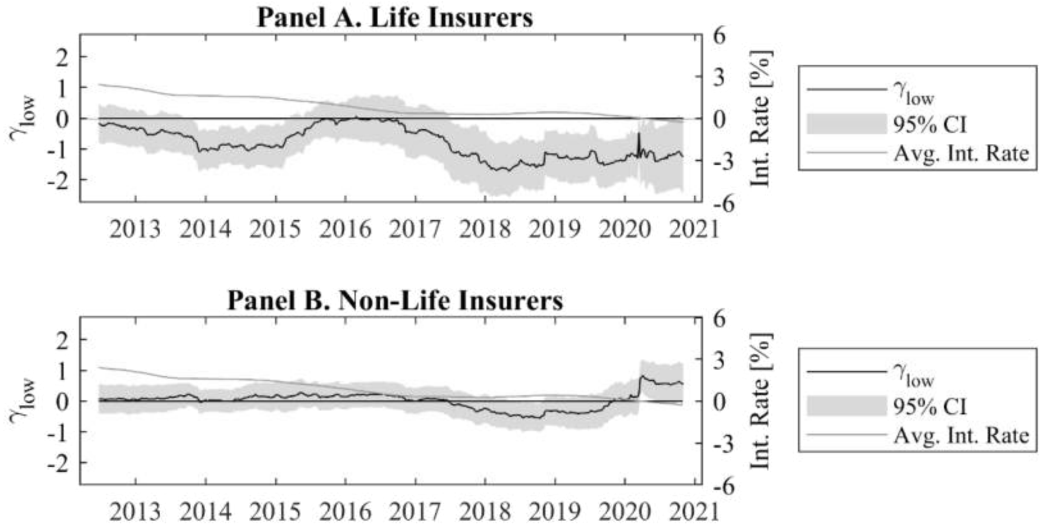


Fig. A8: Statistical Significance of Regression Model for Cyprian Insurers - Premium Shares - Weekly Data

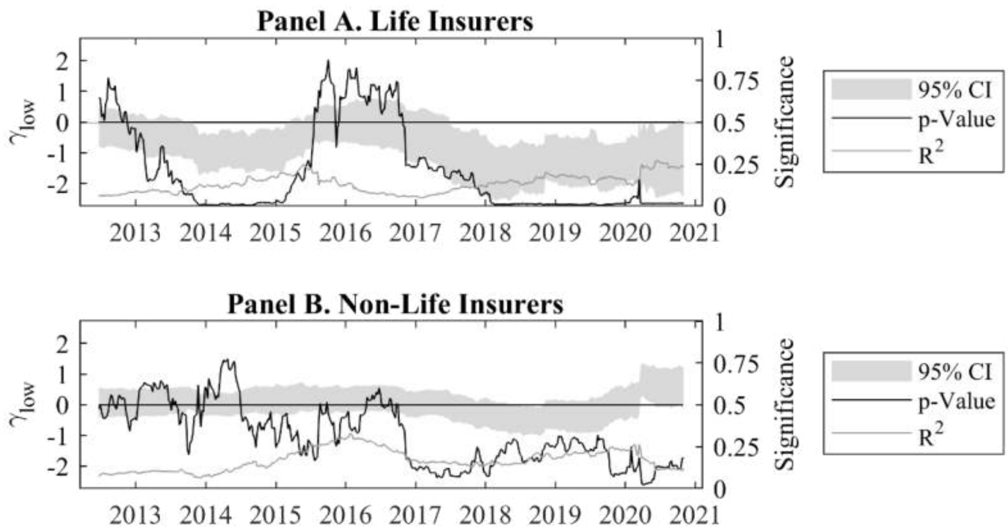


Fig. A9: Changes in Danish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

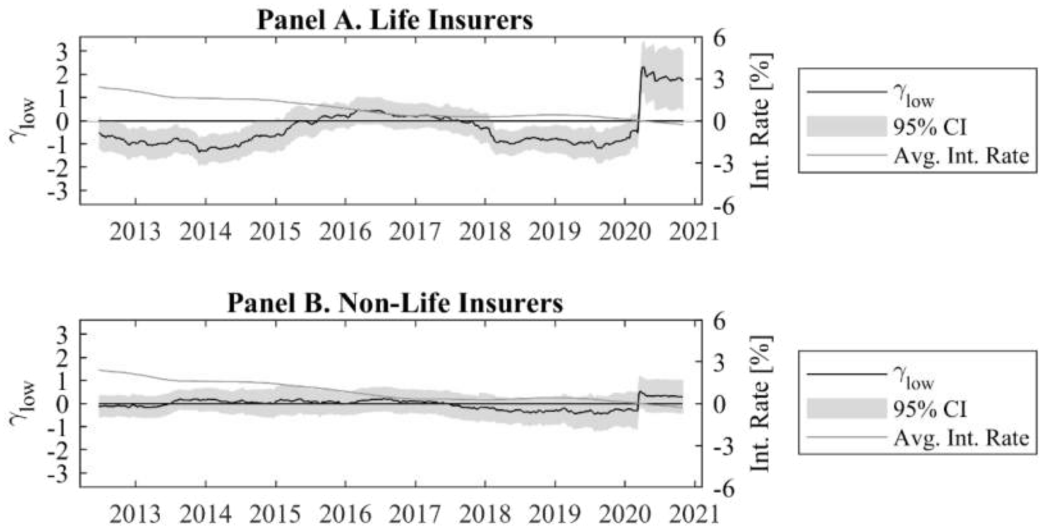


Fig. A10: Statistical Significance of Regression Model for Danish Insurers - Premium Shares - Weekly Data

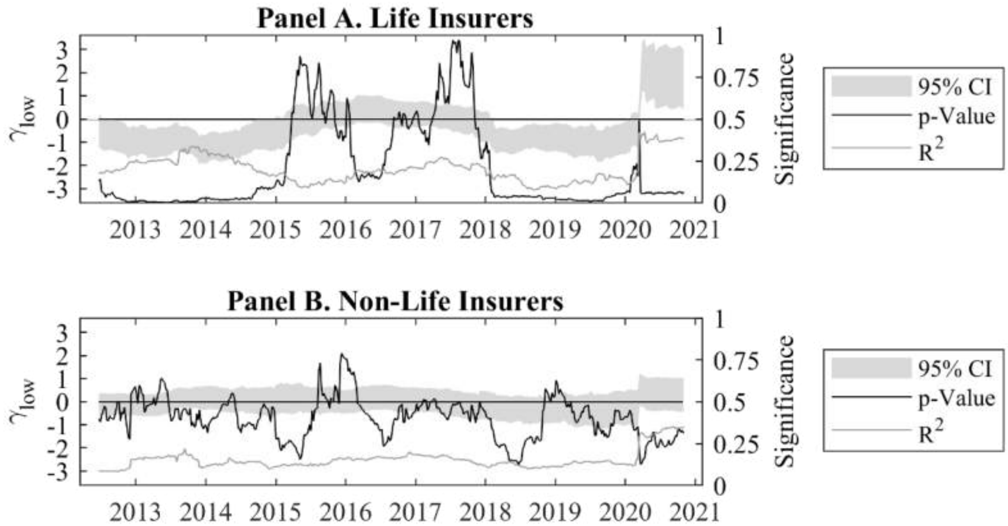


Fig. A11: Changes in Finnish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

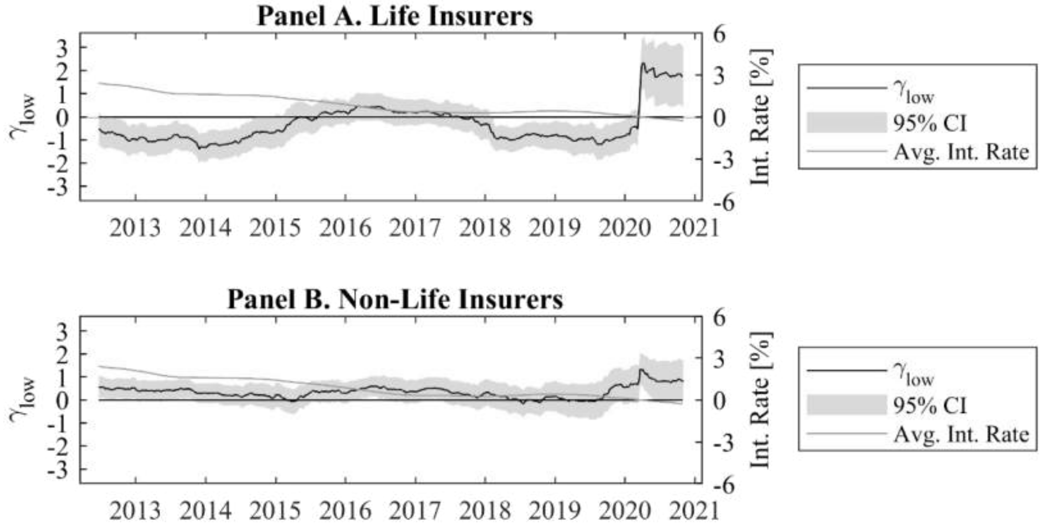


Fig. A12: Statistical Significance of Regression Model for Finnish Insurers - Premium Shares - Weekly Data

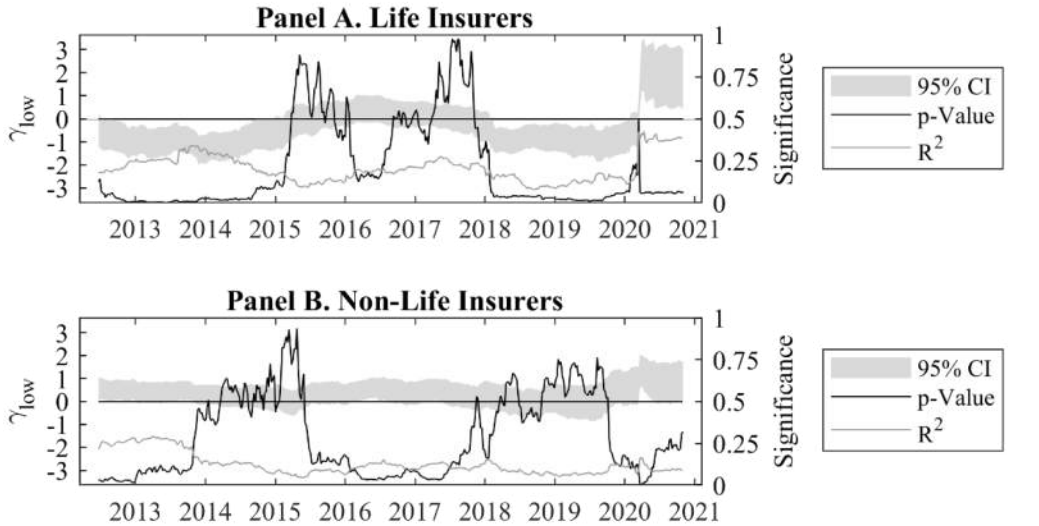


Fig. A13: Changes in French Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

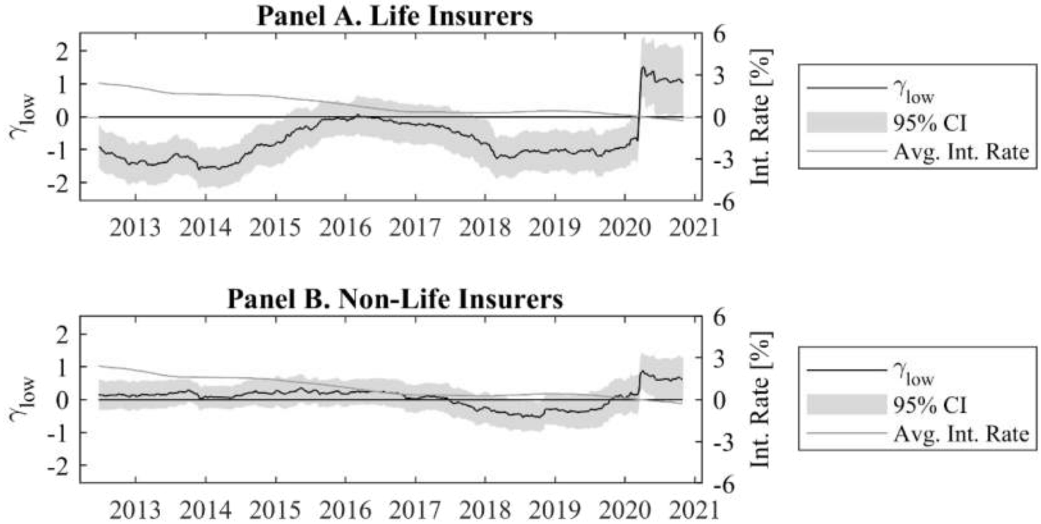


Fig. A14: Statistical Significance of Regression Model for French Insurers - Premium Shares - Weekly Data

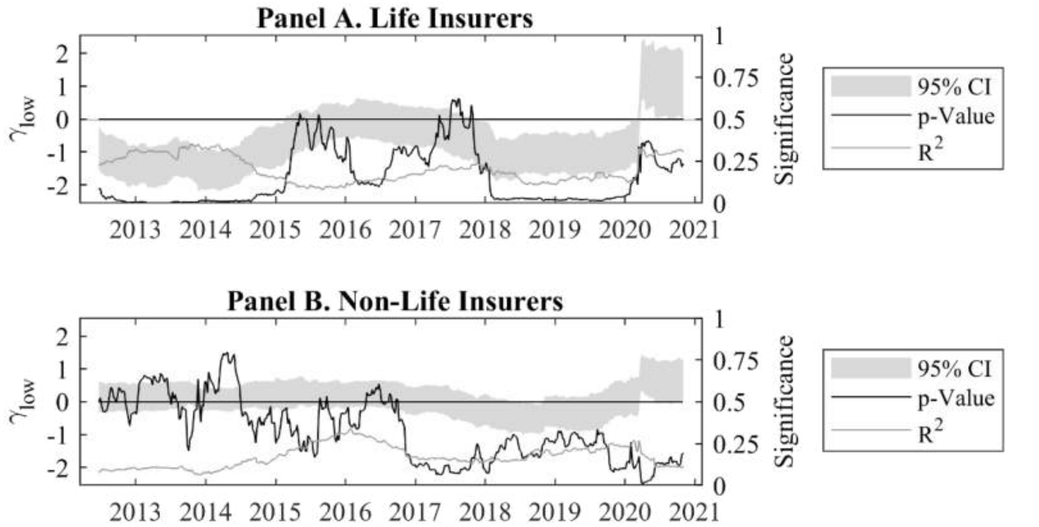


Fig. A15: Changes in German Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

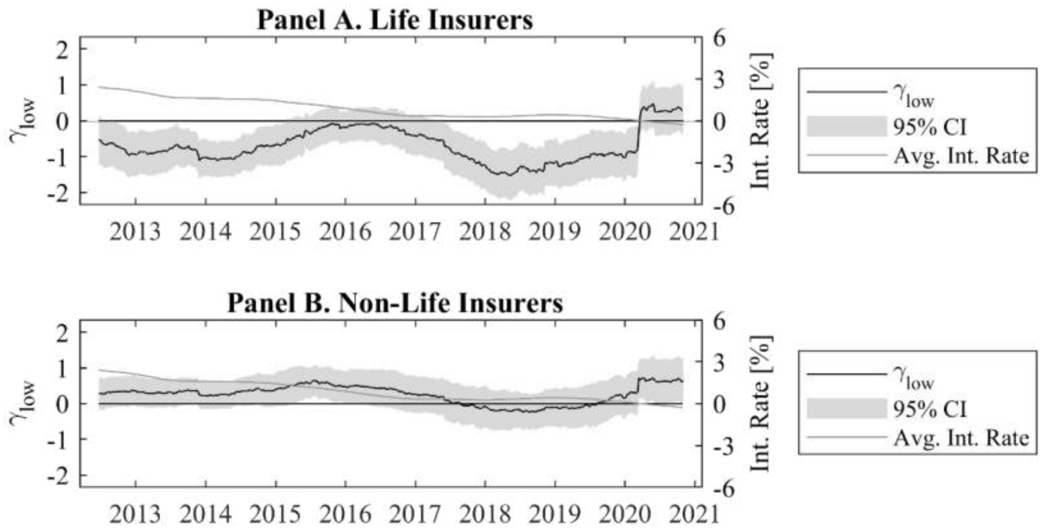


Fig. A16: Statistical Significance of Regression Model for German Insurers - Premium Shares - Weekly Data

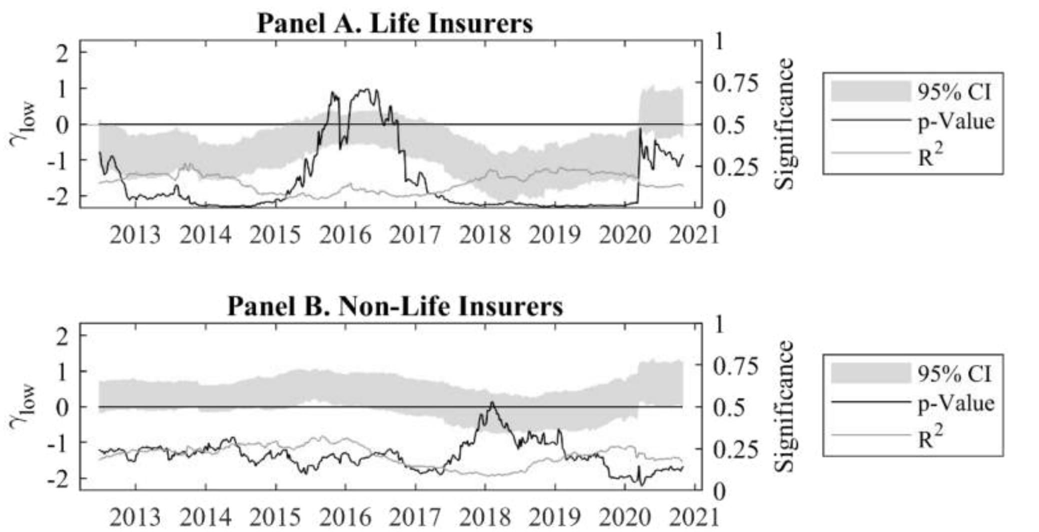


Fig. A17: Changes in Greek Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

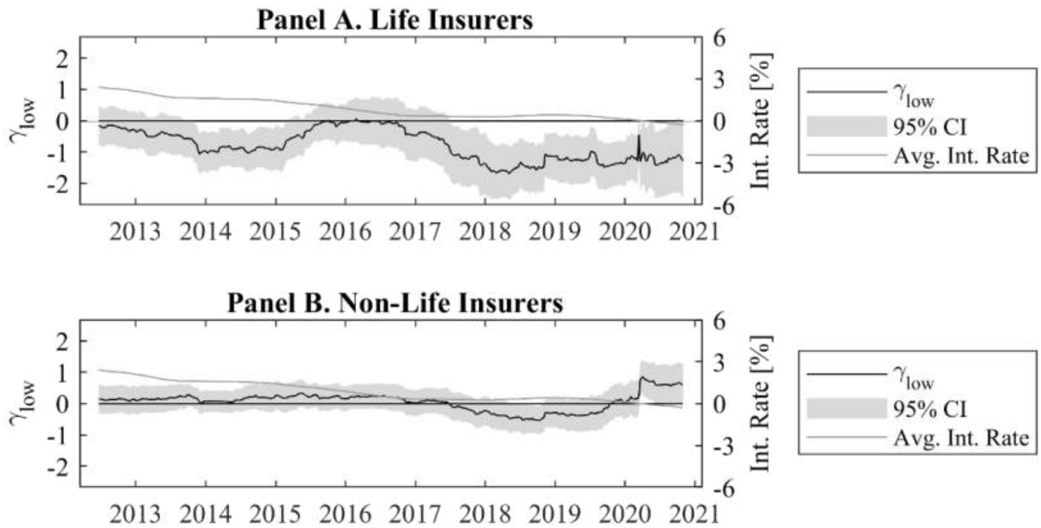


Fig. A18: Statistical Significance of Regression Model for Greek Insurers - Premium Shares - Weekly Data

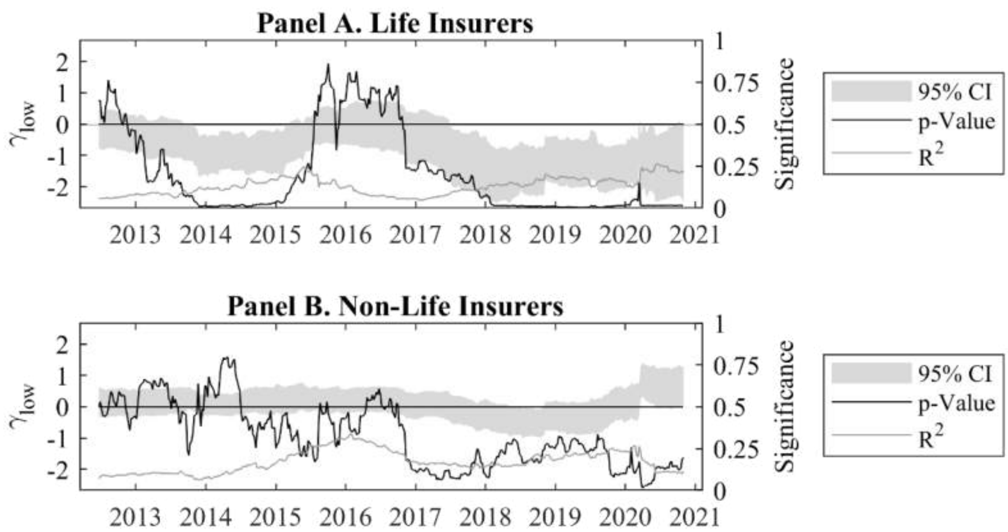


Fig. A19: Changes in Hungarian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

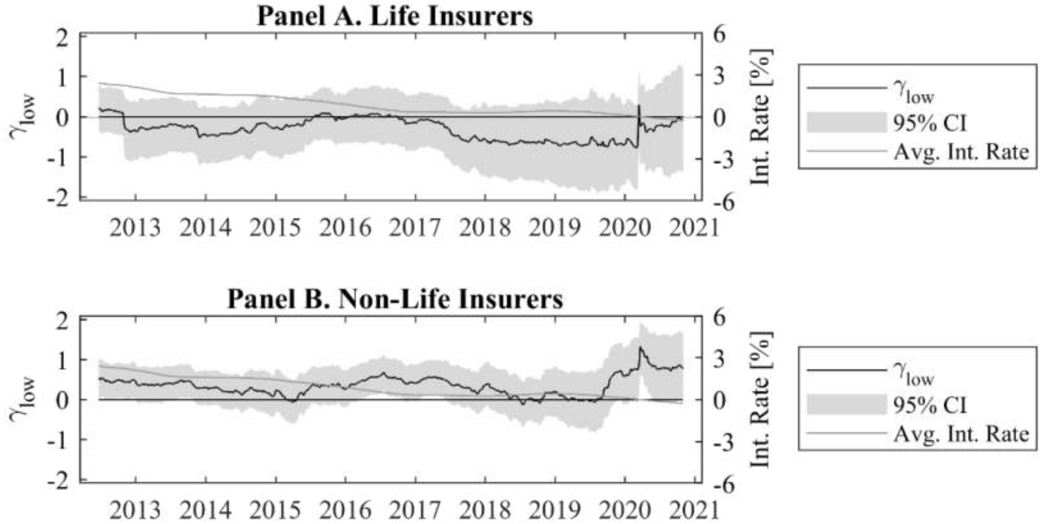


Fig. A20: Statistical Significance of Regression Model for Hungarian Insurers - Premium Shares - Weekly Data

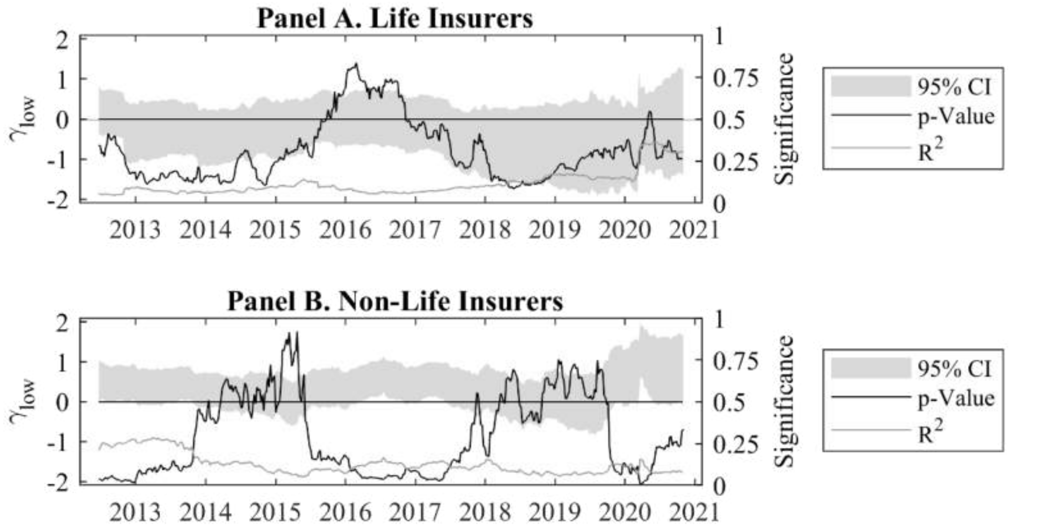


Fig. A21: Changes in Icelandic Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

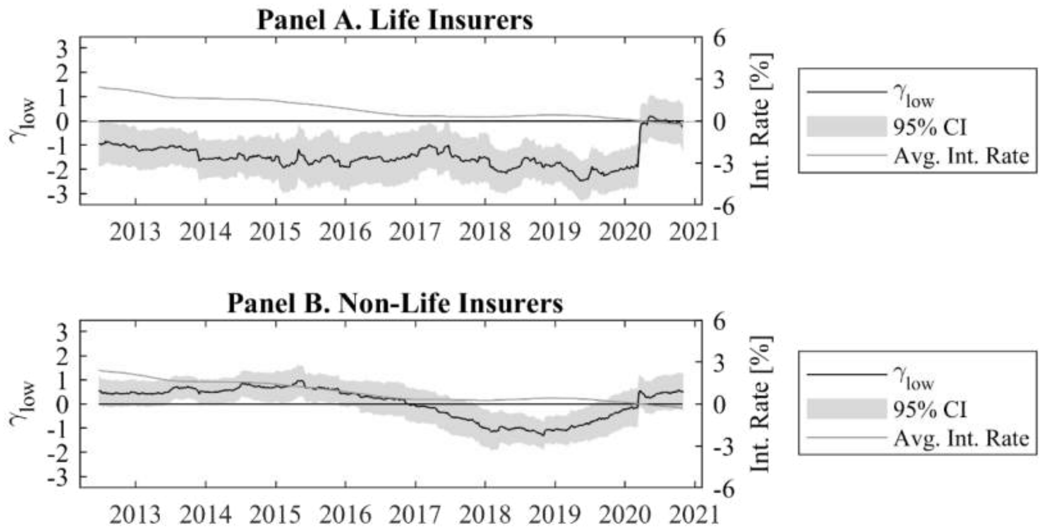


Fig. A22: Statistical Significance of Regression Model for Icelandic Insurers - Premium Shares - Weekly Data

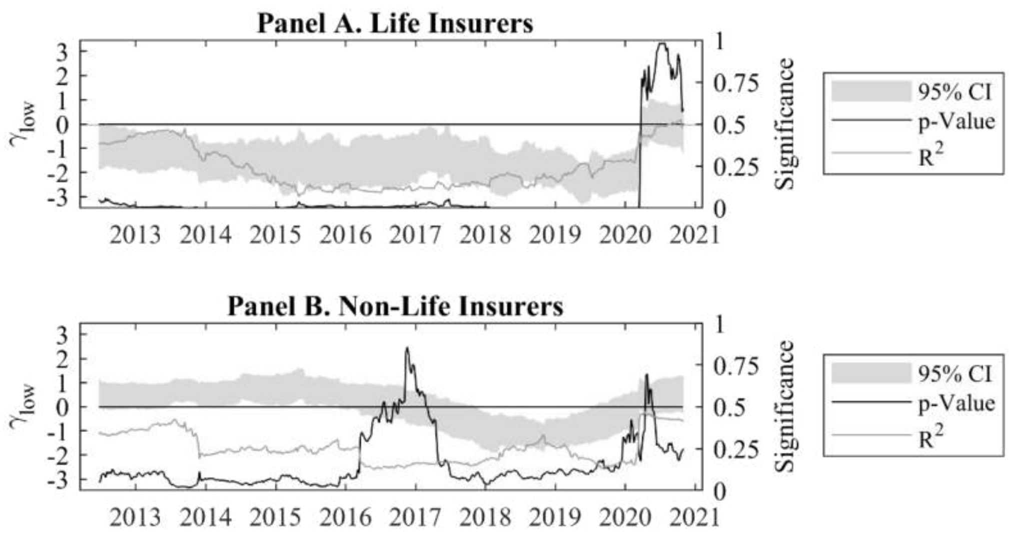
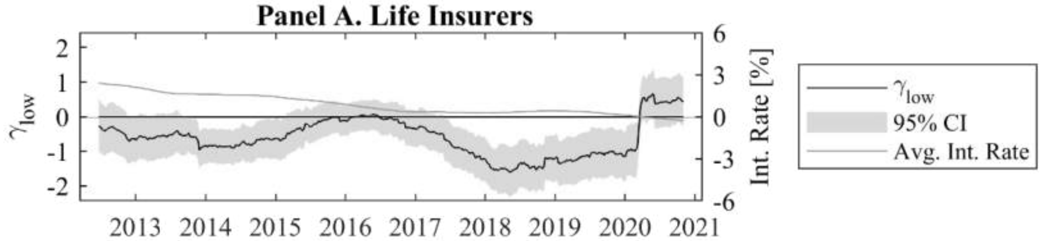


Fig. A23: Changes in Irish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data



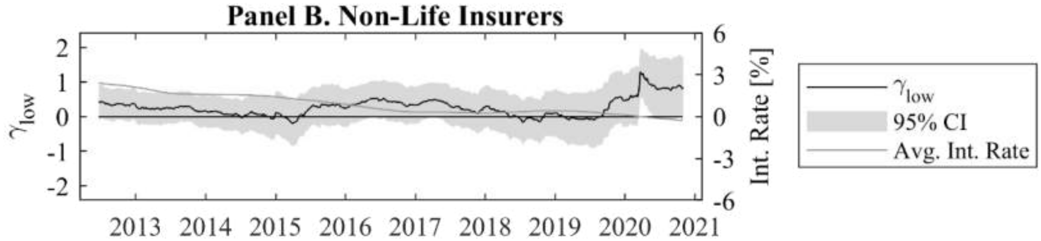
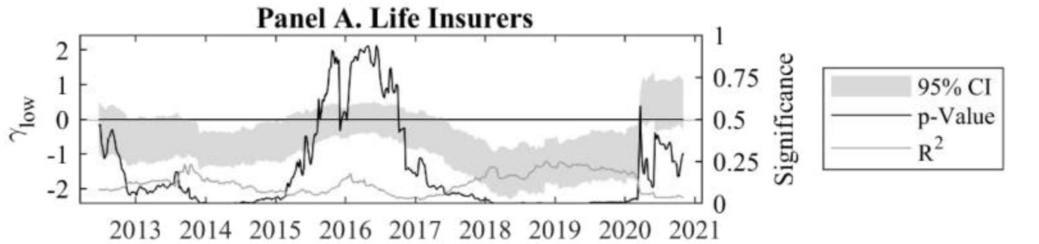


Fig. A24: Statistical Significance of Regression Model for Irish Insurers - Premium Shares - Weekly Data



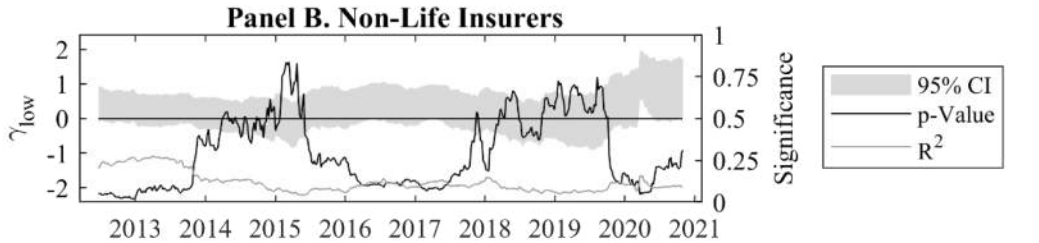


Fig. A25: Changes in Italian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

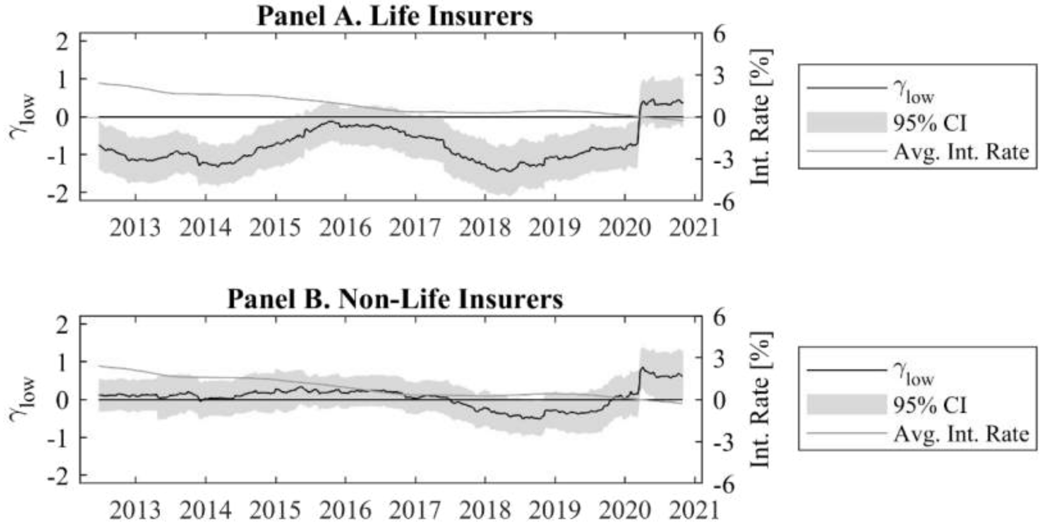


Fig. A26: Statistical Significance of Regression Model for Italian Insurers - Premium Shares - Weekly Data

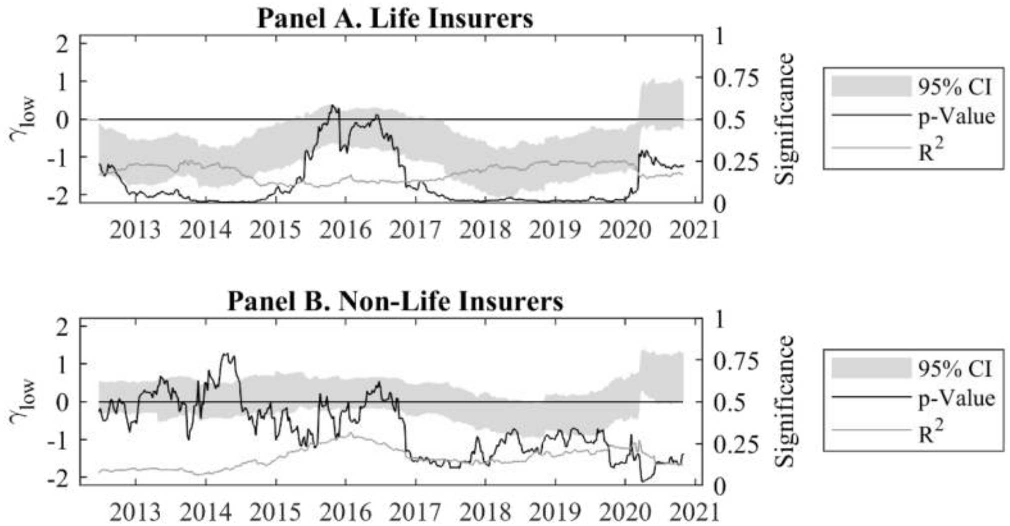


Fig. A27: Changes in Luxembourgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

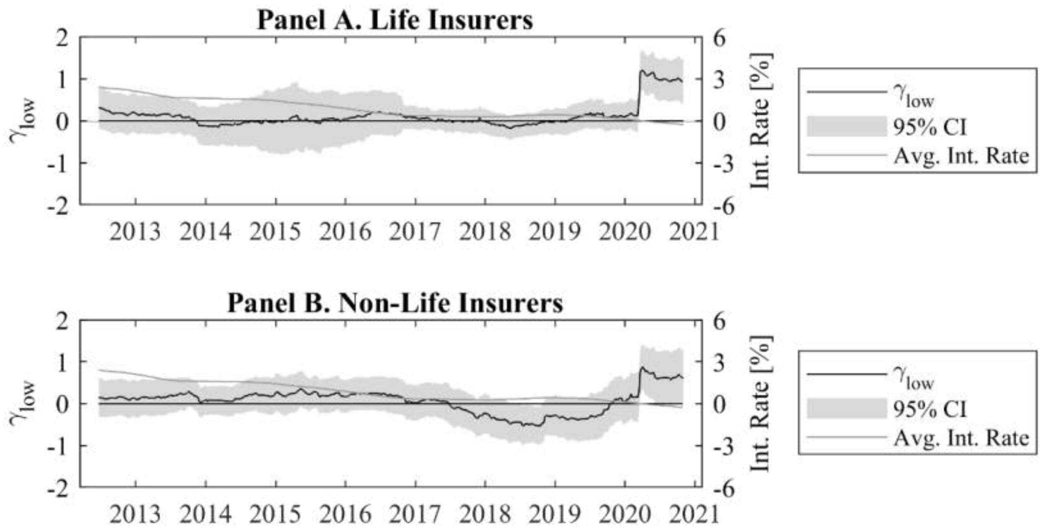


Fig. A28: Statistical Significance of Regression Model for Luxembourgian Insurers - Premium Shares - Weekly Data

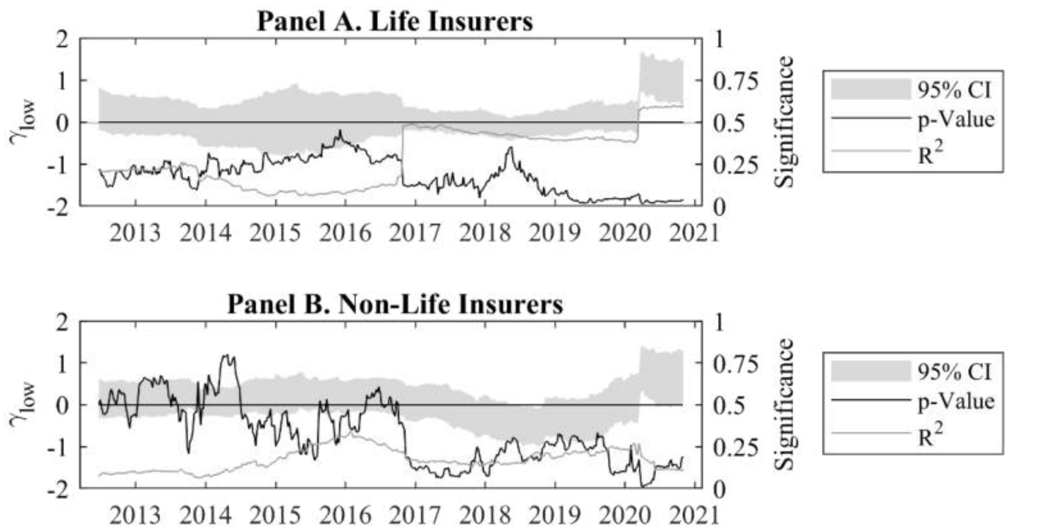


Fig. A29: Changes in Maltese Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

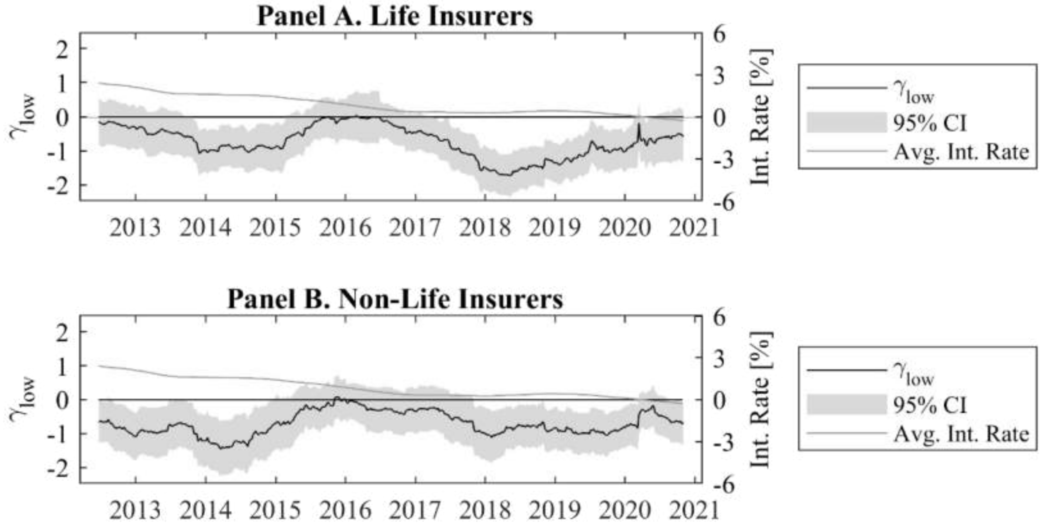


Fig. A30: Statistical Significance of Regression Model for Maltese Insurers - Premium Shares - Weekly Data

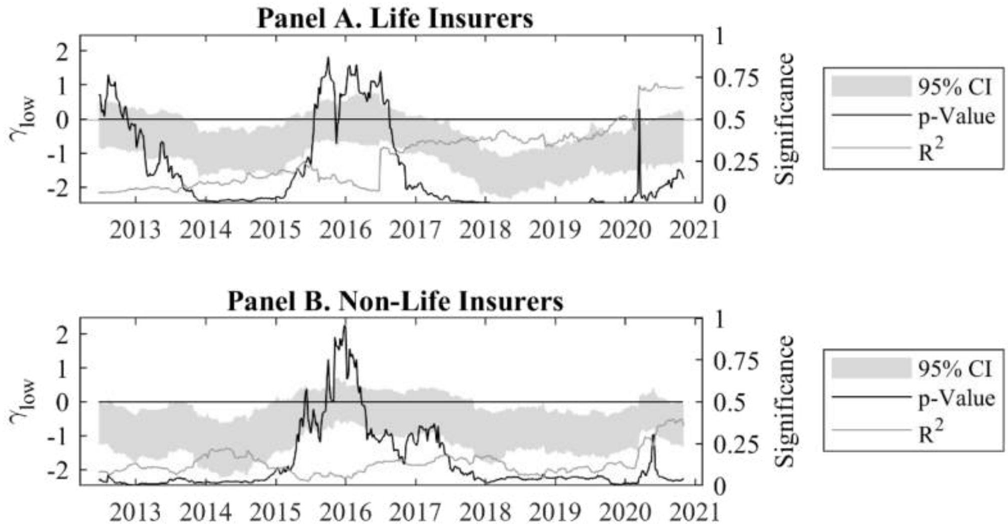
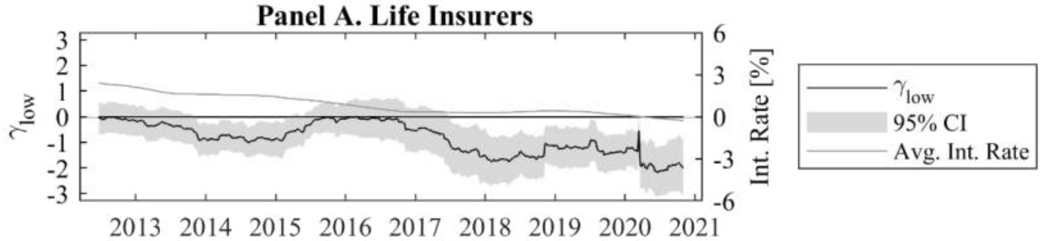


Fig. A31: Changes in Dutch Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data



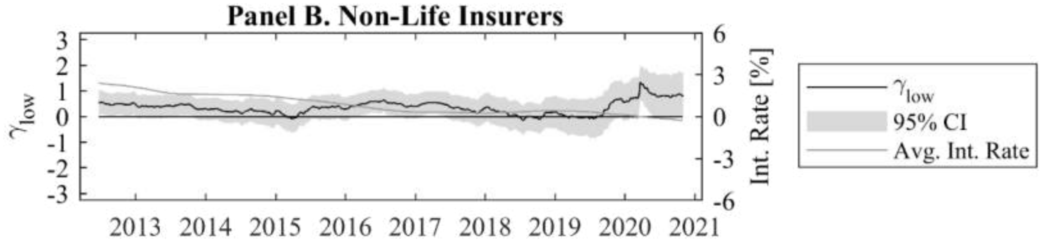
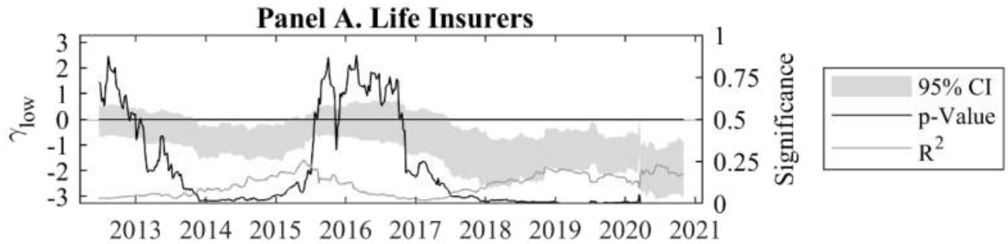


Fig. A32: Statistical Significance of Regression Model for Dutch Insurers - Premium Shares - Weekly Data



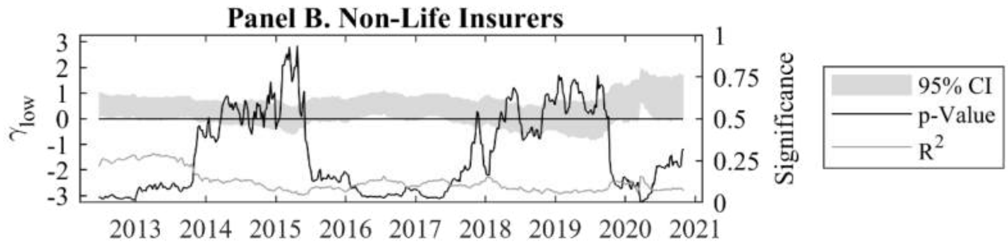


Fig. A33: Changes in Norwegian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

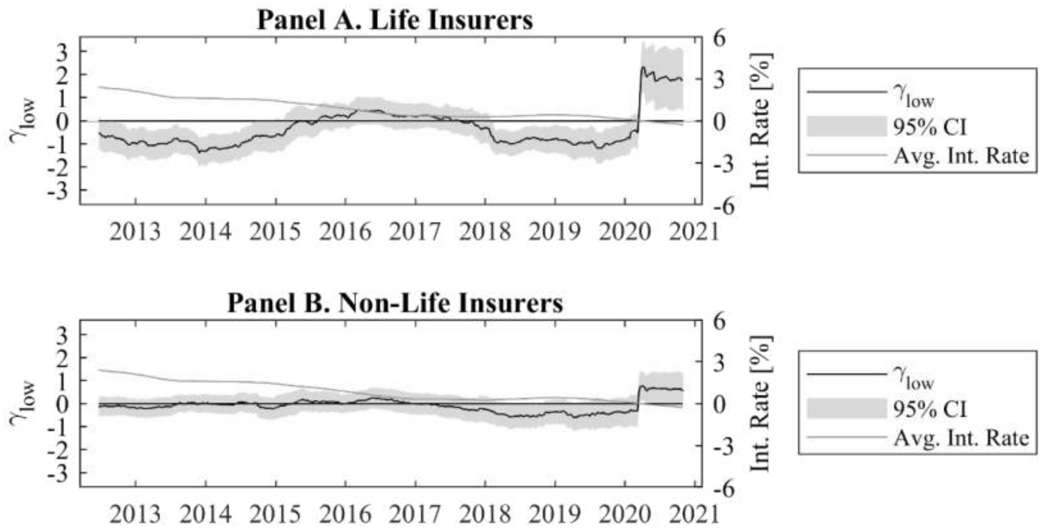


Fig. A34: Statistical Significance of Regression Model for Norwegian Insurers - Premium Shares - Weekly Data

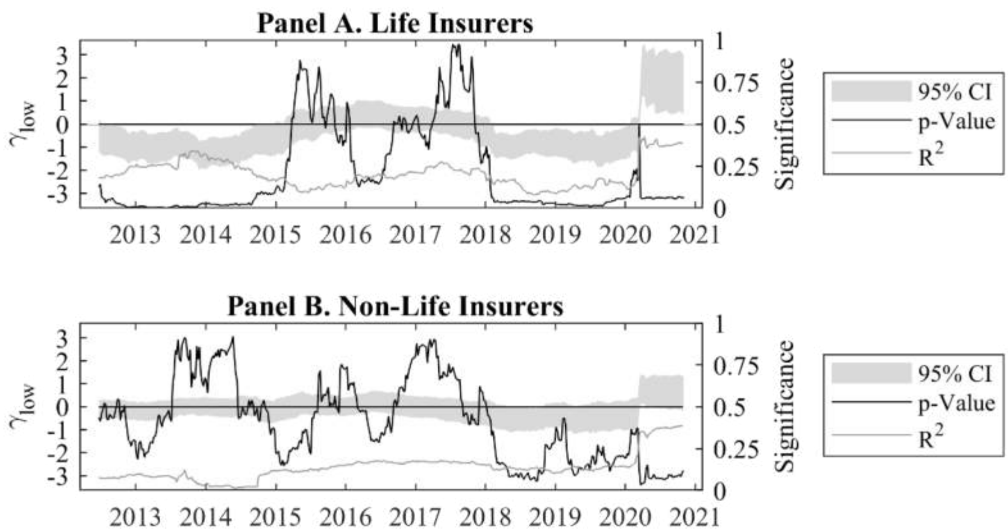


Fig. A35: Changes in Polish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

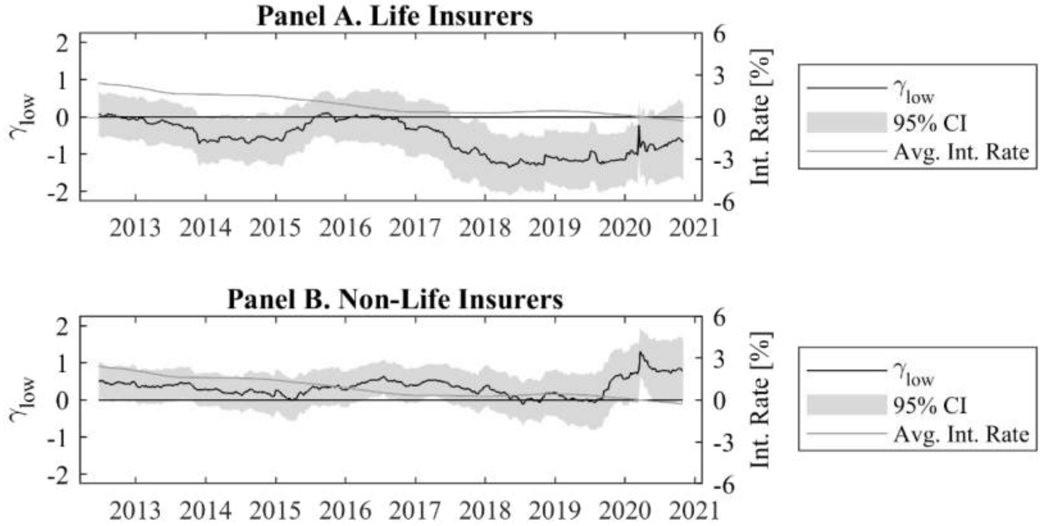


Fig. A36: Statistical Significance of Regression Model for Polish Insurers - Premium Shares - Weekly Data

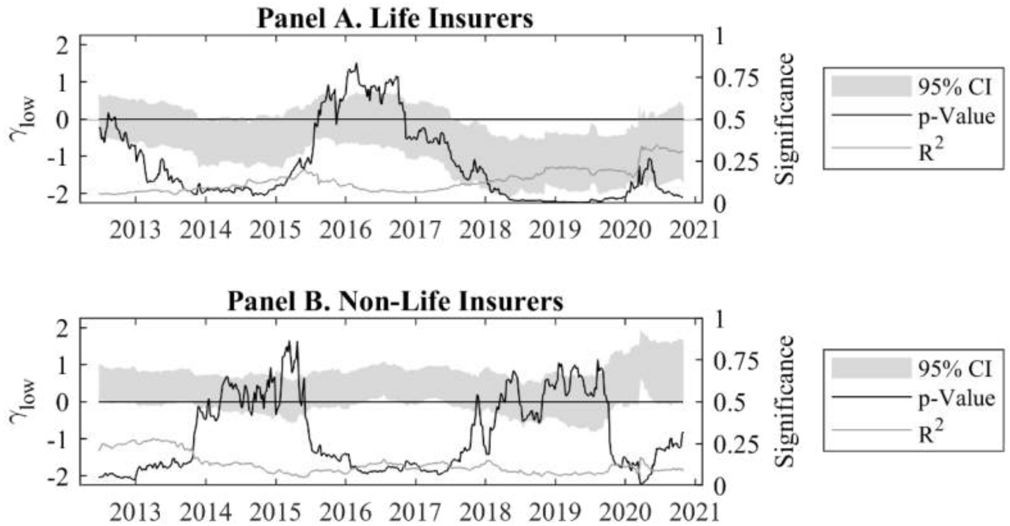


Fig. A37: Changes in Russian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

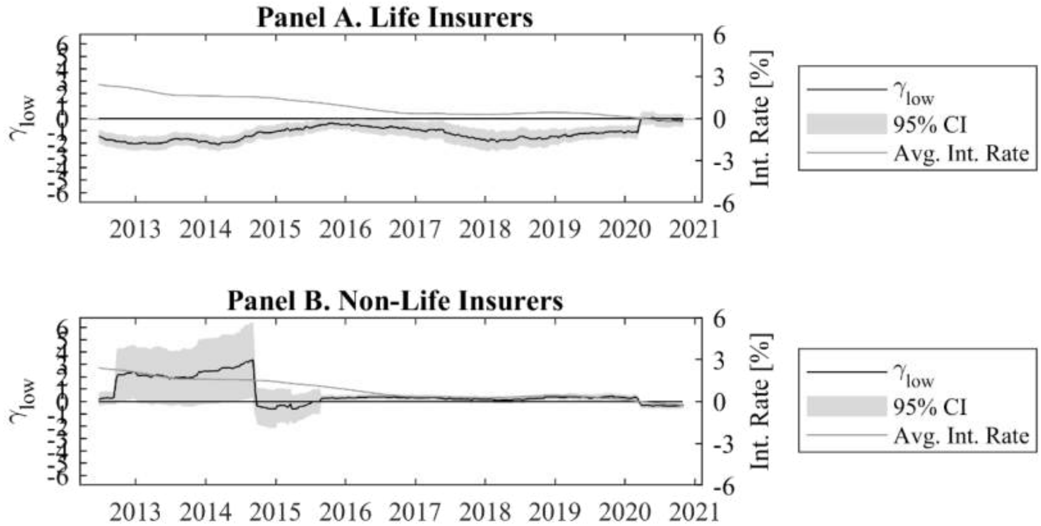


Fig. A38: Statistical Significance of Regression Model for Russian Insurers - Premium Shares - Weekly Data

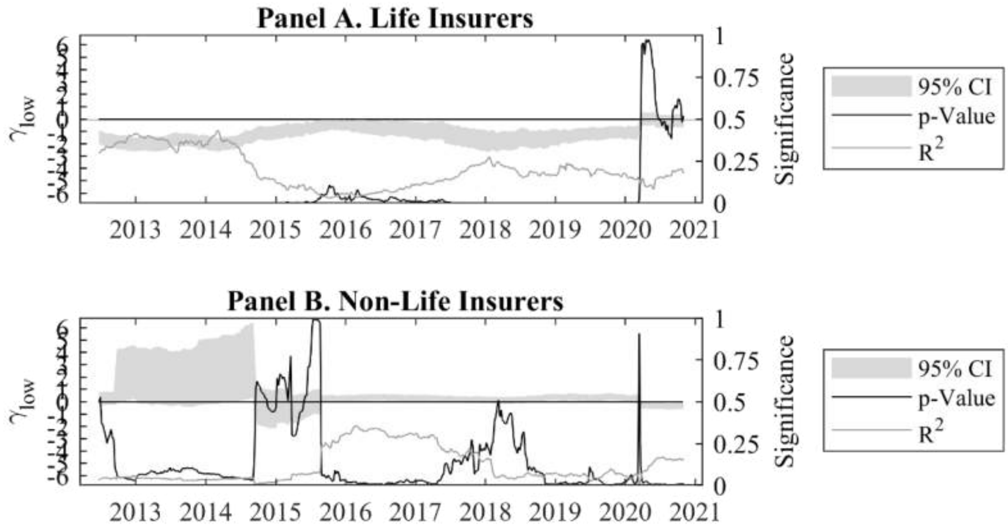


Fig. A39: Changes in Serbian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

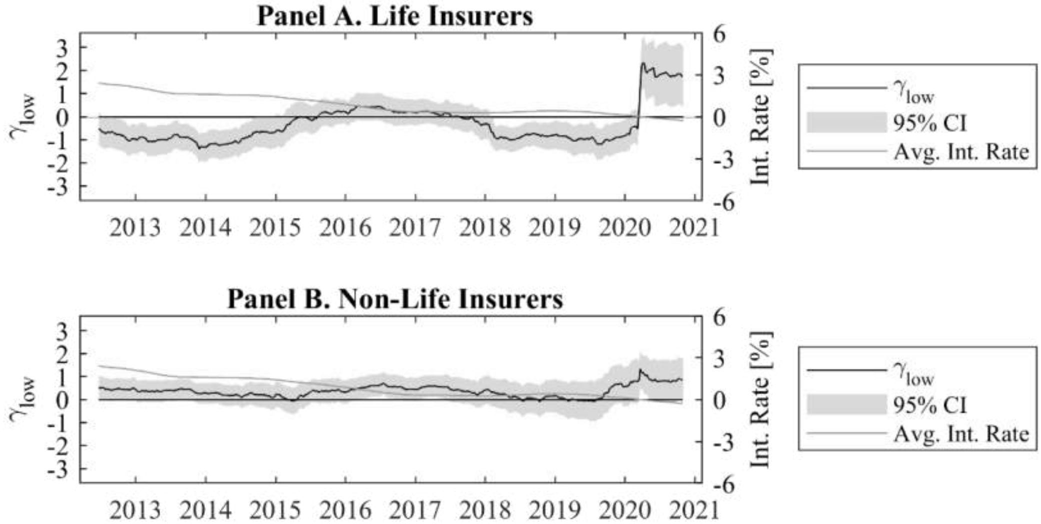


Fig. A40: Statistical Significance of Regression Model for Serbian Insurers - Premium Shares - Weekly Data

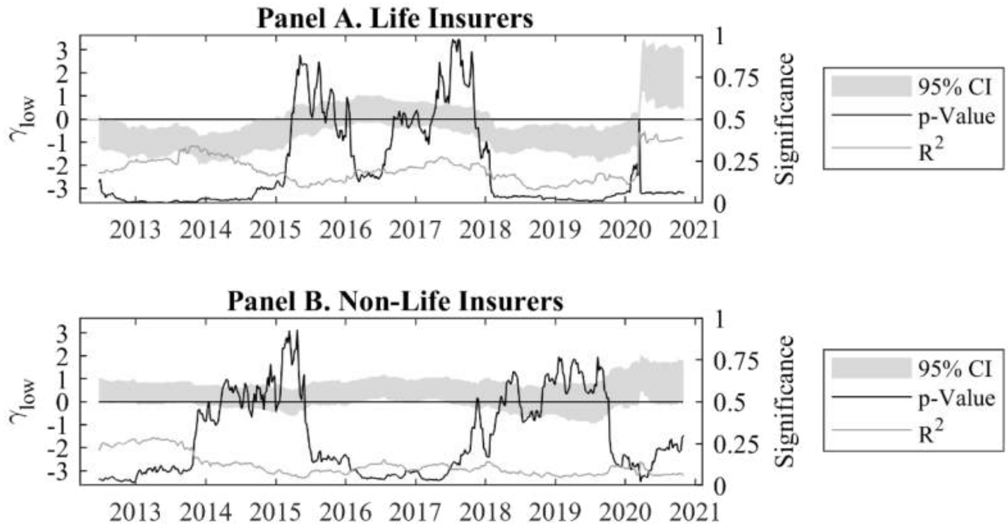


Fig. A41: Changes in Slovenian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

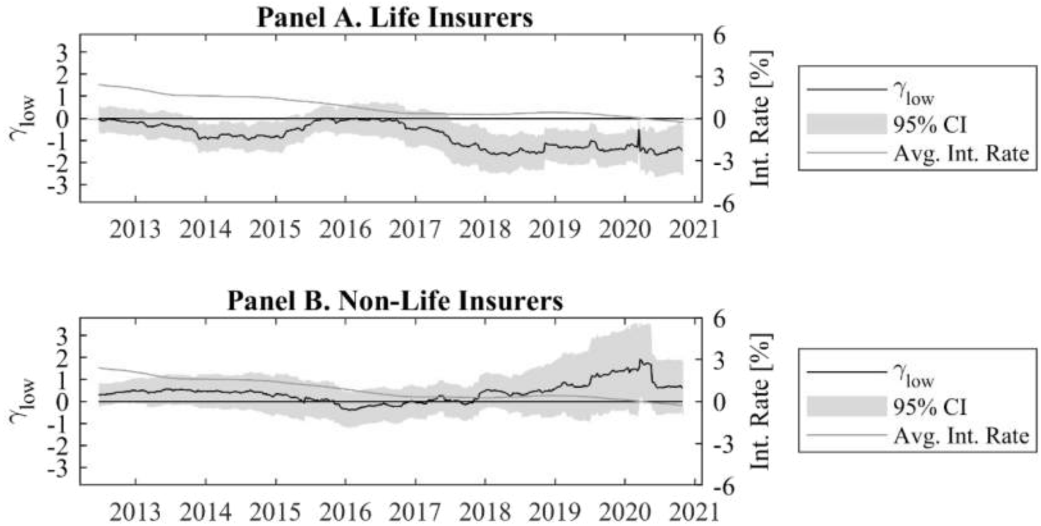


Fig. A42: Statistical Significance of Regression Model for Slovenian Insurers - Premium Shares - Weekly Data

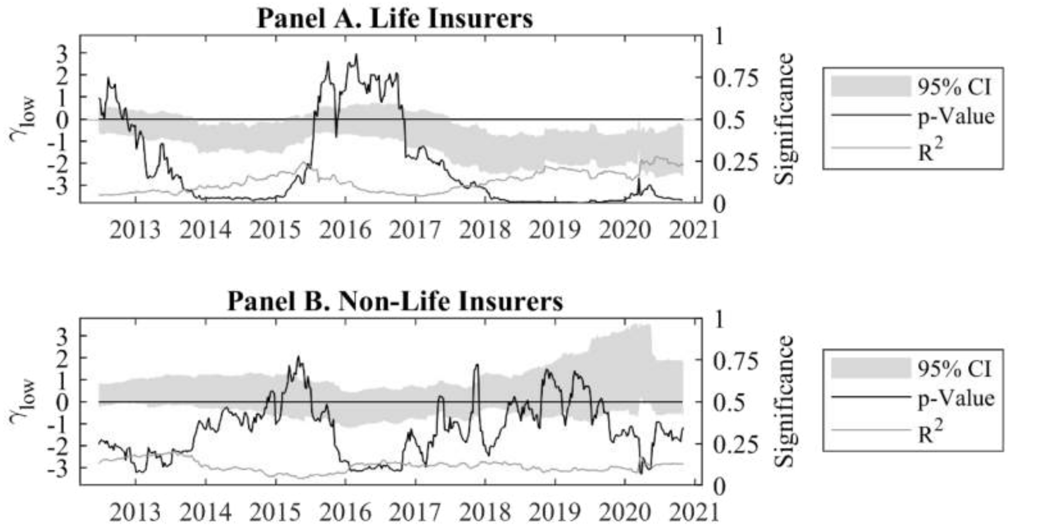


Fig. A43: Changes in Spanish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

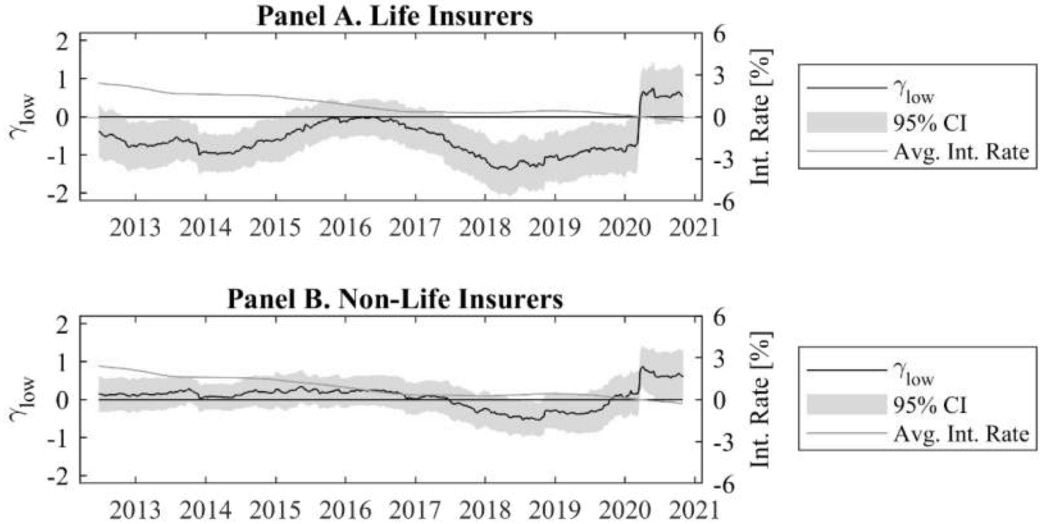


Fig. A44: Statistical Significance of Regression Model for Spanish Insurers - Premium Shares - Weekly Data

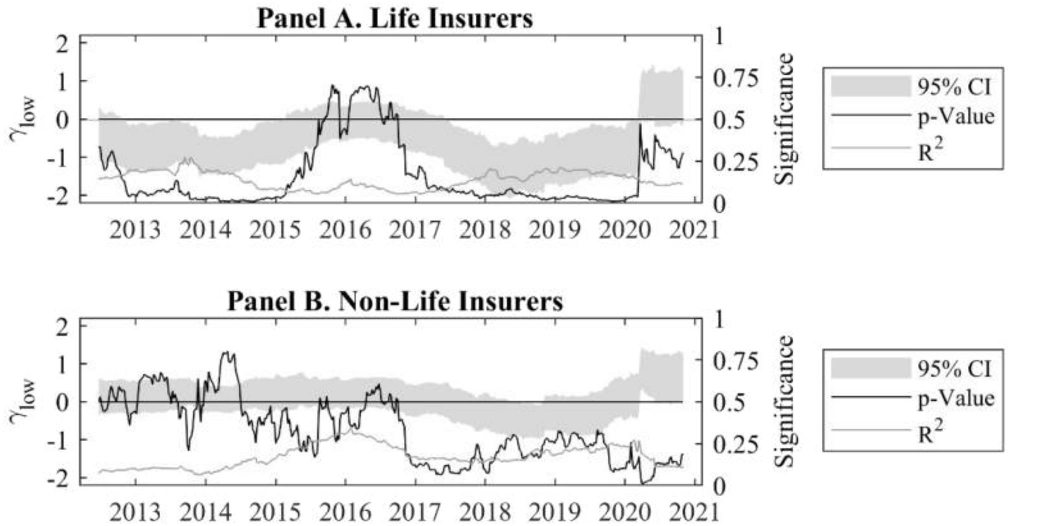


Fig. A45: Changes in Swiss Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

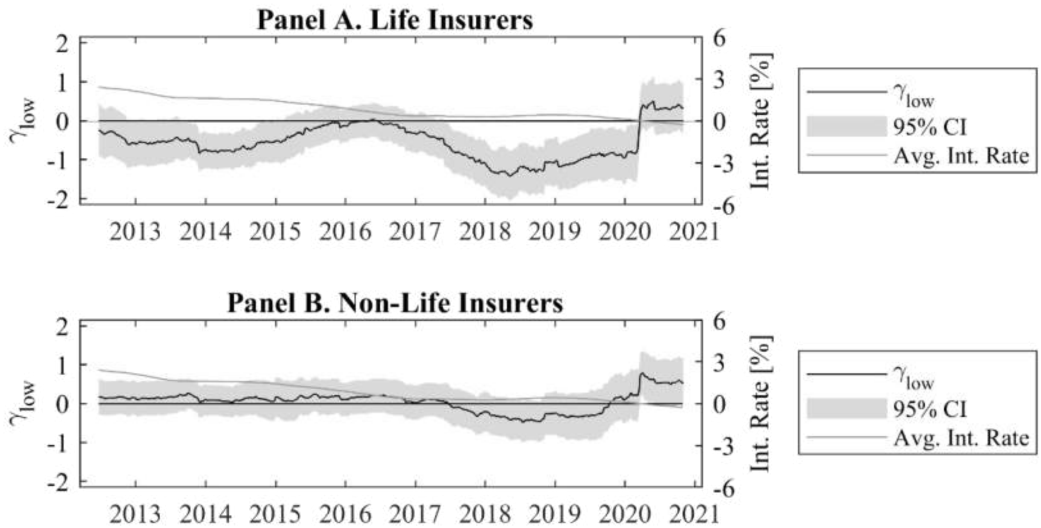


Fig. A46: Statistical Significance of Regression Model for Swiss Insurers - Premium Shares - Weekly Data

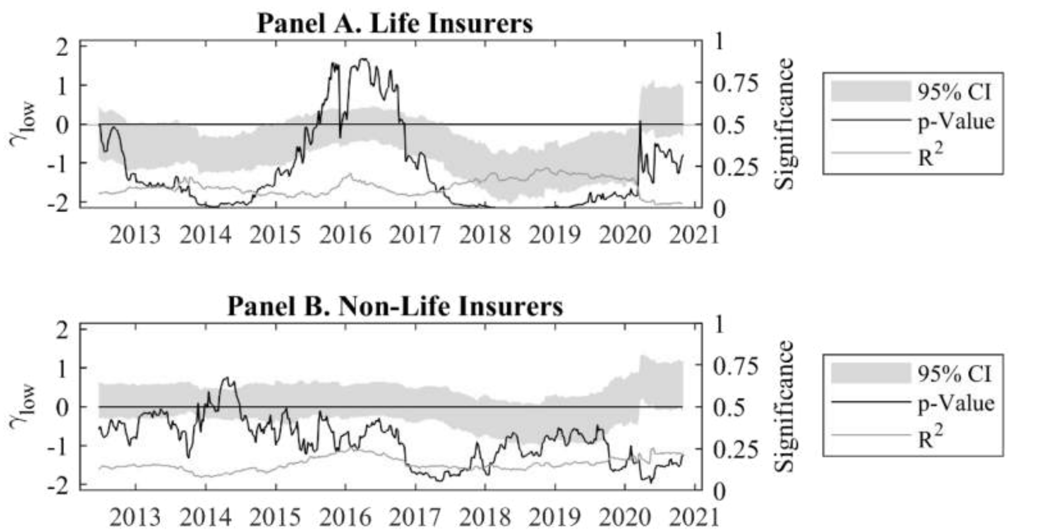


Fig. A47: Changes in Turkish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Weekly Data

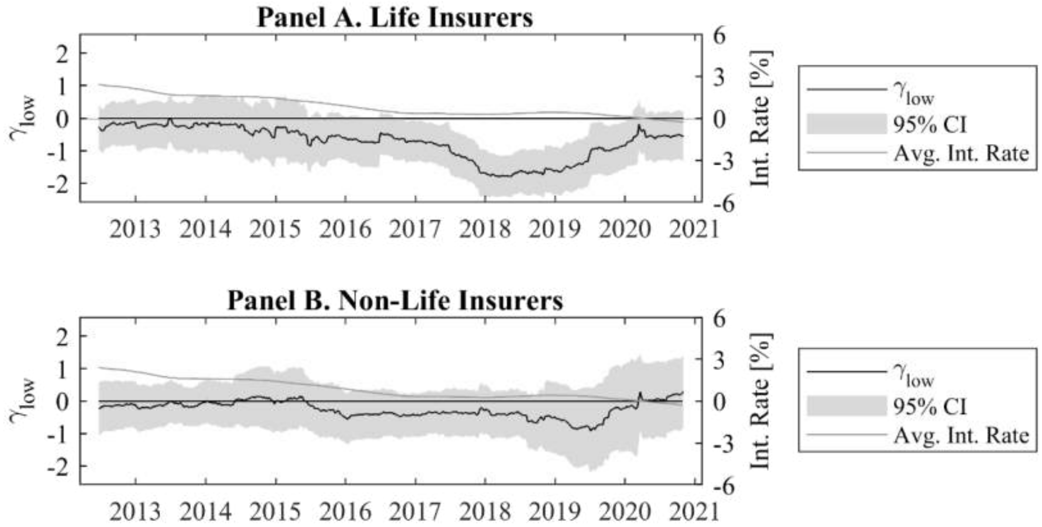
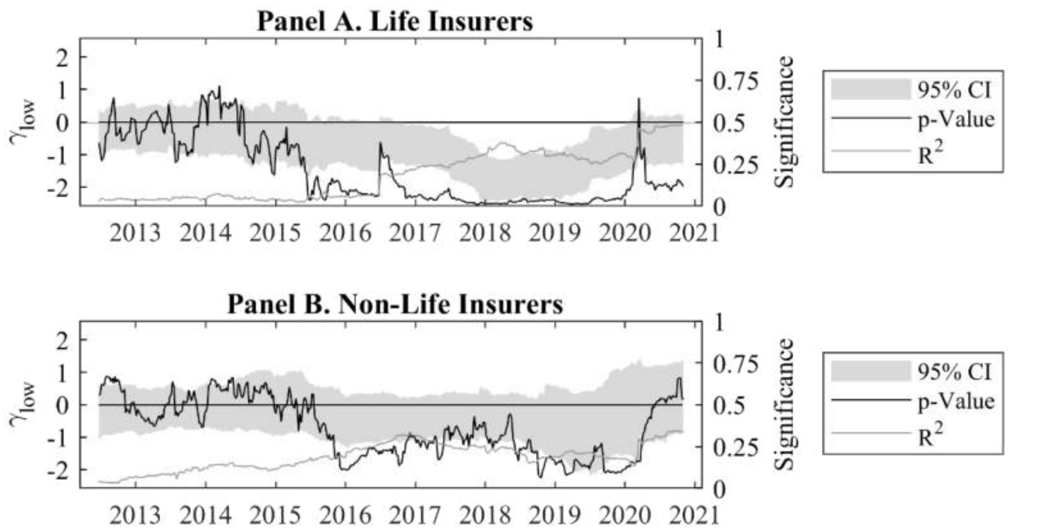


Fig. A48: Statistical Significance of Regression Model for Turkish Insurers - Premium Shares - Weekly Data



Appendix B: Change in European Interest Rate Sensitivities by Country (Premium Share Allocation – Daily Data)

Fig. B1: Changes in Austrian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

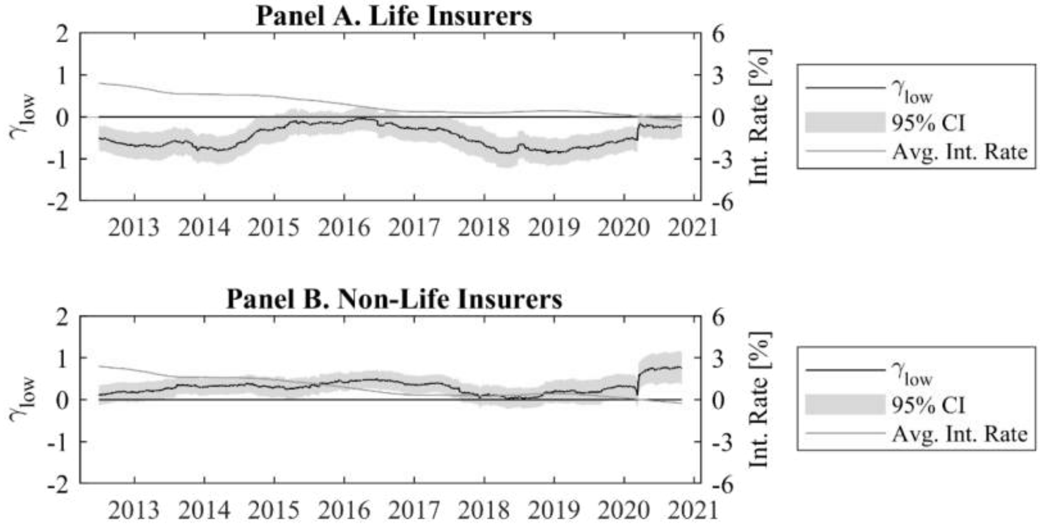


Fig. B2: Statistical Significance of Regression Model for Austrian Insurers - Premium Shares - Daily Data

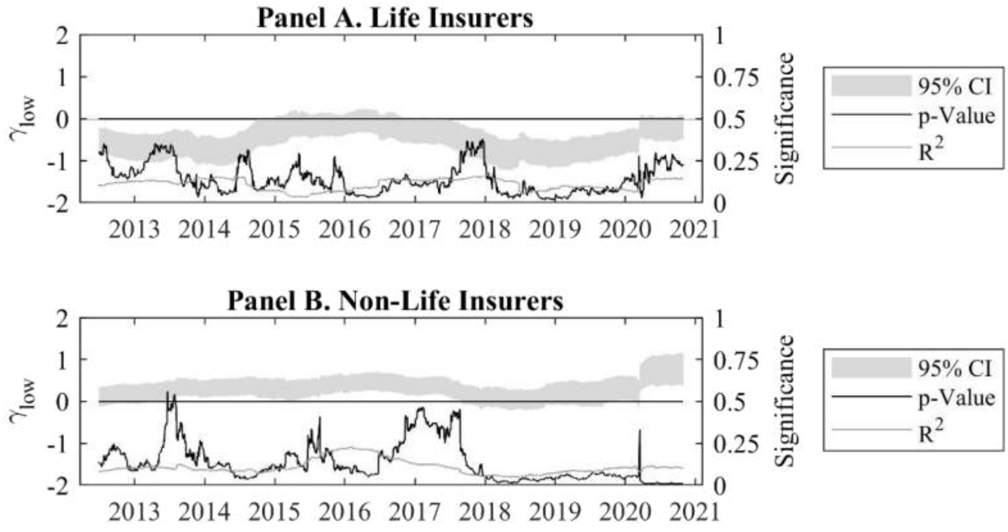


Fig. B3: Changes in Belgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

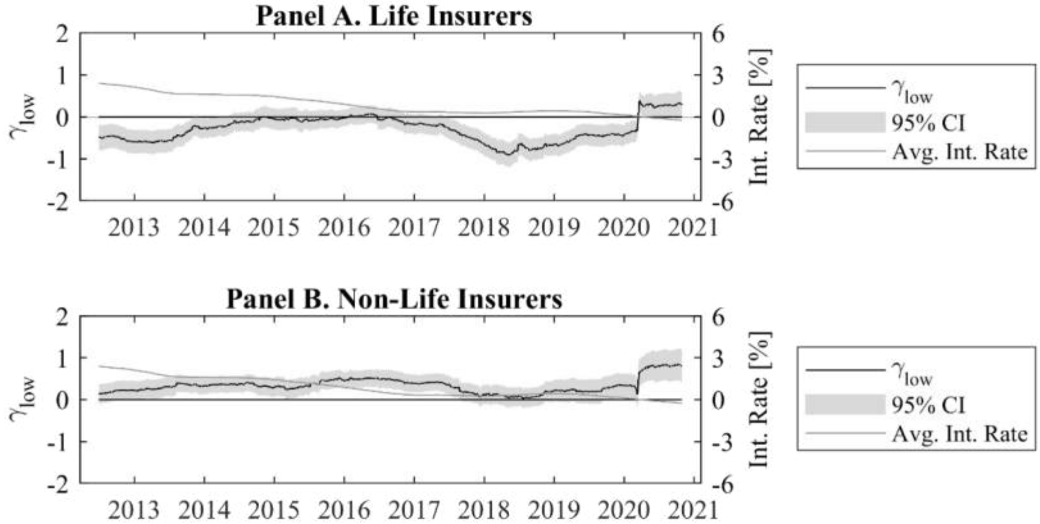


Fig. B4: Statistical Significance of Regression Model for Belgian Insurers - Premium Shares - Daily Data

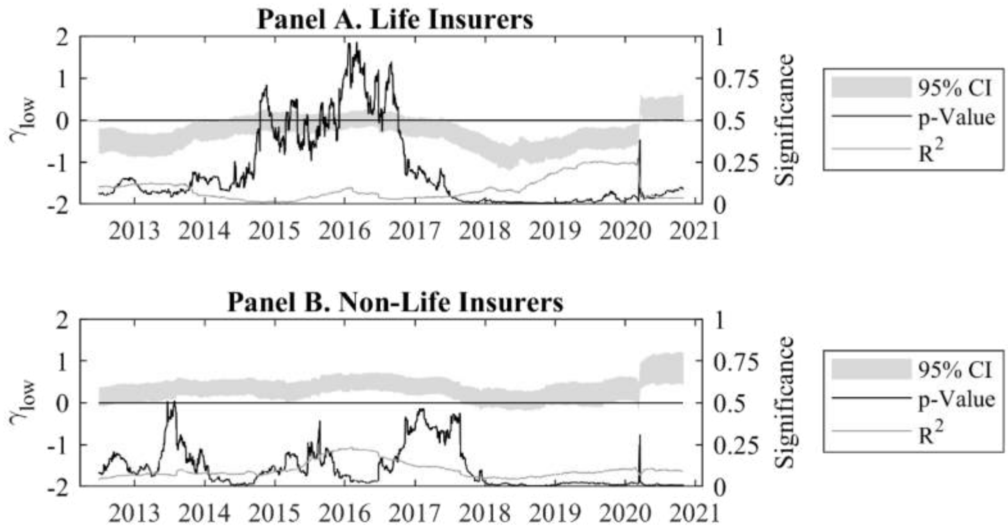


Fig. B5: Changes in Croatian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

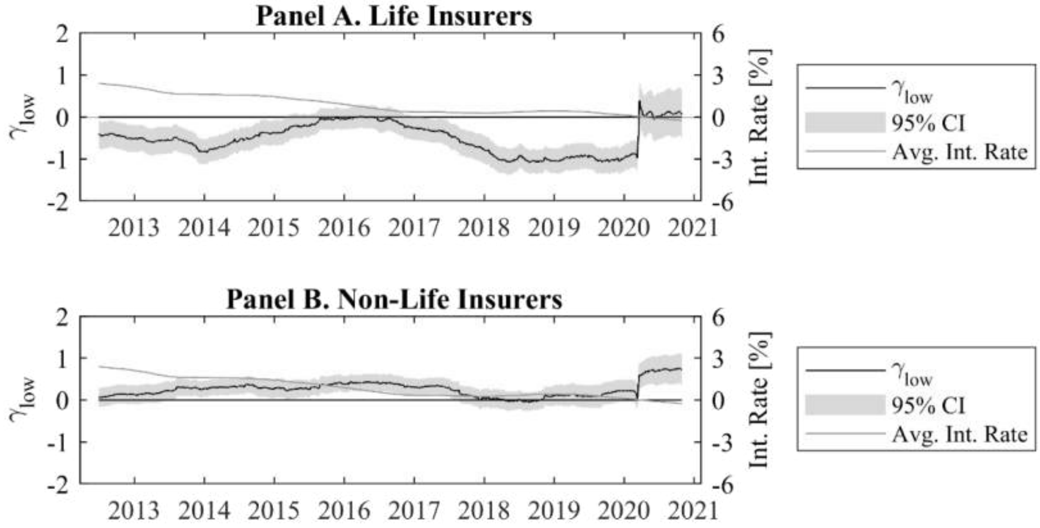


Fig. B6: Statistical Significance of Regression Model for Croatian Insurers - Premium Shares - Daily Data

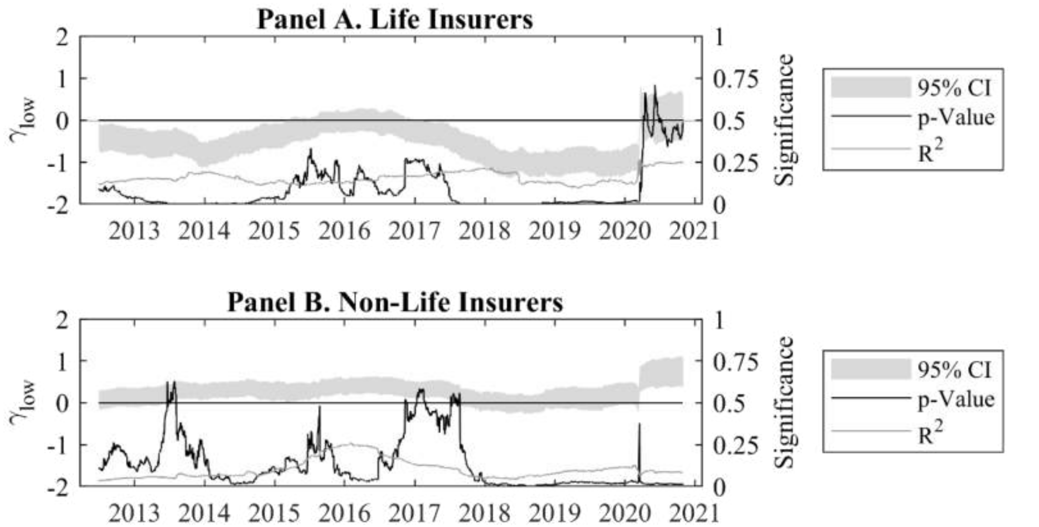


Fig. B7: Changes in Cyprian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

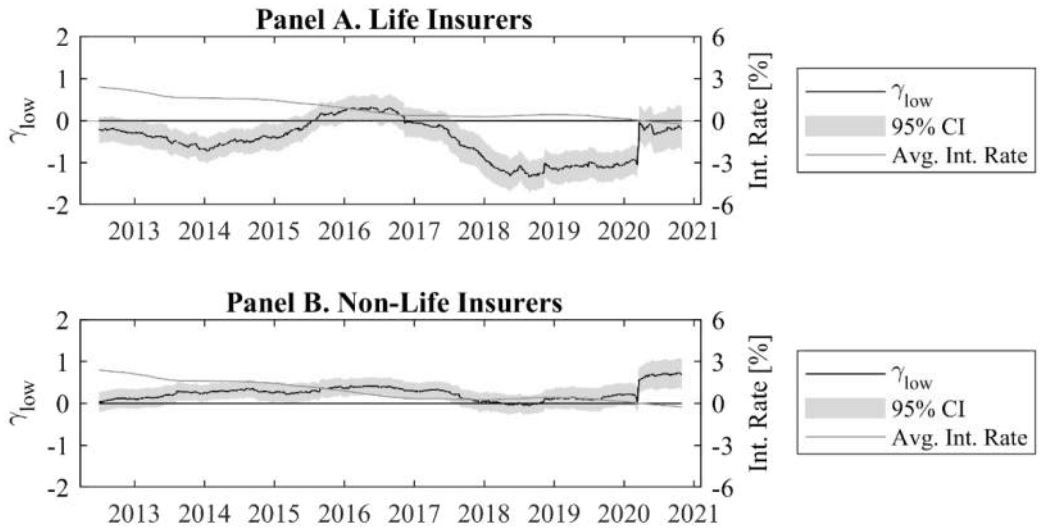


Fig. B8: Statistical Significance of Regression Model for Cyprian Insurers - Premium Shares - Daily Data

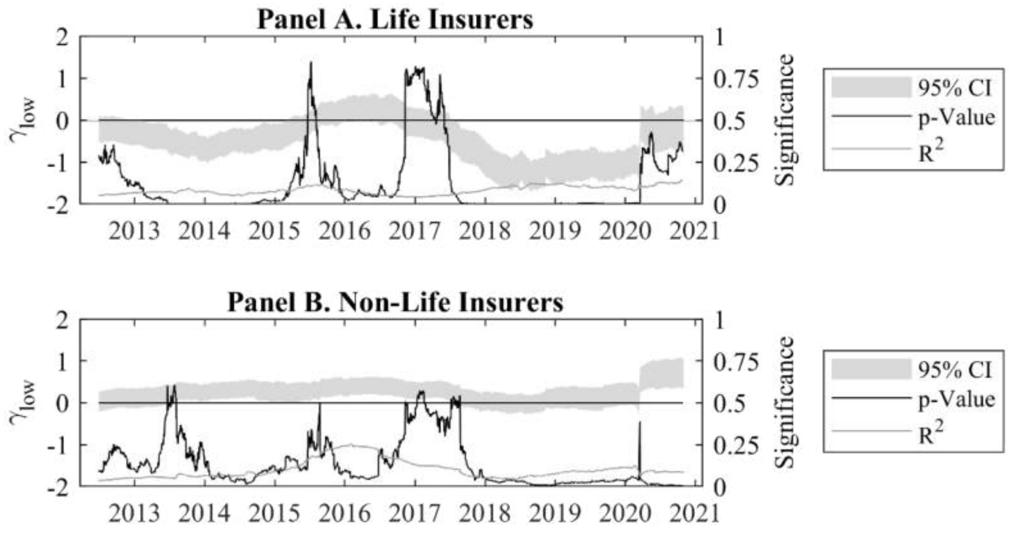


Fig. B9: Changes in Danish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

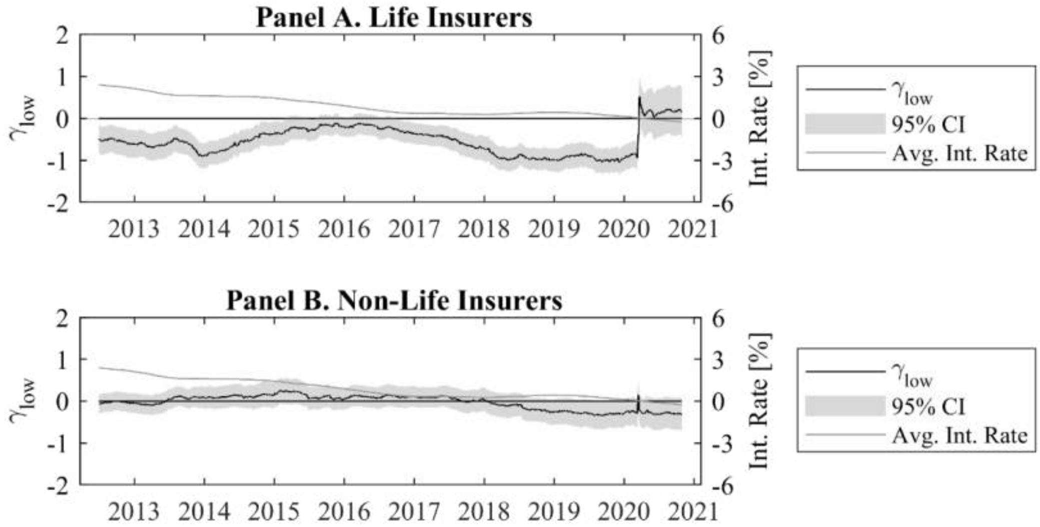


Fig. B10: Statistical Significance of Regression Model for Danish Insurers - Premium Shares - Daily Data

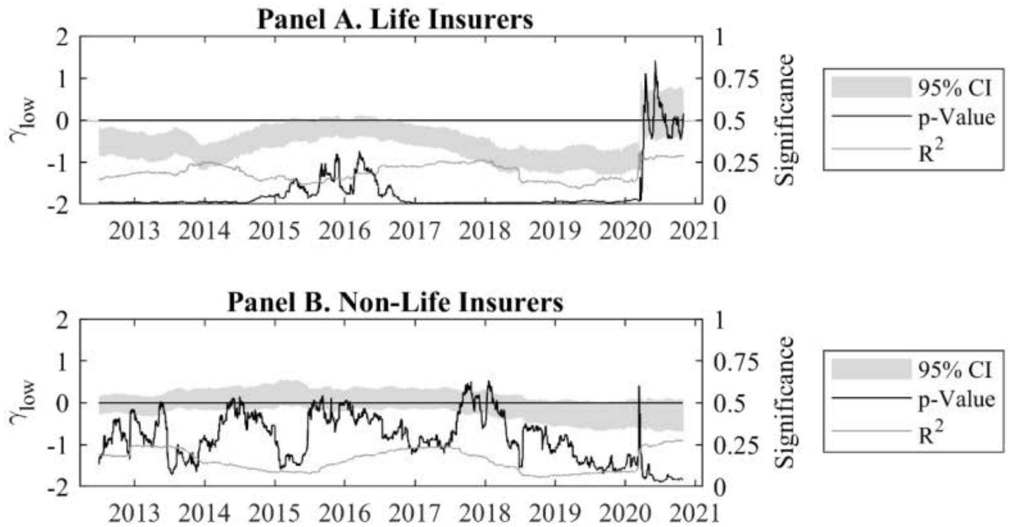


Fig. B11: Changes in Finnish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

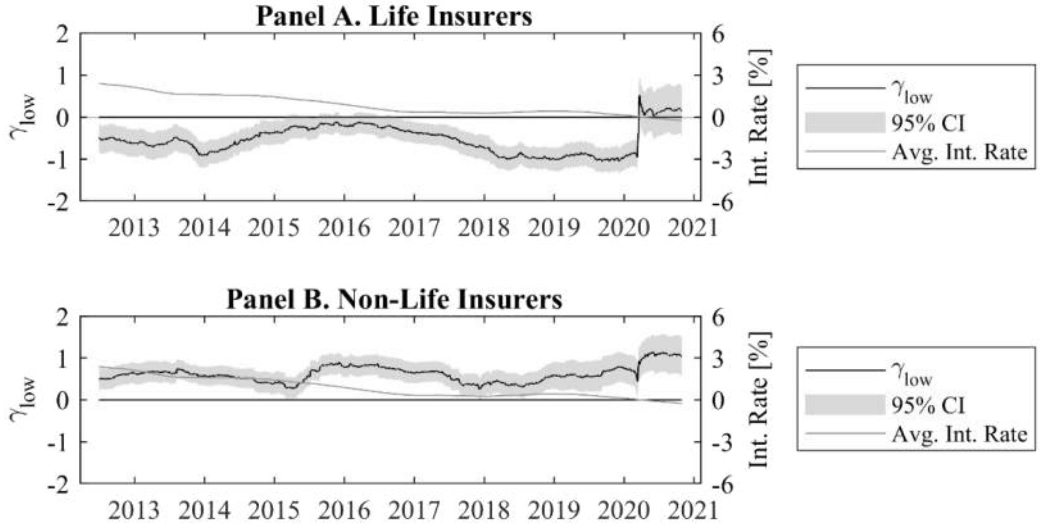


Fig. B12: Statistical Significance of Regression Model for Finnish Insurers - Premium Shares - Daily Data

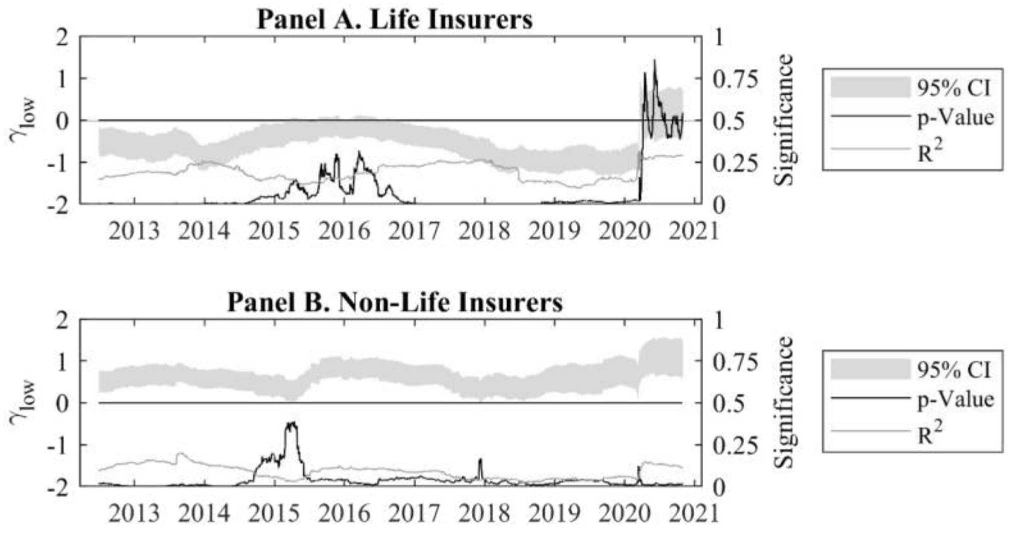


Fig. B13: Changes in French Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

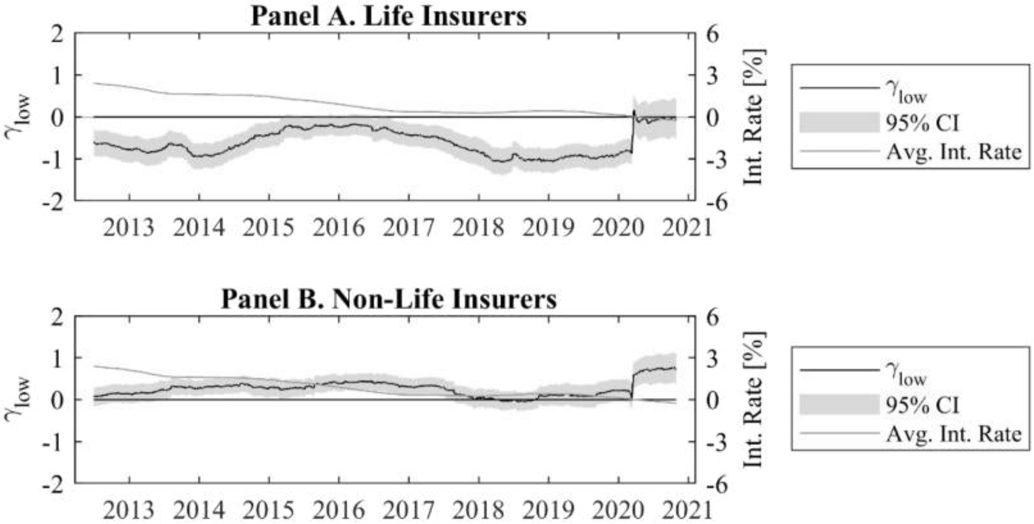


Fig. B14: Statistical Significance of Regression Model for French Insurers - Premium Shares - Daily Data

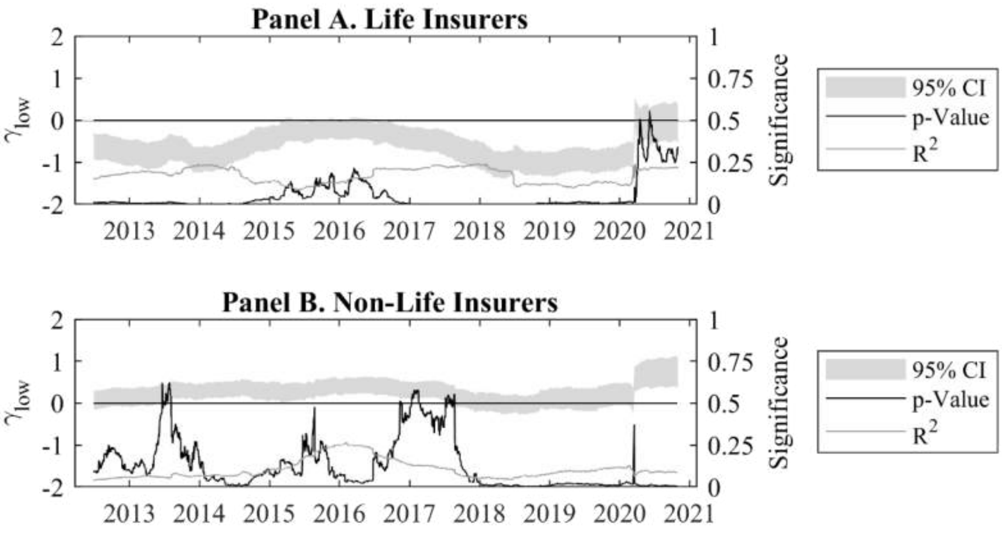


Fig. B15: Changes in German Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

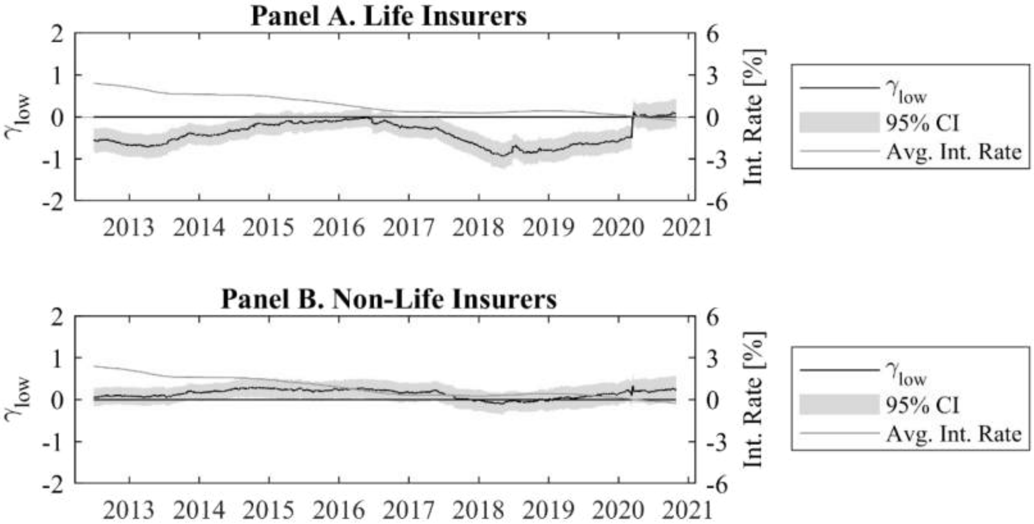


Fig. B16: Statistical Significance of Regression Model for German Insurers - Premium Shares - Daily Data

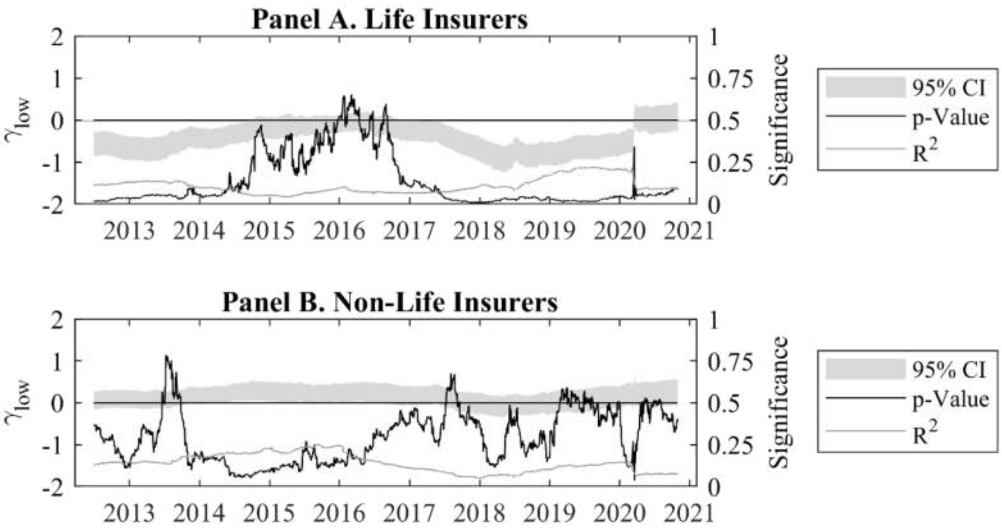


Fig. B17: Changes in Greek Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

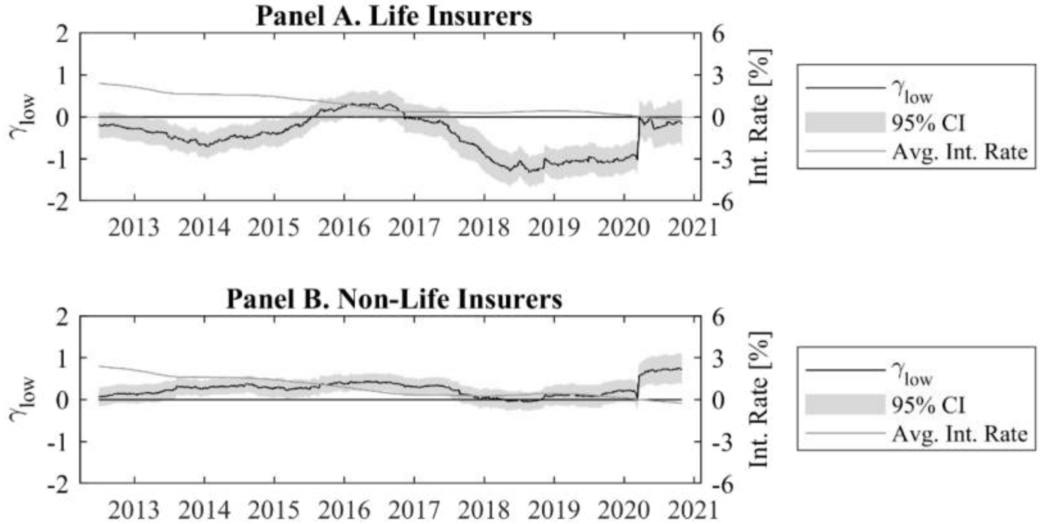


Fig. B18: Statistical Significance of Regression Model for Greek Insurers - Premium Shares - Daily Data

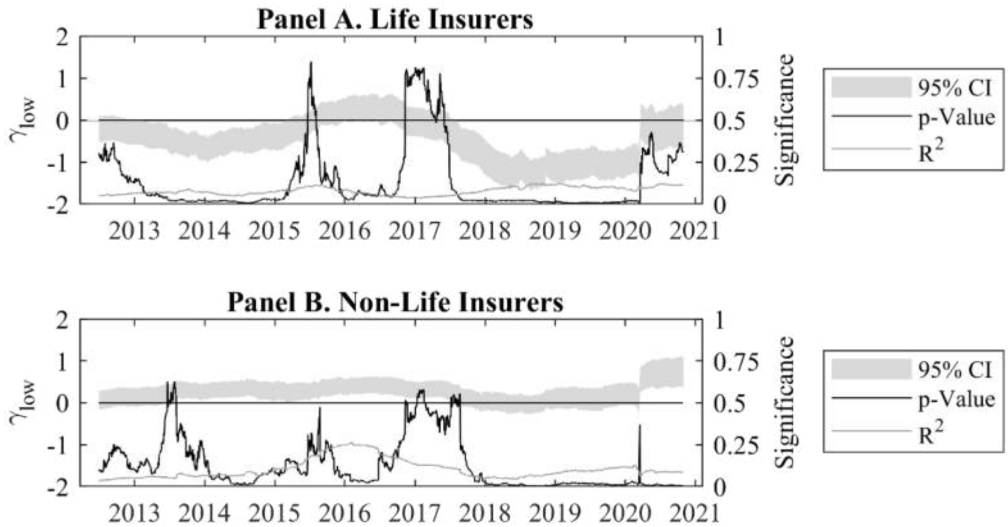


Fig. B19: Changes in Hungarian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

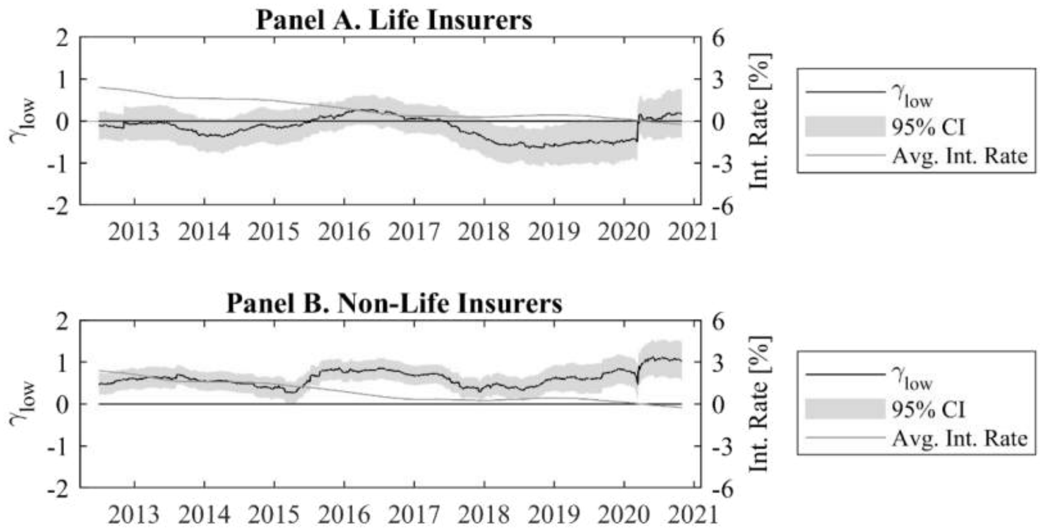


Fig. B20: Statistical Significance of Regression Model for Hungarian Insurers - Premium Shares - Daily Data

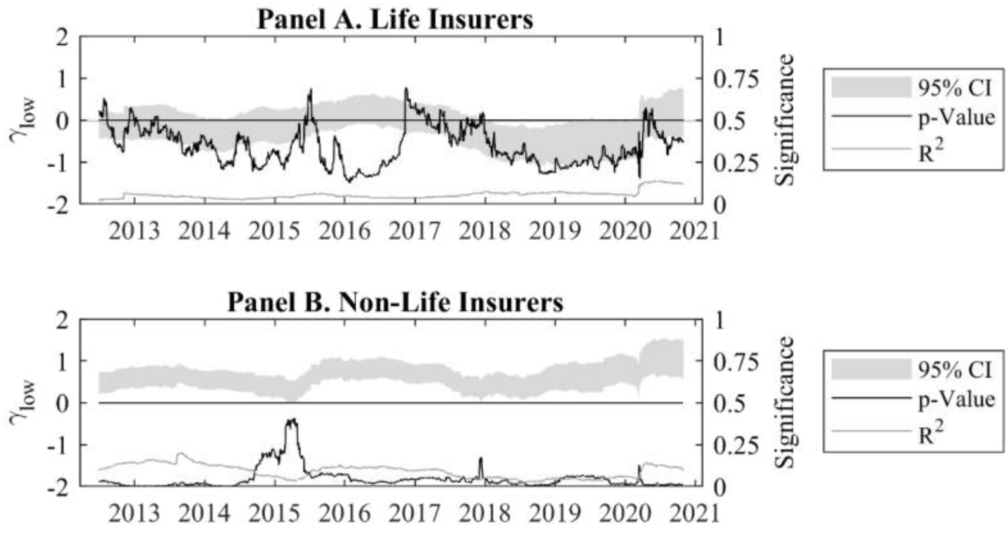


Fig. B21: Changes in Icelandic Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

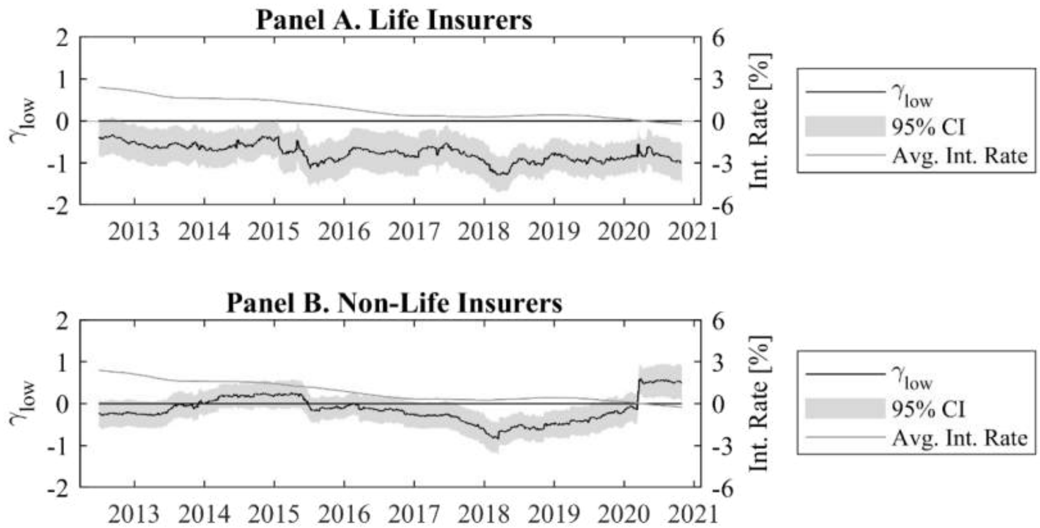


Fig. B22: Statistical Significance of Regression Model for Icelandic Insurers - Premium Shares - Daily Data

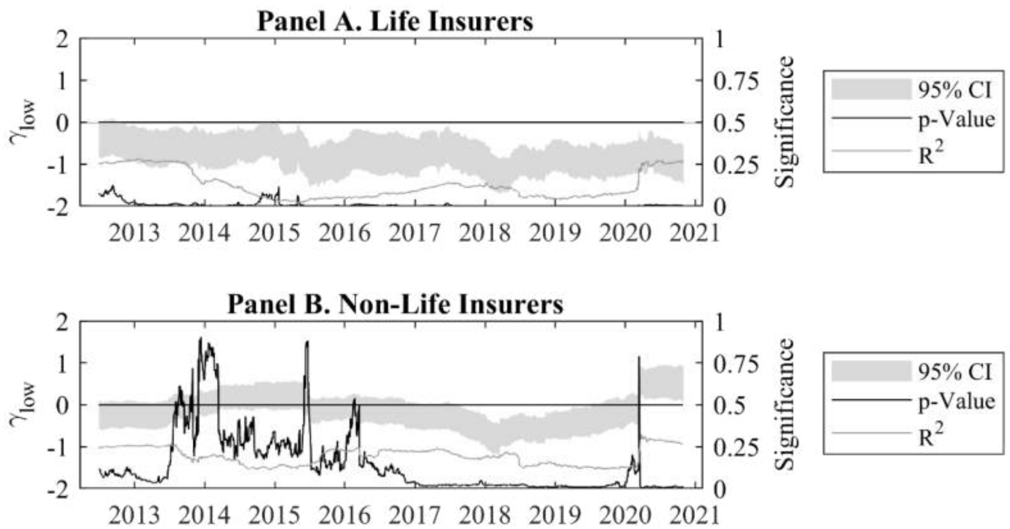


Fig. B23: Changes in Irish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

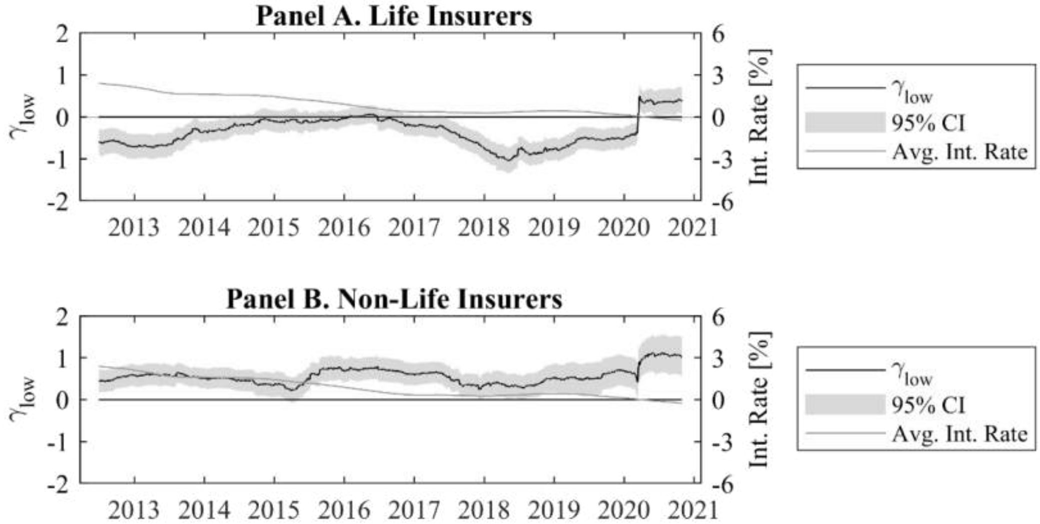


Fig. B24: Statistical Significance of Regression Model for Irish Insurers - Premium Shares - Daily Data

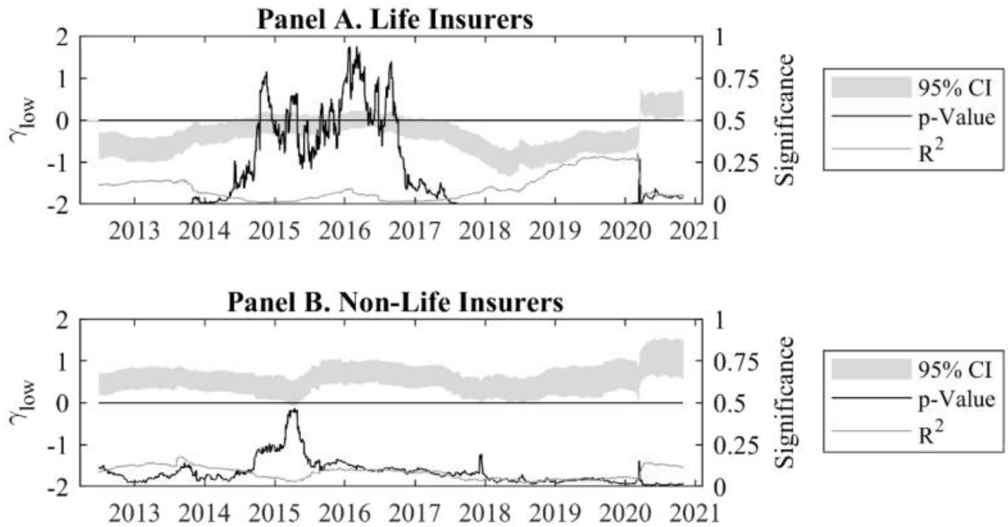


Fig. B25: Changes in Italian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

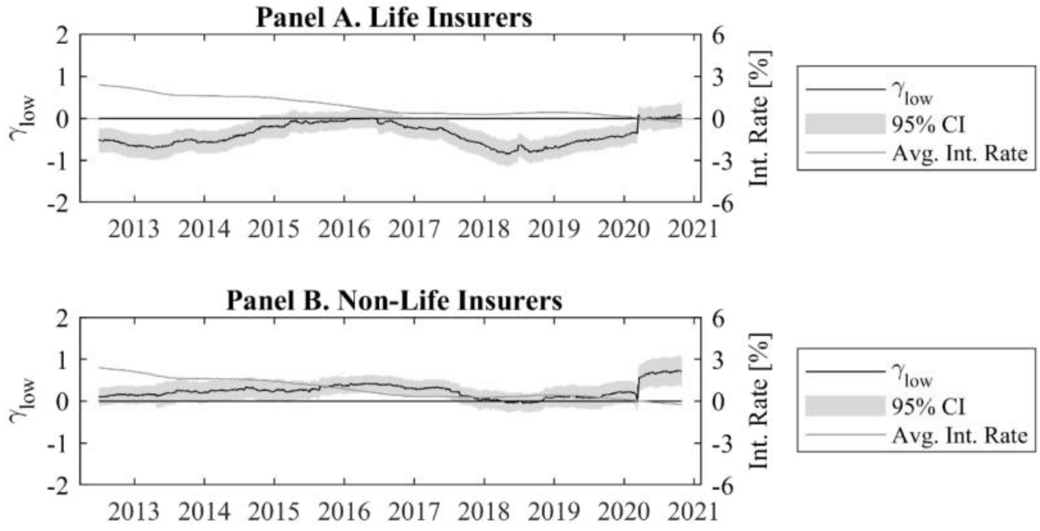


Fig. B26: Statistical Significance of Regression Model for Italian Insurers - Premium Shares - Daily Data

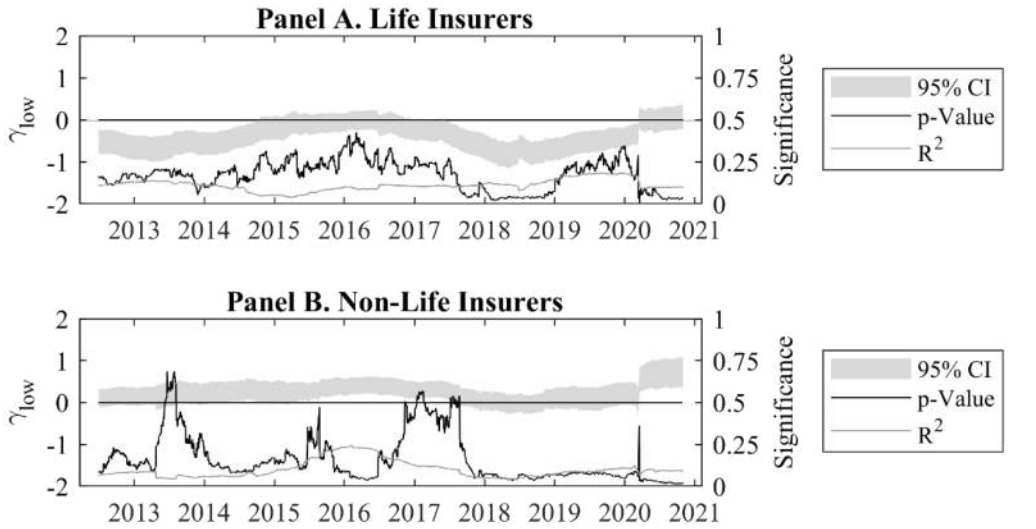


Fig. B27: Changes in Luxembourgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

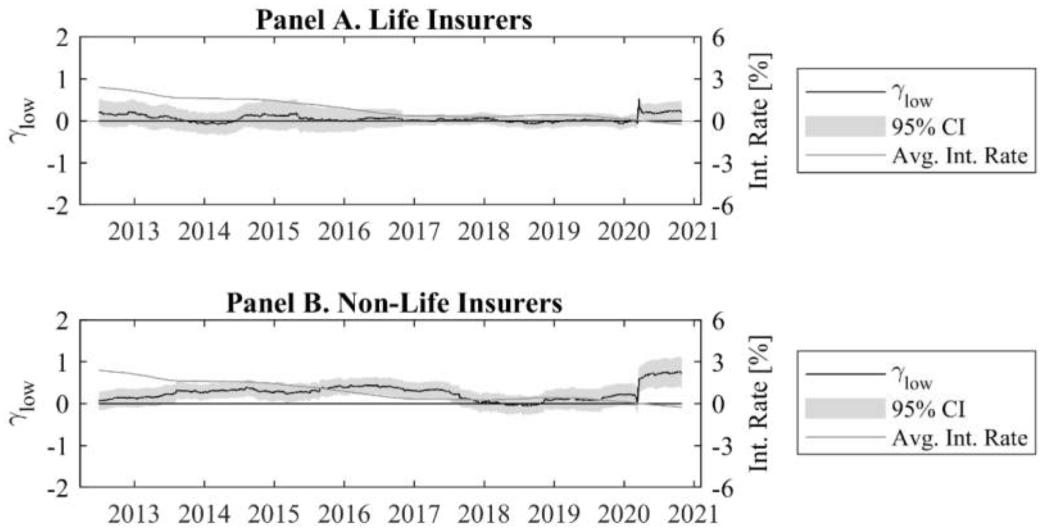


Fig. B28: Statistical Significance of Regression Model for Luxembourgian Insurers - Premium Shares - Daily Data

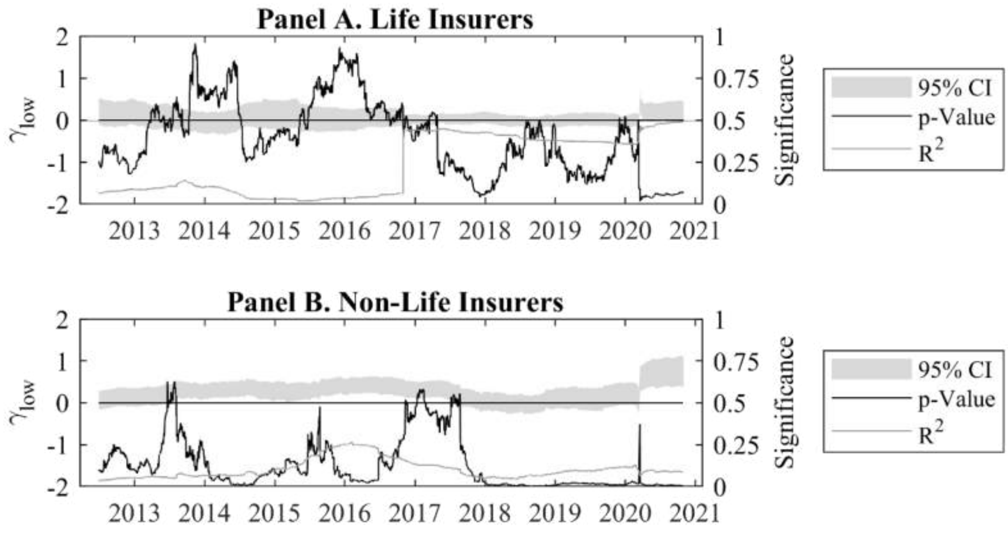


Fig. B29: Changes in Maltese Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

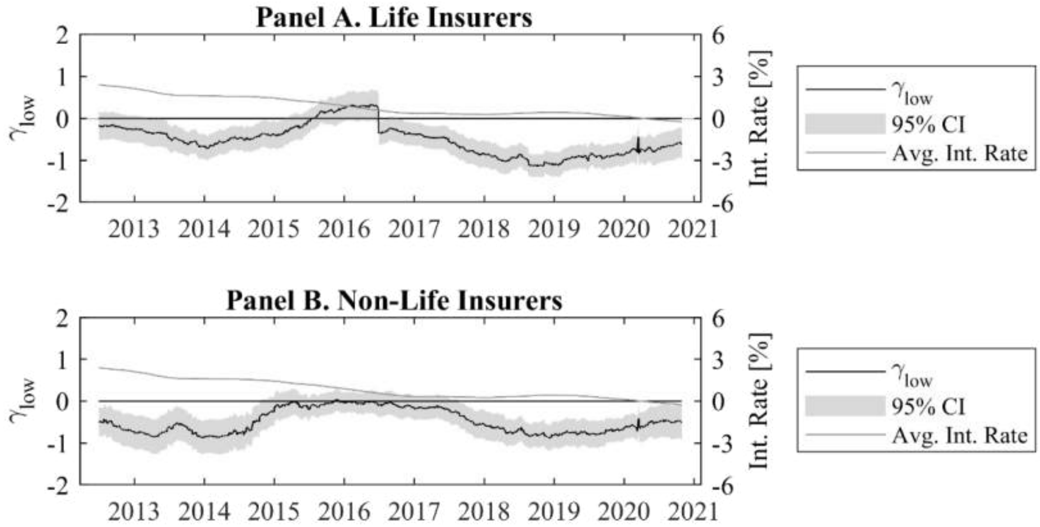


Fig. B30: Statistical Significance of Regression Model for Maltese Insurers - Premium Shares - Daily Data

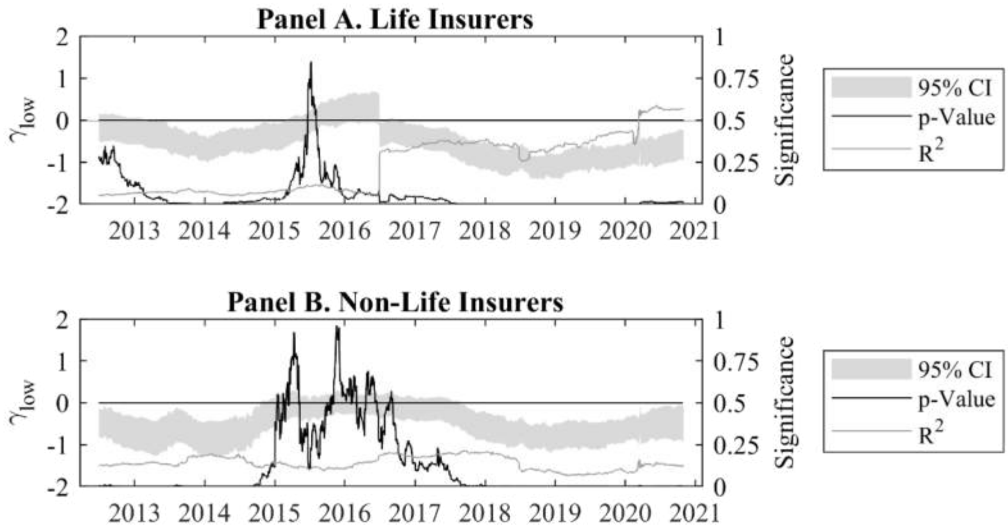


Fig. B31: Changes in Dutch Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

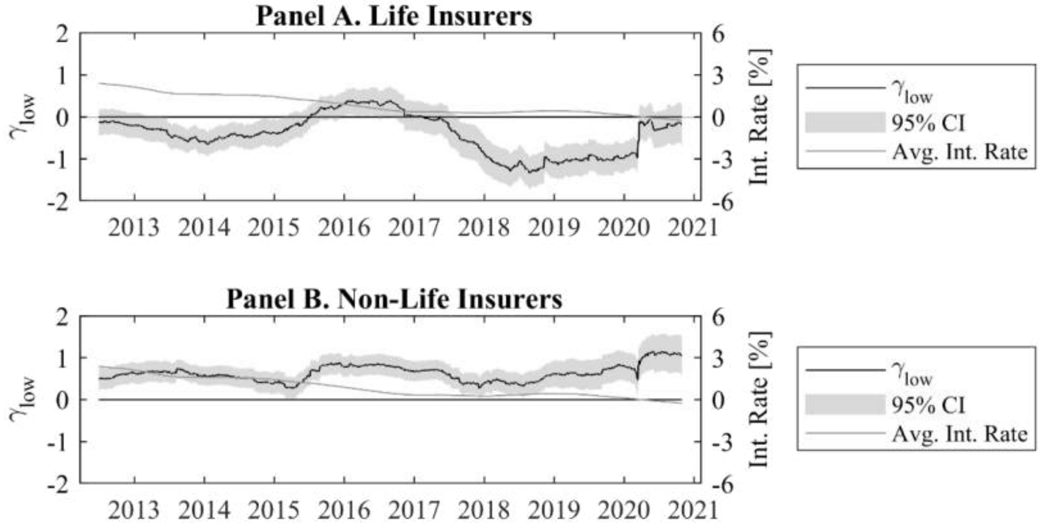


Fig. B32: Statistical Significance of Regression Model for Dutch Insurers - Premium Shares - Daily Data

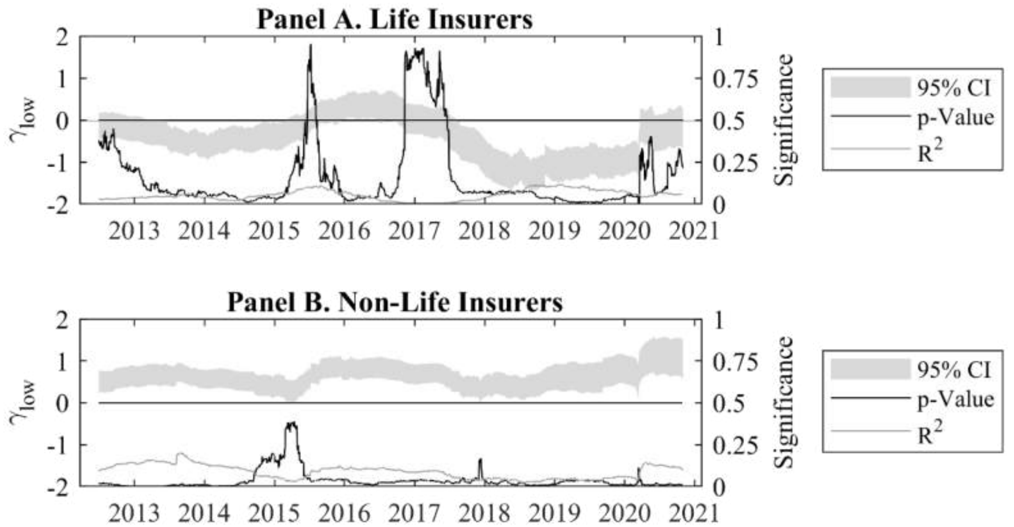
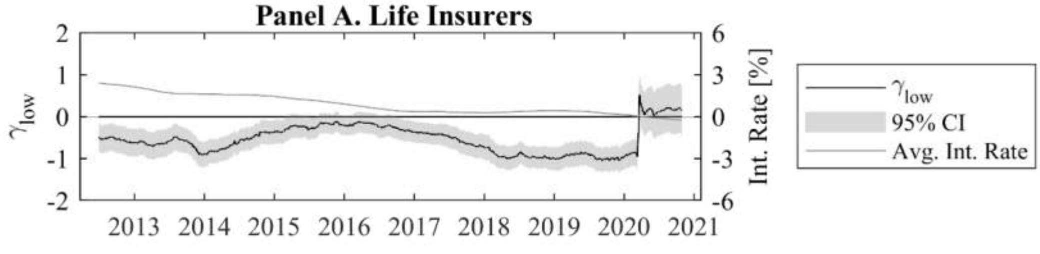


Fig. B33: Changes in Norwegian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

Panel A. Life Insurers



Panel B. Non-Life Insurers

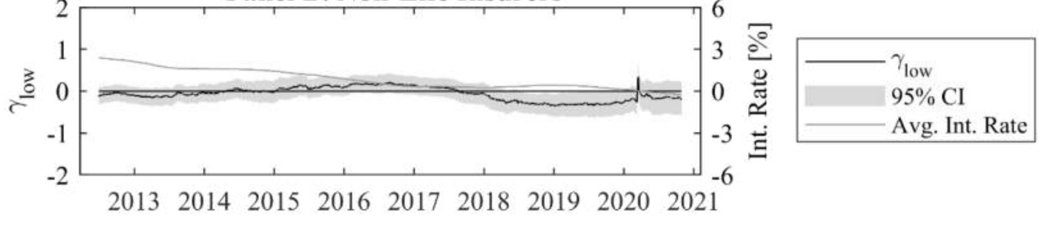
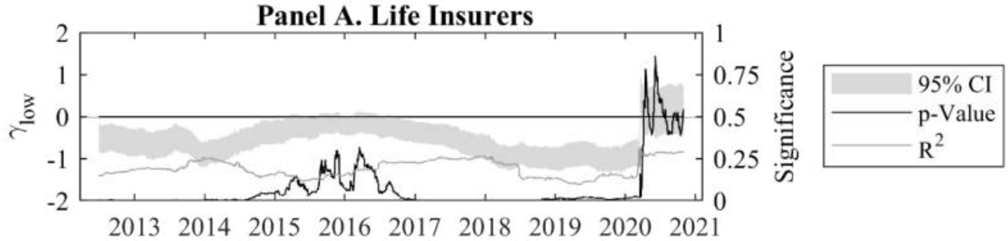


Fig. B34: Statistical Significance of Regression Model for Norwegian Insurers - Premium Shares - Daily Data

Panel A. Life Insurers



Panel B. Non-Life Insurers

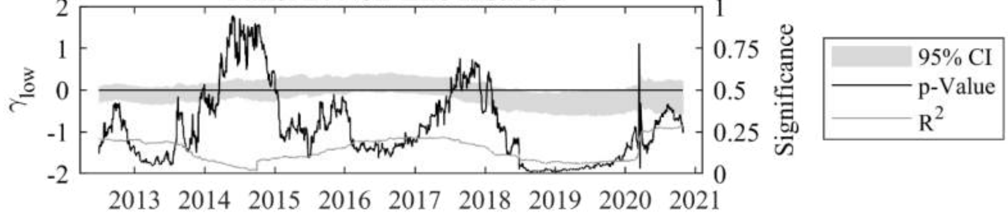


Fig. B35: Changes in Polish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

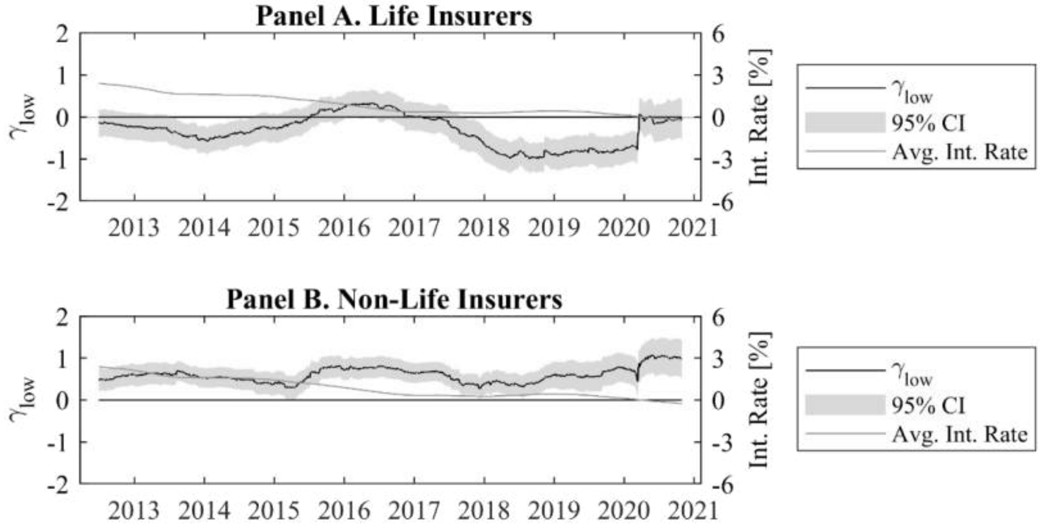


Fig. B36: Statistical Significance of Regression Model for Polish Insurers - Premium Shares - Daily Data

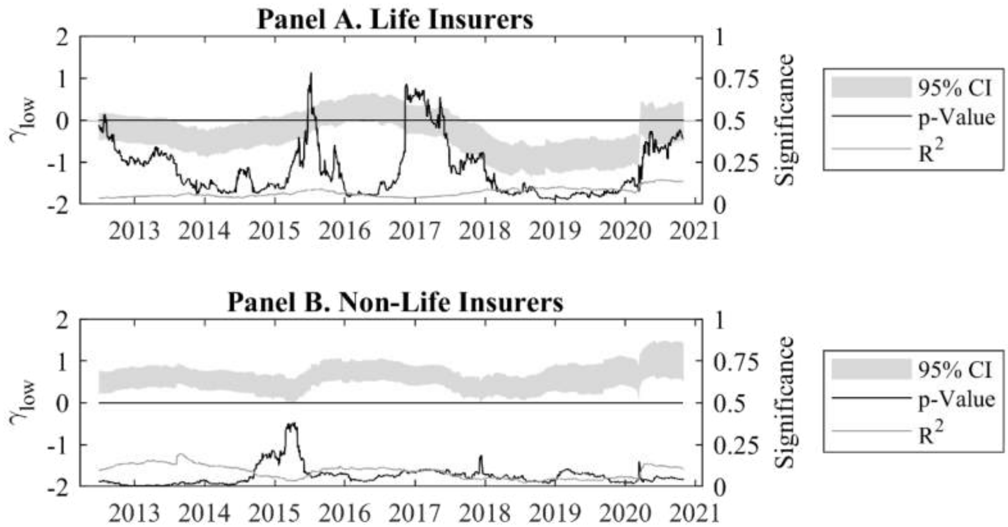


Fig. B37: Changes in Russian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

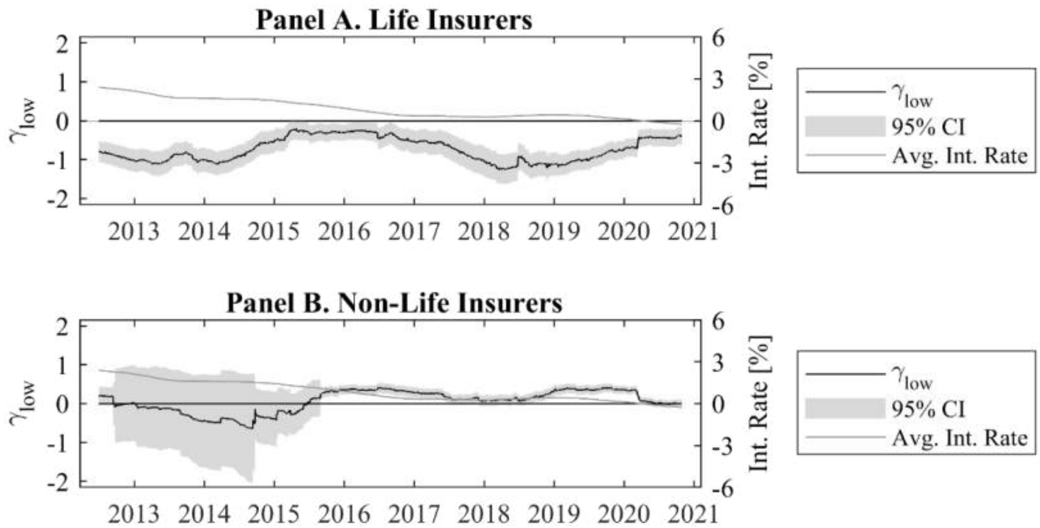


Fig. B38: Statistical Significance of Regression Model for Russian Insurers - Premium Shares - Daily Data

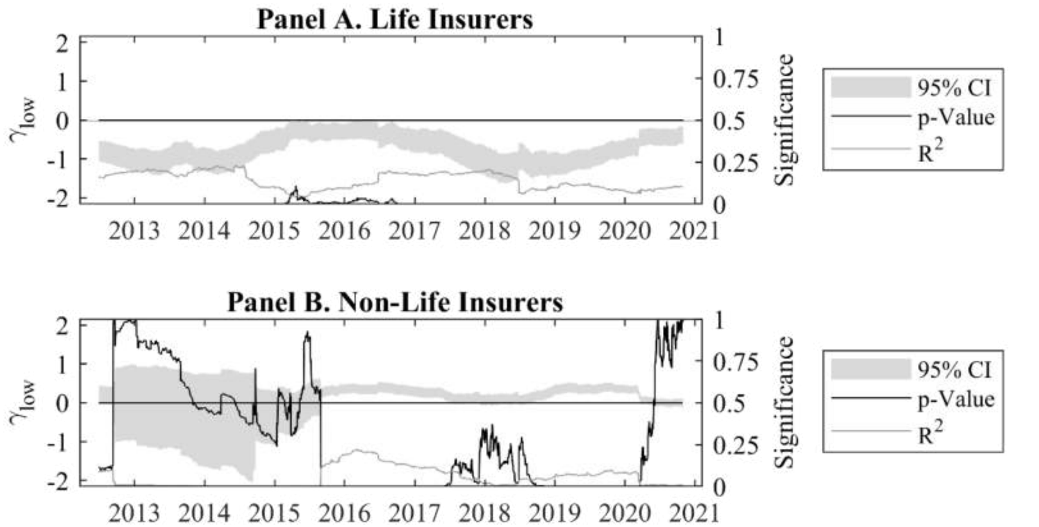


Fig. B39: Changes in Serbian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

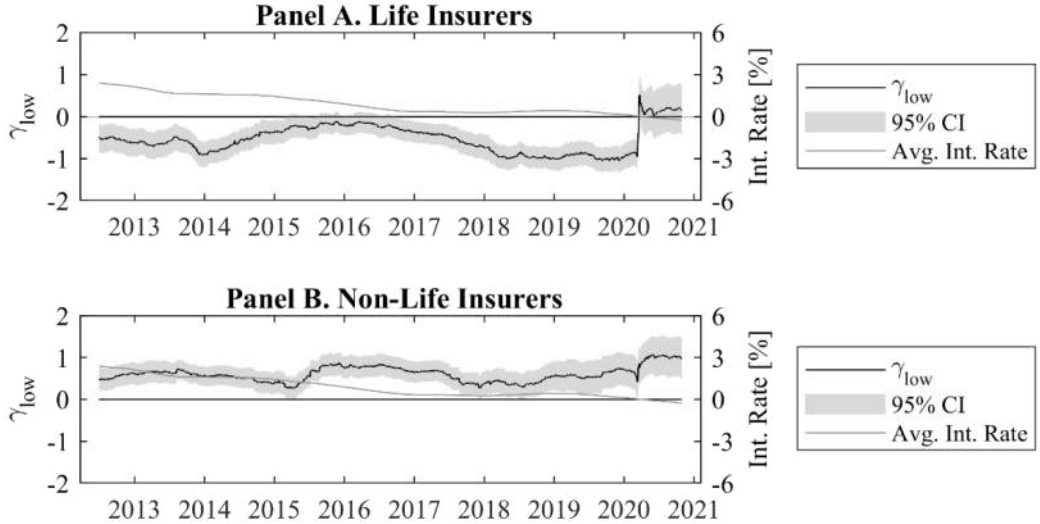


Fig. B40: Statistical Significance of Regression Model for Serbian Insurers - Premium Shares - Daily Data

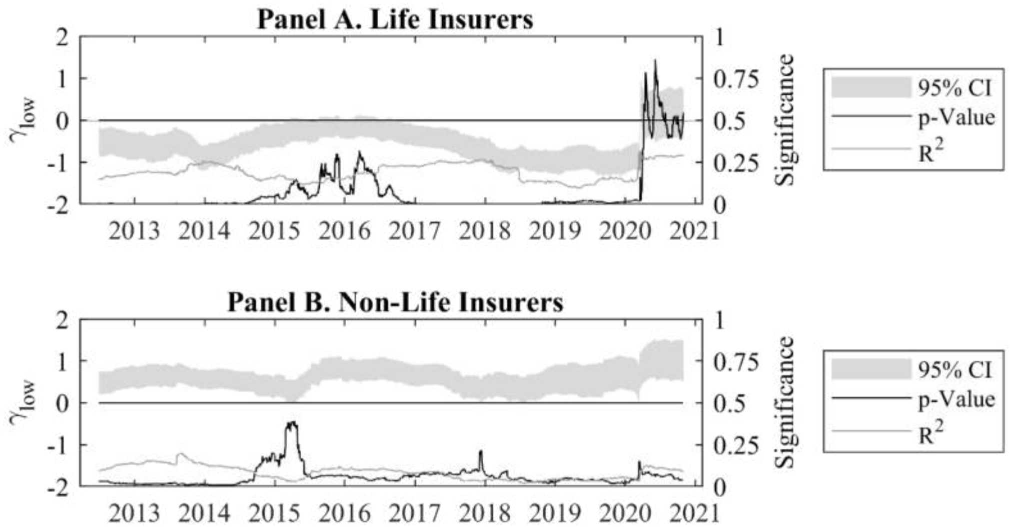


Fig. B41: Changes in Slovenian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

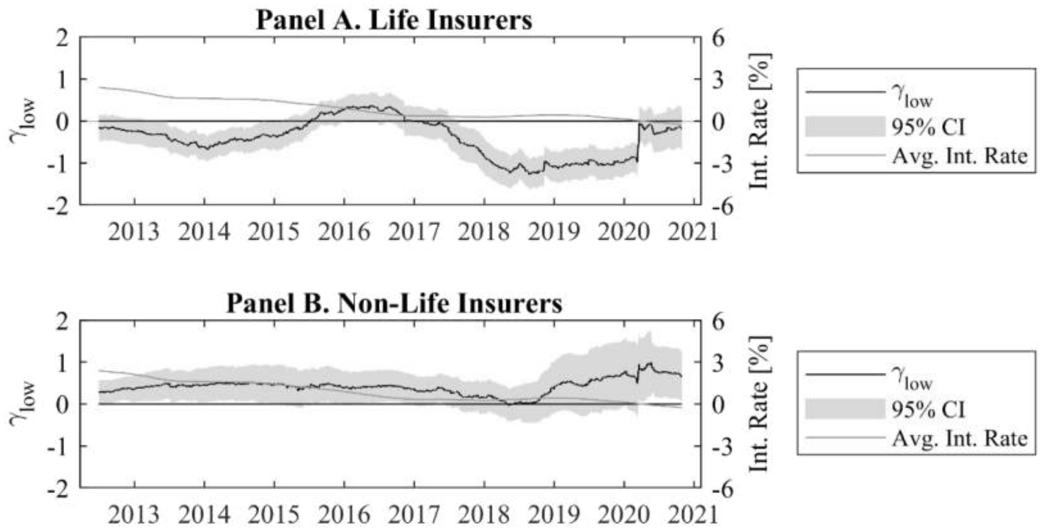


Fig. B42: Statistical Significance of Regression Model for Slovenian Insurers - Premium Shares - Daily Data

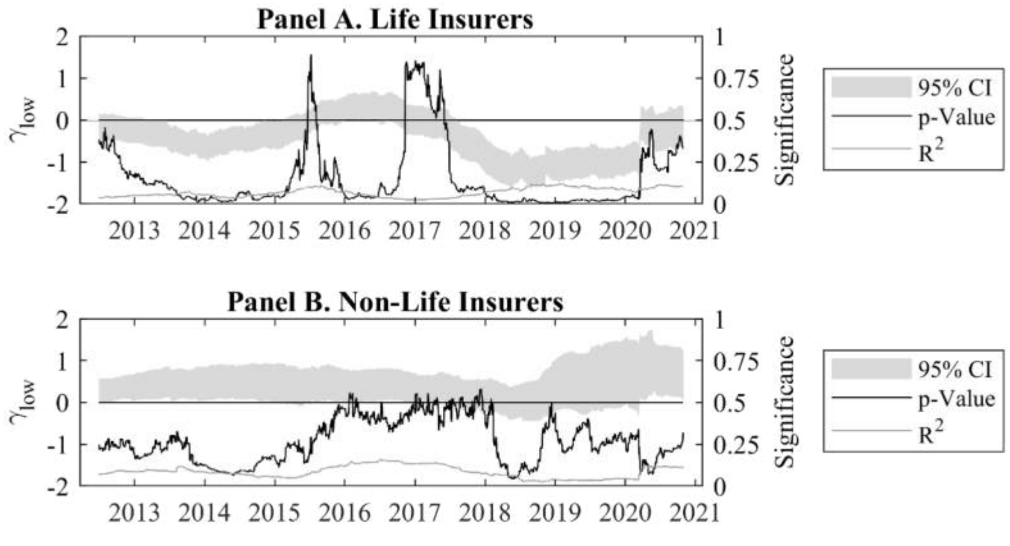


Fig. B43: Changes in Spanish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

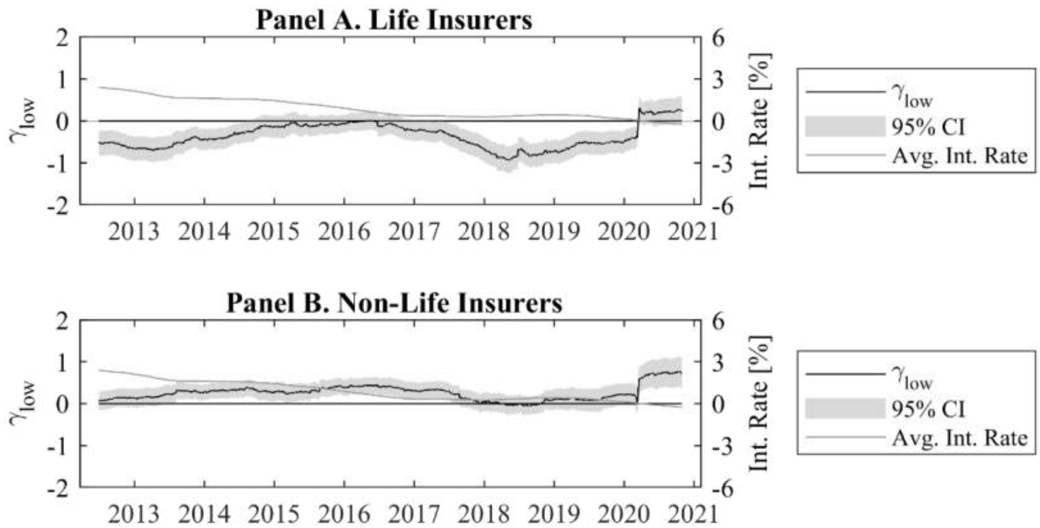


Fig. B44: Statistical Significance of Regression Model for Spanish Insurers - Premium Shares - Daily Data

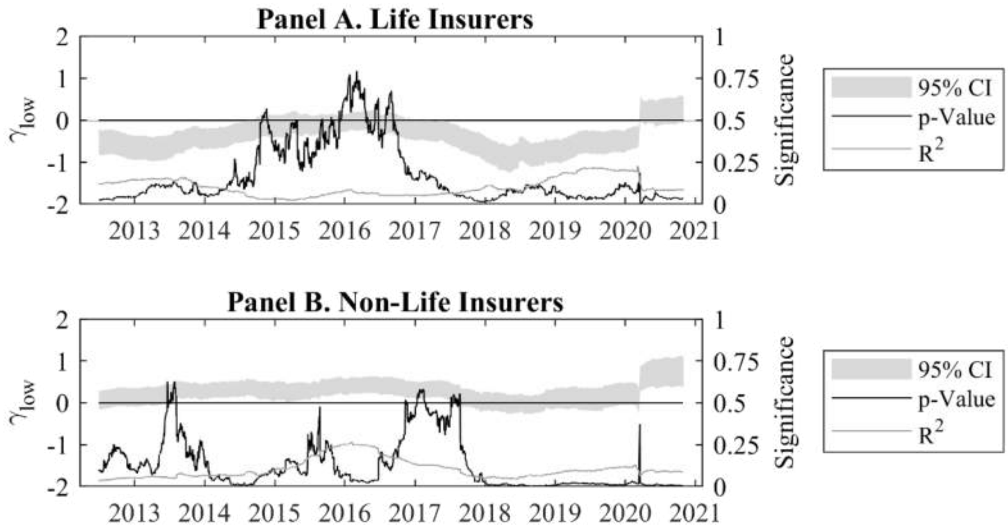
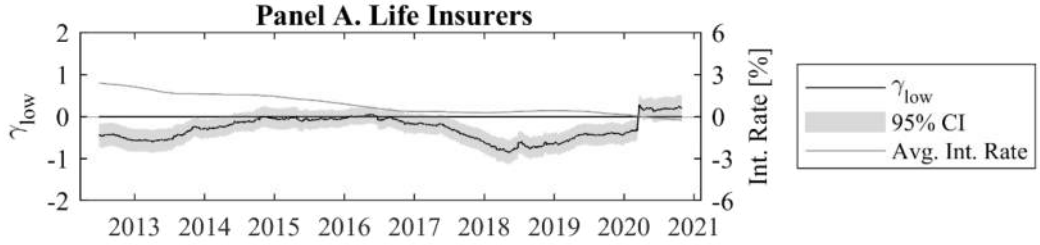


Fig. B45: Changes in Swiss Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data



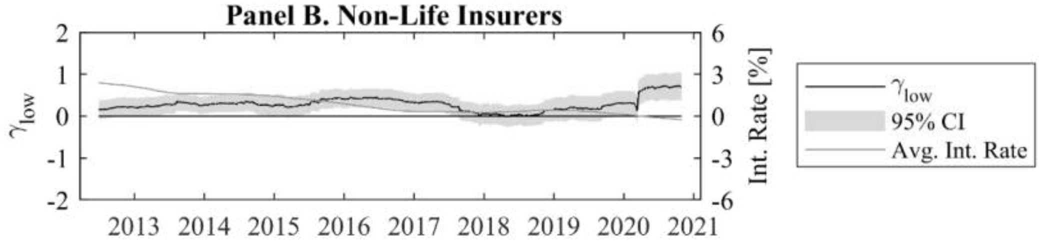
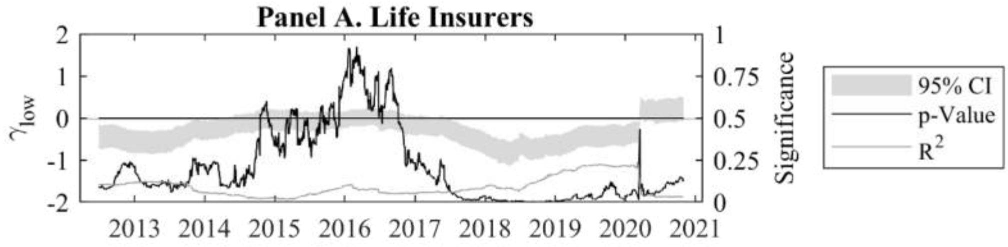


Fig. B46: Statistical Significance of Regression Model for Swiss Insurers - Premium Shares - Daily Data



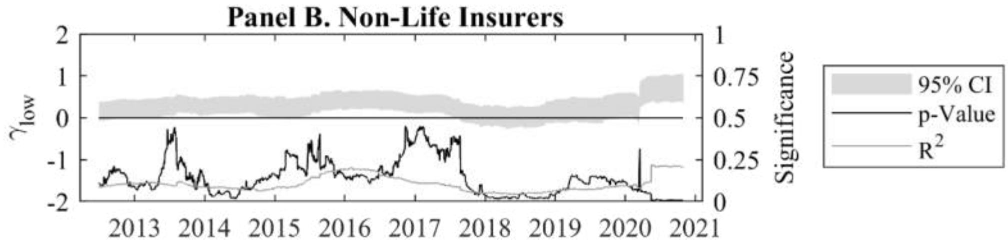


Fig. B47: Changes in Turkish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Premium Shares - Daily Data

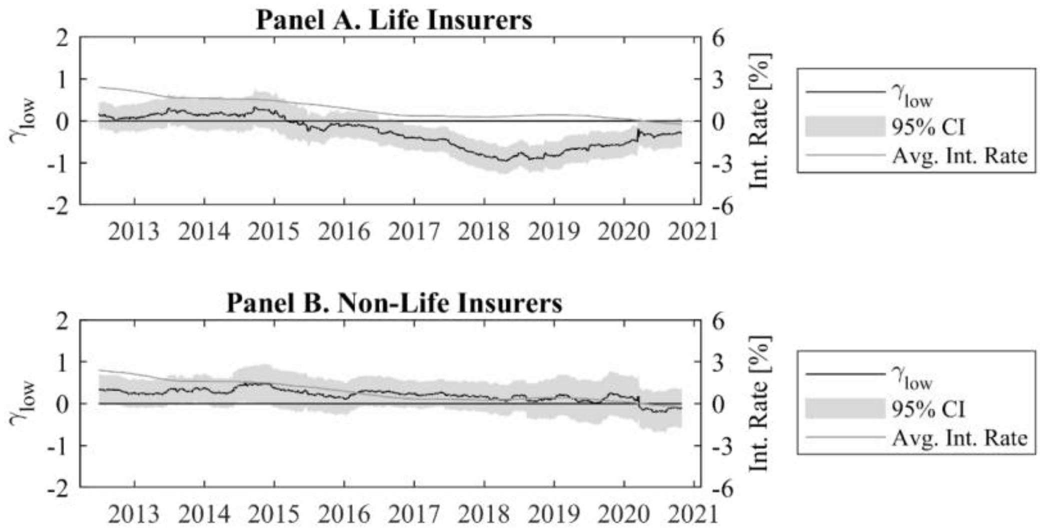
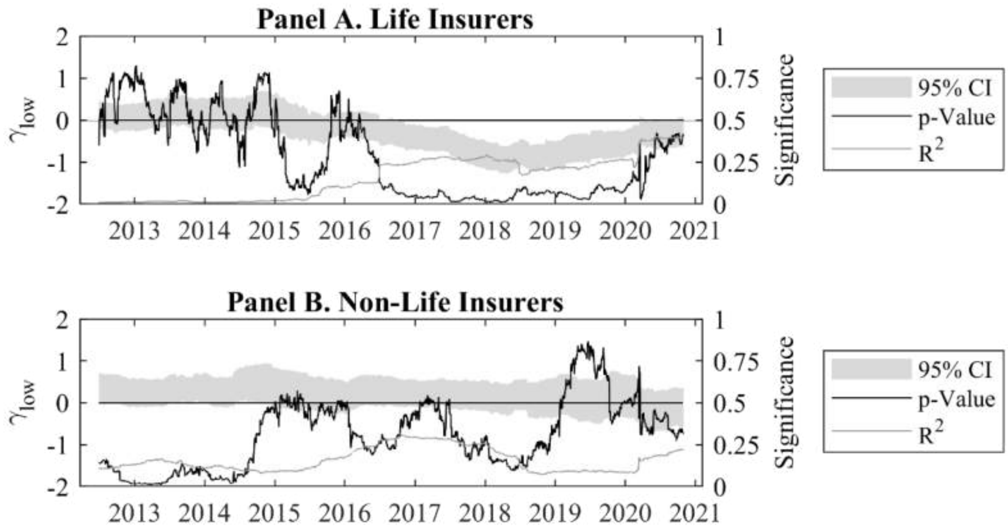


Fig. B48: Statistical Significance of Regression Model for Turkish Insurers - Premium Shares - Daily Data



Appendix C: Change in European Interest Rate Sensitivities by Country (Home Country Allocation – Weekly Data)

Fig. C1: Changes in Austrian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

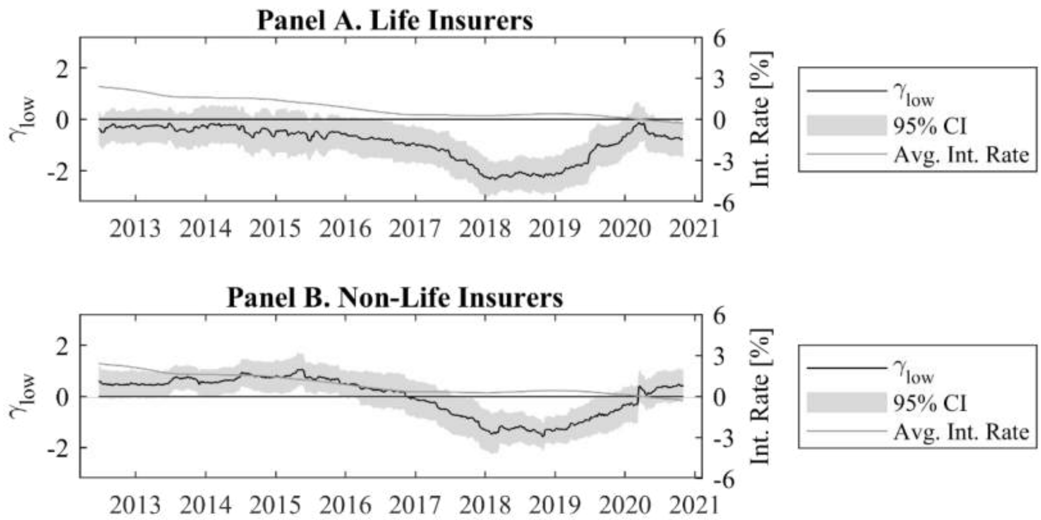


Fig. C2: Statistical Significance of Regression Model for Austrian Insurers - Home Countries - Weekly Data

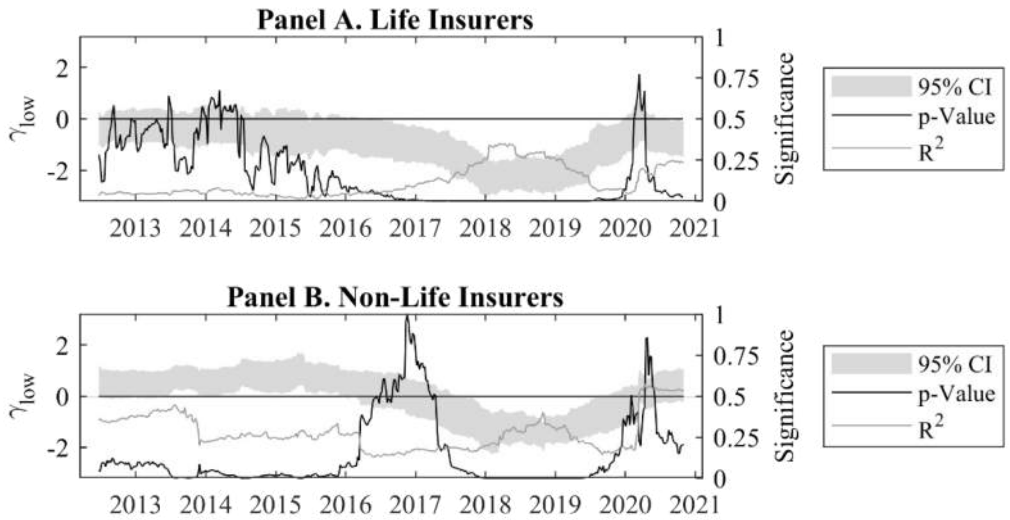


Fig. C3: Changes in Belgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

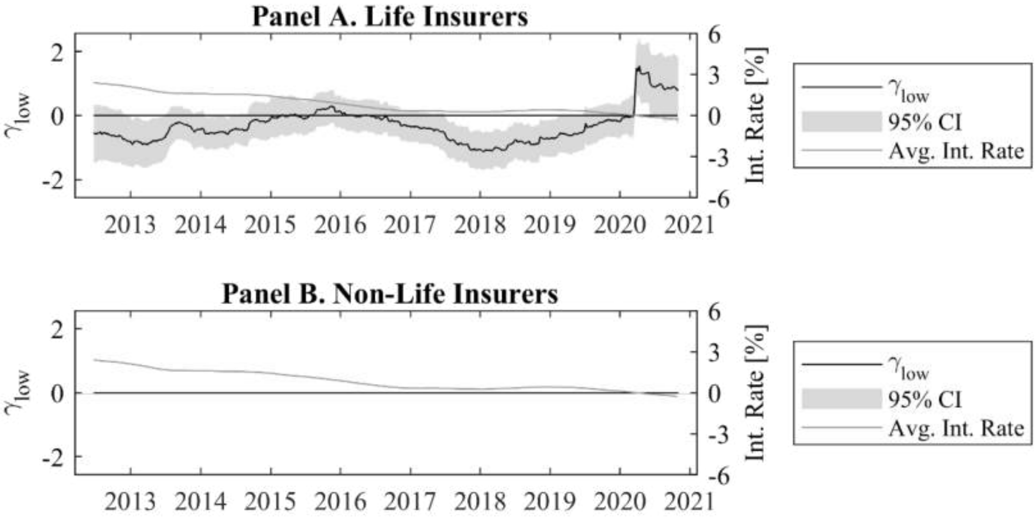


Fig. C4: Statistical Significance of Regression Model for Belgian Insurers - Home Countries - Weekly Data

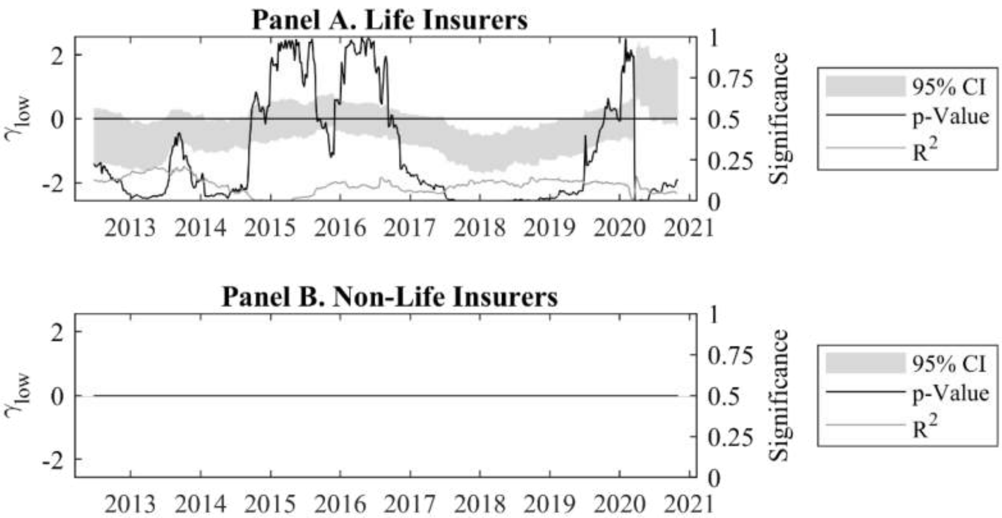


Fig. C5: Changes in Croatian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

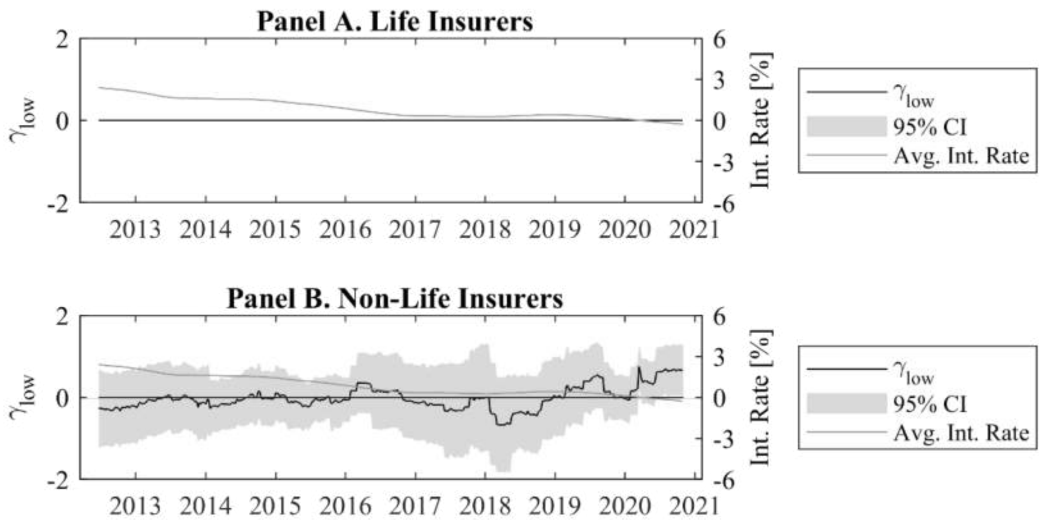


Fig. C6: Statistical Significance of Regression Model for Croatian Insurers - Home Countries - Weekly Data

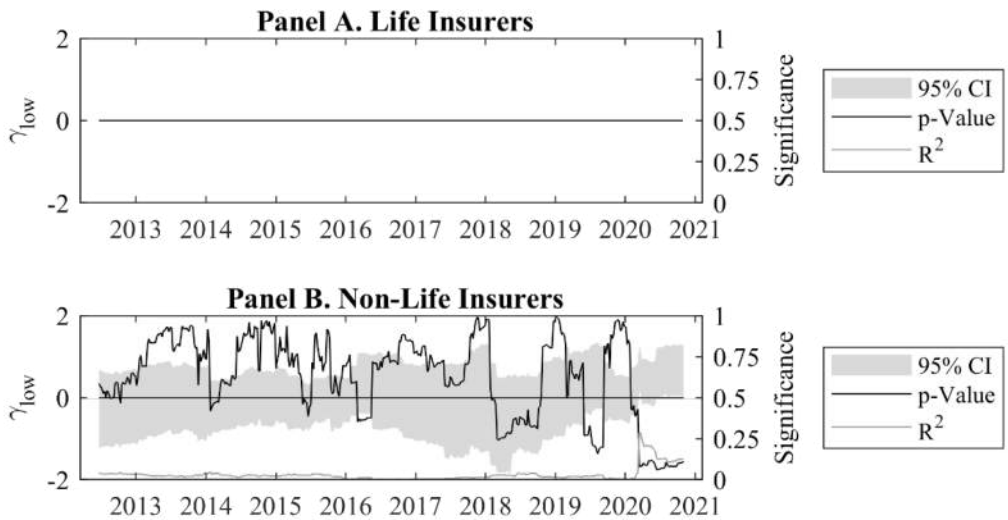


Fig. C7: Changes in Cyprian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

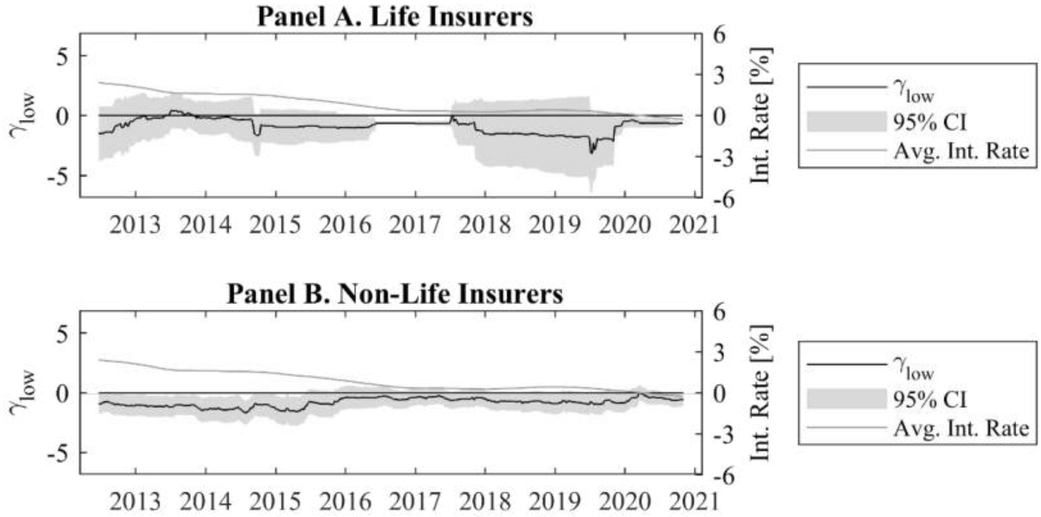


Fig. C8: Statistical Significance of Regression Model for Cyprian Insurers - Home Countries - Weekly Data

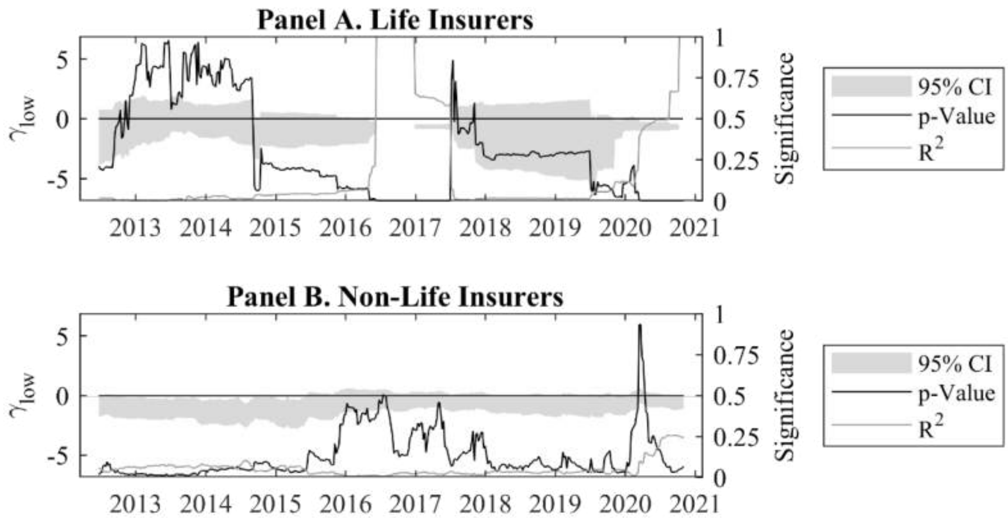


Fig. C9: Changes in Danish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

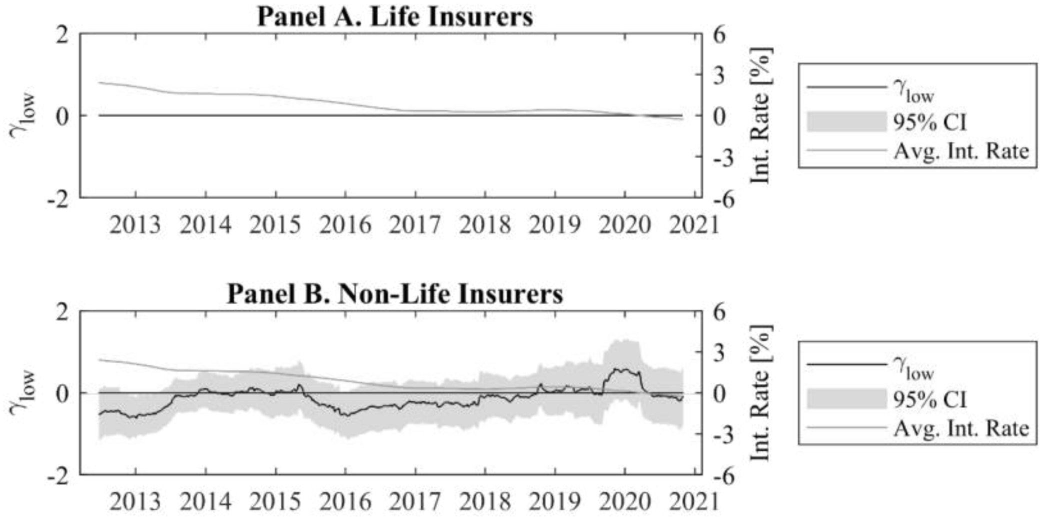


Fig. C10: Statistical Significance of Regression Model for Danish Insurers - Home Countries - Weekly Data

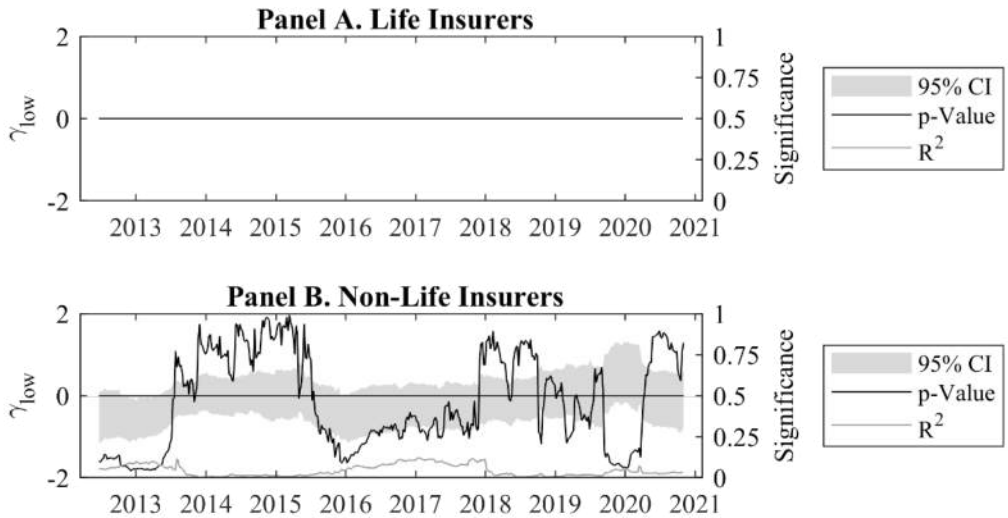


Fig. C11: Changes in Finnish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

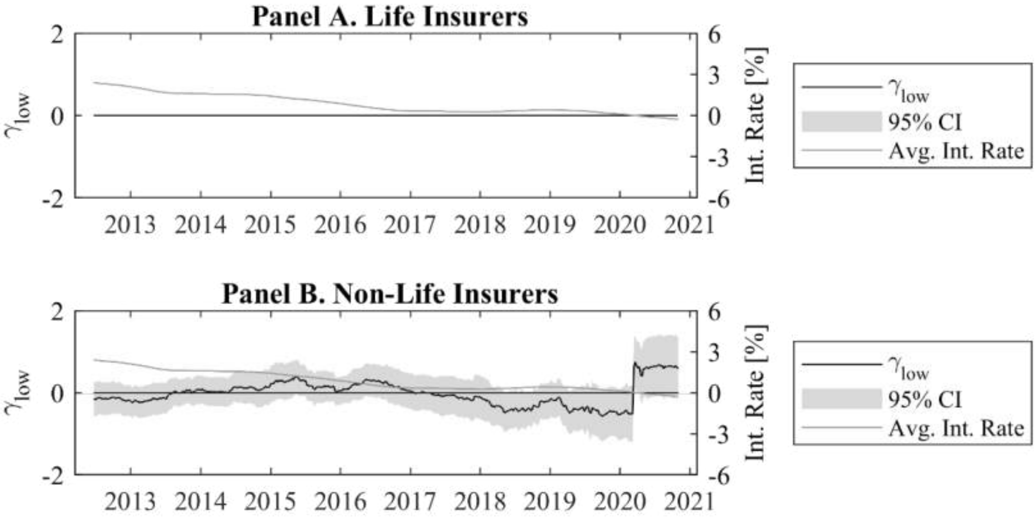


Fig. C12: Statistical Significance of Regression Model for Finnish Insurers - Home Countries - Weekly Data

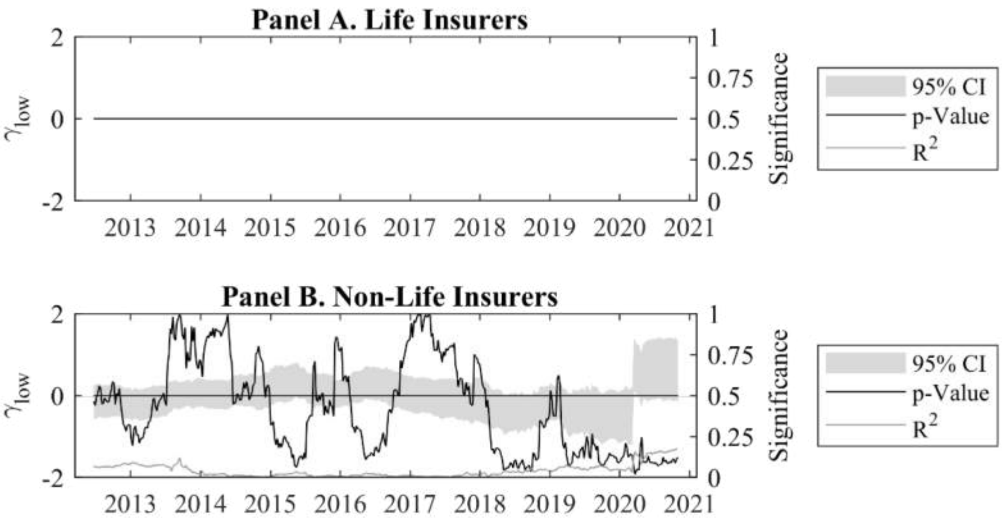


Fig. C13: Changes in French Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

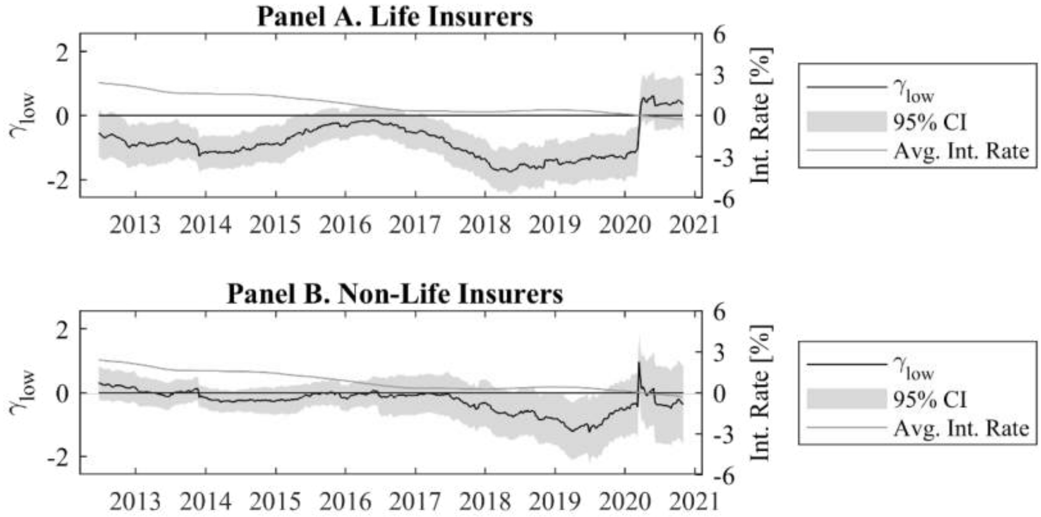


Fig. C14: Statistical Significance of Regression Model for French Insurers - Home Countries - Weekly Data

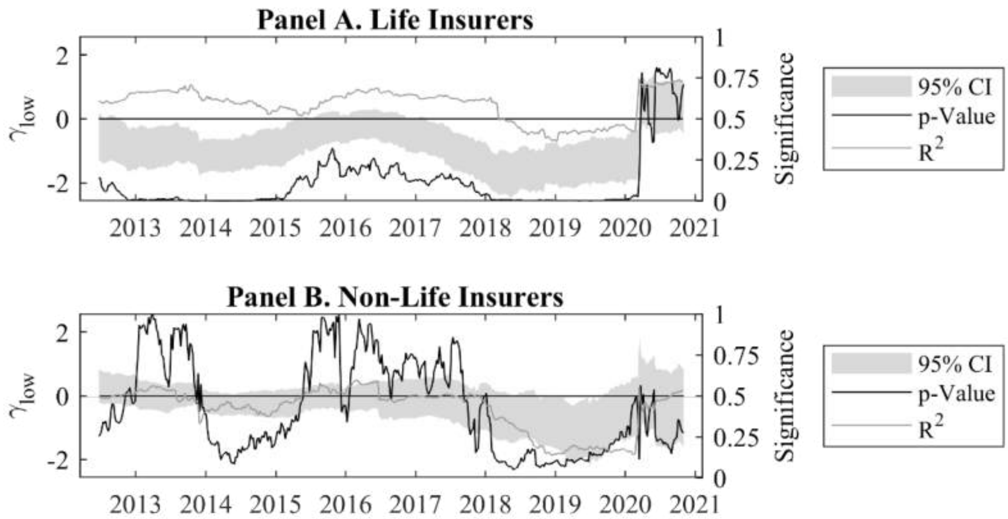


Fig. C15: Changes in German Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

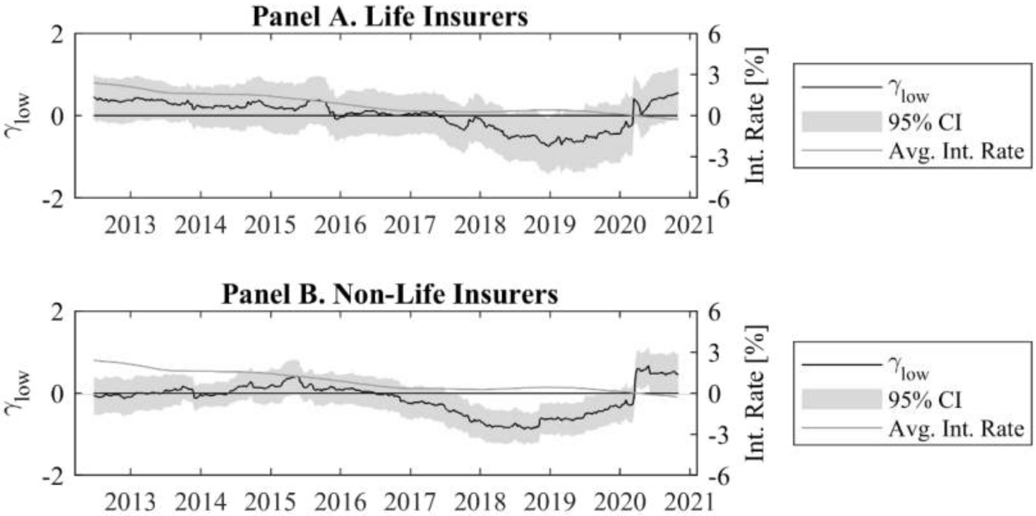


Fig. C16: Statistical Significance of Regression Model for German Insurers - Home Countries - Weekly Data

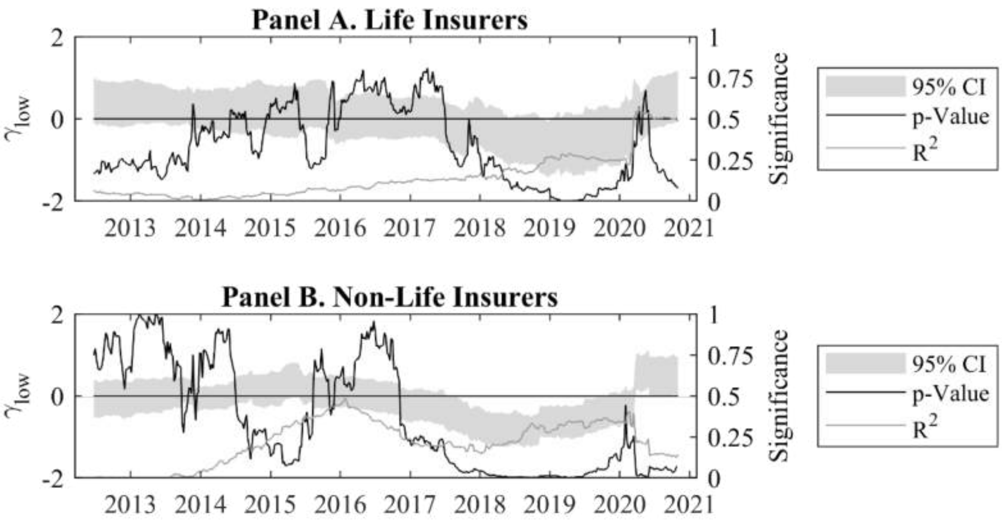


Fig. C17: Changes in Greek Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

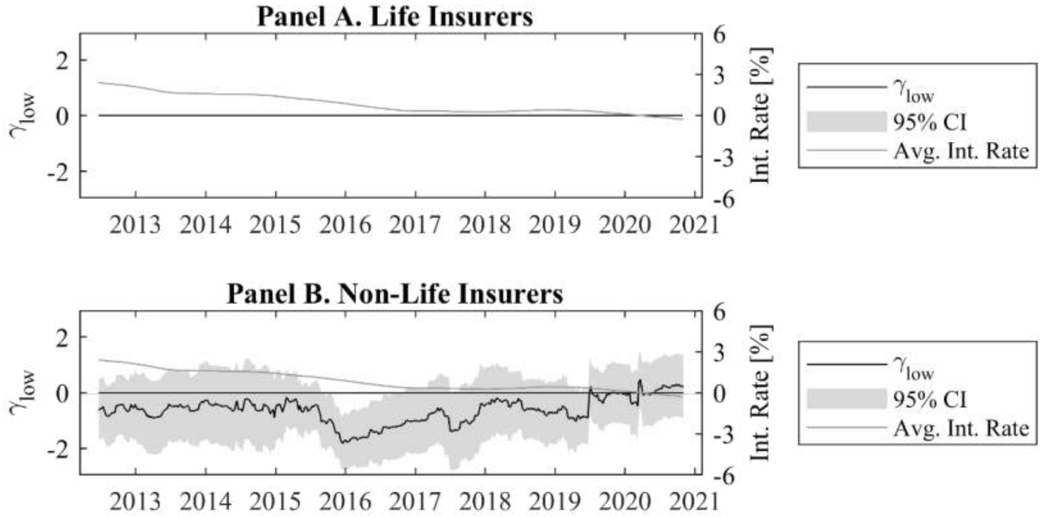


Fig. C18: Statistical Significance of Regression Model for Greek Insurers - Home Countries - Weekly Data

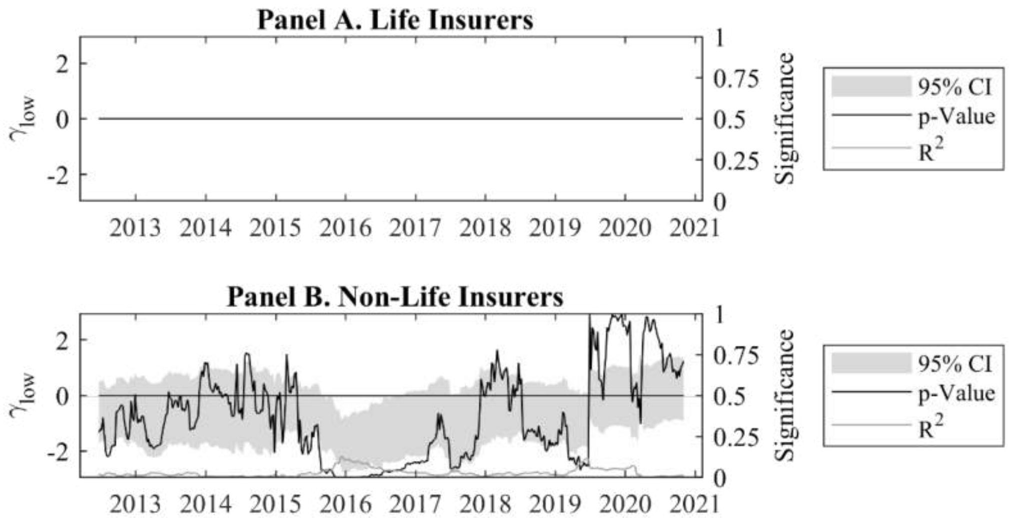


Fig. C19: Changes in Hungarian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

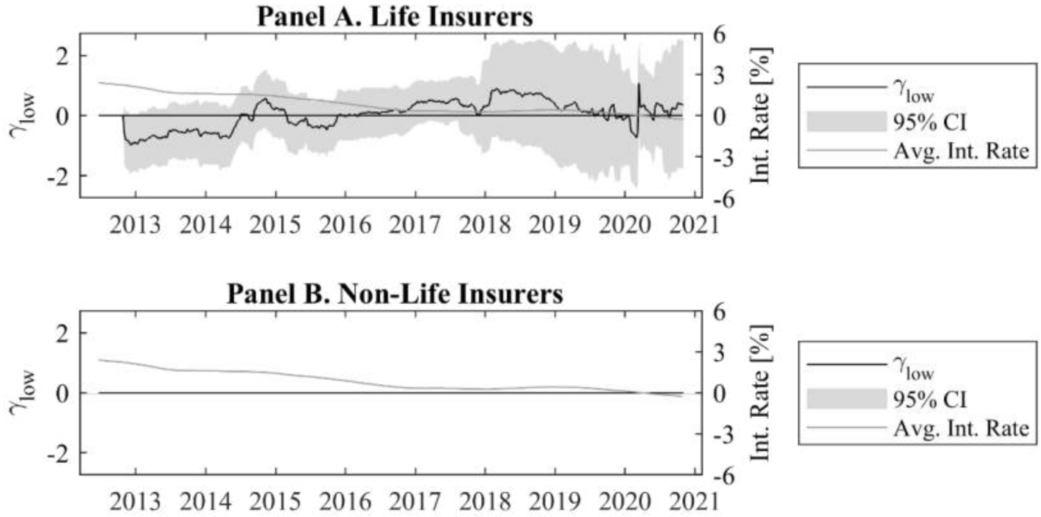


Fig. C20: Statistical Significance of Regression Model for Hungarian Insurers - Home Countries - Weekly Data

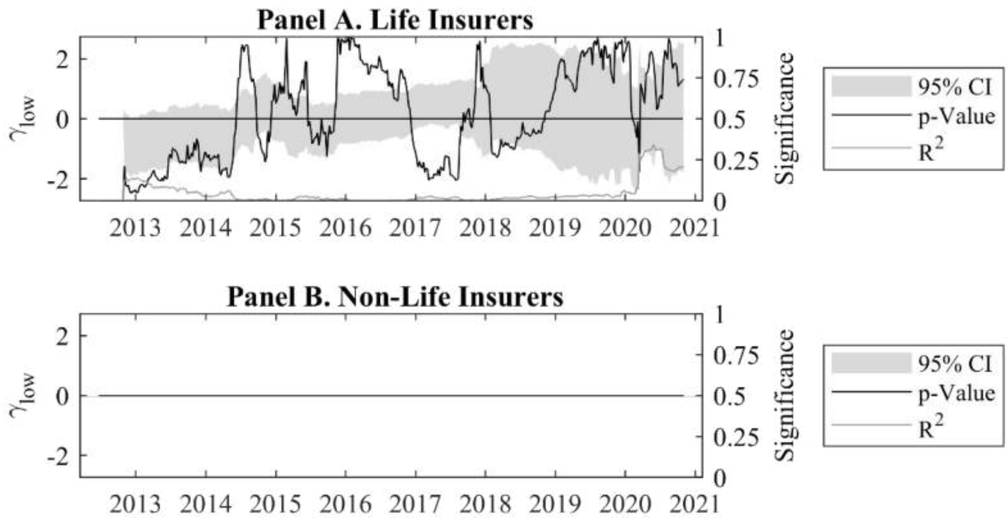


Fig. C21: Changes in Icelandic Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

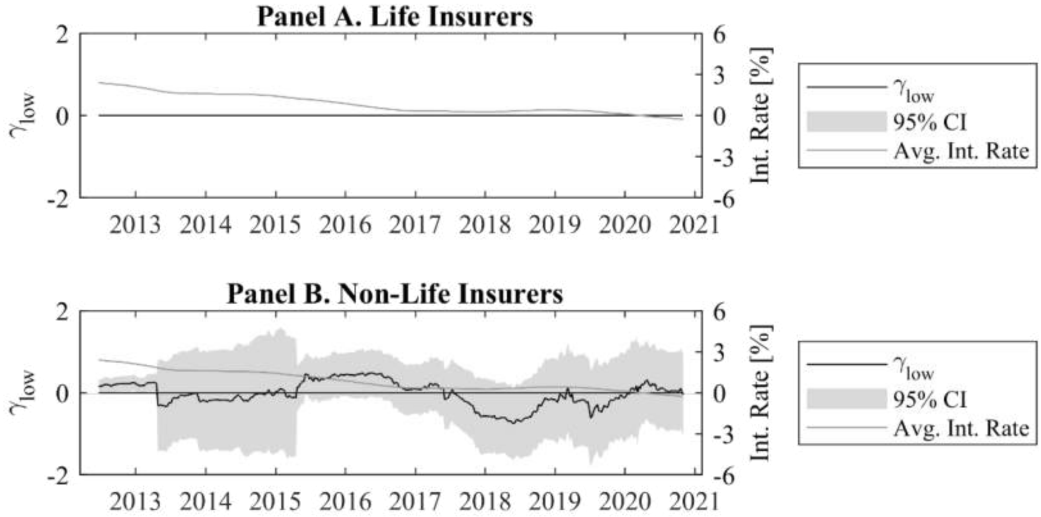


Fig. C22: Statistical Significance of Regression Model for Icelandic Insurers - Home Countries - Weekly Data

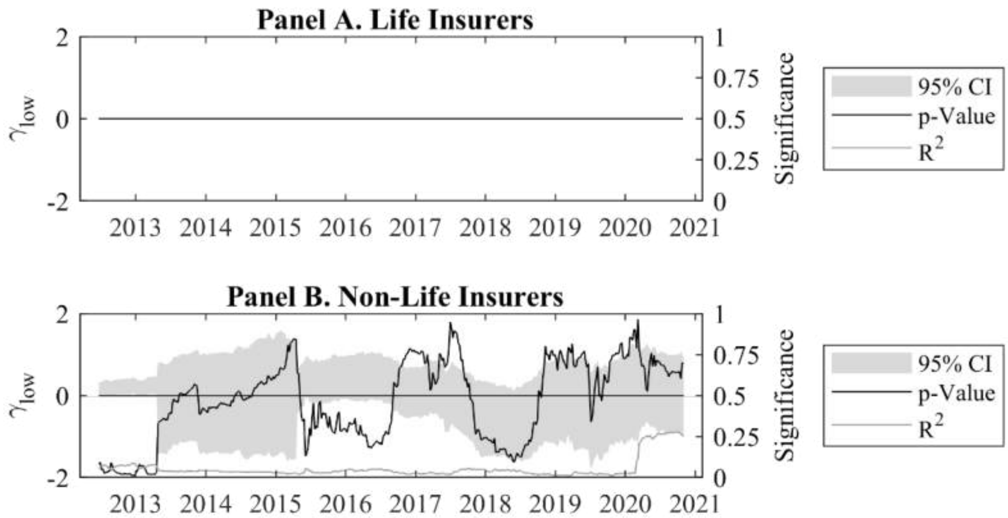
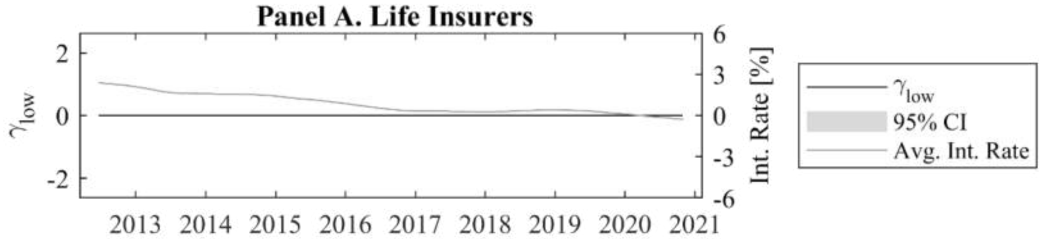


Fig. C23: Changes in Irish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data



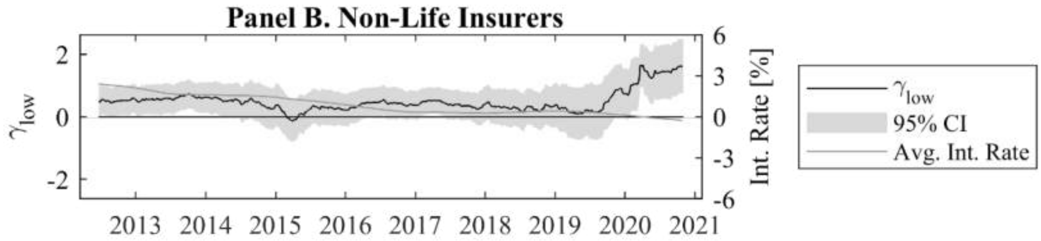
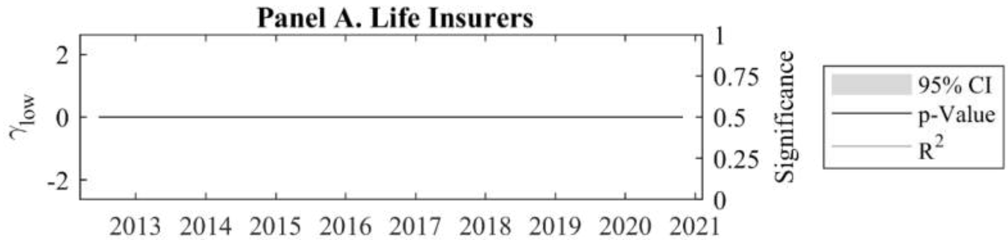


Fig. C24: Statistical Significance of Regression Model for Irish Insurers - Home Countries - Weekly Data



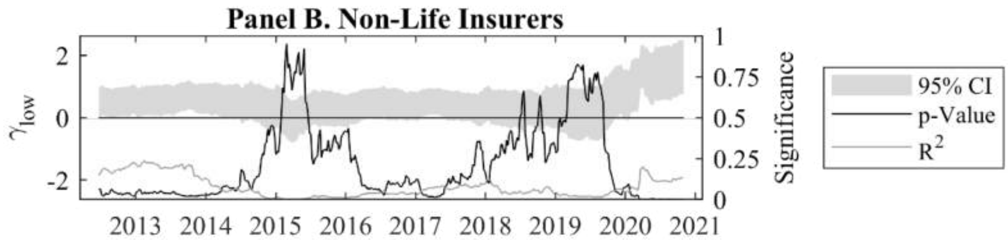


Fig. C25: Changes in Italian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

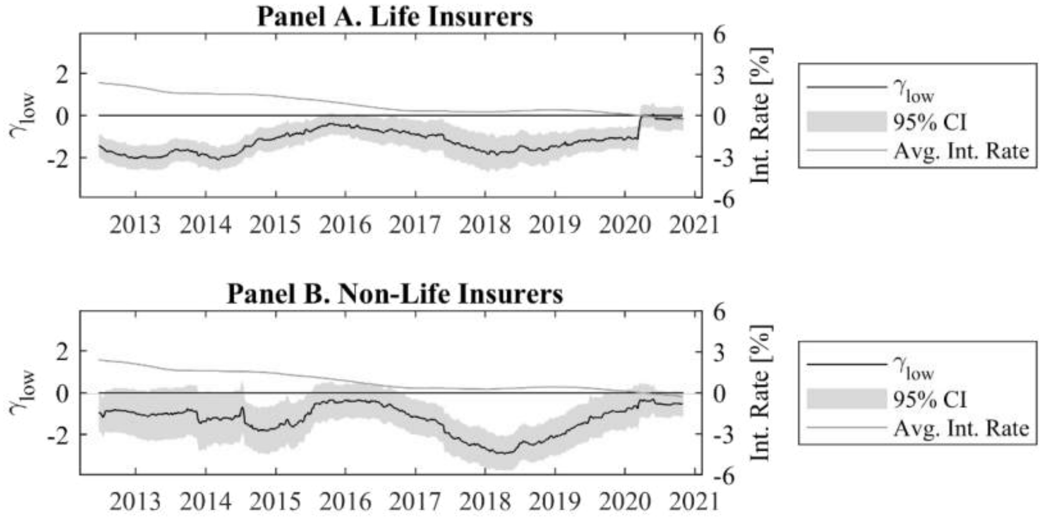


Fig. C26: Statistical Significance of Regression Model for Italian Insurers - Home Countries - Weekly Data

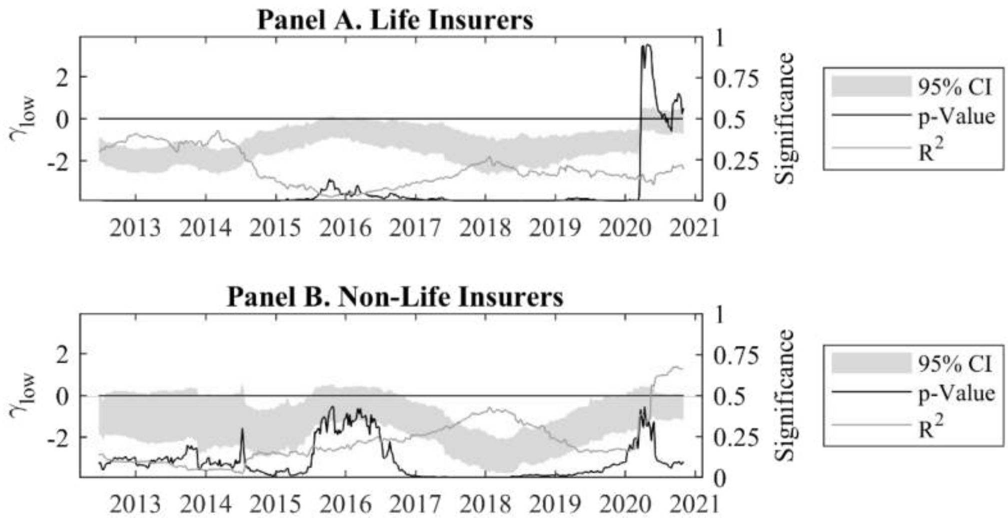


Fig. C27: Changes in Luxembourgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

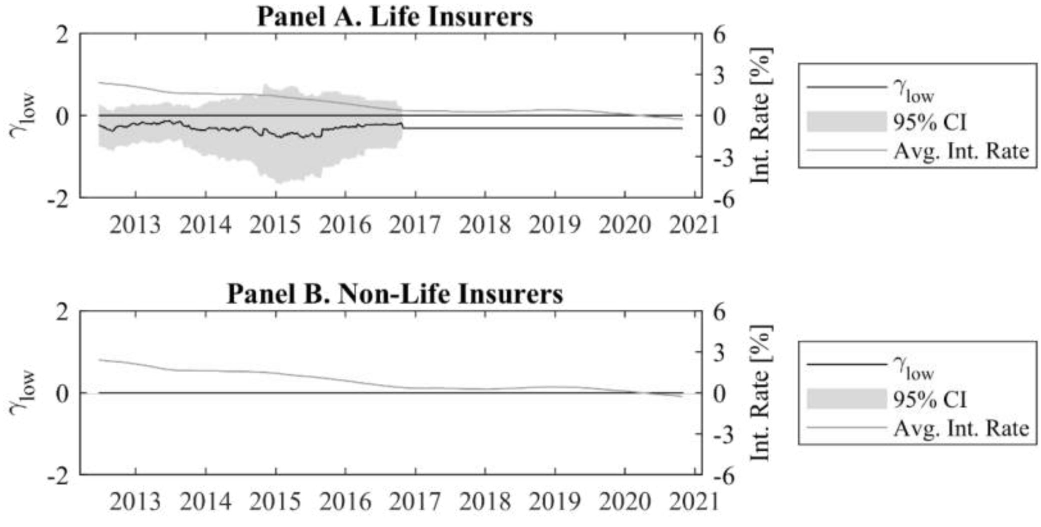


Fig. C28: Statistical Significance of Regression Model for Luxembourgian Insurers - Home Countries - Weekly Data

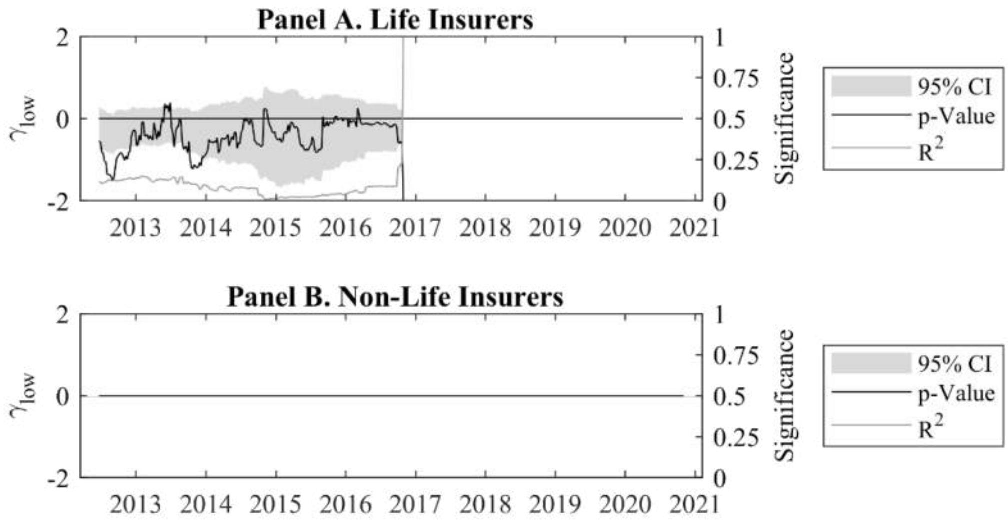


Fig. C29: Changes in Maltese Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

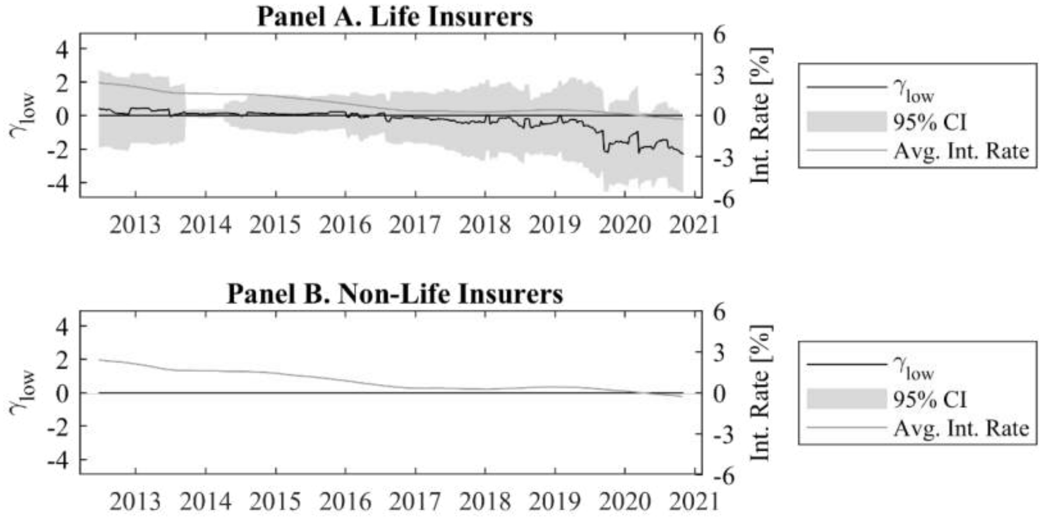


Fig. C30: Statistical Significance of Regression Model for Maltese Insurers - Home Countries - Weekly Data

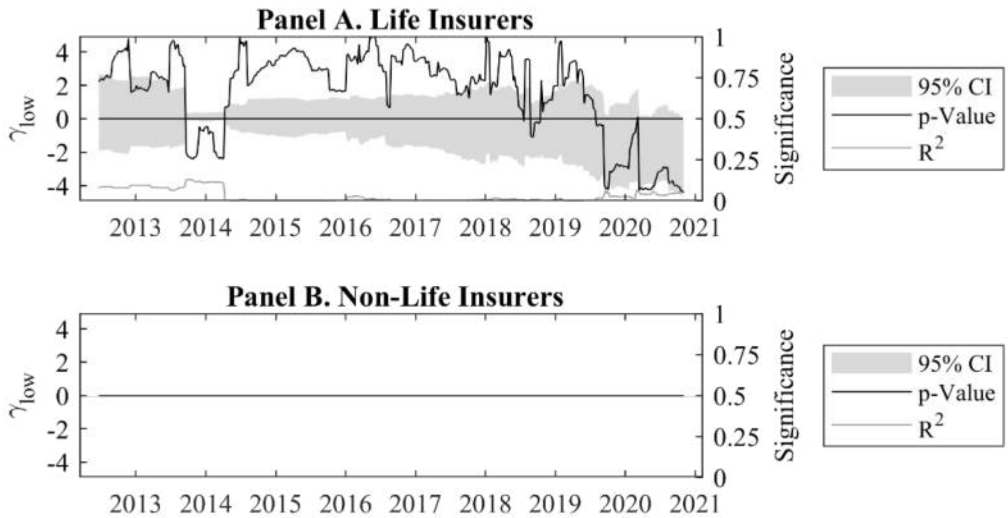


Fig. C31: Changes in Dutch Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

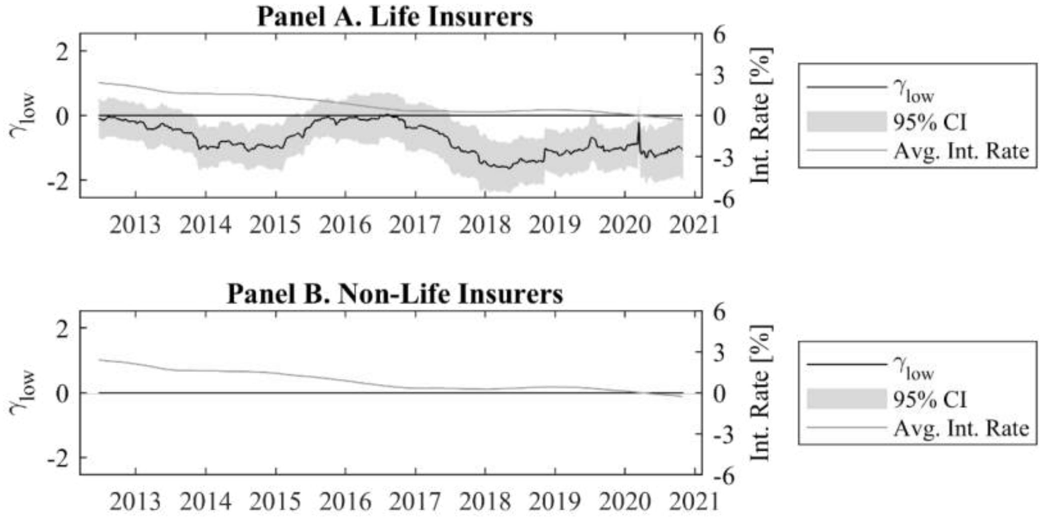


Fig. C32: Statistical Significance of Regression Model for Dutch Insurers - Home Countries - Weekly Data

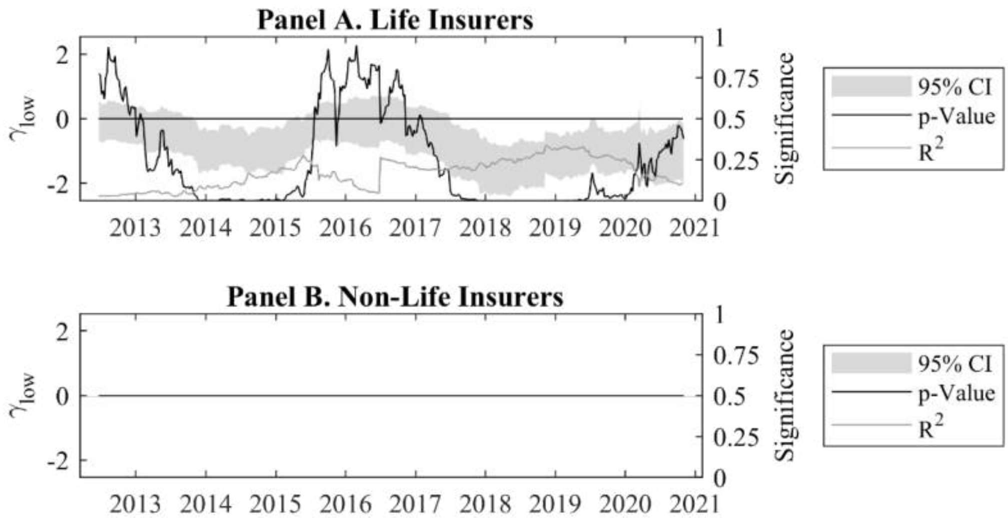


Fig. C33: Changes in Norwegian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

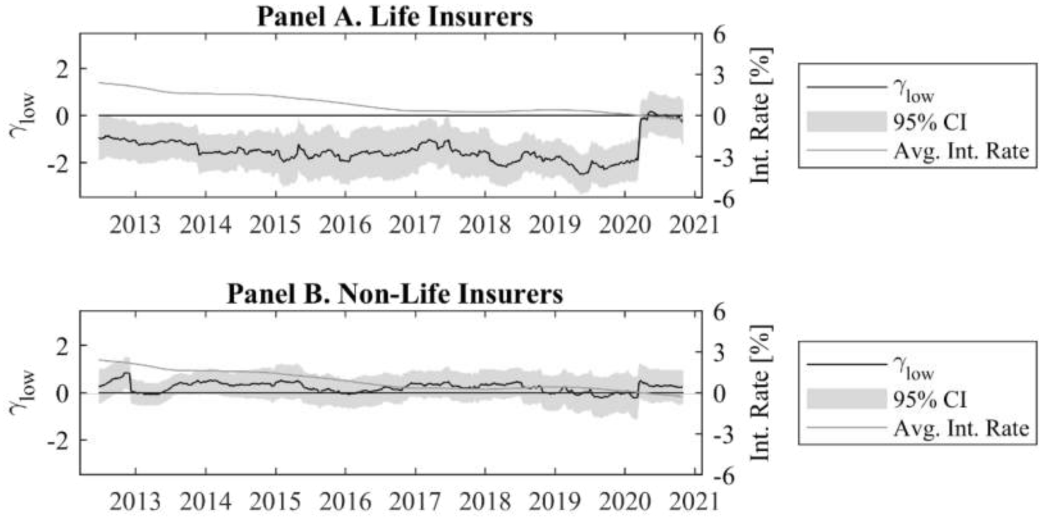


Fig. C34: Statistical Significance of Regression Model for Norwegian Insurers - Home Countries - Weekly Data

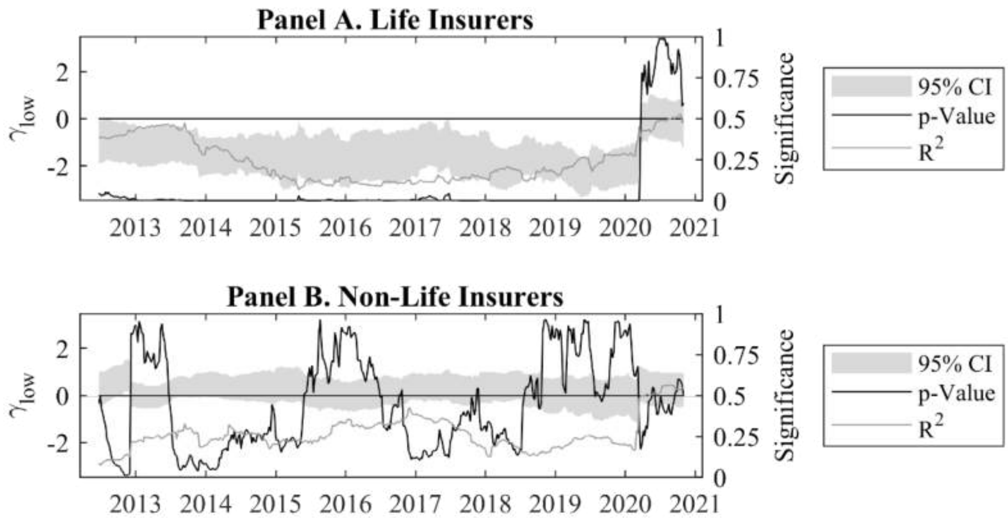


Fig. C35: Changes in Polish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

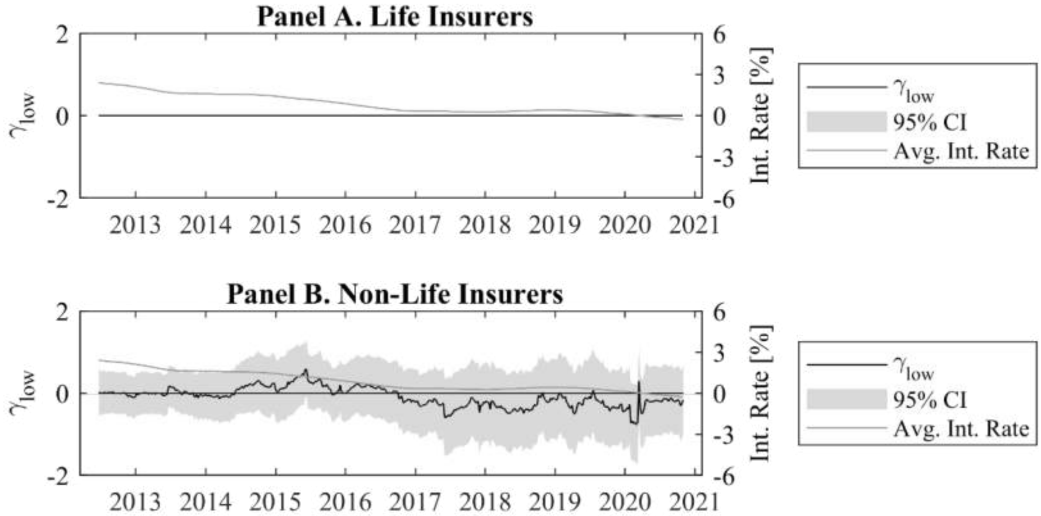


Fig. C36: Statistical Significance of Regression Model for Polish Insurers - Home Countries - Weekly Data

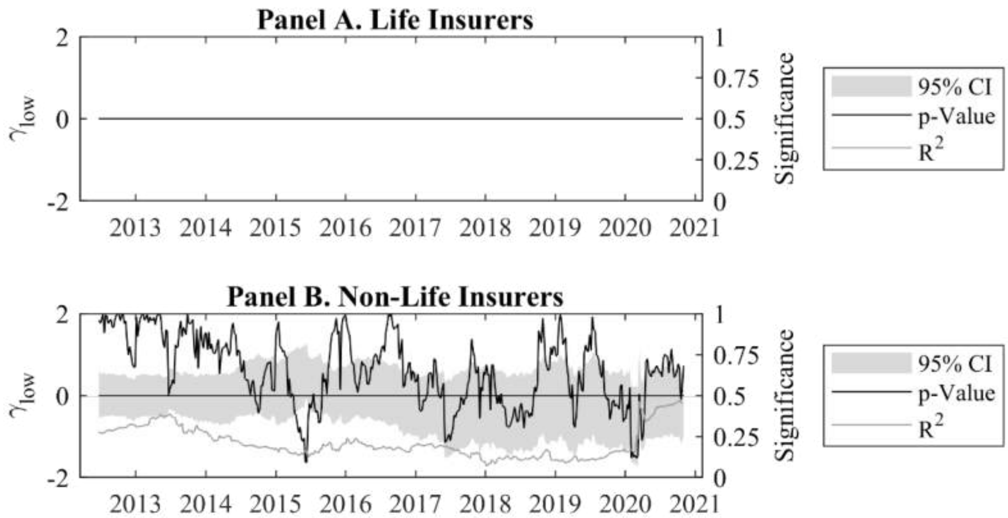
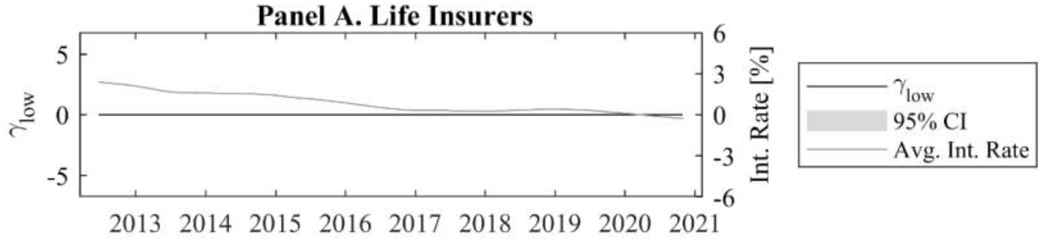


Fig. C37: Changes in Russian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

Panel A. Life Insurers



Panel B. Non-Life Insurers

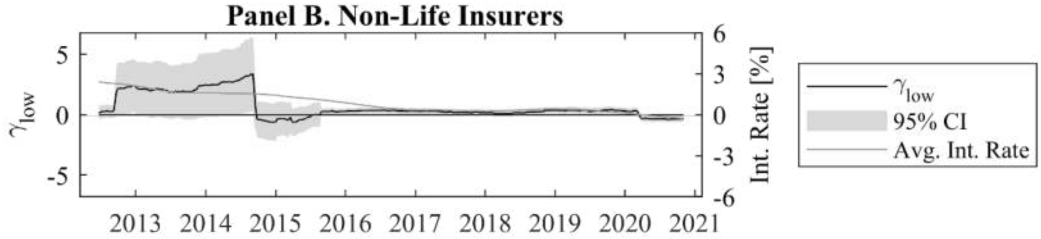
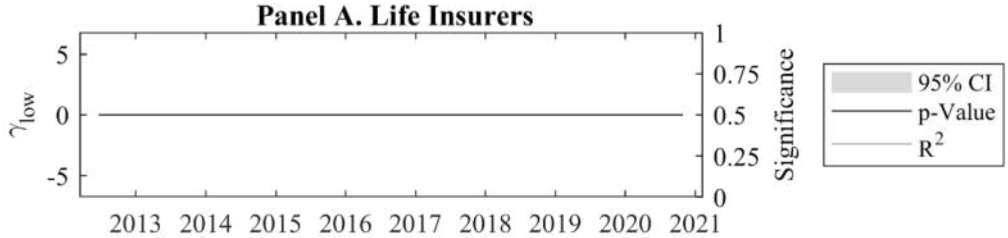


Fig. C38: Statistical Significance of Regression Model for Russian Insurers - Home Countries - Weekly Data

Panel A. Life Insurers



Panel B. Non-Life Insurers

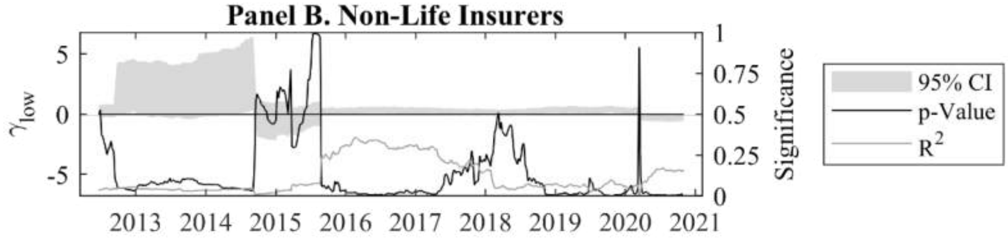


Fig. C39: Changes in Serbian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

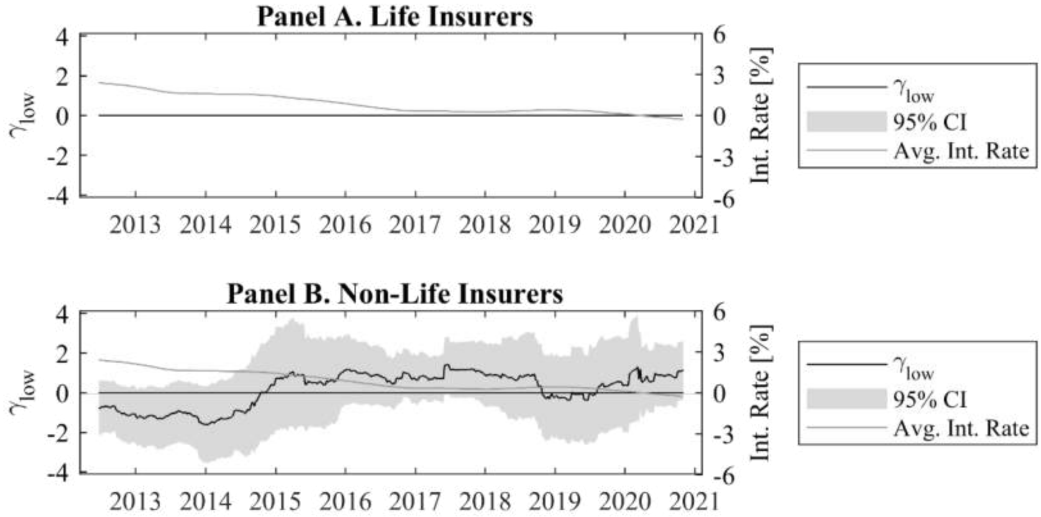


Fig. C40: Statistical Significance of Regression Model for Serbian Insurers - Home Countries - Weekly Data

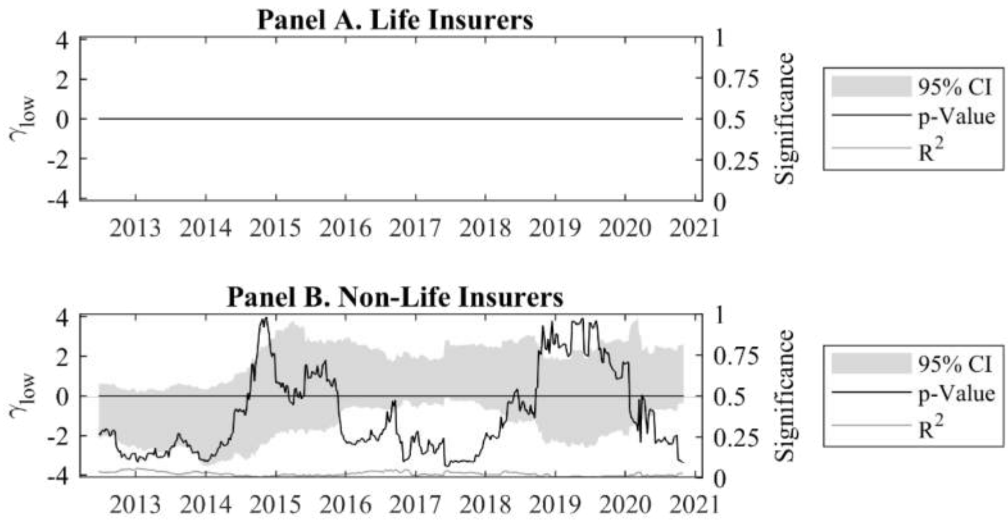


Fig. C41: Changes in Slovenian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

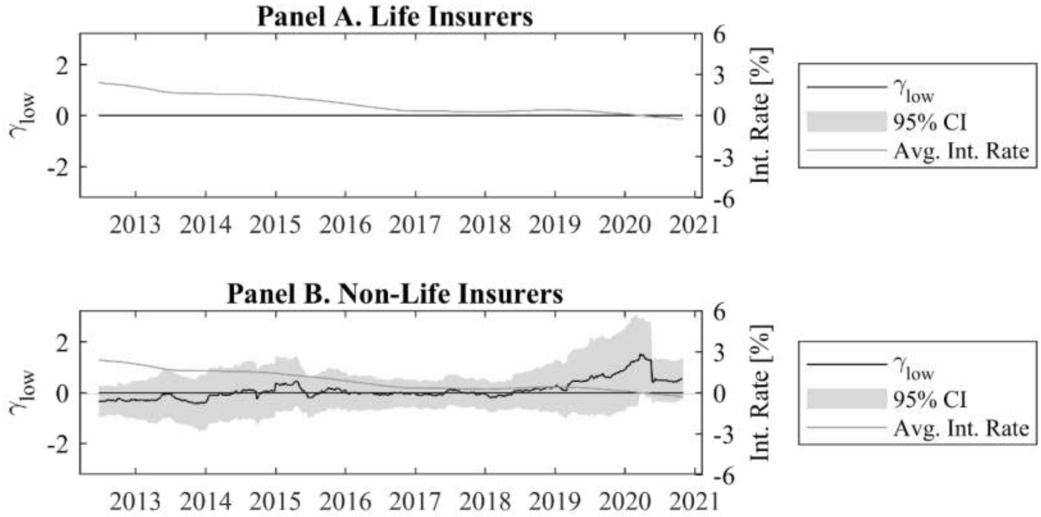


Fig. C42: Statistical Significance of Regression Model for Slovenian Insurers - Home Countries - Weekly Data

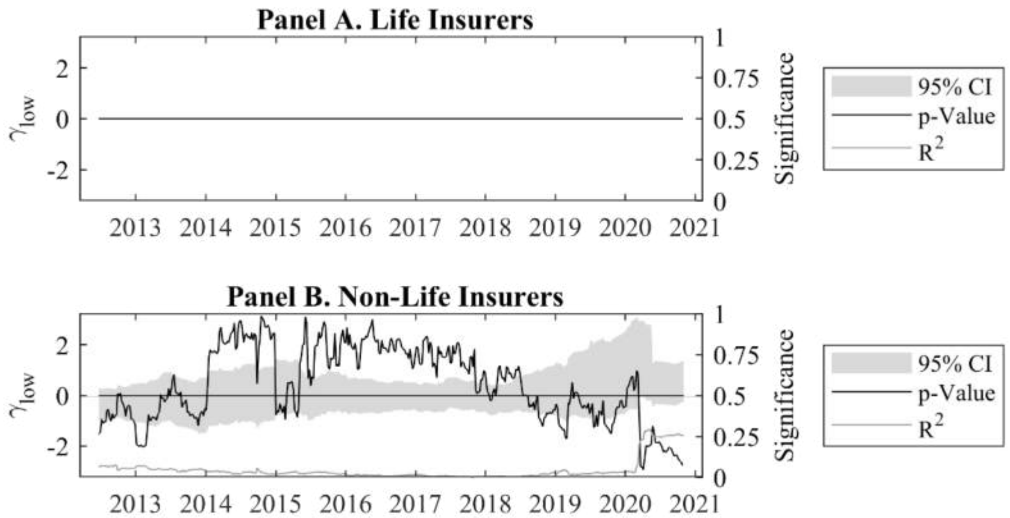


Fig. C43: Changes in Spanish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

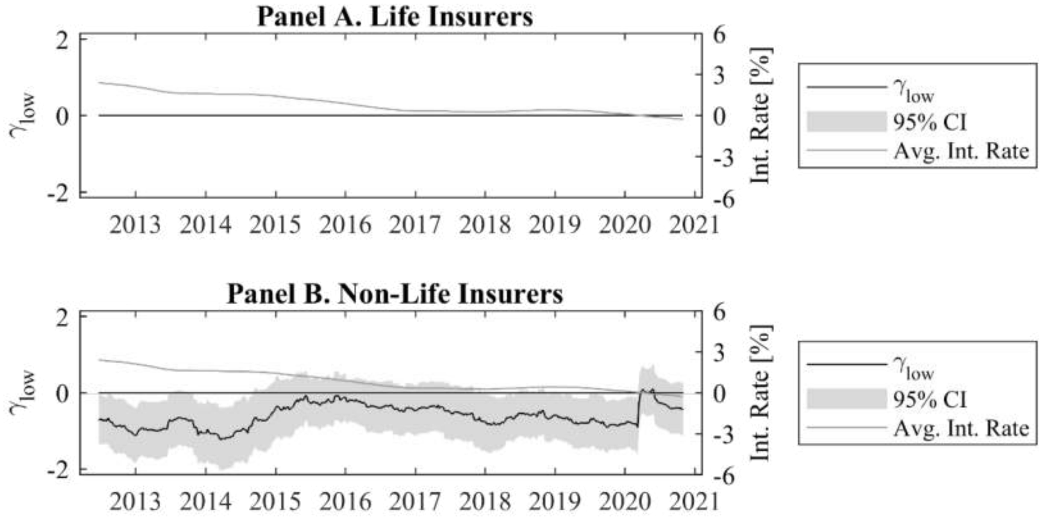


Fig. C44: Statistical Significance of Regression Model for Spanish Insurers - Home Countries - Weekly Data

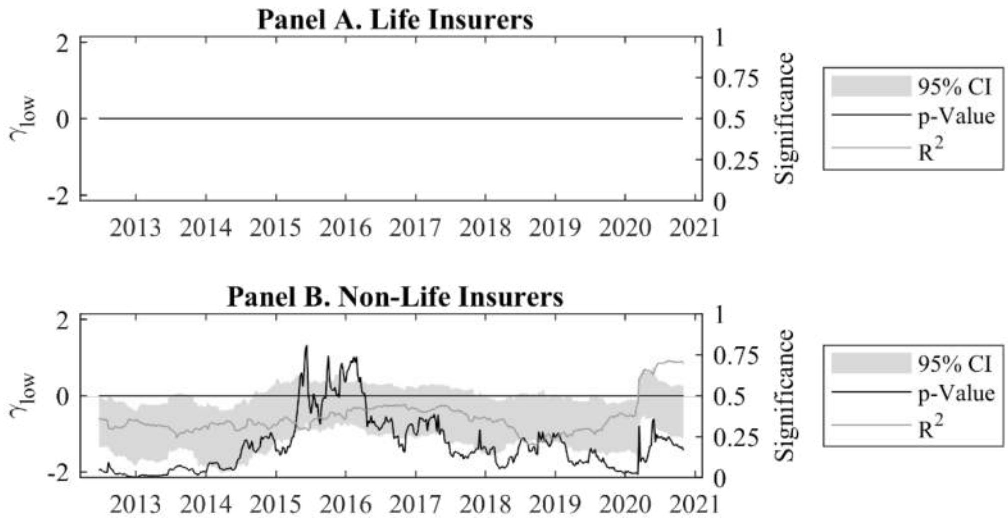


Fig. C45: Changes in Swiss Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

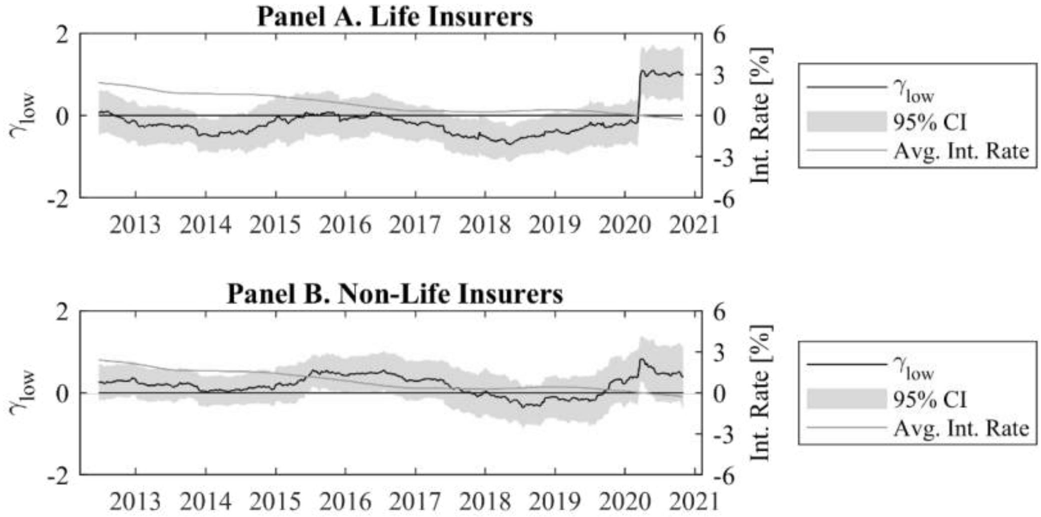


Fig. C46: Statistical Significance of Regression Model for Swiss Insurers - Home Countries - Weekly Data

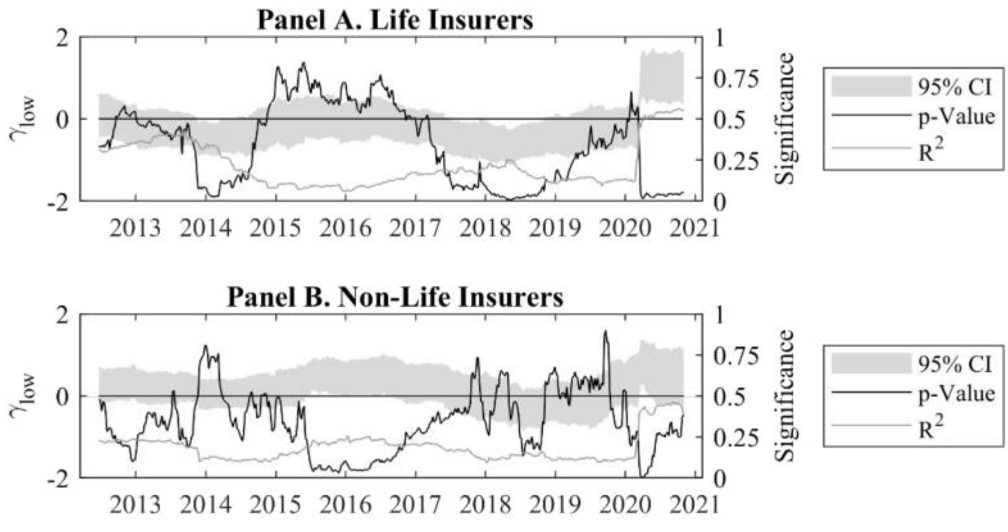


Fig. C47: Changes in Turkish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Weekly Data

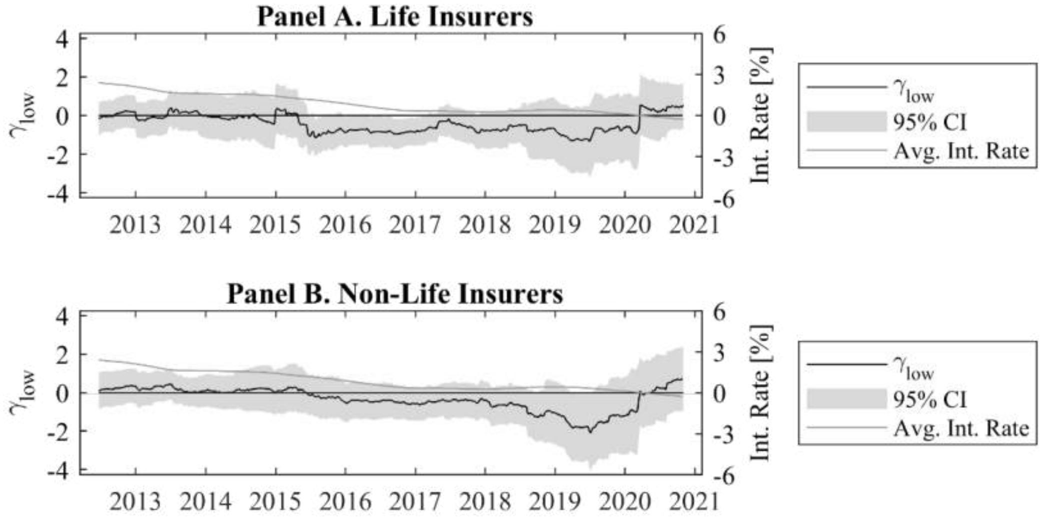
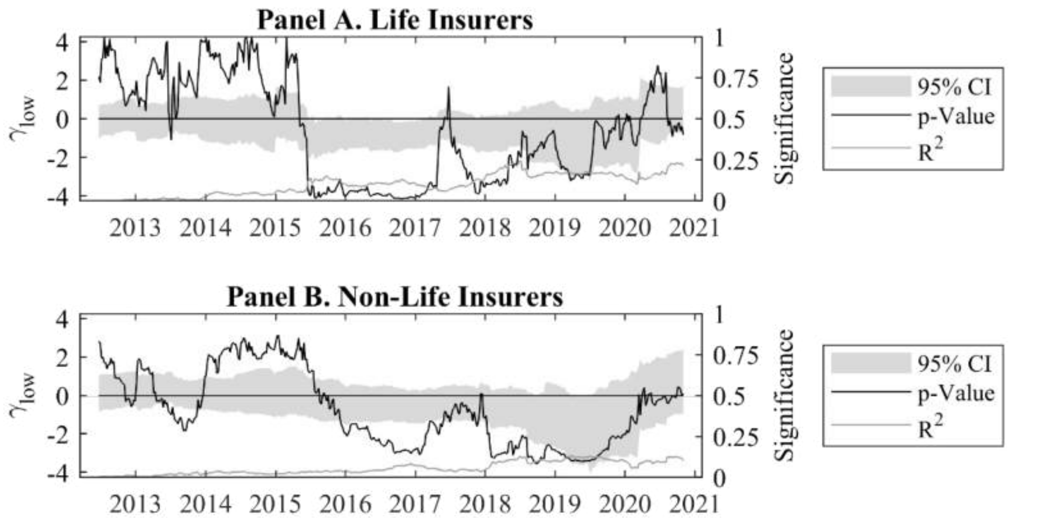


Fig. C48: Statistical Significance of Regression Model for Turkish Insurers - Home Countries - Weekly Data



Appendix D: Change in European Interest Rate Sensitivities by Country (Home Country Allocation – Daily Data)

Fig. D1: Changes in Austrian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

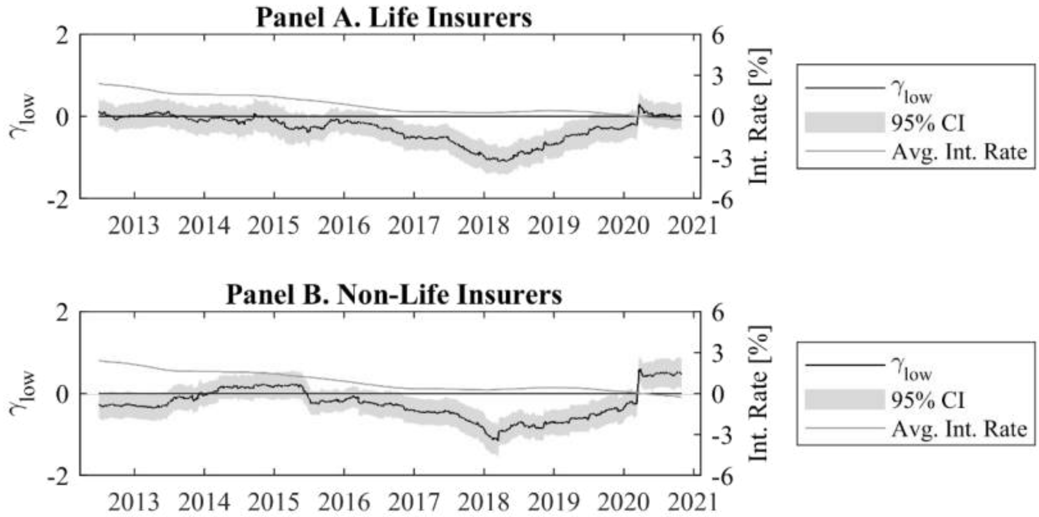


Fig. D2: Statistical Significance of Regression Model for Austrian Insurers - Home Countries - Daily Data

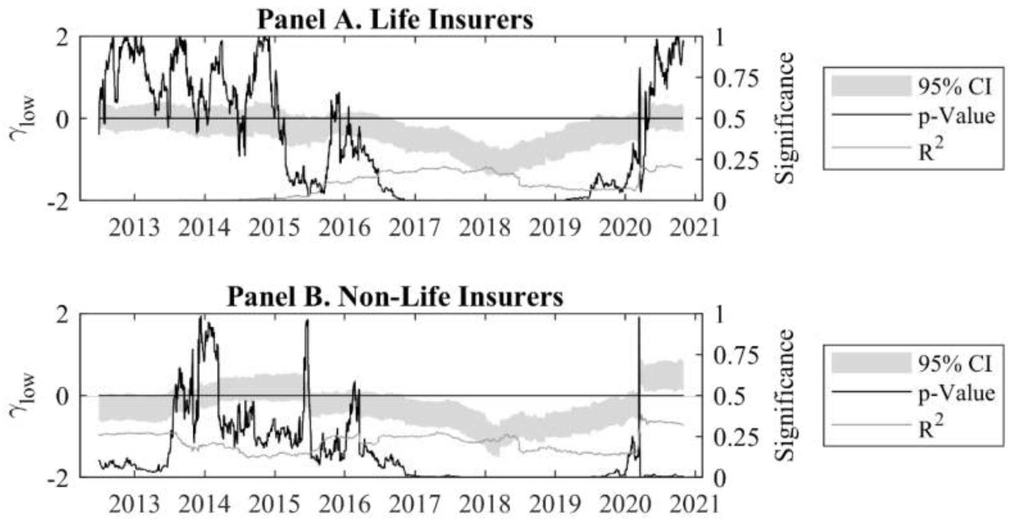


Fig. D3: Changes in Belgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

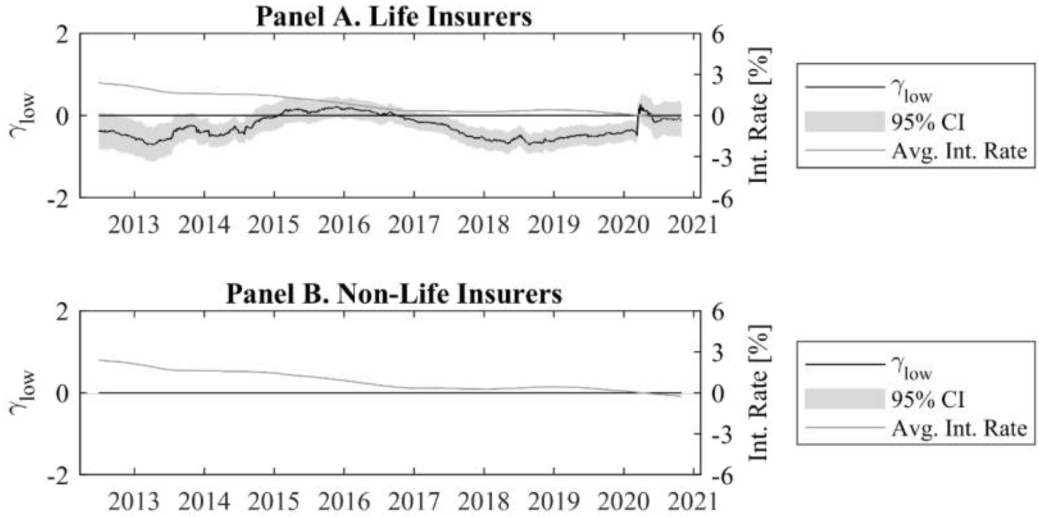


Fig. D4: Statistical Significance of Regression Model for Belgian Insurers - Home Countries - Daily Data

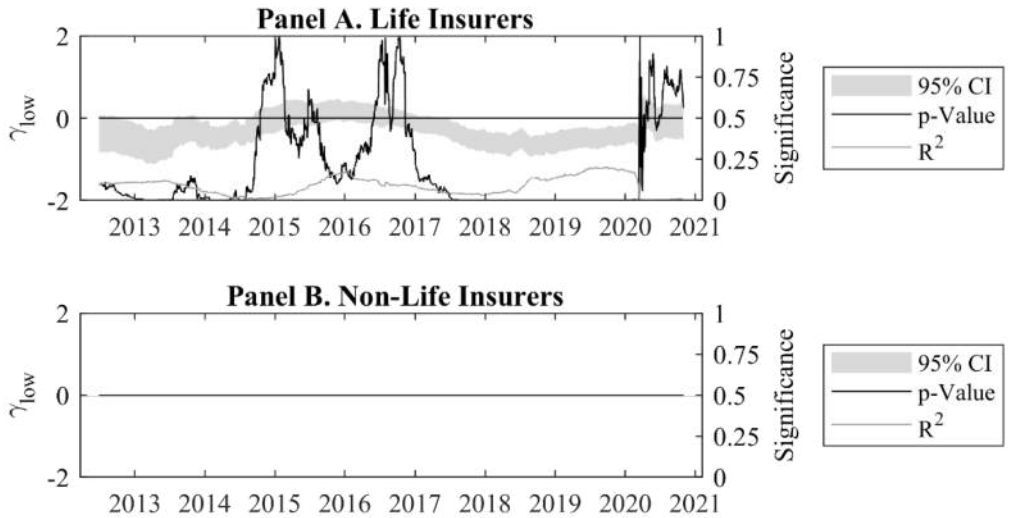


Fig. D5: Changes in Croatian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

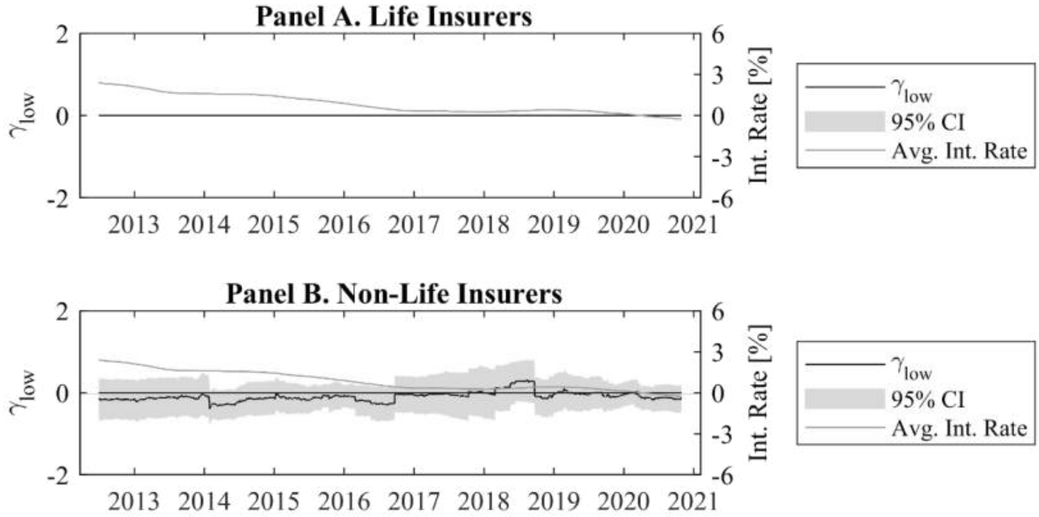


Fig. D6: Statistical Significance of Regression Model for Croatian Insurers - Home Countries - Daily Data

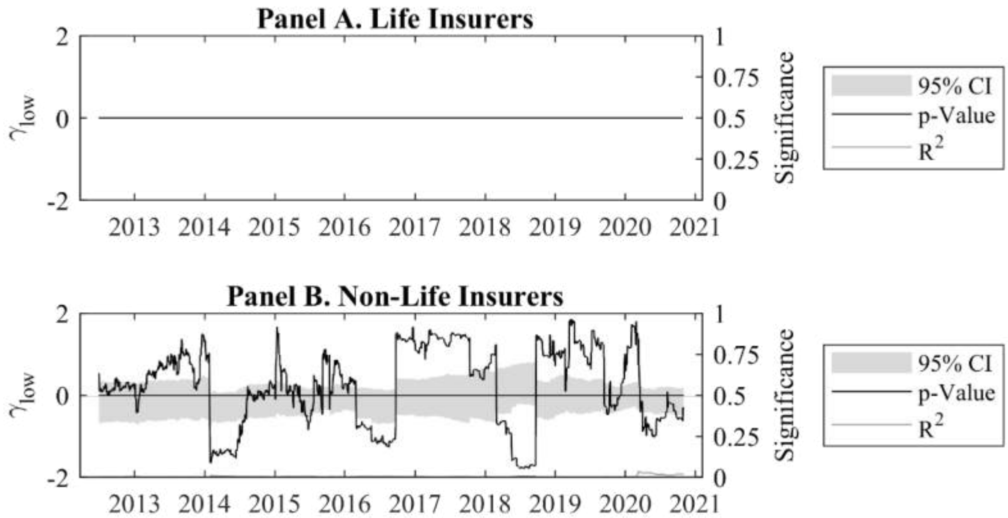


Fig. D7: Changes in Cyprian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

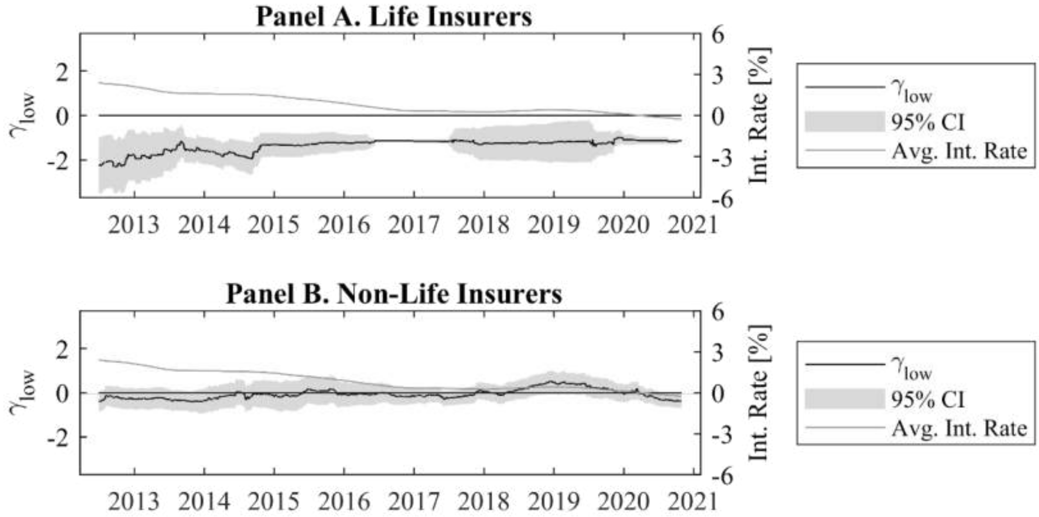


Fig. D8: Statistical Significance of Regression Model for Cyprian Insurers - Home Countries - Daily Data

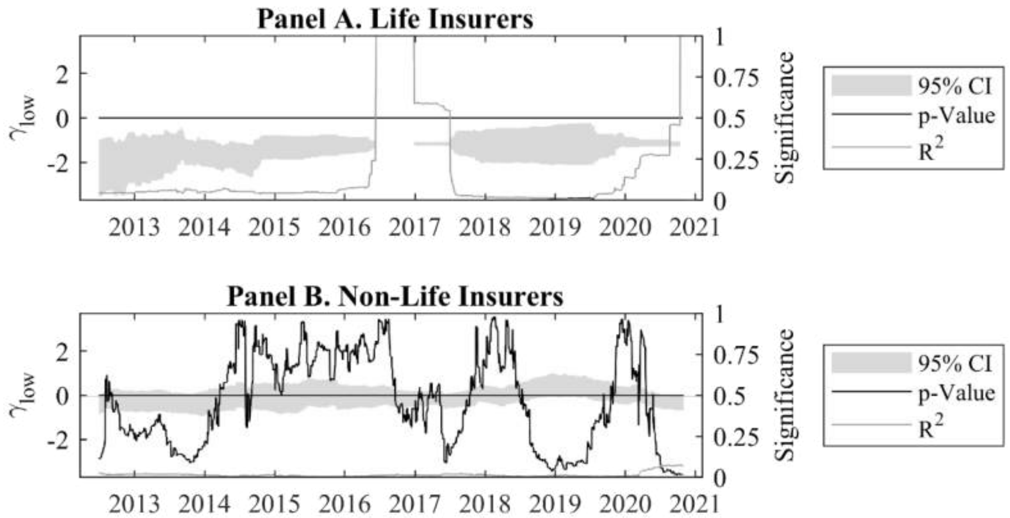


Fig. D9: Changes in Danish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

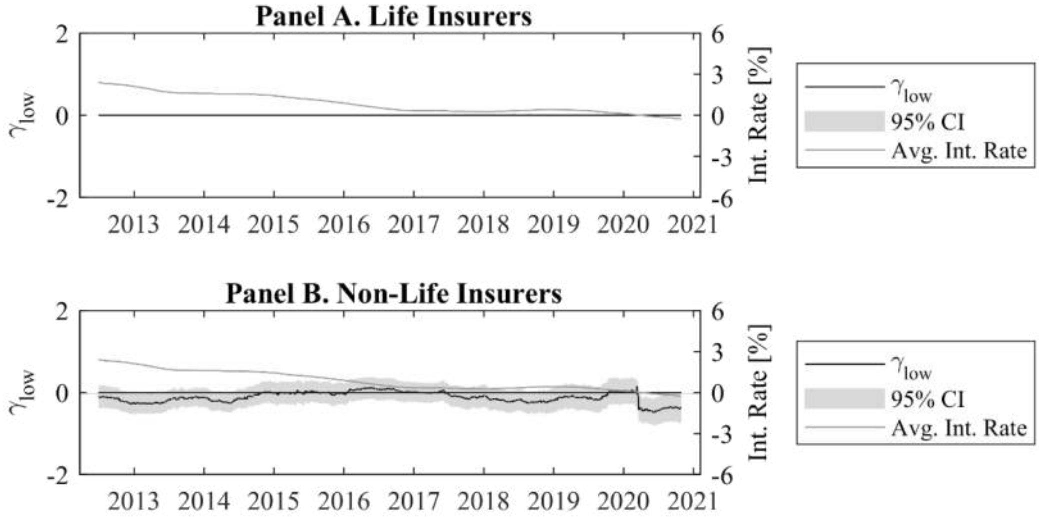


Fig. D10: Statistical Significance of Regression Model for Danish Insurers - Home Countries - Daily Data

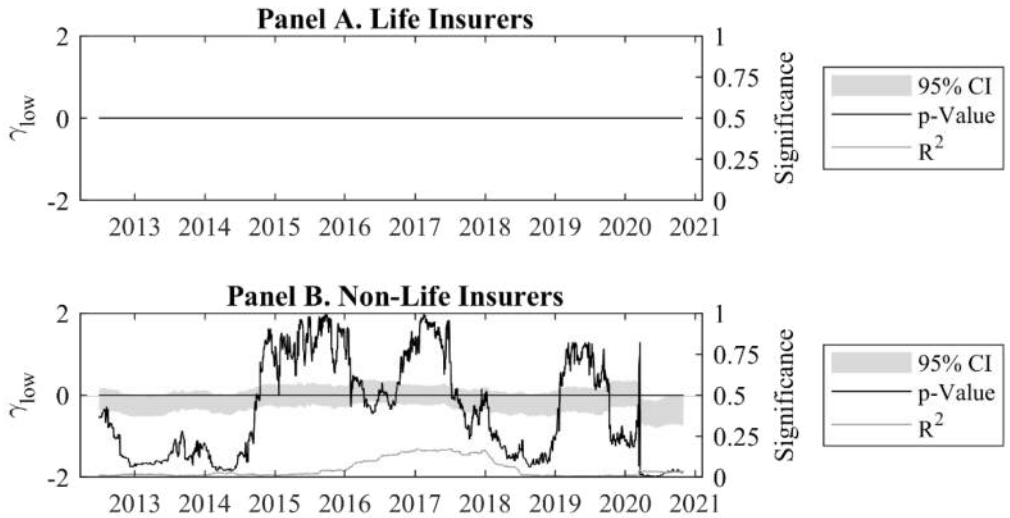


Fig. D11: Changes in Finnish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

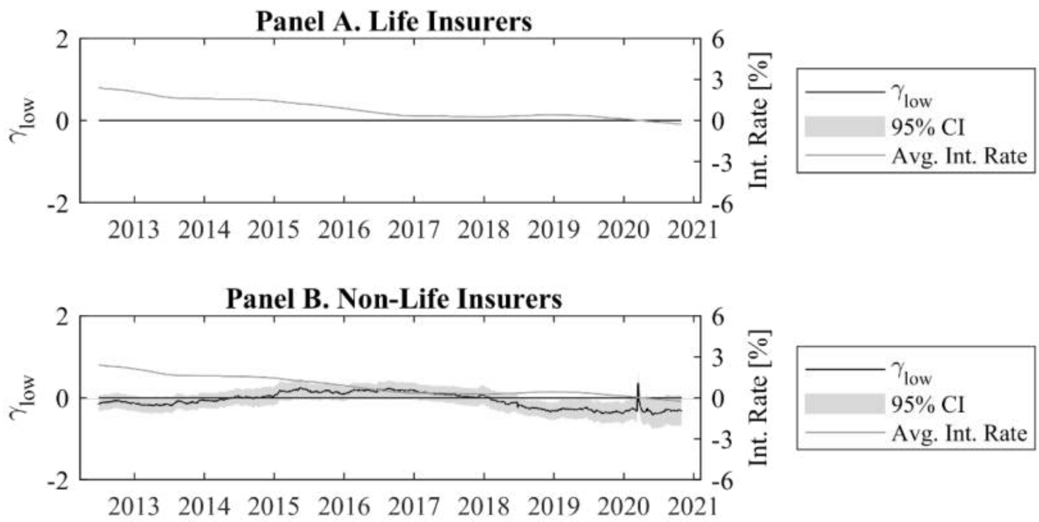


Fig. D12: Statistical Significance of Regression Model for Finnish Insurers - Home Countries - Daily Data

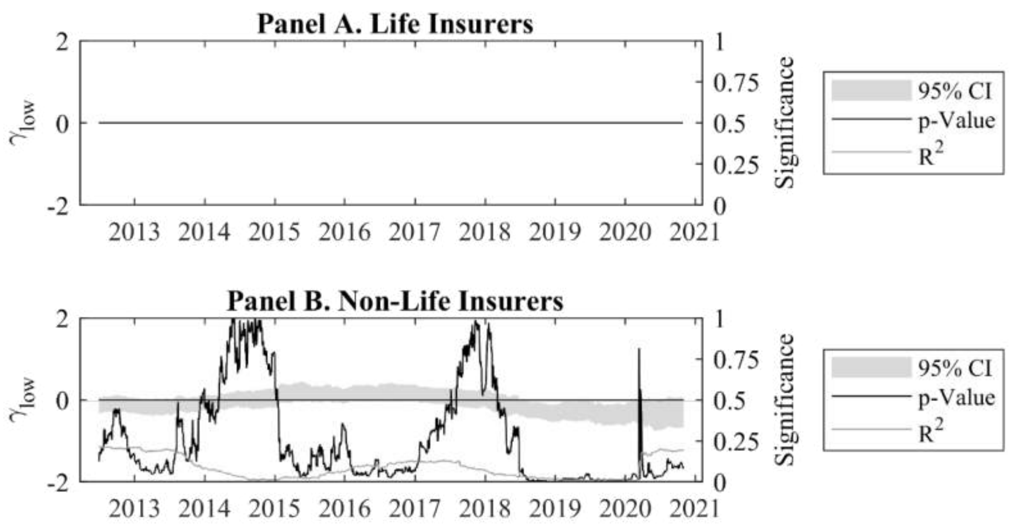


Fig. D13: Changes in French Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

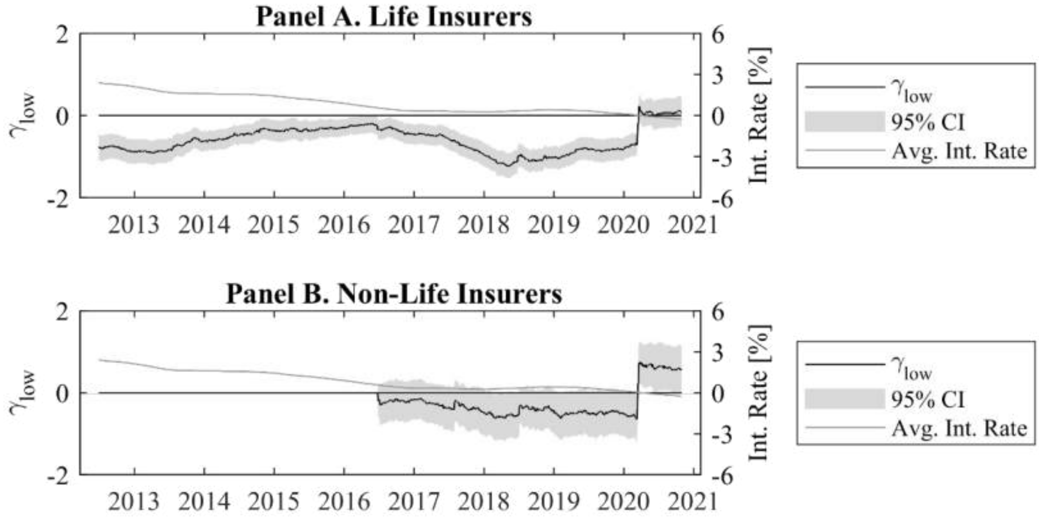


Fig. D14: Statistical Significance of Regression Model for French Insurers - Home Countries - Daily Data

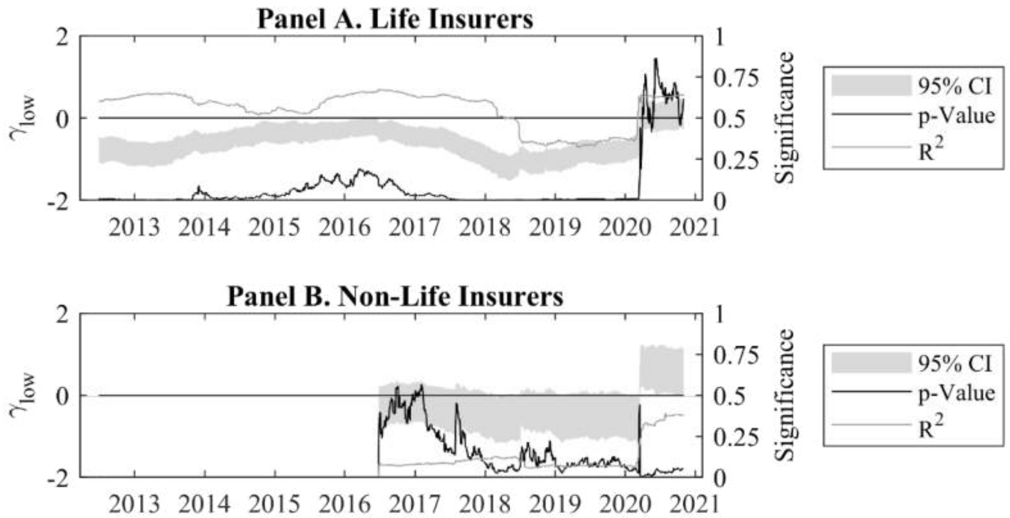


Fig. D15: Changes in German Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

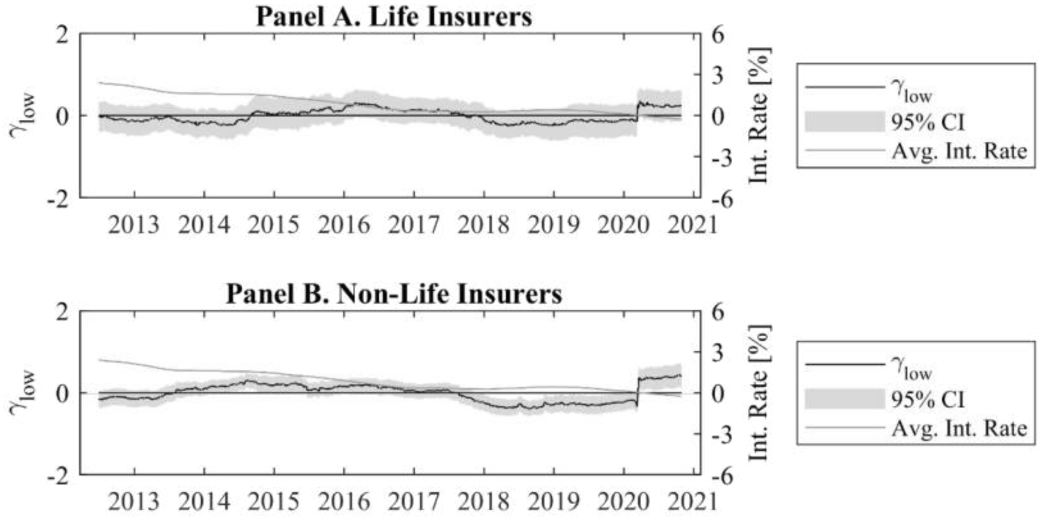


Fig. D16: Statistical Significance of Regression Model for German Insurers - Home Countries - Daily Data

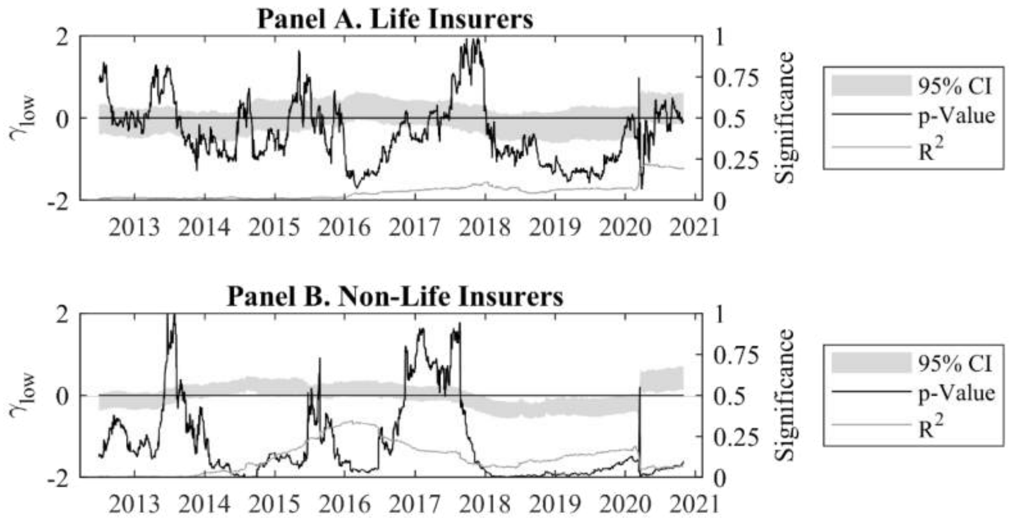


Fig. D17: Changes in Greek Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

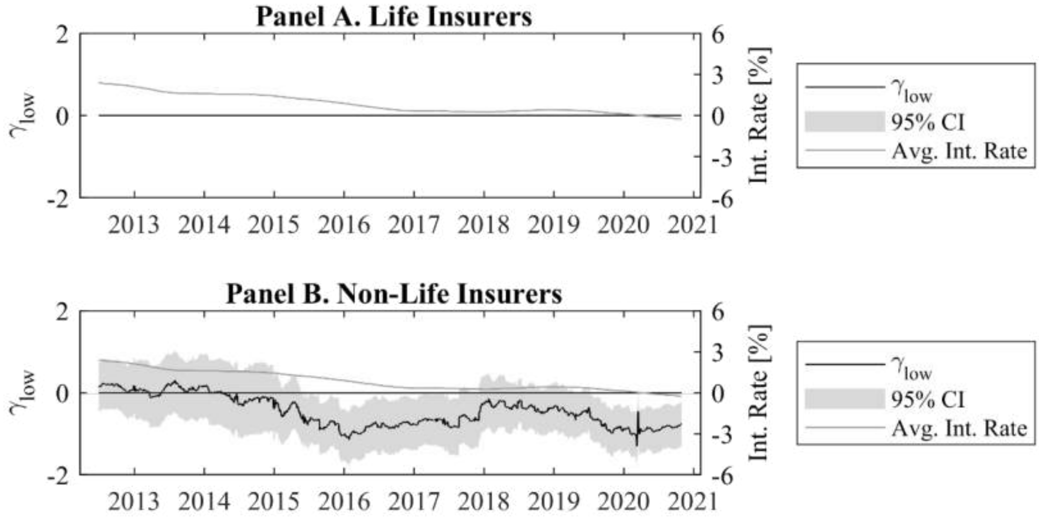


Fig. D18: Statistical Significance of Regression Model for Greek Insurers - Home Countries - Daily Data

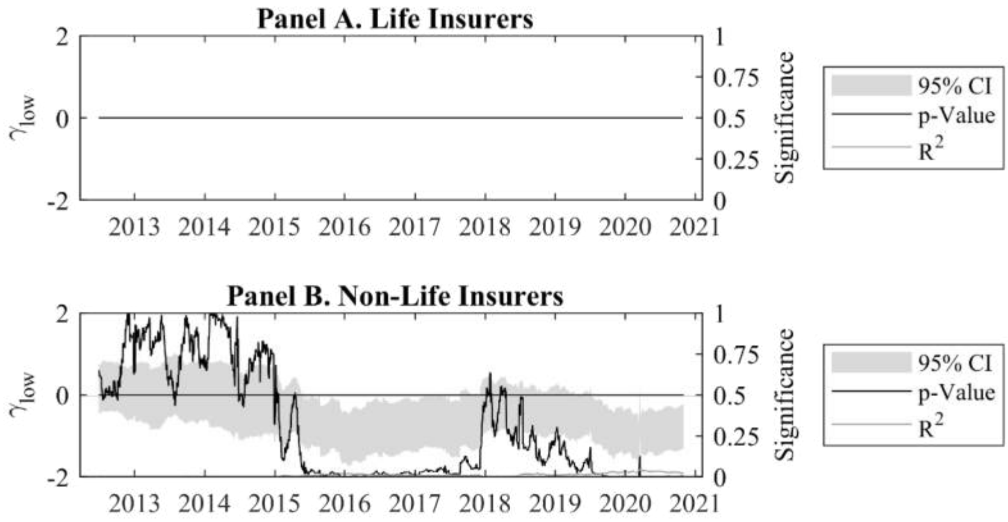


Fig. D19: Changes in Hungarian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

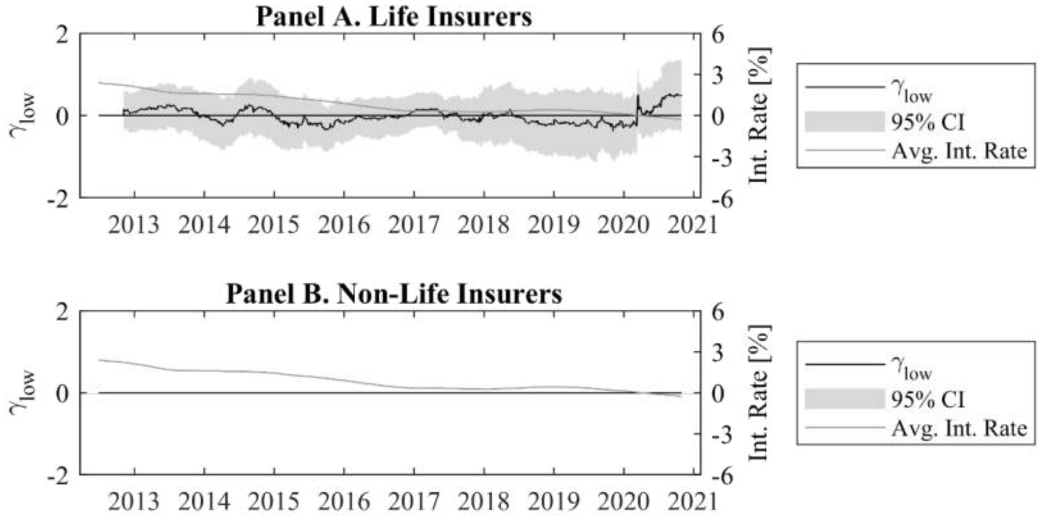


Fig. D20: Statistical Significance of Regression Model for Hungarian Insurers - Home Countries - Daily Data

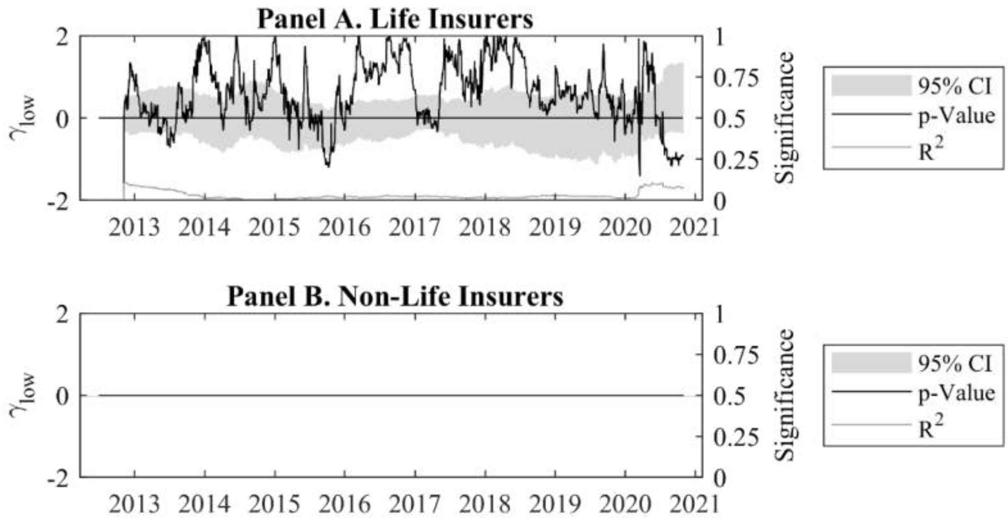


Fig. D21: Changes in Icelandic Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

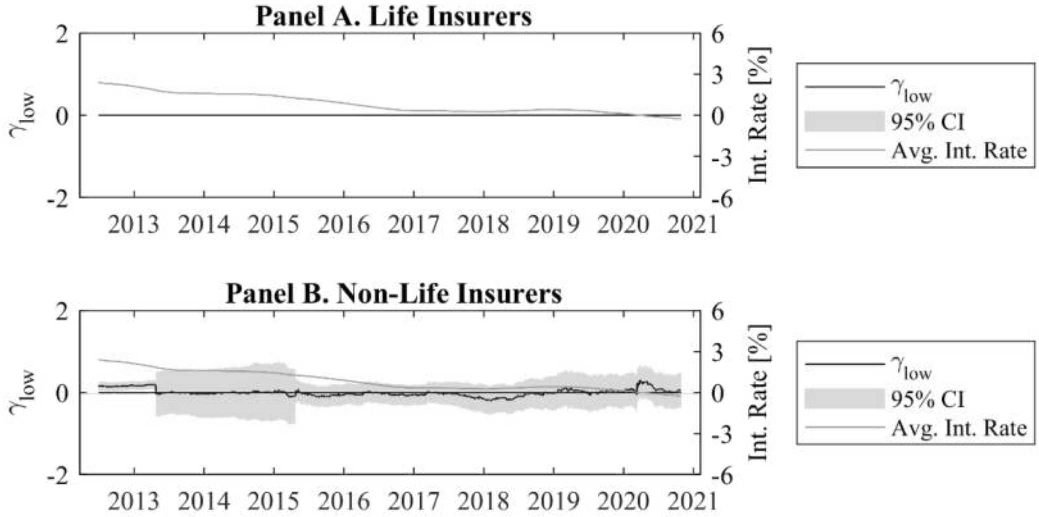


Fig. D22: Statistical Significance of Regression Model for Icelandic Insurers - Home Countries - Daily Data

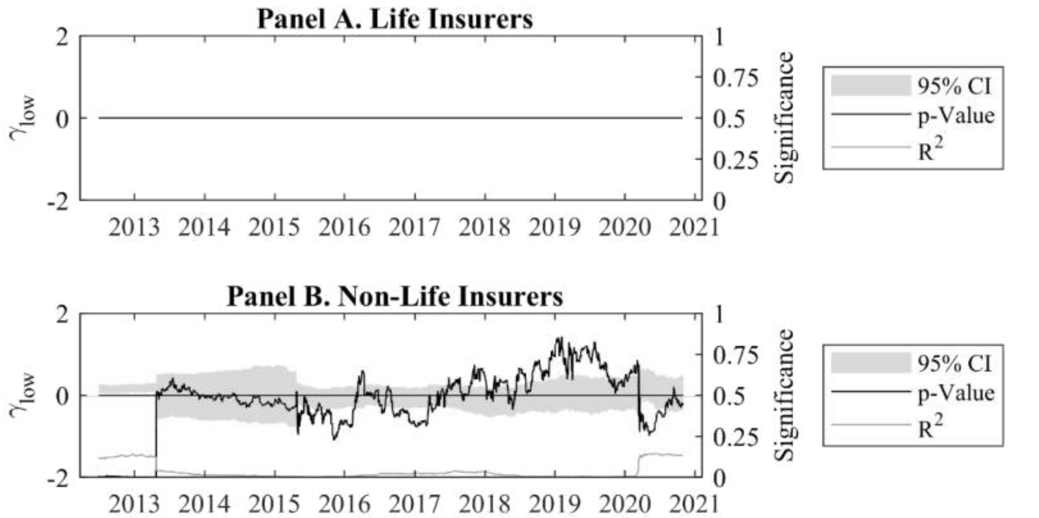


Fig. D23: Changes in Irish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

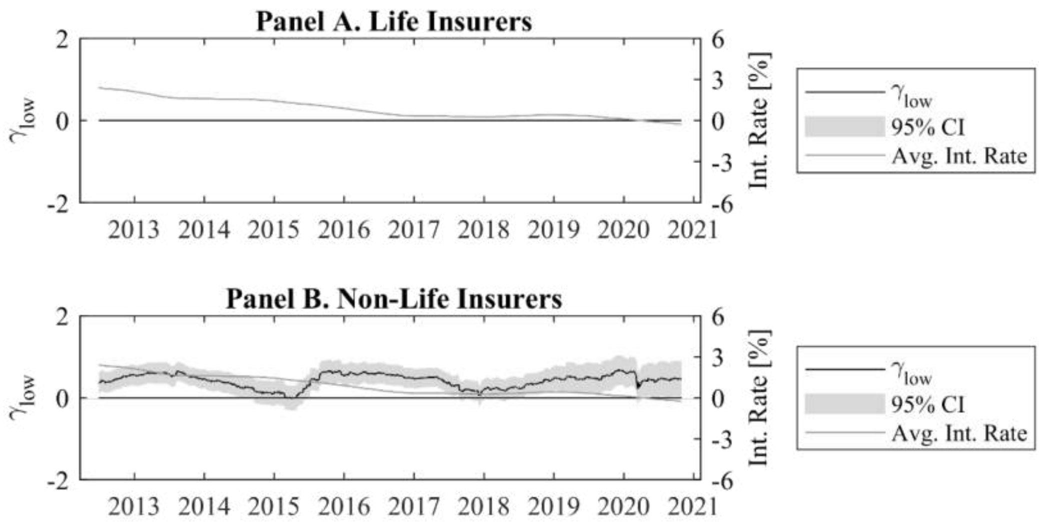


Fig. D24: Statistical Significance of Regression Model for Irish Insurers - Home Countries - Daily Data

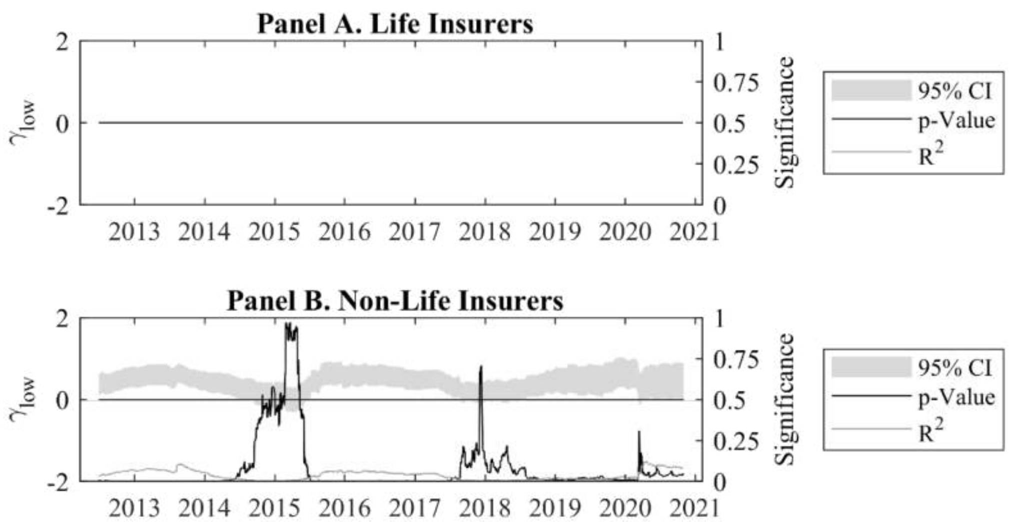


Fig. D25: Changes in Italian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

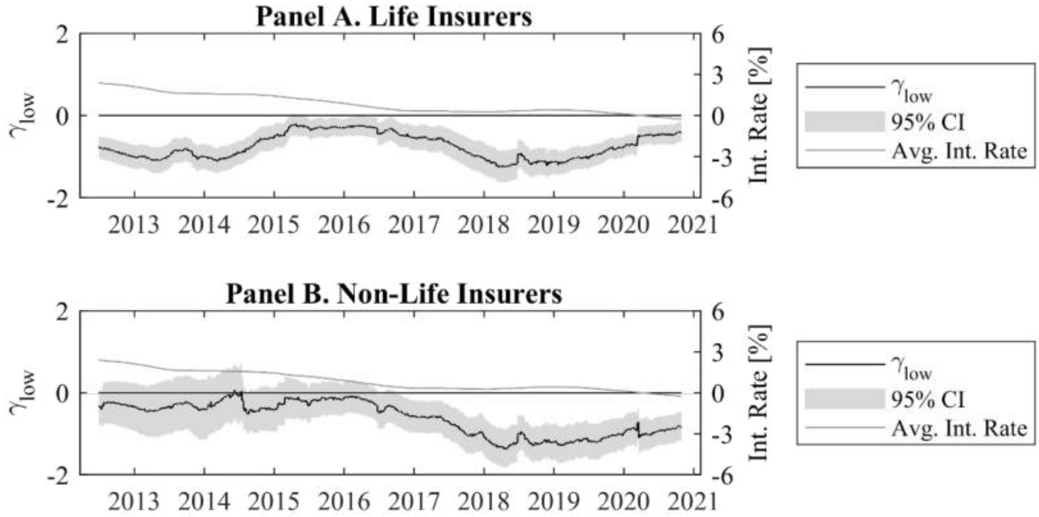


Fig. D26: Statistical Significance of Regression Model for Italian Insurers - Home Countries - Daily Data

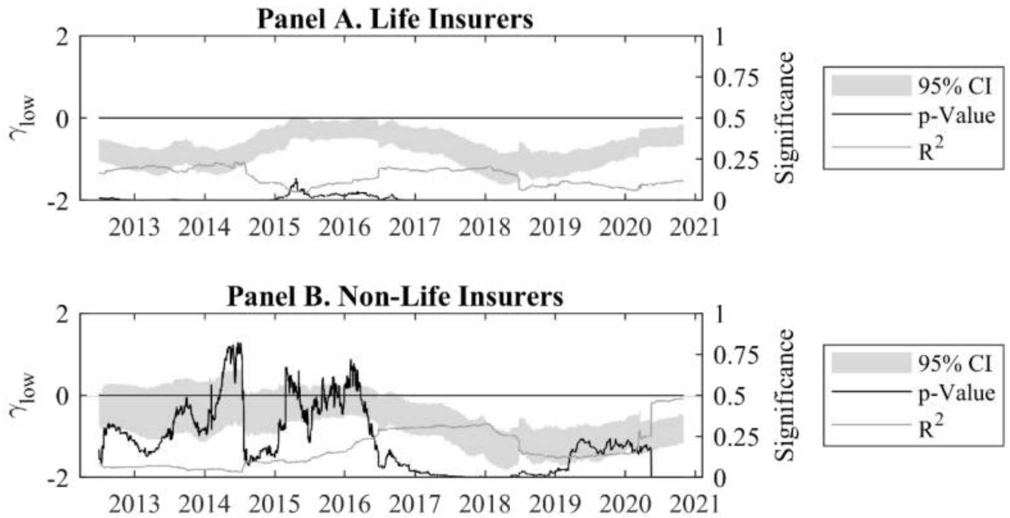


Fig. D27: Changes in Luxembourgian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

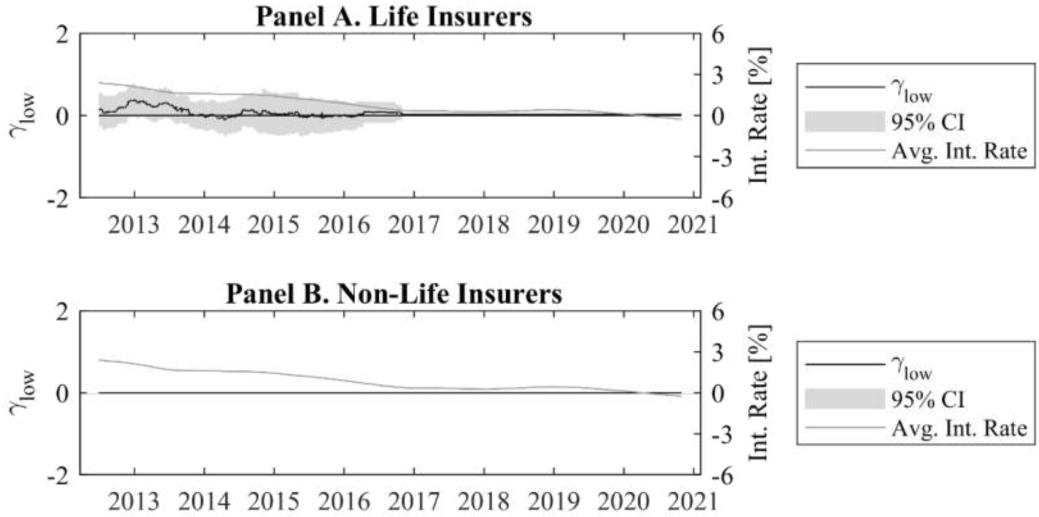


Fig. D28: Statistical Significance of Regression Model for Luxembourgian Insurers - Home Countries - Daily Data

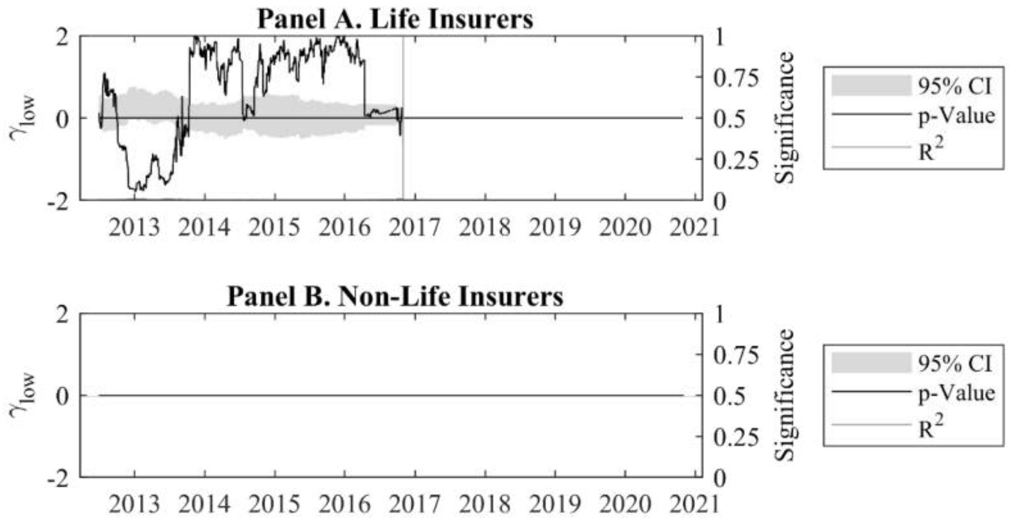


Fig. D29: Changes in Maltese Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

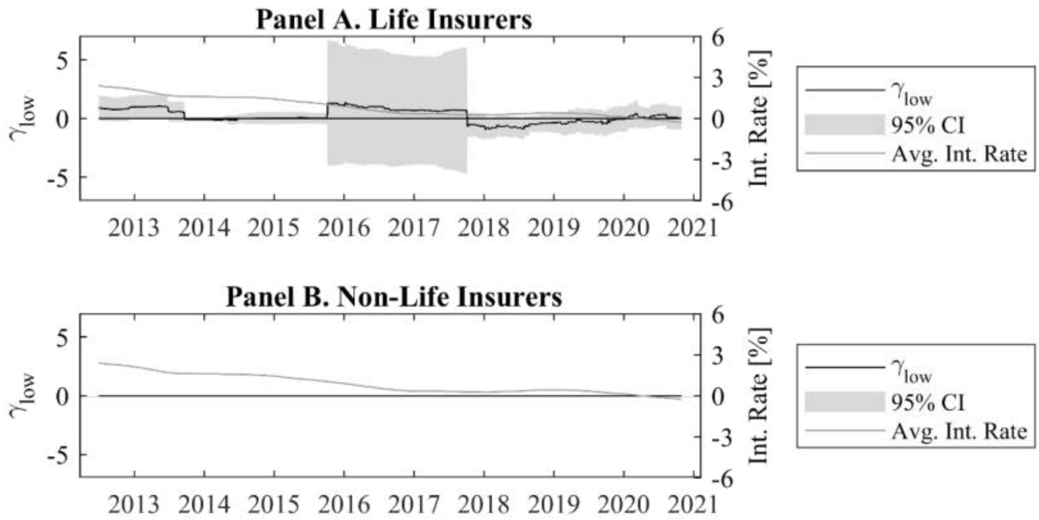


Fig. D30: Statistical Significance of Regression Model for Maltese Insurers - Home Countries - Daily Data

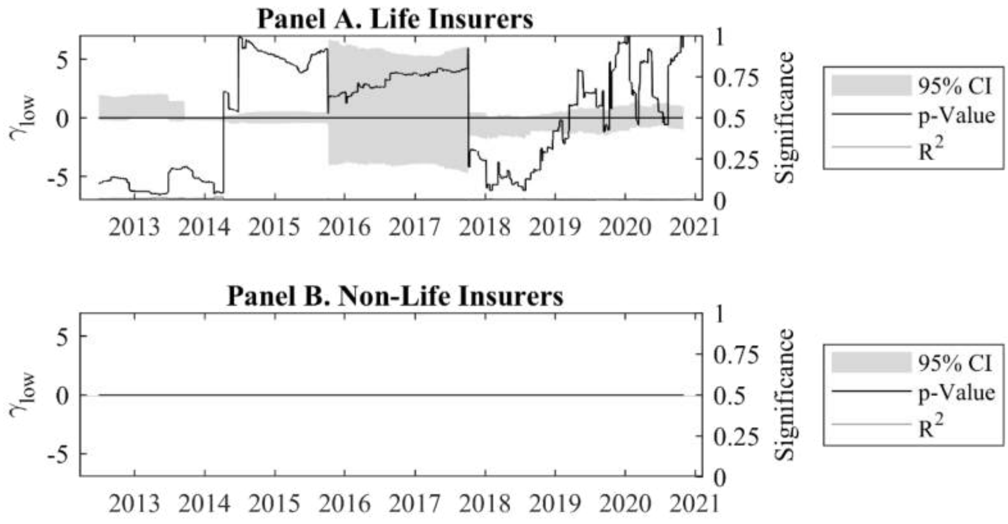


Fig. D31: Changes in Dutch Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

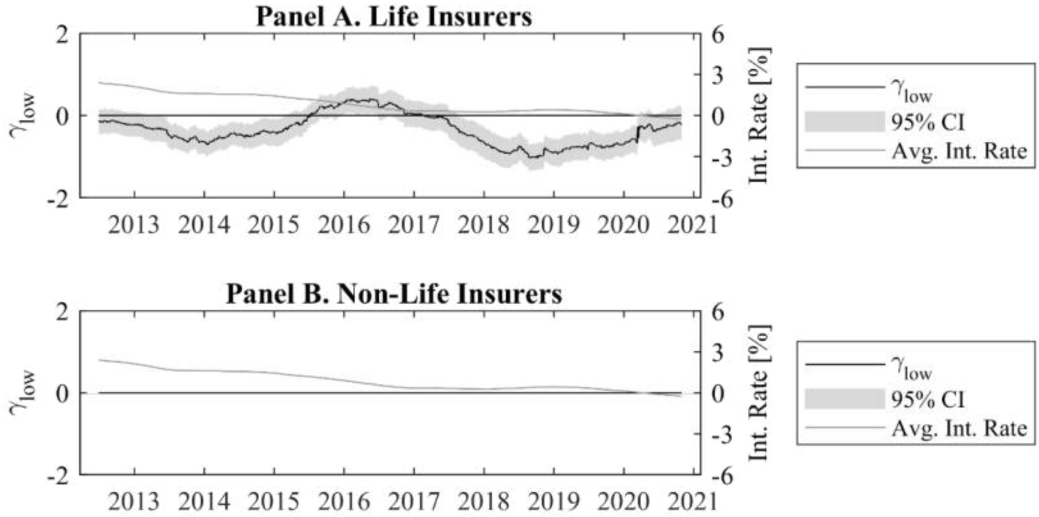


Fig. D32: Statistical Significance of Regression Model for Dutch Insurers - Home Countries - Daily Data

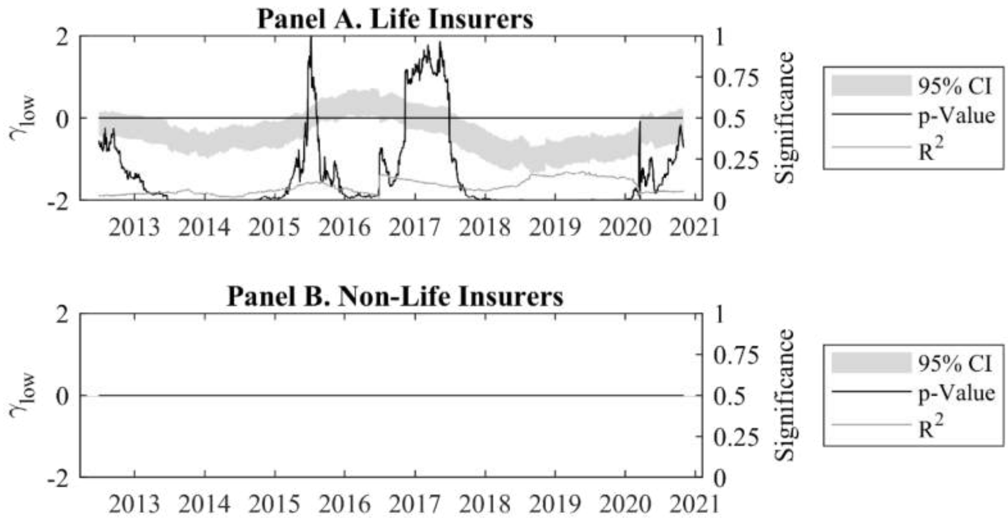


Fig. D33: Changes in Norwegian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

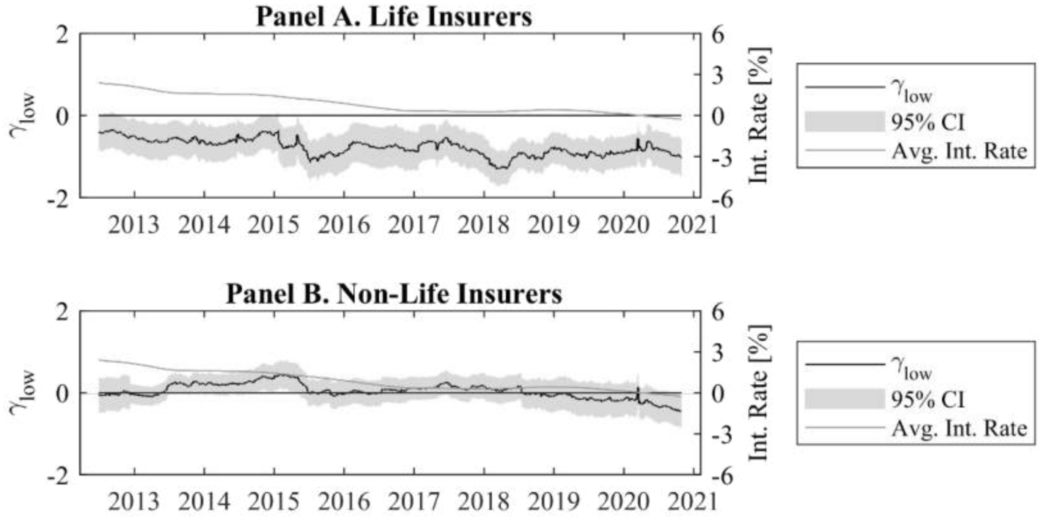


Fig. D34: Statistical Significance of Regression Model for Norwegian Insurers - Home Countries - Daily Data

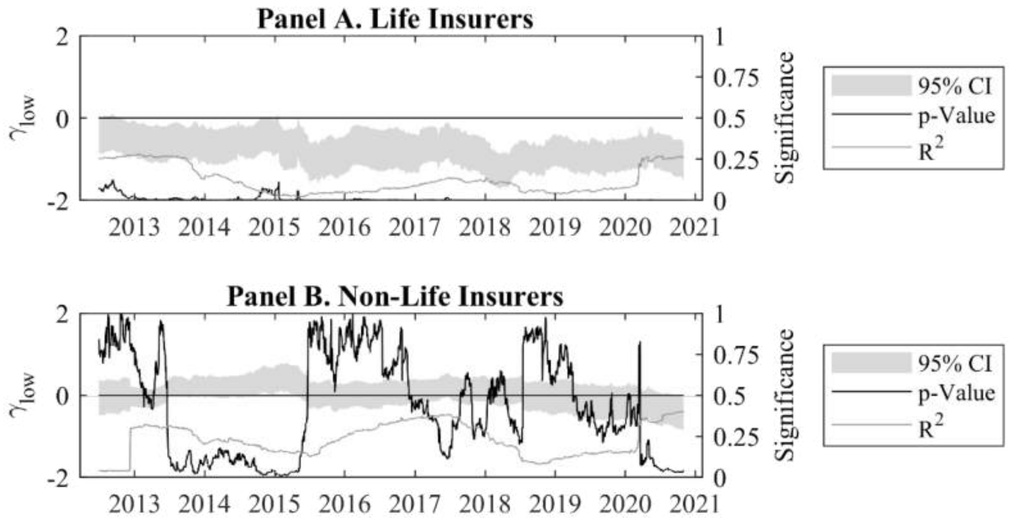


Fig. D35: Changes in Polish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

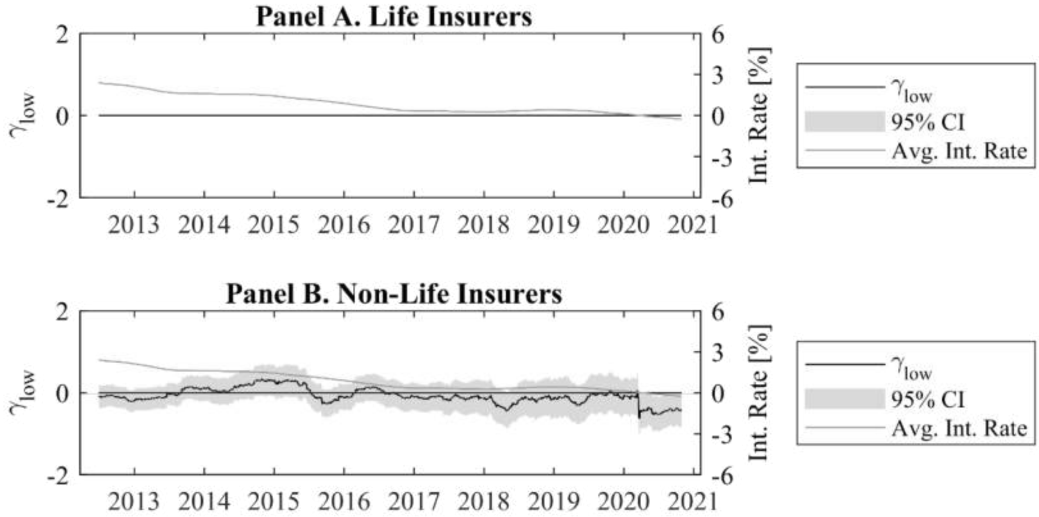


Fig. D36: Statistical Significance of Regression Model for Polish Insurers - Home Countries - Daily Data

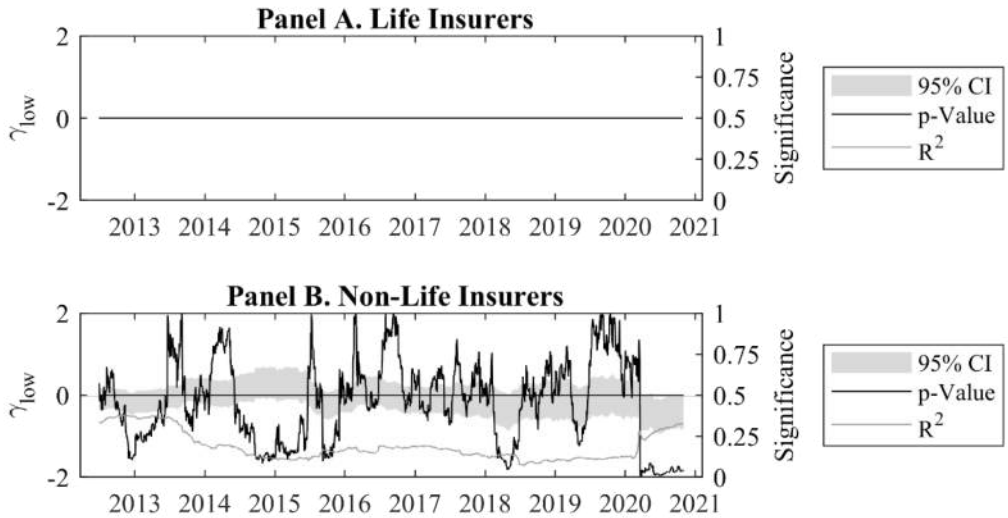


Fig. D37: Changes in Russian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

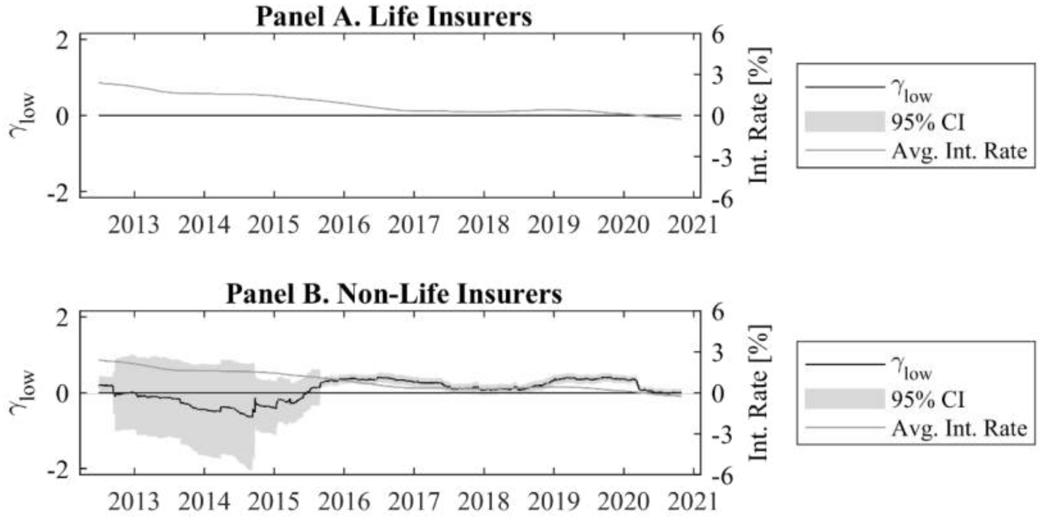


Fig. D38: Statistical Significance of Regression Model for Russian Insurers - Home Countries - Daily Data

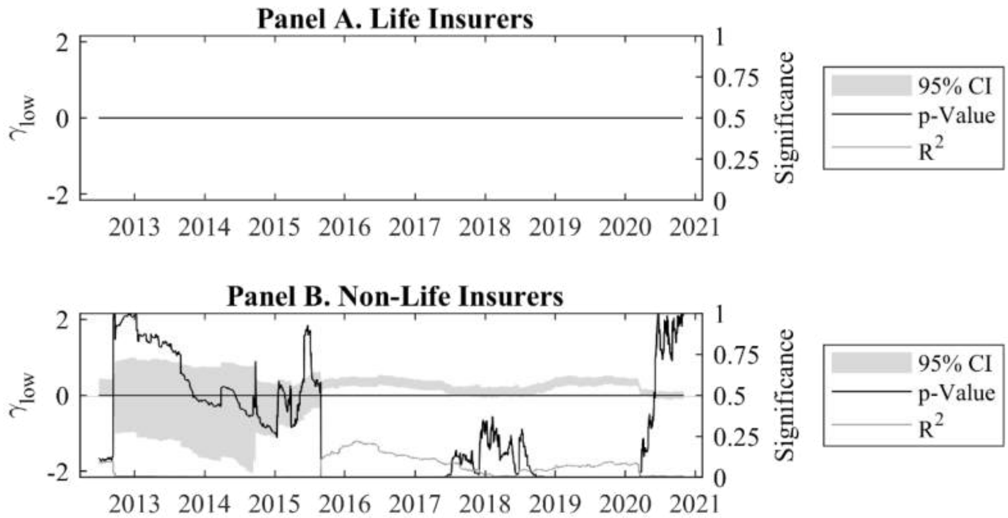


Fig. D39: Changes in Serbian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

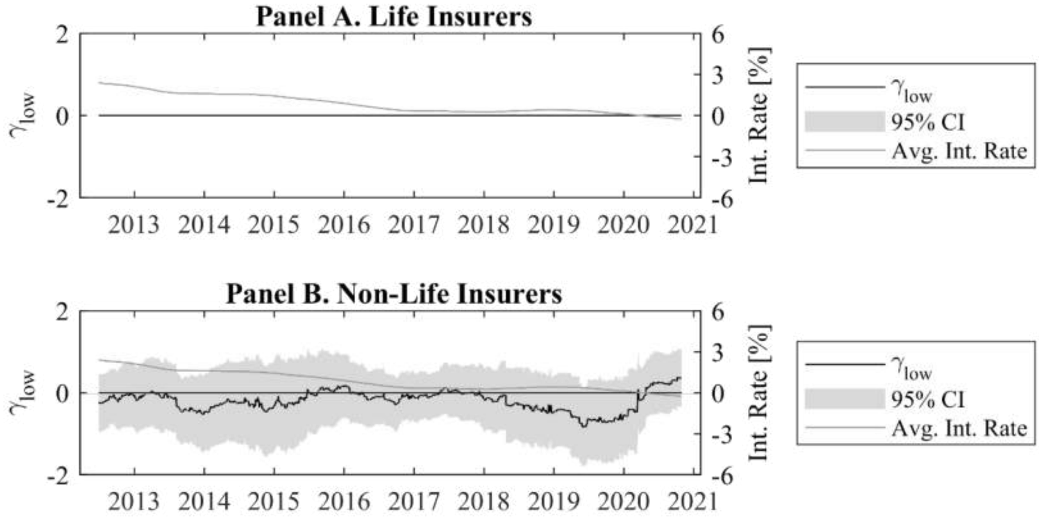


Fig. D40: Statistical Significance of Regression Model for Serbian Insurers - Home Countries - Daily Data

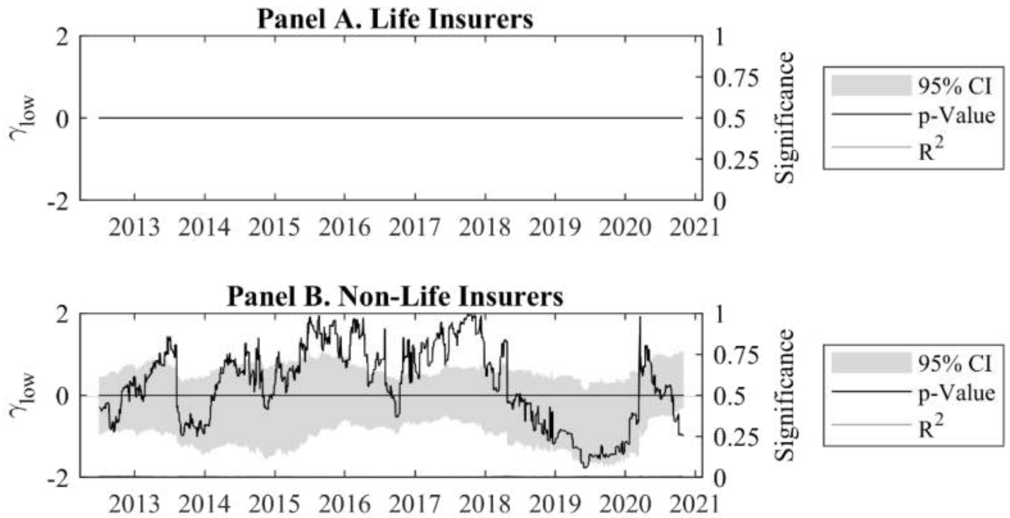


Fig. D41: Changes in Slovenian Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

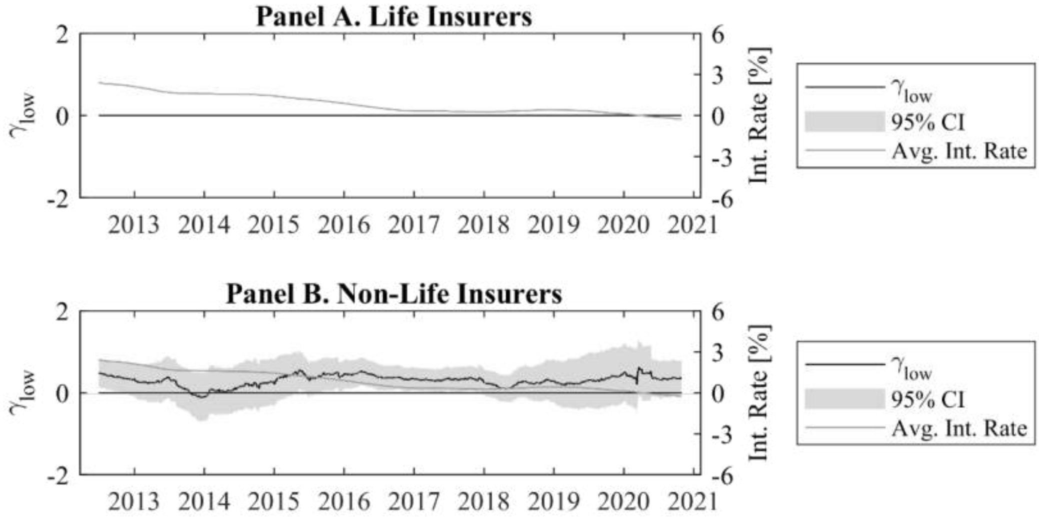


Fig. D42: Statistical Significance of Regression Model for Slovenian Insurers - Home Countries - Daily Data

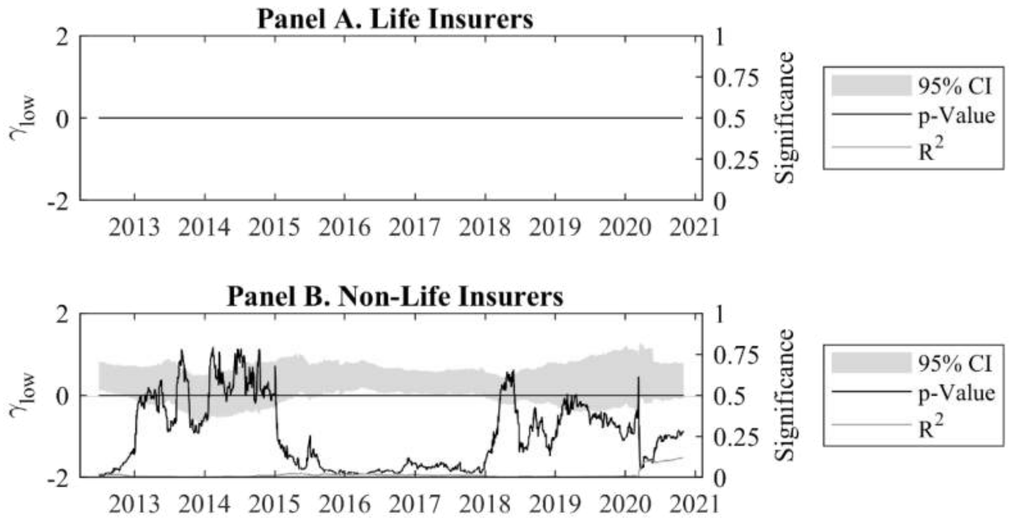


Fig. D43: Changes in Spanish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

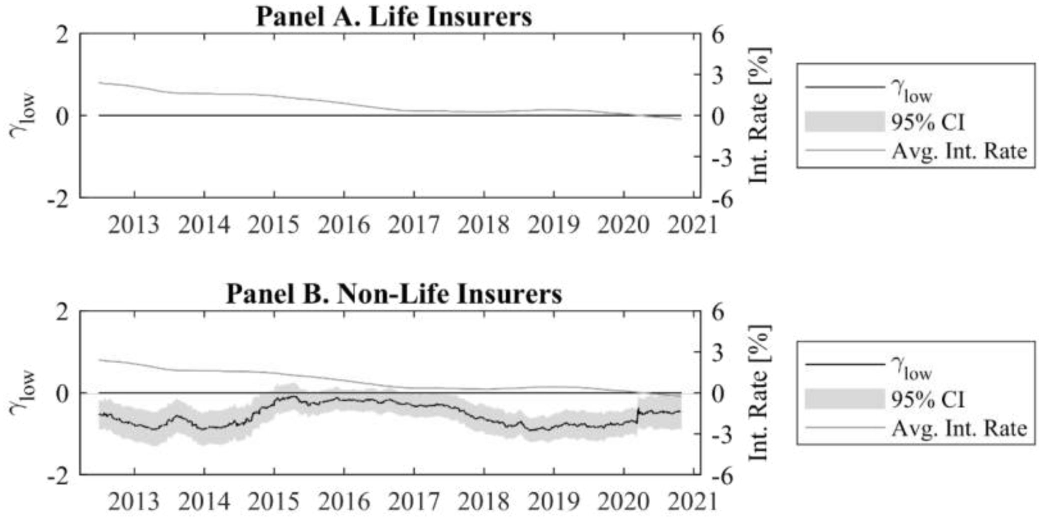


Fig. D44: Statistical Significance of Regression Model for Spanish Insurers - Home Countries - Daily Data

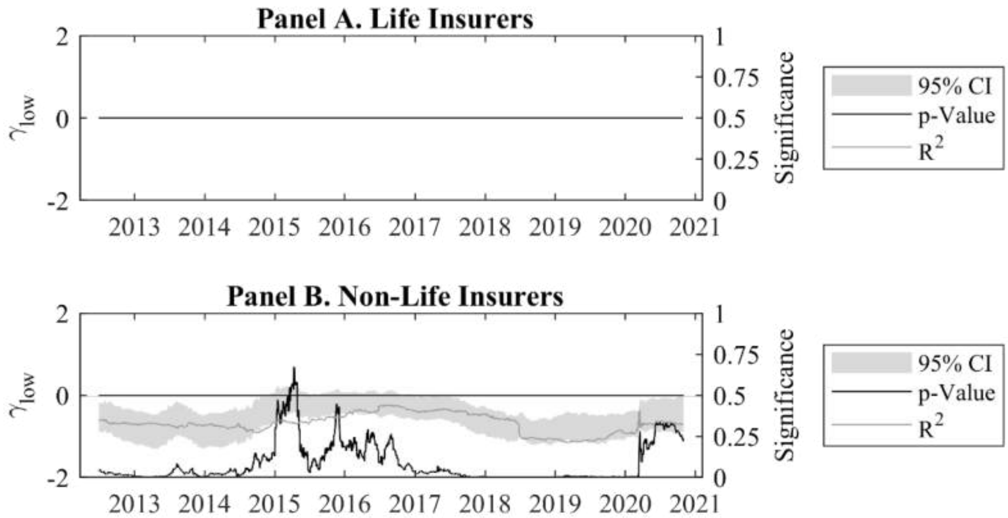


Fig. D45: Changes in Swiss Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data

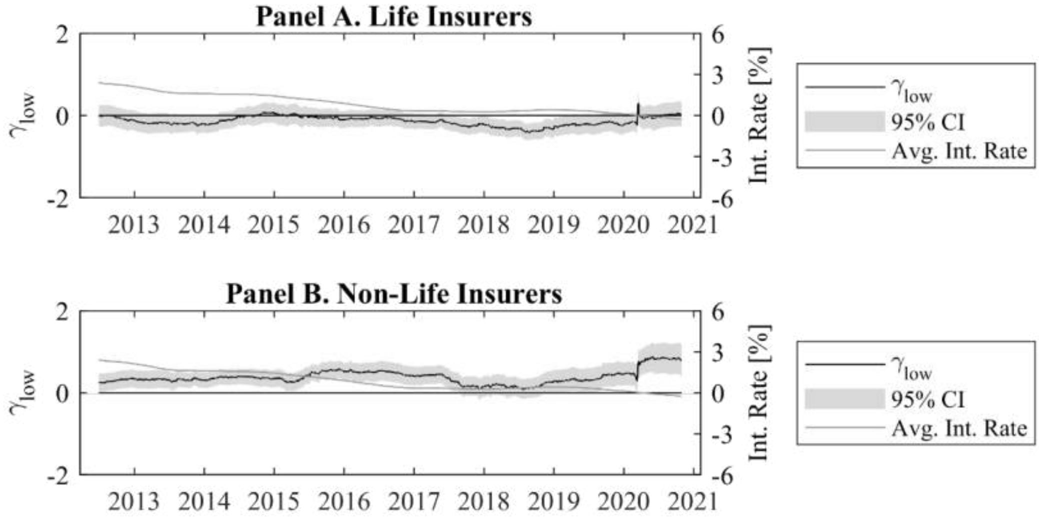


Fig. D46: Statistical Significance of Regression Model for Swiss Insurers - Home Countries - Daily Data

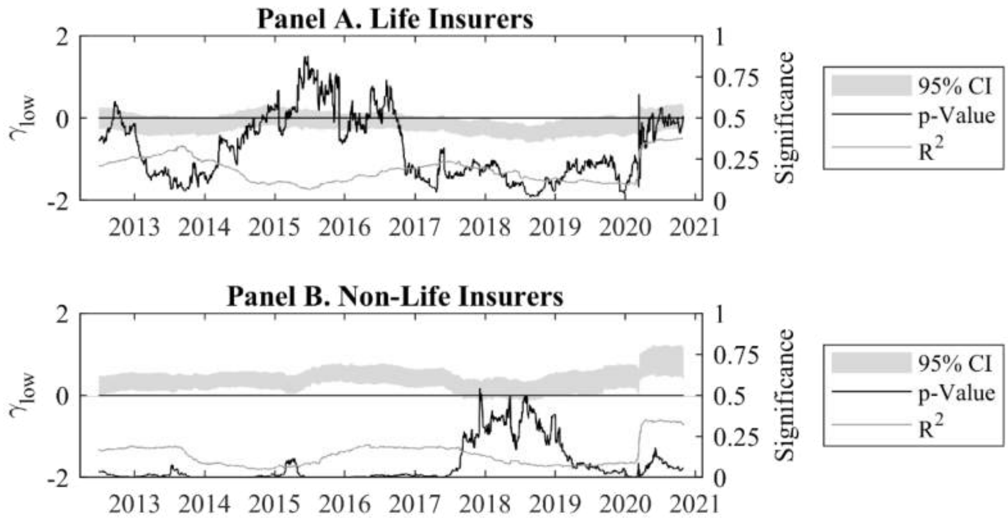
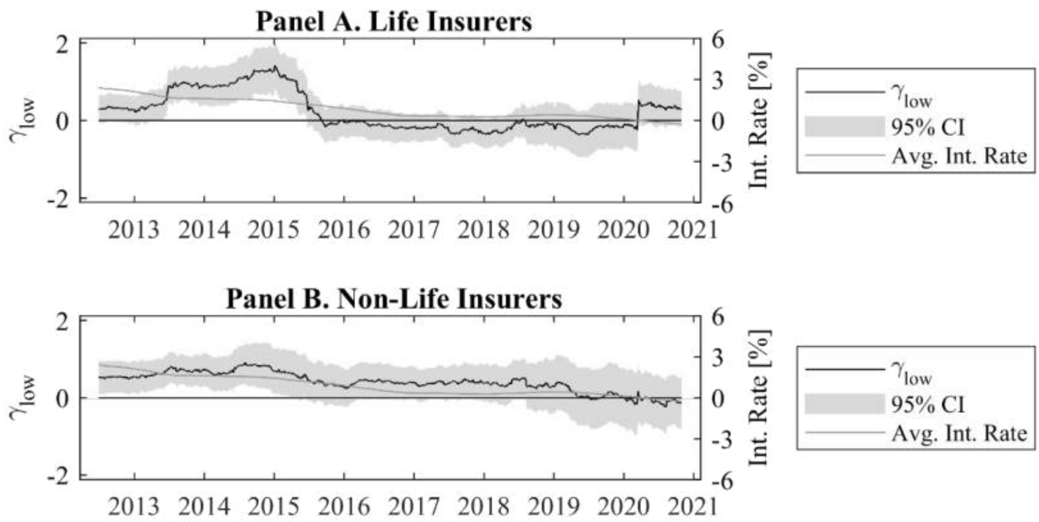


Fig. D47: Changes in Turkish Insurance Sector's Interest Rate Sensitivity Between Normal and Low-Rate Period - Home Countries - Daily Data



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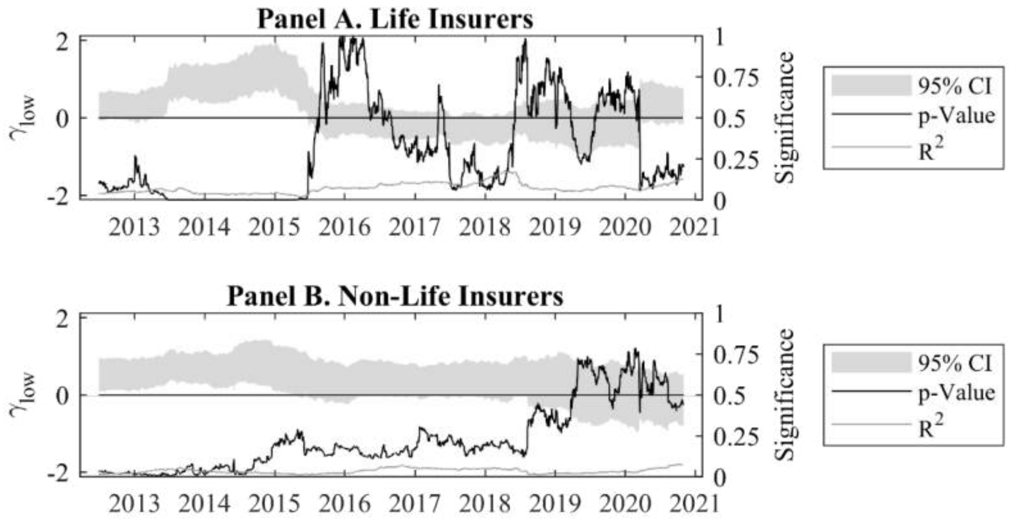

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