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# Interest rate risk of life insurers: Evidence from accounting data

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## Abstract

Life insurers are exposed to interest rate risk as their liability side is typically more sensitive to interest rate changes than their asset side. This paper explores why insurers assume this risk using a new accounting-based method to measure the interest rate sensitivity of assets and liabilities. Calculation at the insurer level yields a wide duration gap with pronounced heterogeneity in the cross-section. This could be explained by alternative investment strategies, such as asset insulation, which are at odds with interest rate risk management. Using a 2014–2018 panel, factors associated with interest rate risk support this view.

## KEYWORDS

asset liability management, duration gap, insurance investment management, interest rate risk, life insurers

## JEL CLASSIFICATION

E43, G11, G22

## 1 | INTRODUCTION

Life insurers assume interest rate risk. This indicates that firm value changes as interest rates fluctuate. The reason for this is that insurers offer long-term savings products with guarantees. In doing so, they must deliver on their promise of fixed interest payments irrespective of their interest income from investments. Matching the maturities of interest-bearing assets and liabilities acts to reduce risk, and it is indeed the case that insurers invest primarily in long-term bonds to match the maturities of their long-term liabilities. However, asset-liability maturity matching is ultimately imperfect and insurers engage in maturity transformation. The liabilities of life insurers, unlike those of banks, typically have maturities that are longer than those of investments. As such, life insurers tend to benefit from rises in interest rates, but lose if interest rates fall.

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Although it is well established that life insurers bear interest rate risk, there is no consensus as to whether this is good practice. In addition, little is known about whether there are significant differences in the cross-section of insurers and, if so, why. This paper discusses the reasons why life insurers assume interest rate risk. In particular, it examines the rationale for assuming interest rate risk as a deliberate choice. The theoretical idea is that risk management is at odds with alternative investment strategies. Insurers have specific expertise in managing financial risk and they have the competitive advantage that they can hold securities for the long term. This is because insurers' future cash outflows are relatively stable and predictable. One typical investment strategy that harnesses this competitive advantage involves holding illiquid and long-term assets to maturity. This strategy saves insurers portfolio adjustment costs and enables them to earn an illiquidity premium. Chodorow-Reich, Ghent, and Haddad (2018) call this asset insulation. By contrast, interest rate risk management involves the holding of liquid assets and regular asset sales and reinvestment and, as such, high portfolio adjustment costs and the realization of short-term value fluctuations. This implies that insurers' asset managers could face a trade-off between interest rate risk reduction and investment strategies.

To reconcile the trade-off with data, this paper develops a new accounting-based method to estimate interest rate risk at an insurer level. The goal is to compare two valuations of the same portfolio under two different interest rate values. Observing market value and book value allows me to do so. Market value reflects the current interest rate, whereas book value reflects the interest rate when the portfolio was first purchased. To estimate interest rate sensitivity, I relate the difference between the two valuations to the change in the discount rate. In other words, the paper uses a reverse engineering approach that extracts interest rate sensitivity from fair value and historical cost accounting data.

This results in estimates of the (modified) duration of assets and liabilities. In portfolio management, duration is a simple and well-known measure of first-order sensitivity to interest rate fluctuations. In insurance, risk managers make similar use of duration to estimate the interest rate sensitivity of asset portfolios and insurance liabilities. My top-down approach allows me to quantify interest rate sensitivity on both sides of the balance sheet at the insurer level for the entire industry within a country. This was not possible with the previous approaches that only work with limited samples or are limited to the asset side. The paper provides the first comprehensive analysis of the duration of the liabilities side for which there is little data.

As an empirical application, I calculate the interest rate risk of German life insurers. The German market provides a rich environment to study interest rate risk. First of all, it is one of the largest insurance markets in the world. In addition, owing to their focus on long-term endowment policies and annuities (e.g., the average contract length of life policies is 31 years) with minimum return guarantees, German life insurers have liabilities that are highly sensitive to interest rates (Berdin & Gründl, 2015; Kablau & Weiß, 2014). This has brought them a great deal of attention regarding the potential risks to financial stability (IMF, 2016). The association between the wide duration gap (i.e., the difference in interest rate sensitivity between liabilities and assets) and capital investment behavior is discussed by Domanski, Shin, and Sushko (2017), who find that the objective of German life insurers of narrowing an existing duration gap puts downward pressure on long-term interest rates. In addition to the interesting market characteristics, it is also worth investigating the German case as I have special, unique data at hand. I exploit data from a recently enacted piece of legislation that makes it possible to observe detailed information on liability valuations with different underlying discount rates. In some other countries, the market value and historical cost value are observed, but not the underlying discount rates.

I obtain on aggregate a modified duration gap for German life insurers of around six. This means that for the sector, a one percentage point drop in interest rates leads to an increase in the market value of liabilities that is approximately six percentage points greater than the relative increase in the market value of assets. I find pronounced heterogeneity of interest rate sensitivity in the cross-section on the asset side and, to an even greater extent, on the liability side. This indicates that insurers are exposed to quite different degrees of interest rate risk. The wide dispersion implies differences in terms of the management of interest rate risk.

Using a 2014–2018 panel, I study factors associated with interest rate risk. The goal is to provide evidence of a trade-off between interest rate risk reduction and alternative investment strategies, such as asset insulation. The challenge is that interest rate risk reduction and asset insulation may be at odds with each other, but they are not fully

exclusive. More generally, there is an empirical challenge to identify a preference where there is only one choice and multiple factors could influence this choice. I tackle the challenge by approximating asset insulation preferences with specific characteristics of insurers' investment behavior. I take advantage of the fact that certain asset classes and a particular trading behavior clearly make sense for asset insulation, while being counterproductive for duration matching. Then, I demonstrate that asset insulation approximated in this way has a strong negative correlation with asset duration. After that, I demonstrate, in an empirical horse race, that the proxy for the asset insulation strategy is a better predictor of investment duration than a duration-matching strategy. This difference in predictability runs counter to the view that the duration of liabilities is the main driver of asset duration. Investment characteristics that are typical for an asset insulation strategy go some way toward explaining why insurers have not changed their asset duration in order to reduce their interest rate risk. Thus, the result suggests that high levels of interest rate risk are at least, to a certain extent, explained by a deliberate choice.

The remainder of the paper is organized as follows. Section 2 develops the theory as to why life insurers bear interest rate risk. Section 3 elaborates as to how accounting valuations can be used to calculate a measure of interest rate risk. Section 4 presents the data and explains the institutional context. Section 5 calculates the duration gap using company-level data and explains the results of the empirical analysis, whereas Section 6 provides my conclusions.

## 2 | WHY DO LIFE INSURERS BEAR INTEREST RATE RISK?

### 2.1 | Initial thoughts

This section deals with possible explanations for interest rate risk exposure. Households demand life insurance policies with guarantees as long-term savings schemes for various reasons, including the benefits of compulsory saving, tax advantages, and insurers' expertise in managing long-term capital market risks. Because customers seek these policies, the long-term horizon on the liability side of insurers' balance sheets is a business feature. Product characteristics of existing contractual relationships determine it and cannot be influenced in the short term.<sup>1</sup> Therefore, I take the long duration on the liability side as a given.

It is the duration on the asset side, then, that determines the interest rate risk exposure. The question is, given the long duration on the liability side, why do managers decide not to invest in matching long-dated assets? There is no easy answer to this question and, to my knowledge, there has been no research that studies the optimal amount of interest rate risk that insurers should bear. I see two possible kinds of explanations. First, interest rate risk could be a deliberate choice. That is, there are greater benefits for the firm associated with interest rate risk than costs. In addition, interest rate risk could be accidental in the sense that insurers have a liability side that they cannot purchase in capital markets.

### 2.2 | Interest rate risk exposure as a deliberate choice

#### 2.2.1 | Firm perspective

Interest rate risk comes with costs and benefits. Regarding costs, a duration mismatch gives rise to reinvestment risk as future interest income is uncertain and, as a consequence of falling interest rates, may fall short of interest expenses (French, Vital, & Minot, 2015). A prolonged low interest rate environment could lead to a situation where sufficient returns can no longer be earned. As IMF (2016) highlights, sector-wide interest rate risk also contributes to macro-prudential risk as it increases the common exposure to market risk within the insurance sector. Finally, insurers could miss out on additional yield potential when the yield curve is upward sloping.

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<sup>1</sup> Even though the liability duration is fixed in the short term, it can, of course, be reduced in the long term. To reduce the liability duration, the main candidate is new business. Kojien and Yogo (2015) find that insurers changed their offering of policies during the financial crisis with the goal of adjusting the structure of their liability side. In addition to the slow-acting effect of new business, insurers could sell existing contracts to other companies, purchase reinsurance solutions (Kojien & Yogo, 2016), or try to nudge their policyholders to surrender their contracts.



There are benefits associated with investment strategies that have the side effect of increased interest rate risk. Insurers have specific expertise in managing interest rate risk and, when compared to other intermediaries, they can expect to hold investments for the long term. Chodorow-Reich et al. (2018) argue that life insurers are asset insulators. They create value by buying illiquid and high transaction cost securities and holding them to maturity. The reason for this value creation is that insurers can pursue an investment strategy that is complementary to their stable liabilities. This strategy saves insurers portfolio adjustment costs and enables them to earn an illiquidity premium. Asset insulation is not feasible for other investor types as their financing is less long term. This strategy is, to a certain extent, contrary to a duration-matching strategy as the two strategies require different investment choices. Duration matching involves the holding of liquid assets and regular asset sales and reinvestment, and, as such, significant portfolio adjustment costs and the realization of short-term value fluctuations. It is sufficient for insurers' investment managers to believe in asset insulation benefits. It does not matter whether such a strategy really generates higher returns or not.

It is useful to distinguish asset insulation from reaching for yield. Following Haltom (2013) and Choi and Kronlund (2017), reaching for yield suggests that a low interest rate environment incentivizes asset managers to shift their portfolio holdings toward riskier assets because they are eager to reach a target level of investment return. This risk tends to materialize only in rare events such that, in most cases, higher returns are generated. The main difference to asset insulation is that reaching for yield implies taking a bet that risk premiums will not materialize. Asset insulation, in contrast, implies undertaking an option that is risky for most investors, but not for insurers. For example, insurers may not be concerned, due to their long-term perspective, if assets cannot be sold over a longer period due to illiquidity. This does not apply to investors with short-term financing. Reaching for yield includes many sub-strategies. Some of them are consistent with asset insulation (e.g., buying leveraged loans and private debt). In fact, insurers state that reaching for yield is a major motivation for a shift of investments toward more illiquid assets. In any case, reaching for yield is, to some extent, aligned to asset insulation and also, in part, contrary to interest rate risk management, in particular with respect to illiquid assets.

### 2.2.2 | Policyholder perspective

Firm and policyholder interests regarding duration matching are not aligned if policies offer a minimum return that is irrespective of investment returns. In an unregulated insurance industry, policyholders recognize the incentive problem and could use contracts to limit risk taking (Mayers & Smith, Jr., 1981). However, this is usually not possible, as advocated by Plantin and Rochet (2009), with incomplete contracts. Policyholders are not sophisticated investors, and a prudential authority is needed to introduce regulatory constraints.

It is difficult to gauge the extent to which regulatory constraints are binding, such that companies reduce their interest rate risk as a result. Empirical evidence generally underlines an association between regulation and interest rate risk. The risk is higher in countries in which it is penalized less by way of specific reserve requirements or less transparent due to historical cost valuation on the balance sheet (Moody's, 2015). Several papers emphasize the link between valuation rules in regulation and asset allocation. Becker (2016) provides an overview as to how insurers accumulate more risk than intended and how regulation-driven investment practices distort investment decisions. Fleuriot and Lubochinsky (2005) demonstrate the effect of accounting methods using the example of reform in Denmark. Following a stipulated change in the discount rates used for provisions, Danish life insurers substantially increased the duration of their investments. Koijen and Yogo (2015) and Ellul, Jotikasthira, Lundblad, and Wang (2014) determine that noneconomic valuation in external accounting can distort investment decisions. Becker and Ivashina (2015) find that insurers' asset allocation depends upon regulatory requirements related to bond ratings. Finally, Andonov, Bauer, and Cremers (2017) note that pension funds increase risk taking in response to a regulatory link between the liability discount rate and the expected rate of return on assets.

At the start of 2016, European insurers entered a new regulatory era with the launch of Solvency II. This regulatory framework has two key principles: the introduction of risk-based capital requirements and the mark-to-market measurement for assets and liabilities. Under Solvency II, capital requirements take interest rate risk into account with due

emphasis. Simply put, the greater an insurer's interest rate risk, the higher the capital requirements. Thus, with Solvency II, interest rate risk management is a key factor in the optimization of investment portfolios (Braun, Schmeiser, & Schreiber, 2017). However, in the past and, in particular, in Germany, this was not quite so. Before Solvency II, the regulatory landscape differed among countries. For instance, the United Kingdom was early in introducing capital requirements that were sensitive to duration matching (Swain & Swallow, 2015) and Solvency II has been evolutionary, rather than revolutionary. For Germany, where the regulatory regime has been based around historical cost accounting, Solvency II has been a large change (Rae et al., 2018). This suggests that, particularly in Germany, regulatory constraints varied over time. Prior to 2016, the constraints of regulation addressing interest rate risk had a limited effect, whereas after 2016, the constraints of regulation have a large effect.

Taking all this into account, the degree of interest rate risk assumed before Solvency II ultimately depends upon the optimization of the firm and the relationship between the marginal benefit from this and marginal costs. The exact relationship is, however, difficult to estimate. Therefore, I do not attempt to estimate an optimal amount of duration matching. Instead, I examine the trade-off between a specific investment strategy, asset insulation, and risk management.

### 2.3 | Accidental explanation

The accidental explanation, in the sense that life insurers have a liability side that they cannot purchase in capital markets, is a story often told by practitioners. Some argue that there is a shortage of long-term bonds. In addition, a dearth of long-term bonds puts pressure on yields at the long end of the maturity spectrum (Greenwood & Vayanos, 2010). Besides, ultra-long bonds usually belong to the safe assets category and researchers observe a shortage of safe assets, such that the yield on safe assets is so low that they become unattractive as an investment class (Caballero, Farhi, & Gourinchas, 2017).

Recent evidence suggests that asset cash flows denominated in euro with a maturity of 30 years are sufficiently available to cover life insurers' liability cash flows up to 30 years and markets for ultra-long euro-denominated sovereign bonds are sufficiently liquid (ESRB, 2017). Furthermore, German insurers historically held only a small share of the ultra-long bonds outstanding, and they have only recently increased their share (Shin, 2017). Finally, there is no significant cross-country association between asset durations as reported by EIOPA (2014) and the average term to maturity of government securities. On the basis of these empirical observations, I believe it is not plausible that a shortage of long-term bonds alone can explain limited duration matching.

## 3 | MEASURING INTEREST RATE SENSITIVITY

### 3.1 | Approaches

In the literature thus far, there are three approaches to estimating the interest rate risk of insurers. First, in a bottom-up approach, the European insurance regulator EIOPA (2014) and (2016) estimates, in the context of its stress tests, the interest rate risk at the country level. It uses detailed internal cash flow data requested from a sample of insurers for this purpose. A bottom-up approach is convenient. However, owing to data constraints, it is not feasible for most research purposes. In addition, Berends, McMenamin, Plestis, and Rosen (2013), Brewer, Carson, Elyasiani, Mansur, and Scott (2007), and Hartley, Paulson, and Rosen (2016) use a top-down approach to estimate the interest rate sensitivity of insurers' stock prices. However, the main constraint here is that only a few insurers are listed, and those that are typically operate several business segments. Finally, Kirti (2017) and Domanski et al. (2017) estimate the duration of investments on an asset-by-asset basis, whereas on the liability side they use simple estimates. This reflects that it is especially difficult to estimate the duration on the liability side and not so much on the asset side. To my knowledge, the present paper is the first to estimate insurers' interest rate risk using accounting data, which has the advantage of estimating interest rate risk separately for assets and liabilities at the insurer level for broad and balanced samples.

### 3.2 | Reverse engineering with accounting data

This approach reverse engineers inputs used by insurers when they estimate valuations of assets and liabilities for reporting purposes. The process is as follows. First, insurers project cash flows. Then, the cash flows are discounted with different legally stipulated discount rates depending upon the purpose of the reported present value. I take different present value estimates and, together with the stipulated discount rates, reverse engineer the implicit duration used by insurers as an input in their estimations.

Modified duration ( $Dur$ ) is a measure of first-order interest rate sensitivity. It is defined as the semi-elasticity, the relative change in value  $V$  for an absolute change in the discount rate  $r$ .

$$Dur \equiv -\frac{\partial V}{\partial r} \frac{1}{V} \quad (1)$$

In principle, modified duration is defined if the market value is continuous and differentiable with respect to the discount rate. As a stricter version of the duration measure, I assume that the underlying cash flow is not contingent on the discount rate. I discuss this assumption in detail in Subsection 5.6.

Consider  $r_0$  and  $r_0 + \Delta r$  as two discount rates. I relate the change between two values  $V_{r_0}$  and  $V_{r_0+\Delta r}$  to a change in discount rates from  $r_0$  to  $r_0 + \Delta r$ . This means modified duration is determined by linear approximation:

$$Dur_{r_0} \cong -\frac{V_{r_0+\Delta r} - V_{r_0}}{\Delta r} \frac{1}{V_{r_0}}. \quad (2)$$

With discretization, the accuracy of the duration measure depends upon the curvature of the relationship between the market value and discount rates. The relationship is convex and the sensitivity increases when discount rates fall. Equation (2) measures the slope of the secant line between the market values for two discount rate levels that lies between the sensitivity at the lower market value (higher discount rate) and the sensitivity at the higher market value (lower discount rate).

Equation (2) sheds light on what inputs are needed. It is my goal to compare two valuations of the same portfolio under two different interest rate values. The idea followed here is that observing market value and book value allows doing so. Market value reflects the current interest rate, whereas book value reflects the interest rate when the portfolio was first purchased.

Let us consider a historical cost accounting regime. Each item has two observable valuations: the book value at historical cost  $BV$  and the market value  $MV$ .  $MV_{r_0+\Delta r}$  and  $BV_{r_0+\Delta r}$  are observable, but  $MV_{r_0}$  and  $BV_{r_0}$  are not. I approximate  $MV_{r_0}$  with  $BV_{r_0+\Delta r}$ , which is sensible if some conditions are met. First, the book value and the market value were identical when rates are  $r_0$ . In addition, the book value does not change when rates change ( $BV_{r_0+\Delta r} = BV_{r_0} \forall \Delta r$ ). These conditions are typically met in a strict historical cost accounting regime.

I transform Equation (2) with a view to an approximation of the modified duration by the standardized amount by which the market value differs from the book value relative to the underlying change in discount rates.

$$Dur_{r_0} \cong -\frac{MV_{r_0+\Delta r} - BV_{r_0}}{\Delta r} \frac{1}{BV_{r_0}}. \quad (3)$$

I improve this approximation by making two extensions. Equation (3) only considers the value effect of a change in discount rates. With the use of accounting values, one must consider that time has passed since the discount rates changed and that some book–market differences disappear due to portfolio shifts. These are in particular gains trading. Insurers sell their winners, assets with a significant difference between their market value and book value, and, in doing so, they generate profits by realizing capital gains (Ellul, Jotikasthira, Lundblad, & Wang, 2015).

I set the current year as  $v_0 + \Delta v$  and the time of discount rate change in the past as  $v_0$  with  $\Delta v > 0$ .  $\Delta v$  represents the number of years that have passed.  $Inc_{v_0+\Delta v}$  is the sum over the years  $\Delta v$  of the yearly gains through portfolio changes. The following holds:

$$Dur_{r_0, v_0} \cong -\frac{MV_{r_0+\Delta r, v_0} - BV_{r_0, v_0} + Inc_{v_0+\Delta v}}{\Delta r} \frac{1}{BV_{r_0, v_0}}. \quad (4)$$



Equation (4) is similar to Equation (3), apart from the stipulation that the discount rate change takes place without any passage of time. Because I observe neither  $MV_{r_0+\Delta r, v_0}$  nor  $BV_{r_0, v_0}$ , I need an approximation based on  $MV_{r_0+\Delta r, v_0+\Delta v}$  and  $BV_{r_0, v_0+\Delta v}$ , which I observe. I approximate the change in the book–market difference for a change in observation time.

For a simple presentation, I use a valuation at different years  $z$  of a future payment  $a$  at time to maturity  $T$ . I start with a time structure that discount rates changed from  $r_0$  to  $r_0 + \Delta r$  just after the item was recognized on the balance sheet and then, from time  $v_0$ , a time  $\Delta v$  passed while rates remained constant. The market value is calculated with the current interest rate  $r_0 + \Delta r$  as the discount rate. For the book value, the prechange rate  $r_0$  is the discount rate. Book and market values conditional on observation year  $z \in \mathbb{N}$  can be written as

$$MV_{r_0+\Delta r}(z) = \frac{a}{(1 + r_0 + \Delta r)^{T-z}}, \quad (5a)$$

$$BV_{r_0}(z) = \frac{a}{(1 + r_0)^{T-z}}. \quad (5b)$$

This means that the face value is discounted back to an earlier date with a later year  $z$ . The sensitivity to a change in  $z$  is

$$\frac{\partial MV_{r_0+\Delta r}}{\partial z} \frac{1}{MV_{r_0+\Delta r}} = \frac{\ln(1 + r_0 + \Delta r) a}{(1 + r_0 + \Delta r)^{T-z}} \frac{1}{MV_{r_0+\Delta r}} = \ln(1 + r_0 + \Delta r), \quad (6a)$$

$$\frac{\partial BV_{r_0}}{\partial z} \frac{1}{BV_{r_0}} = \frac{\ln(1 + r_0) a}{(1 + r_0)^{T-z}} \frac{1}{BV_{r_0}} = \ln(1 + r_0). \quad (6b)$$

In the following, I approximate the value change at interest level  $r_0 + \Delta r$  for an absolute time change. A multi-period value change is derived from multiple stages of one period difference equations. Consider a change of  $\Delta v$  years. This provides the following relationship between the market and book values at year  $v_0 + \Delta v$  and year  $v_0$ :

$$MV_{r_0+\Delta r, v_0+\Delta v} \cong (1 + \ln(1 + r_0 + \Delta r))^{\Delta v} MV_{r_0+\Delta r, v_0}, \quad (7a)$$

$$BV_{r_0, v_0+\Delta v} \cong (1 + \ln(1 + r_0))^{\Delta v} BV_{r_0, v_0}. \quad (7b)$$

The later the discount rate changed, the less the present value increased with the passage of time. I relax the full consideration of the time passage effect, which is attributable to the basic case of an abrupt change in discount rates first, and time passage afterward. Instead, I take half of the time period of  $\Delta v$  in the exponent. This roughly approximates that interest rates uniformly decreased over time. It gives the following approximate relationship:

$$MV_{r_0+\Delta r, v_0+\Delta v} \cong (1 + \ln(1 + r_0 + \Delta r))^{0.5\Delta v} MV_{r_0+\Delta r, v_0}, \quad (8a)$$

$$BV_{r_0, v_0+\Delta v} \approx (1 + \ln(1 + r_0))^{0.5\Delta v} BV_{r_0, v_0}. \quad (8b)$$

Then, I derive the following estimate of the book market difference that considers the time passing effect:

$$MV_{r_0+\Delta r, v_0} - BV_{r_0, v_0} \cong \frac{MV_{r_0+\Delta r, v_0+\Delta v}}{(1 + \ln(1 + r_0 + \Delta r))^{0.5\Delta v}} - \frac{BV_{r_0, v_0+\Delta v}}{(1 + \ln(1 + r_0))^{0.5\Delta v}} + Inc_{v_0+\Delta v}. \quad (9)$$



This gives the following approximation of the duration prior to the change in discount rate and the related time change:

$$Dur_{r_0, v_0} \cong \frac{\frac{MV_{r_0+\Delta r, v_0+\Delta v}}{(1+\ln(1+r_0+\Delta r))^{0.5\Delta v}} - \frac{BV_{r_0, v_0+\Delta v}}{(1+\ln(1+r_0))^{0.5\Delta v}} + Inc_{v_0+\Delta v}}{\Delta r} \cdot \frac{1}{\frac{BV_{r_0, v_0+\Delta v}}{(1+\ln(1+r_0))^{0.5\Delta v}}} \quad (10)$$

Thus, the duration estimate is the relative change in the valuation of market over book value divided by the discount rate change, where the book and market values are the currently observed valuations discounted back to the time of recognition on the balance sheet. Because the book value is discounted at a different rate than the market value, the difference in valuation between the market and book values changes through discounting relative to the undiscounted difference. This reflects that the currently observed difference in valuation differs from the original valuation difference. In addition, an adjustment is made to cover portfolio changes.

Using Equation (10), the duration of liabilities  $Dur_{r_0, v_0}^{\text{Liabilities}}$  and the duration of assets  $Dur_{r_0, v_0}^{\text{Assets}}$  can be separately calculated. The duration gap is the difference between the two.

$$\text{Duration gap} = Dur_{r_0, v_0}^{\text{Liabilities}} - Dur_{r_0, v_0}^{\text{Assets}} \quad (11)$$

This difference should be interpreted as a comparison of sensitivities and not as a difference in value changes because the asset value usually exceeds the liability value.

### 3.3 | Simulations

To analyze the quality of the duration estimate, I construct hypothetical asset portfolios calibrated with the yield curve of German sovereign bonds. The portfolios consist of sovereign bonds purchased between 2004 and 2013. For the year 2014, I calculate both the actual modified duration and the duration estimate using Equation (10). One assumption is that coupons of bonds are equal to the yield at the time of bond issuance. The first portfolio consists only of a single 30-year German sovereign bond purchased in 2004. In 2014, the estimated duration of this portfolio is 13.4, which is 2% higher than the actual duration (13.1). The second portfolio consists of two 30-year German sovereign bonds, one purchased in 2004 and one purchased in 2009. In 2014, the estimated duration is 15.4, which is 1% higher than the actual duration. The third portfolio consists of ten 30-year German sovereign bonds, one purchased in each year from 2004 to 2013. In 2014, the estimated duration is 17.0, which is 2% higher than the actual duration.

These simulations demonstrate that the duration estimate is accurate. The estimation error does not change substantially between the simulated portfolios and exemplifies that the heterogeneity in the time at which the assets were added to the portfolio does not significantly affect the estimation accuracy.

## 4 | APPLICATION TO GERMAN LIFE INSURERS

### 4.1 | German insurance sector

As an empirical application, I estimate the interest rate risk of German life insurers. This subsection introduces important characteristics.

Life insurance within Germany is always regulated as a standalone entity and, consequently, it is organized and managed as a separate subsidiary. In 2014, there are 86 German life insurers that are subsidiaries of 54 insurance groups. Among the groups, 15 are listed on the stock exchange, four are nonlisted private corporations, 28 are mutual insurance companies, six are public sector firms, and one is the policyholder protection scheme, a corporation with German life insurers as the shareholders. The listed groups include insurance companies headquartered in Germany (e.g., Allianz and Munich Re) as well as companies with headquarters abroad (e.g., Axa, Generali, and Zurich). Most of the groups

operate only in insurance, but a few are large diversified groups with additional activities in asset management and banking.

Germany has a large insurance industry with endowment policies and annuities as important long-term saving vehicles.<sup>2</sup> Total financial assets of the life sector are 818 billion euro (year 2014), which corresponds to about 28% of the gross domestic product (GDP). Approximately 90% of financial assets are fixed income investments. The vast majority of customers' claims and the corresponding liabilities of insurers have fixed interest rates. The premium reserve is the most important liability at 750 billion euros. Life insurers create this provision to provide for future net benefit obligations that are guaranteed and attributed to individual policies. If in the following, the term liabilities are used, then this refers to the premium reserves.

The fixed interest liabilities arise from minimum return guarantees that are applied on a year-by-year basis to the policyholders' savings (Eling & Holder, 2013). The minimum return is set at the inception of the contract and cannot be changed afterward. All insurance contracts entered into within the same period have the same minimum return. For example, all insurance contracts entered into between July 1994 and June 1999 provide 4%. Over time, the minimum return guarantee was reduced for new contracts. For this reason, the average is essentially determined by the years in which the policies were sold. The industry average in 2014 is 3.1%, which is much higher than current market yields. This implies that the expense for the minimum return makes up the lion's share of expenses. This contrasts with, for example, France where the average minimum return is much lower and usually not binding (Hombert & Lyonnet, 2019).

German life insurers' liabilities are highly sensitive to interest rates. EIOPA's (2014) estimate for the duration gap of Germany's life sector is one of the widest of all the countries included in its analysis. Typical characteristics of long duration insurance policies are long-term contracts with a long-term accumulation phase that provide fixed minimum returns that are independent of the underlying investment returns. Alternative popular products with lower or no fixed interest rate guarantees, such as unit-linked policies, have rarely been sold in Germany. The tax system has also contributed to long duration policies as very long-term annuity policies with an accumulation phase offer tax advantages compared to other saving options. In contrast to Germany, life insurers in the United States have a narrower duration gap and those in the United Kingdom have none at all.<sup>3</sup>

## 4.2 | Basics of German insurance accounting

This paper uses insurance data taken from single entity balance sheets. Life insurers prepare their single entity financial statements in accordance with German generally accepted accounting principles, the German Commercial Code (*HGB*), and regulatory provisions.

On the asset side, investments are, in principle, valued at the lower of current market value or historical cost. In the low interest rate environment, this implies that fixed income securities are carried at par value. Insurers also report the difference between market and book values. For this reason, the financial statements disclose two valuations for investments that differ mainly in terms of the discount rate.

Liabilities are valued at the present value of expected cash flows. There are two parts, an interest rate insensitive reserve (denoted here as the book value) and an interest rate sensitive surcharge, the additional interest provision. The surcharge has the effect of adjusting the level of reserves toward the market value. The reasoning is to increase provisions for under-provisioned policies. However, the adjustment is only partial and there remains a significant

<sup>2</sup>Simply put, an endowment policy is a savings vehicle for which policyholders pay monthly premiums and the full benefit becomes due at an expiry date (or before if the policyholder dies). Annuity policies provide life-long annuity payments after either a large one-time payment or as a savings vehicle following the payment of regular monthly premiums. Term life policies, in contrast, do not accumulate savings and benefits are only paid if the policyholder dies before the expiry.

<sup>3</sup>EIOPA (2014) and Moody's (2015) provide overviews of duration gaps by country. There is no comprehensive estimate of the duration of U.S. life insurers. Estimates are available from the International Monetary Fund, which assumes a duration gap of two based on expert judgment and discussion with market participants (IMF, 2015, p. 60) and from Moody's, which estimates a duration gap of less than one based on data reported by large insurance companies (Moody's, 2015). In contrast, empirical studies, such as Berends, McMenamin, Plestis, and Rosen (2013), find considerable interest rate risk for U.S. insurers. An estimate for the United Kingdom is included in EIOPA (2014).

**TABLE 1** Descriptive statistics of key balance sheet items for the year 2014 (bn euro)

Balance sheet items	Mean	SD	Median	Total
Book value assets	10.8	21.7	3.7	814
Underlying discount rates	3.7%	0.5%	3.6%	
Market value assets	12.6	26.5	4.1	948
Underlying discount rates	1.0%	0.2%	1.0%	
Book value liabilities	10.2	19.9	3.6	767
Underlying discount rates	3.1%	0.3%	3.1%	
Market value liabilities	12.2	23.8	4.2	918
Underlying discount rate	1.2%	0.0%	1.2%	

*Note.* The table provides descriptive statistics of key balance sheet items for 75 German life insurers in 2014 based on the German generally accepted accounting principles. The book value of liabilities is the premium reserve and excludes the additional interest provision. The market value of liabilities is the premium reserve including the additional interest provision and the hidden losses approximated with what is known in the German legislation as the safeguarding amount. The underlying discount rate for the book value of the premium reserve is the average discount rate reported by insurers. The underlying discount rate for the market value of liabilities is the market rate used for calculating the safeguard amount, which is the same for all insurers. The underlying discount rate for the book value of assets is based on average yearly coupon payments. For the discount rate for the market value, an estimate based on the portfolio composition is used.

portion of hidden losses. It recently became possible to observe the hidden losses on the balance sheet and, as such, the market value of insurer liabilities. In 2014, there was a major reform in Germany, the Life Insurance Reform Act, which included a block on dividend payouts. Insurers are only allowed to distribute dividends depending upon the hidden losses carried on the liability side. Thus, I effectively have two valuations of liabilities that differ primarily in terms of their discount rate. The difference between the two valuations, the book value and the market value, is the sum of the hidden losses and the additional interest provision.

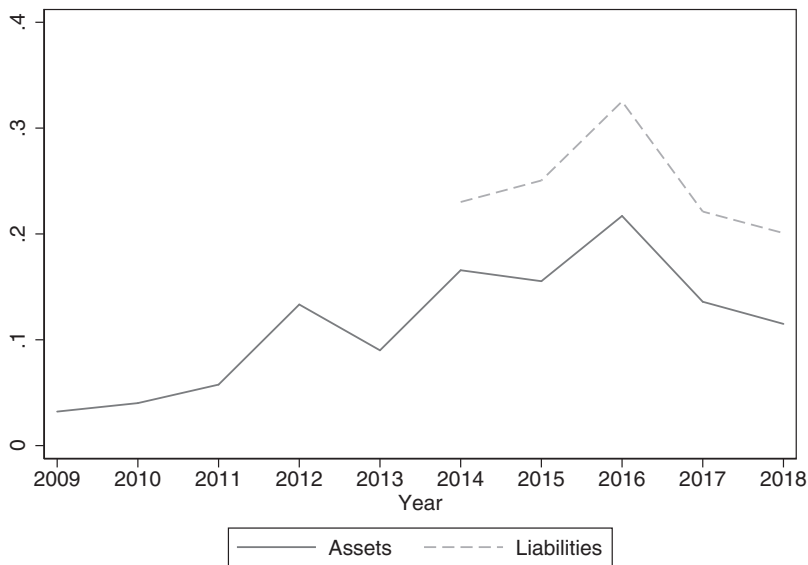
### 4.3 | Dataset

The dataset I use is the extended forecast collected by the Federal Financial Supervisory Authority (*BaFin*). The publicly unavailable cross-sectional dataset includes detailed reports from the financial reporting systems of all German life insurers. The data are based on company business plans at September 30 for the full year assuming stable capital market conditions for the fourth quarter. The detailed accounting and business plan data are collected in the process of preparing financial statements, but are not published.

For the year 2014, the data contain 86 life insurers, of which I exclude three insurers with missing observations. These three are very small insurers. In 2014, all three combined have liabilities of around 0.25 billion euro compared to an average of 9 billion euro. This leaves me with a sample of 83 insurers.

The dataset is available yearly. The 2014 edition is the first one that includes data on the market value on the liability side. Thus far, four more recent versions have become available that include this information, the 2015–2018 editions. The annual cross-sections are merged on the basis of a unique identification number for the insurers. Adding the additional years reduces the sample to 75 insurers. This is due to eight insurers going out of business, being converted to a pension fund, or reporting missing data. These insurers are relatively small with average liabilities of 0.5 billion euro.

To provide an overview of the data, Table 1 presents the key balance sheet items and the underlying discount rates for the year 2014. The total market value of investments is 16% higher than the book value. This difference in valuation corresponds to a decrease in discount rates of 2.7 percentage points. The total market value of liabilities is 20% higher than the book value. This difference in value corresponds to a decrease in the average underlying discount rate of 1.9 percentage points. Already, these descriptive statistics suggest that liabilities are more sensitive to interest rate changes than assets.



**FIGURE 1** Book-market difference of German life insurers, asset versus liability side

*Note.* The graph displays the aggregate book-market difference relative to the book value of 75 German life insurers over time. The solid line displays assets and the dashed line displays liabilities based on German generally accepted accounting principles. The book value of liabilities is the premium reserve and excludes the additional interest provision. The book-market difference is the additional interest provision and the hidden losses approximated with what is known in the German legislation as the safeguarding amount; 2014 is the first year that includes data on the market value on the liability side.

Figure 1 compares the development of book-market differences between the asset and the liability side. It is evident that the difference on the liabilities side exceeds the difference on the assets side. This is an indication of higher interest rate sensitivity on the liabilities side.

Insurers report income from gains trading in their profit and loss statements. In 2014, the aggregate valuation reserves that disappeared due to the realization of capital gains are 28 billion euro or 21% of the book-market difference. The corresponding effect on liabilities is that some policyholders lapse their insurance contracts and policyholders receive approximately the book value of the provisions. The difference between the book value and market value can be regarded as a lapse gain. I use the yearly lapse rate of insurers and multiply it for each year by the observed book-market difference. In 2014, the aggregate hidden losses that disappeared due to lapses are 27 billion euro or 18% of the book-market difference.

## 5 | RESULTS

### 5.1 | Estimation of the duration gap

On the basis of the data discussed in the previous section, I calculate the duration of assets and liabilities for German life insurers, as well as the difference between the two, the duration gap. In the aggregate, this sector has an estimated asset duration of 11 and a liability duration of 17 in 2014 (Table 2). The resulting duration gap amounts to six. This suggests that a one percentage point decrease in interest rates leads to an increase in the market value of liabilities that is approximately six percentage points greater than the relative increase in the market value of assets. The aggregate view weighs larger insurers more heavily than smaller ones. The median duration gap is larger than the aggregate

**TABLE 2** Interest rate sensitivity estimate of German life insurers (2014–2018)

		Total	Mean	SD	p25	p50	p75
2014	Asset duration	11.4	10.0	1.7	8.8	10.0	11.0
	Liability duration	17.1	17.4	3.8	14.1	16.8	20.0
	Duration gap	5.7	7.4	4.1	4.2	6.8	10.4
2015	Asset duration	11.9	10.7	2.2	9.1	10.6	12.1
	Liability duration	17.4	18.3	4.6	14.7	17.8	20.6
	Duration gap	5.5	7.5	5.0	4.1	6.6	10.0
2016	Asset duration	14.0	12.3	2.3	10.6	12.1	13.9
	Liability duration	17.5	18.7	5.9	15.8	17.8	20.8
	Duration gap	3.4	6.4	6.2	2.5	5.4	8.4
2017	Asset duration	13.8	11.6	2.2	10.3	11.4	12.9
	Liability duration	16.1	16.9	3.7	14.5	16.4	18.9
	Duration gap	2.4	5.3	4.3	2.8	4.7	7.3
2018	Asset duration	14.9	12.6	3.0	11.0	12.7	14.5
	Liability duration	15.7	16.9	4.6	14.2	16.1	19.0
	Duration gap	0.8	4.3	5.9	1.1	3.3	6.1

Note. The table provides the descriptive statistics of the modified durations estimated in Equation (10) and the duration gap estimated in Equation (11) for 75 German life insurers. The wider the duration, the more sensitive is the value of the balance sheet side to a change in interest rates. The wider the duration gap, the more an insurer is exposed to interest rate risk.

estimate implying that smaller insurers tend to have a wider duration gap than larger insurers. In fact, the insurers with particularly large duration gaps tend to be small.

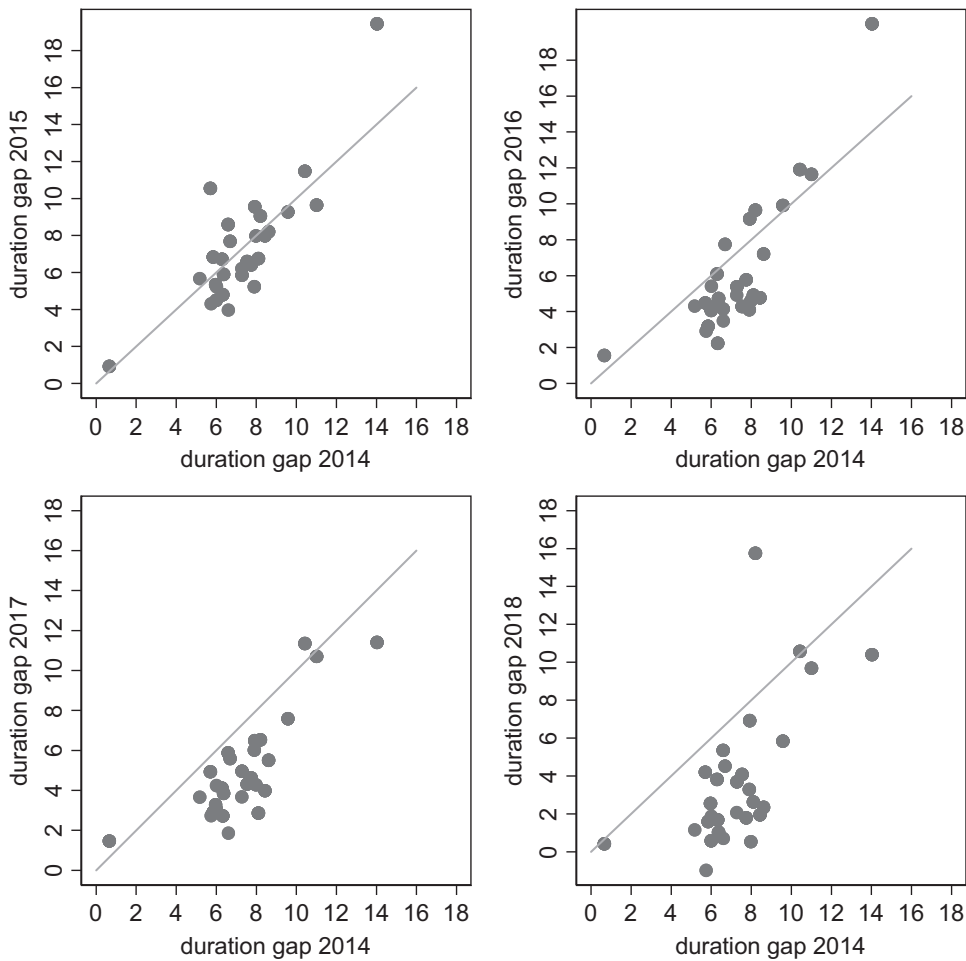
Reviewing the time series, both asset and liability duration grow over time until 2016. Asset duration grows more strongly and the duration gap narrows. Insurers adjust their portfolio, but the adjustment takes place gradually so that the duration gap slowly narrows over time. This result is largely in line with the development described by Domanski et al. (2017). It is also consistent with the result of Kojien, Koulischer, Nguyen, and Yogo (2017) that insurers were net buyers of government bonds in the environment of quantitative easing and falling interest rates.

Other results are in a similar range. EIOPA (2014) derives a (Macaulay) duration for assets of 10 and for liabilities of 21. The rating agency Assekurata estimates the modified duration for fixed income investments at eight for 2011 with an upward trend since that time. The German insurance association estimates in an unpublished analysis the modified duration for fixed income investments at seven for 2009, again with an upward trend since then, and the duration for liabilities at 15 (no estimate for different years). Domanski et al. (2017) estimate the asset duration at about 10 for 2010 with an upward trend since.

To provide an overview of the association between the duration gaps across different years, I graphically compare the duration gap of the year 2014 with the duration gaps of other years (Figure 2). The correlation between the individual years is high.

## 5.2 | Variation in interest rate risk between insurers

Figure 3 illustrates the distribution of the estimated duration between insurers, both for the asset and the liability side. The variation in duration on the liability side is wider than on the asset side. Although the asset duration is approaching a normal distribution, the distribution of the liability duration is relatively broad with a long tail. The wide distribution of liability durations illustrates that it is advisable to take into account large differences when making statements about the interest rate risk of life insurers. The cross-insurer standard deviation of the gap is 4.1 for the year 2014, which is



**FIGURE 2** Comparison of duration gap estimates between years

*Note.* The scatterplots illustrate the association between the duration gaps estimated in Equation (11) across different years. The dots are averages between three insurers selected at random to comply with data confidentiality. The mid-lines indicate combinations for which the duration gap is identical in both years.

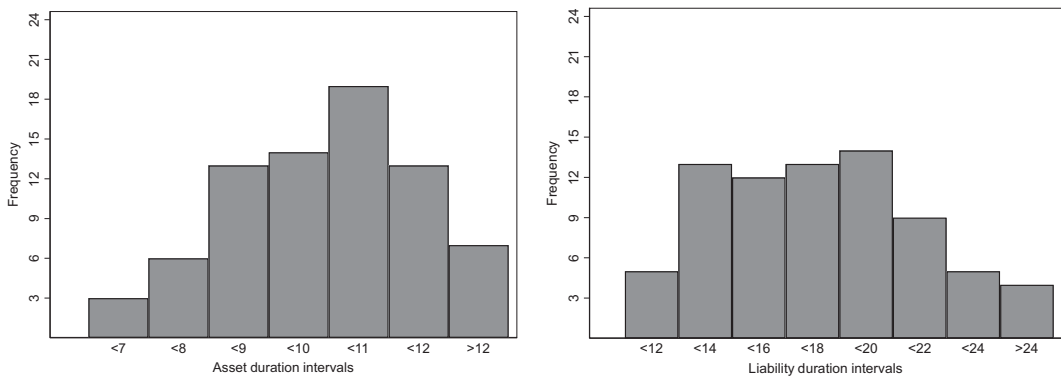
higher than the cross-country standard deviation of 3.6 reported by EIOPA (2014). A comparison of distributions on the asset and liability sides indicates that the variation of both contributes to the cross-sectional differences in the duration gap.

### 5.3 | Relationship between liability duration and product characteristics

The wide liability duration results from the product characteristics of existing contractual relationships. To investigate the relationship between liability duration and the product characteristics,  $P_{i,t}$ , I estimate:

$$\left( Dur_{r_0, v_0}^{Liabilities} \right)_{i,t} = \beta_0 + \beta_1 P_{i,t} + \varepsilon_{i,t}. \quad (12)$$

Standard errors are clustered by group to address the potential correlation of insurers' durations across the firms in a group. Extreme values of liability duration are set to the mean plus/minus the 2.5 standard deviations if they exceeded this value. I use both random effects and pooled models. The first product characteristic is a dummy variable capturing



**FIGURE 3** Distribution of asset and liability duration (2014)

*Note.* The histograms provide the distribution of the modified durations estimated in Equation (10) for 75 German life insurers for the year 2014. The left-hand side indicates the distribution of asset durations and the right-hand side reports the distribution of liability durations. The wider the duration, the more sensitive is the value of the balance sheet side to a change in interest rates. Each bin illustrates the number of insurers with a duration within the interval.

whether the insurer is a direct insurer. These are insurers that do not work with brokers or insurance agents. Instead, they sell policies primarily through their websites. This variable is an indication of recently established contracts with a lower guaranteed rate and less accumulated funds. The lower level of consultation needed may also indicate that policies are, to a lesser extent, used for retirement savings and more for other saving purposes. The second variable is the share of term life policies relative to other life insurance policies. Term life policies are insurance policies without a saving accumulation that are mainly a protection against death. In addition, I control for the share of annuity policies relative to other life insurance policies. Annuity policies usually have a long duration because they are lifelong (i.e., they end with the death of the policyholder). The fourth variable is the share of contracts expired over the last 5 years relative to the total number of contracts 5 years ago. A high variable indicates a relatively low remaining contract length of a contract portfolio. Finally, I control for the level of yearly sales commissions paid relative to the book value of liabilities. This variable captures the extent to which insurers rely on new business and, in particular, new business sold by sales agents and brokers. All of the variables are available on an insurer-year level. Descriptive statistics are displayed in Table 4.

The results displayed in Table 3 indicate that liability durations tend to be wider for insurers with a focus on annuity policies and for insurers that sell products through sales agents and brokers. The pooled regression results suggest that high sales provisions are correlated with liability duration. As expected, insurers with more recently expired contracts tend to have lower liability duration. However, this effect is not significant. Overall, the regression results indicate that product characteristics are an important factor in explaining the cross-sectional differences in liability duration.

## 5.4 | Relationship between asset duration and liability duration

Asset–liability management implies that insurers with higher liability duration should have higher asset duration. The idea is that the investment process is liability driven. An insurer should adjust the duration of its investment portfolio as the duration of its liabilities changes. This implies that, in theory, liability duration causes asset duration. Figure 4 compares asset and liability durations in the cross-section of insurers from 2014 to 2018. Given complete matching, all of the dots would be on the mid-line. However, this requires only low degrees of freedom for investment management and only limited opportunities to follow alternative investment strategies. The relationship between asset and liability durations is weak. The scatterplots suggest that the two sides of the balance sheet are barely related. This implies

**TABLE 3** Association between liability duration and product characteristics

Variable	Dependent variable: Liability duration	
	(1)	(2)
	Random effects Coeff. (SE)	Pooled Coeff. (SE)
Direct insurer	−4.9*** (1.5)	−4.0*** (1.4)
Share term life policies	5.1 (3.5)	4.4 (2.9)
Share annuity policies	6.4** (3.1)	7.1** (3.0)
Share contracts expired last 5 years	−3.3 (4.5)	−3.6 (4.3)
Sales provisions paid	3.0 (31.1)	31.6* (16.1)
Year fixed-effects	Yes	Yes
Adj. R <sup>2</sup>	.24	.28

Note. The table presents the results from Panel Regression (12). The sample consists of 75 life insurers from 2014 to 2018. The dependent variable is the liability duration estimated in Equation (10). Column (1) displays results of a random effects regression, whereas Column (2) provides those of a pooled-model. Standard errors are clustered by group and displayed in brackets. \*, \*\* and \*\*\* represent significance at the 1%, 5%, and 10% level, respectively.

limited liability-driven investment and insurers giving low priority to duration matching compared with other investment objectives.

To investigate the asset–liability correlation of investment duration with liability duration, I estimate:

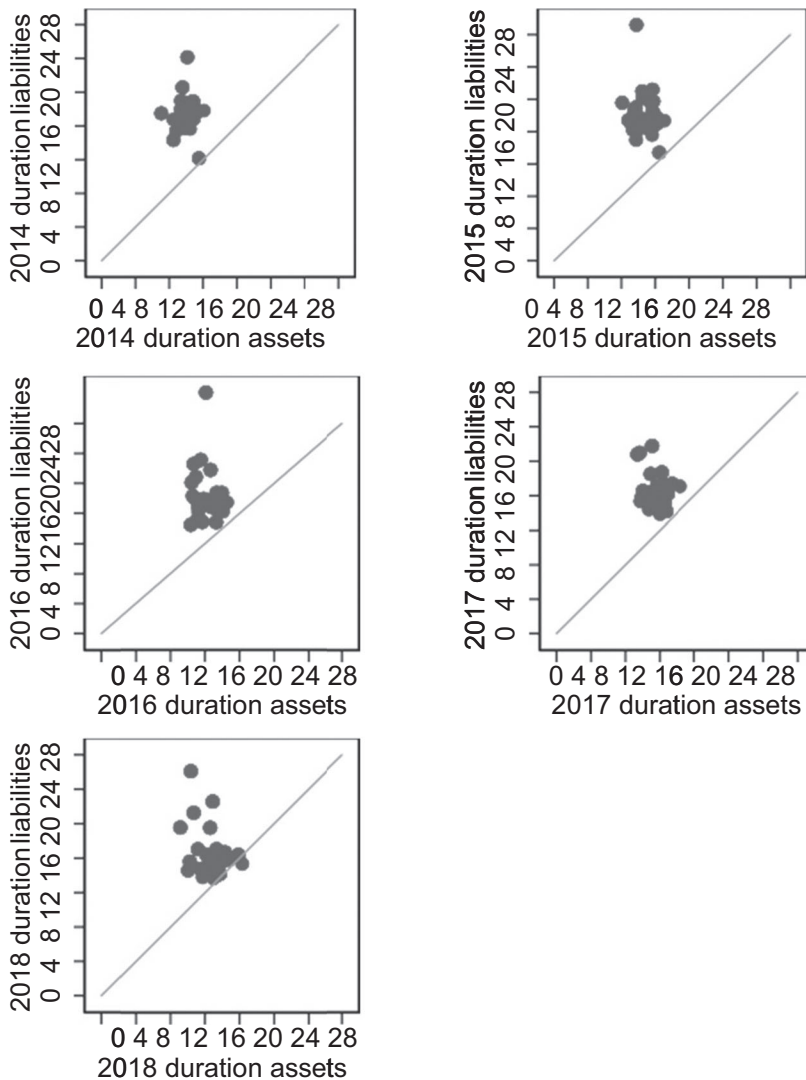
$$\left(Dur_{r_0, v_0}^{Assets}\right)_{i,t} = \beta_0 + \beta_1 \left(Dur_{r_0, v_0}^{Liabilities}\right)_{i,t} + \beta_2 X_{i,t} + \beta_3 P_{i,t} + \varepsilon_{i,t}. \quad (13)$$

Standard errors are clustered by group to address the potential correlation of insurers' durations across the firms in a group. Extreme values of the duration measures are set to the mean plus/minus the 2.5 standard deviations if they exceeded this value. I use both fixed effects and random effects models. The liability duration cannot be influenced by the insurer in the short term, whereas the asset duration is the result of decisions by the insurers' investment managers. Nevertheless, the regression results should, in principle, only be interpreted as the correlation between the asset-side and liability-side duration. If insurers seek to exactly match the durations of assets and liabilities, I would expect  $\beta_1 = 1$ . Where asset–liability management takes place, but duration matching is done only partially, I expect  $\beta_1$  to be substantially larger than 0, but below 1.

Some specifications include firm characteristics  $X_{i,t}$  and product characteristics  $P_{i,t}$ . Table 4 displays the detailed descriptive statistics of the firm and product characteristics. I expect asset and liability duration to differ between insurers with different attributes, though I do not have directional hypotheses. The first firm characteristic is the size measured by the natural logarithm of the book value of liabilities. A dummy variable is used to control for insurers in run-off. These are insurers that have stopped selling new policies. I also control for growth perspectives measured by the planned annual premium growth in percent during the next 3 years. Further dummy variables are used to control for the following aspects: whether the final shareholder of the life insurer is an exchange-listed group, a mutual insurance company, or a public sector firm. The remaining insurers' final shareholders are private corporations or it is the policyholder protection scheme. Finally, I control for whether an insurer used interest rate derivatives as a hedging instrument from 2010 to 2013. The derivatives data are taken from regulatory reporting.

Table 5 displays the results. The relationship between asset and liability duration is not significantly different from zero. In addition, the coefficient is far from one. This is contrary to liability-driven investment. It suggests that insurers do not attach great priority to duration matching. The control variables reduce the strength of the effect, but do not change the lack of significance.





**FIGURE 4** Comparison of the distribution of asset and liability duration of German life insurers (2014–2018)

*Note.* The scatterplots illustrate the relationship between the asset duration on the x-axis and the liability duration on the y-axis from 2014 to 2018, both estimated in Equation (10), for 75 German life insurers. The greater the duration, the more sensitive is the value of the balance sheet side to a change in interest rates. The dots are averages between three insurers selected at random to comply with data confidentiality. The mid-line indicates combinations for which the asset duration equals the liability duration. The distance to the mid-line indicates the duration gap.

## 5.5 | Role of asset insulation

This subsection examines the trade-off between interest rate risk reduction and investment strategies. Asset insulation preferences are approximated with specific traits of insurers' investment behavior, as certain asset classes and a particular trading behavior make sense for asset insulation, while being counterproductive for duration matching. Characteristics from the past must be used as the interest rate risk calculated in this paper is the result of investment strategies from the past. Detailed data on predefined categories of investments are available for the German market, but not on an asset-by-asset basis. On this basis, I use five variables whose values can be considered typical for asset insulation.

**TABLE 4** Descriptive statistics of life insurer attributes

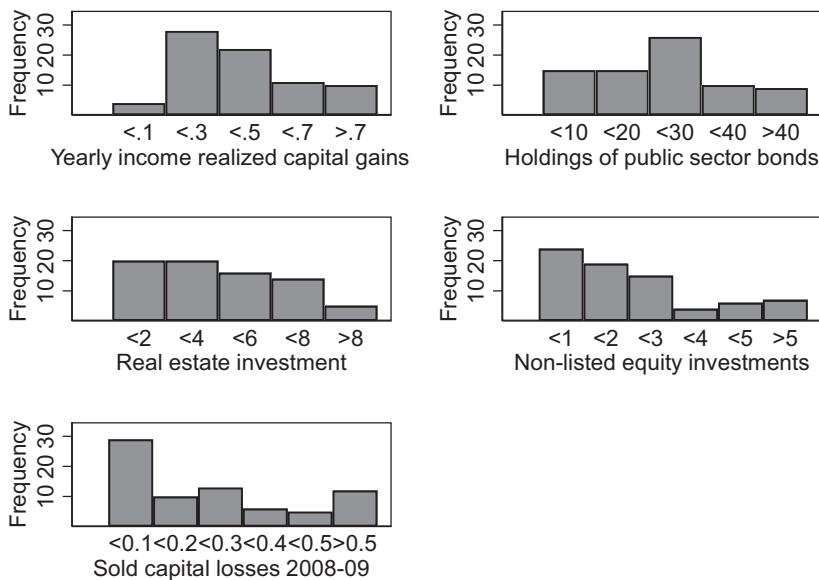
Variable	Mean	SD	p25	Median	p75
Firm characteristics					
Planned premium growth	−0.05	5.20	−1.80	.21	2.08
Run-off	0.07	0.25	0	0	0
Size (log premium reserve)	15.04	1.65	14.03	15.17	16.38
Final shareholder listed group	0.36	0.48	0	0	1
Final shareholder mutual insurer	0.45	0.50	0	0	1
Final shareholder public	0.11	0.31	0	0	0
Interest rate derivatives	0.44	0.50	0	0	1
Product characteristics					
Direct insurer	0.08	0.27	0	0	0
Share term life policies	0.26	0.27	0.07	0.15	0.35
Share annuity policies	0.49	0.27	0.35	0.47	0.71
Share contracts expired last 5 years	0.18	0.13	0.11	0.16	0.21
Sales provisions paid	0.013	0.027	0.002	0.006	0.011

*Note.* This table reports the descriptive statistics of company attributes separated by firm characteristics and product characteristics. The firm characteristics include two continuous variables: projected premium growth for the next 3 years measured in percent and size measured as the natural logarithm of the book value of the premium reserve. It also includes the following dummies. Participating in run-off and being a subsidiary where the final shareholder is a listed group, a mutual insurance company, or in public ownership. The remaining insurance companies are subsidiaries of a private corporation that is not listed or the policyholder protection scheme. Finally, it includes as a dummy variable the use of derivatives as a hedging instrument from 2010 to 2013. The product characteristics includes one dummy variable regarding whether the insurer is a direct insurer (i.e., it does not work with brokers or insurance agents). All of the other variables are continuous variables: the share of term life policies to all policies, the share of annuity policies to all policies, the number of contracts expired over the last 5 years relative to the total number of contracts 5 years ago, and yearly sales provisions paid to agents and brokers relative to the book value of liabilities.

**TABLE 5** Association between asset and liability duration

Dependent variable: Asset duration									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Fixed effects			Random effects			Pooled model		
Variable	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Liability duration	0.047 (0.058)	0.046 (0.052)	0.034 (0.039)	0.039 (0.049)	0.041 (0.051)	0.027 (0.048)	0.002 (0.040)	0.026 (0.041)	−0.003 (0.048)
Firm characteristics	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Product characteristics	No	No	Yes	No	No	Yes	No	No	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R <sup>2</sup>	.51	.56	.59	.15	.34	.39	.15	.35	.42

*Note.* The table reports results from Panel Regression (13). The sample consists of 75 life insurers from 2014 to 2018. The dependent variable is the asset duration and the variable is the liability duration, both estimated in Equation (10). Columns (1)–(3) display the results of a fixed effects regression, Columns (4)–(6) that of a random effects regression, and Columns (7)–(9) that of a pooled model. Standard errors are clustered by group and displayed in brackets. \*, \*\*, and \*\*\* indicate a significance level of 0.1%, 5%, and 10%, respectively.



**FIGURE 5** Distributions of typical investment features that suggest a prevalence of an asset insulation strategy (%)

*Note.* The top-left histogram presents the distribution of asset turnover measured as the average yearly income from realized capital gains from 2006 to 2013 as a percentage of total investments for the year 2014. The higher the income, the greater the asset turnover. A high level indicates a low degree of asset insulation. The top-right histogram provides the distribution of public sector bond holdings measured as the holdings of public sector bonds as a percentage of total investments for the year 2013. A high level indicates a low level of asset insulation. The center-left histogram reports the distribution of real estate investments measured as the holdings of real estate investments as a percentage of total investments for the year 2013. A high level indicates a high level of asset insulation. The center-right histogram illustrates the distribution of nonlisted equity investments measured as the holdings of nonlisted equity as a percentage of total investments for the year 2013. A high level indicates a high level of asset insulation. The bottom-left histogram presents the distribution of realized capital losses from 2008 to 2009 divided by total investments during these years. A high level indicates a low level of asset insulation. The sample is 75 German life insurers. Each bin illustrates the number of insurers with a level within the interval.

The first variable covers the holding period of investments. I use the average yearly income from realized capital gains between 2006 (i.e., the first available year) and 2013 (i.e., the last year prior to the first measure of interest rate risk) observed in the accounting statements. Income is shown relative to the market value of total investments in 2014. The higher this proxy, the greater the share of securities sold at a profit before the maturity date. This approximates asset turnover and the tendency whether an insurer holds assets for the short run or the long run. For insurers with a full buy-and-hold strategy, this variable is 0. The more an insurer pursues an asset insulation strategy, the lower I expect this variable to be. The reason for this is asset insulators hold securities through price fluctuations and, as such, trade less. This is also in line with evidence in Chen, Huang, Sun, Yao, and Yu (2019) that insurers who hold a more illiquid bond portfolio tend to have lower portfolio turnover. Being an asset insulator is related to holding an illiquid portfolio.

In contrast, it is advisable for a duration matching strategy to regularly sell assets. A typical strategy for extending the duration of asset holdings is to replace securities with a diminished duration with newer long-dated securities because the duration of an asset typically declines over time because the residual maturity shrinks (DeCosta, Leng, & Noronha, 2017). A histogram illustrates some heterogeneity between insurers with the median insurer retaining a yearly income from gains trading of 0.3% relative to total investments (e.g., top-left side of Figure 5).

The second variable covers the type of investments. Insurers miss opportunities to create value if they hold a certain amount of public sector bonds. Instead, the advantage of asset insulation is greatest if illiquid and volatile securities

are held. In contrast, public sector bonds are essential for duration matching as they are often the only bonds available with very long-term maturities. I use the share of public sector bonds compared to total investments in 2013, 1 year before the period used for the remaining analysis (2014–2018). The more insurers pursue an asset insulation strategy, the lower I expect this variable to be. There is considerable heterogeneity among insurers with the median insurer's holdings of 23% relative to total investments (e.g., top-right side of Figure 5). The third variable covers real estate investments. Real estate is an attractive investment class for asset insulation as real estate investments are illiquid and have high transaction costs. In contrast, real estate is of limited use for duration matching because the duration of real estate is typically lower than the duration of long-term bonds (Constantinescu, 2010) and, at the same time, higher transaction costs do not permit a regular adjustment of portfolios. I use the share of real estate investments compared to total investments in 2013. The variable covers the following investments: (a) direct investment in land and land rights, (b) direct investment in real estate, (c) shares of real estate companies, (d) real estate investment trusts, (e) shares in closed-end real estate funds, and (f) shareholder loans to real estate companies. Although many insurers invest less than 2% in real estate, there are those that invest considerable shares in this investment class (e.g., center-left side of Figure 5).

The fourth variable covers nonlisted equity investments, an investment class that is also typically illiquid and has high transaction costs. The variable covers the following investments: (a) intragroup equity investments, (b) private equity investments, and (c) shares in private–public partnerships. I use the share of nonlisted equity investments compared to total investments in 2013. Most insurers invest less than 2% of their portfolios in nonlisted equity, though there are some that invest a considerable share of their portfolios in this asset class (e.g., center-right side of Figure 5).

Finally, the fifth variable covers realized capital losses during the peak of the financial crisis in 2008–2009. During this time, the prices of many financial securities plummeted, particularly those of equity and other risky assets. If insurers sold assets at market prices below book prices, they would have realized capital losses. However, if they held securities to maturity, potential losses would not be included in this income category. In 2008, German insurers realized, on aggregate, capital losses of 2.3 billion euro, an increase of 90% compared to 2007 and of 230% compared to 2006. The realization of capital losses on this scale is at odds with the idea of asset insulation that insurers could actually hold securities to maturity and, as such, endure interim losses. Although it was indeed the case that many insurers did not realize any capital losses at all, there are some who realized losses amounting to more than 0.5% of assets. Overall, the distribution is right-skewed (e.g., bottom-left side of Figure 5).

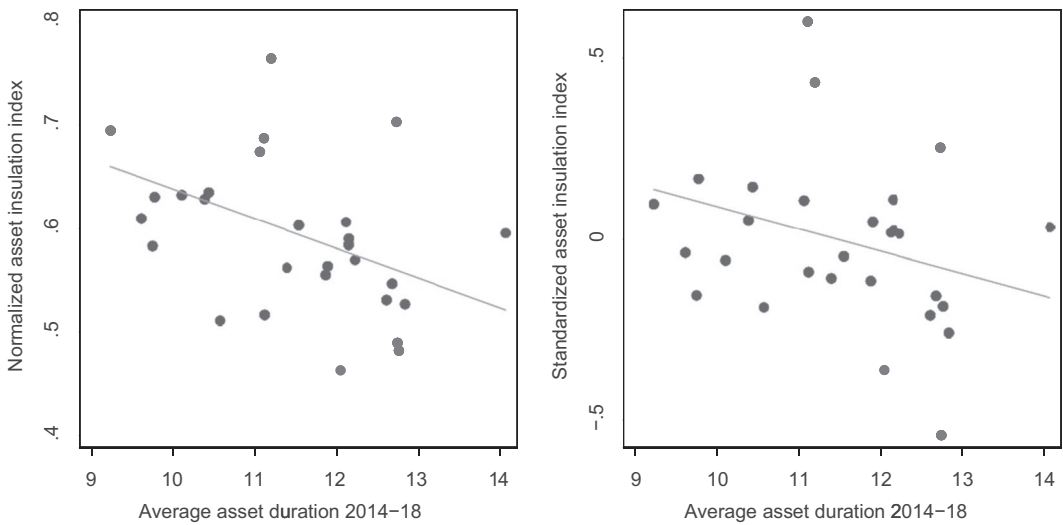
I construct two indices of asset insulation with five variables all having an equal weight. The first one is a normalized index between zero and one. For asset turnover, public sector bonds, and realized losses in 2008–2009, it is one minus the cross-sectional quantile category divided by the number of insurers. For real estate and nonlisted equity investment, it is the cross-sectional quantile category divided by the number of insurers. The second one is a standardized index using the z-score of the five variables. Asset turnover, public sector bonds, and realized losses enter the index with a negative algebraic sign, whereas real estate and nonlisted equity investment enter the index with a positive algebraic sign. The higher the indices, the greater the degree of asset insulation. Figure 6 displays the scatterplots between asset duration and the two indices of asset insulation. In line with a trade-off, the correlation is negative.

Table 6 displays a correlation matrix of the five variables, the indices, and the asset duration estimate. All of the correlations are mostly as predicted. That is, insurers with higher asset duration invest more in public sector bonds, less in nonlisted equity, trade more often, and realized more capital losses during the financial crisis. Only the correlation with real estate investment is largely zero. The correlation of the asset insulation indices with asset duration is negative as expected.

To conduct an empirical horse race between interest rate risk reduction and asset insulation, I estimate the following regressions whose results are compared with Equation (13):

$$\left( Dur_{r_0, v_0}^{Assets} \right)_{i,t} = \alpha_0 + \alpha_1 Traits_i + \alpha_2 X_{i,t} + \alpha_3 P_{i,t} + \varepsilon_{i,t}, \quad (14a)$$

$$\left( Dur_{r_0, v_0}^{Assets} \right)_{i,t} = \beta_0 + \beta_1 AssetInsulation_i + \beta_2 X_{i,t} + \beta_3 P_{i,t} + \varepsilon_{i,t}, \quad (14b)$$



**FIGURE 6** Distribution of asset duration and the proxy for the degree of asset insulation

*Note.* The scatterplots illustrate the relationship between the average asset duration from 2014 to 2018 on the x-axis and indices for the degree of asset insulation for 75 German life insurers. The dots are averages between three insurers selected at random to comply with data confidentiality. Asset duration is estimated in Equation (10). The greater the duration, the more sensitive is the value of the balance sheet side to a change in interest rates. The index displayed on left-hand side measures the degree of asset insulation as a normalized index. The index displayed on the right-hand side measures the degree of asset insulation as a standardized index. The higher the indices, the more likely the investment strategy of an insurer has the typical traits of an asset insulator strategy.

where the dependent variable is the asset duration of insurers  $i$  at year  $t$ ,  $Traits_i$  is a vector of characteristics (Var1 to (Var5) in Table 6, and  $AssetInsulation_i$  is one of two indices (I1) and (I2) in Table 6, which approximate asset insulation. The regressions include firm characteristics  $X_{i,t}$  and product characteristics  $P_{i,t}$  as in Equation (13), which includes time-varying variables, as well as variables that do not change over time. First, I estimate a random effects model with and without firm characteristics included (Columns 1 and 2). Column (3) displays a pooled model without a control for company characteristics. Column (4) reports the same model, but with firm characteristics included.

Table 7 displays the results. For multivariate regressions, any interpretation should bear in mind that the small sample and multicollinearity make it difficult to obtain significant results for each variable. I find the coefficient of asset turnover is highly significantly positive in all specifications. The effect of public sector bond holdings on asset duration is also significantly larger than zero in all specifications. The effect of real estate investment on asset duration is, as expected, negative, but not significant in most specifications. The estimated effect of nonlisted equity is negative as expected, though it is not significantly different from zero. The effect of realized losses in 2008–2009 does not have the expected algebraic sign (even though the bivariate correlation indicated otherwise). The indices of asset insulation have a negative significant effect in all specifications. In summary, investment features that approximate asset insulation have a significant negative effect on asset duration.

In a comparison of the regression of asset duration on liability duration (Table 5) and the regression of asset duration on the indices for asset insulation (Table 7), I find that asset insulation is much better at explaining asset duration than the liability duration. This result suggests that asset insulation goes some way toward explaining why insurers have not changed their asset duration in order to reduce their interest rate risk.

It is important to acknowledge that the empirical analysis is based on correlations. The same effect could result from omitted variables that are related to asset duration, as well as to the investment features. I explicitly control for firm characteristics to mitigate this concern. Nevertheless, there is not a conclusive identification strategy, so the results should be interpreted carefully.

**TABLE 6** Correlation matrix of the asset duration estimate, asset insulation indices, and the five characteristics typical for asset insulation

			Predicted correlation with asset duration	Dur	I1	I2	Var1	Var2	Var3	Var4	Var5
Dur	Mid asset duration 2014–2018			1.00							
I1	Asset insulation (norm.)	–	–.34	1.00							
I2	Asset insulation (stand.)	–	–.29	.87	1.00						
Var1	Asset turnover	+	.49	–.20	–.31	1.00					
Var2	Public sector bonds	+	.38	–.68	–.64	.18	1.00				
Var3	Real estate	–	.13	.53	.51	.40	–.14	1.00			
Var4	Non-listed equity	–	.07	.55	.38	.31	–.02	.45	1.00		
Var5	Realized losses 2008–2009	+	.06	–.15	–.52	.36	.18	.02	.25	1.00	

*Note.* The table reports the correlation matrix calculated for 75 German life insurers. Dur is the average asset duration from 2014 to 2018 for each year estimated in Equation (10). I1 measures the degree of asset insulation as a normalized index. I2 measures the degree of asset insulation as a standardized index. The higher the indices, the more likely the investment strategy of an insurer has the typical traits of an asset insulator strategy. Both indices are based on Var1–Var5. Var1 is the average yearly realized capital gain between 2006 and 2013 relative to total investment in percent. A high level indicates a low level of asset insulation. Var2 is the average holding of public sector bonds relative to total investment in 2013 in percent. A high level indicates a low degree of asset insulation. Var3 is the investment in real estate relative to total investment in 2013 in percent. A high level indicates a high degree of asset insulation. Var4 is the natural logarithm of the investment in nonlisted equity relative to total investment in 2013 in percent plus one. A high level indicates a high degree of asset insulation. Var5 is the natural logarithm of average yearly capital losses in 2008 and 2009 relative to total market value of investments plus one. A high level indicates a low degree of asset insulation.

## 5.6 | Data application and measurement: Discussion and robustness checks

### 5.6.1 | Nominator

The duration measure used in this paper is based on the comparison of two accounting valuations. It implies the assumption that observed differences between historical cost valuation and market values are predominantly attributable to a change in the level of discount rates. This is valid as life insurers invest primarily in fixed income securities and liabilities are calculated as the present value of guaranteed future payments. Balance sheets of insurers change very little over time and short-term holdings of derivatives play only a minor role.

Accounting data may underestimate the risk mitigating effect that some future cash flows are not fixed. Variability of future cash flows is disregarded in my setting, two sources of which are meaningful. Typical contracts in Germany pay a higher benefit to customers for investment income that significantly exceeds the contract-specific minimum guarantee (i.e., future discretionary benefits). One concept to incorporate future discretionary benefits is effective duration based on scenarios (Briys & De Varenne, 1997). However, I believe that interest rate risk is not materially reduced by the argument that in future, in some scenarios, there are additional variable benefits that could be reduced in stress scenarios. Thus, I see modified duration as the more intuitive and more useful measure.

Another source of variability of future cash flows is the policyholder option to surrender contracts. Empirical studies report many reasons why policyholders let their contracts lapse (Nolte & Schneider, 2017). Insurers can calculate that a significant proportion of their obligations for a distant future will be incurred much earlier. From a purely financial view, the option to lapse becomes more valuable when interest rates rise (Tsai, 2009). However, in a low interest rate environment, lapses are unattractive and this does not change with moderate increases in interest rates. Rather, in a low interest rate environment, an increase in lapses is a tail risk. Lapses would rise if interest rates rose sharply

**TABLE 7** Panel regression: Relationship between asset duration and the proxy for the degree of asset insulation

Variable	(1)		(2)		(3)		(4)		(5)		(6)	
	Random Effects						Pooled					
	Predicted	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	SE
Regression (14a)												
Dependent variable: Asset duration												
Asset turnover	+	4.1***	(0.92)	4.2***	(0.88)	3.5***	(1.0)	4.1***	(0.92)	4.3***	(0.90)	3.9*** (1.0)
Public sector	+	0.051**	(0.020)	0.031*	(0.018)	0.012	(0.018)	0.051**	(0.020)	0.029*	(0.017)	0.018 (0.015)
Real estate	-	-0.010	(0.010)	-0.090	(0.086)	-0.08	(0.10)	-0.010	(0.096)	-0.11	(0.08)	-0.13 (0.09)
Nonlisted equity	-	-0.014	(0.55)	-0.27	(0.41)	-0.46	(0.63)	-0.14	(0.55)	-0.29	(0.40)	-0.30 (0.50)
Losses 2008–2009	+	-1.6*	(0.85)	-1.1	(0.82)	-1.4	(0.92)	-1.6*	(0.85)	-1.0	(0.83)	-0.99 (0.85)
Adj. R <sup>2</sup>		.40		.50		.51		.40		.50		.54
Regression (14b)												
Dependent variable: Asset duration												
Insulation index	-											
(normalized)		-5.8***	(1.8)	-6.1***	(2.1)	-5.3***	(1.8)	-5.8***	(1.8)	-6.2***	(2.1)	-5.6*** (1.8)
Adj. R <sup>2</sup>		.24		.40		.46		.24		.41		.47
Regression (14b)												
Dependent variable: Asset duration												
Insulation index	-	-1.2**	(0.56)	-1.4**	(0.64)	-0.9*	(0.54)	-1.2**	(0.56)	-1.4**	(0.63)	-1.1* (0.58)
(standardized)												
Adj. R <sup>2</sup>		.21		.39		.43		.21		.43		.45
Firm characteristics	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Product characteristics	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note. The table reports the regression results for a panel of 75 German life insurers from 2014 to 2018. The dependent variable is the asset duration estimated in Equation (10). The upper part of the table uses five investment features as a vector of variables as in Equation (14a). The lower part of the table uses two asset insulation indices as in Equation (14b). The first variable is the average yearly realized capital gain between 2006 and 2013 relative to total investment in percent. The second variable is the average holding of public sector bonds relative to total investment in 2013 in percent. The third variable is the investment in real estate relative to total investment in 2013 in percent. The fourth variable is the natural logarithm of the investment in nonlisted equity relative to total investment in 2013 in percent plus one. The fifth variable is the natural logarithm of average yearly capital losses in 2008 and 2009 relative to total investment in percent plus one. Columns (1)–(3) display the results of a random effects regression, and Columns (4)–(6) present results from a pooled model. Standard errors are clustered by group and displayed in brackets. \*, \*\*, and \*\*\* represent significance at the 1%, 5%, and 10% level, respectively.

TABLE 8 Robustness check regressions with simpler measures of interest rate sensitivity

Dependent variable	(1) Correlation asset duration	(2) Liability interest rate sensitivity (calculated in parallel to dependent variable)		(3) Insulation index (normalized)		(4) Insulation index (standardized)	
		Coeff.	SE	Coeff.	SE	Coeff.	SE
Asset book–market difference/book value of assets	48%	0.13*	(0.08)	−0.072**	(0.031)	−0.012	(0.009)
Asset book–market difference/market value of assets	48%	0.17*	(0.10)	−0.055**	(0.025)	−0.009	(0.007)
Asset book–market difference/(book value of assets × change of interest rates)	68%	0.020	(0.046)	−4.5***	(1.2)	−0.91**	(0.37)
Asset book–market difference/(market value of assets × change of interest rates)	69%	0.008	(0.055)	−3.7***	(1.0)	−0.75**	(0.30)

Note. The table provides pooled regression results for a panel of 75 German life insurers from 2014 to 2018. The dependent variables are alternative, simpler measures of asset interest rate sensitivity based on the difference between the book and the market value of assets. Column (1) displays the correlation between the dependent variables and the asset duration estimated in Equation (10). The regressions displayed in Column (2) use simpler measures of liability interest rate sensitivity as variables that are calculated in analogy to the asset side based on the observed difference between the book and the market value of liabilities. The regressions reported in Column (3) use an index that measures the degree of asset insulation as a normalized index as a variable. The regressions presented in Column (4) use an index that measures the degree of asset insulation as a standardized index as a variable. All regressions include year fixed effects. Standard errors are clustered by group and displayed in brackets. \*, \*\*, and \*\*\* represent significance at the 1%, 5%, and 10% level, respectively.





(Förstemann, 2019; Kubitz, Berdin, & Gründl, 2019). Therefore, lapse behavior does not materially influence future cash flows, at least in the context of a persistent low interest rate environment or a moderate rise in interest rates.

In sum, there are concepts for considering interest rate sensitive cash flows, such as effective duration. However, effective duration can only be interpreted with respect to the scenarios compared. This paper focuses on interest rate risk that is based on fixed cash flows from guarantees and should be interpreted accordingly.

### 5.6.2 | Discount rates and time

Equation (10) uses an industry-wide discount rate prescribed by regulators for discounting of liability market values. For the book value of liabilities, I find an insurer-specific underlying discount rate. In many jurisdictions, life insurers are required to report estimated market/fair values and historical costs. However, it is the underlying discount rates that are frequently not observed. The dataset has the main advantage that I observe both. On the asset side, both discount rates must be estimated. I estimate the discount rate for the book value at an insurer level based on average yearly coupon payments. The idea is that coupon payments roughly correspond to the yield at the issue date. Regarding the discount rate for the market value of assets, I estimate the current yield based on the insurer-specific portfolio split between investment-grade bonds and high yield bonds. For the share of investment-grade bonds, I use the average current yield of outstanding debt securities in Germany. For the high yield bonds, I use the sum of the average current yield of debt securities in Germany and the spread of euro denominated high yield corporate bonds.

The time estimate on the investment side is based on a matching of the current return adjusted for portfolio risk with the yield of a typical investment, German mortgage covered bonds outstanding with 10 years maturity, by year in the past. For 2014, this approach results in an average asset age of 6.0 years with a standard deviation of 0.8. For the liability side, I use a contract breakdown by guaranteed interest rate that can be transformed in a contract breakdown by starting year. For 2014, this approach gives me an average contract age estimate of 13 years with a standard deviation of 2.4.

As a robustness check, I repeat the analysis with simple estimates of interest rate sensitivity starting with the ratio of the book–market difference to the book value. This is important as it could be argued that the asset insulation indices and discount rates used in the estimation partially rely on related input such that the association could be mechanical. The use of sensitivity estimates without discount rates is robust to this argument. Table 8 displays the results that are similar to the ones obtained previously. The effect of asset insulation is negative and highly significant in most specifications. The effect of the interest rate sensitivity of liabilities, calculated in analogy to the asset side, is much lower.

## 6 | CONCLUSION

This paper sheds light on the still incomplete picture regarding the degree of insurers' interest rate risk and why insurers assume this risk. Using a new approach and innovative leverage of existing data, it estimates the duration of assets and liabilities. Calculation at the insurer level for German life insurers yields wide duration gap with pronounced heterogeneity in the cross-section. A panel analysis supports the view that insurers could assume interest rate risk as a deliberate choice with the goal of following alternative investment strategies rather than pursuing a strict duration matching strategy.

The results of this paper have important implications for the understanding and interpretation of insurers' interest rate risk. Insurance policies compete with other intermediaries' products. Insurers might be able to generate extra returns in the short term through investment strategies that distinguish insurers' investment approach from the other intermediaries. Potential additional profits add to the attractiveness of insurance products for policyholders. The creation of value is, however, limited by the trade-off that alternative investment strategies have the side effect of higher interest rate risk. Life insurance is a business with a long horizon, and short-term private benefits come with long-term risks. A prolonged low interest rate environment could lead to the materialization of reinvestment risk and eventually solvency problems. The consequences of distress are borne by policyholders at the time of the failure (or

the insurance protection fund), not by managers and policyholders at the time when the increased investment returns were realized. This trade-off points toward an important role for prudential regulation.

Degrees of freedom of investment are important. However, interest rate risk should be limited to a degree that long-term risk is kept at bay. Regulation takes place in several ways. Since 2016, Europe's Solvency II regime sets capital requirements that are responsive to interest rate risk. This is a huge step forward compared to the previous regulations that differed widely in Europe. Regulation in Germany before Solvency II was particularly unresponsive to interest rate risk. One could argue that differences in regulation were driving the difference in interest rate risk assumed among countries. I see this as an important area for further research. One interesting point to keep in mind is that the regulation of interest rate risk, even under Solvency II, is not strict in every way. For example, negative interest rates are not further stressed and it is assumed that rates cannot decrease further. This suggests that, ultimately, capital requirements for interest rate risk are limited in a very low interest rate environment. Further research into effects of this aspect would be helpful.

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