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 interest rate sensitivity. Calculation at the insurer level yields on average a wide duration gap with pronounced heterogeneity in the cross-section. Insurers with less duration matching tend to have a lower asset turnover, lower holdings of government bonds and higher holdings of real estate. All three features suggest that duration gaps can be explained by profitable investment strategies which are at odds with interest rate risk management.

Keywords: Life insurance, interest rate risk, insurance investment management, asset liability management, duration gap

JEL classification: E43, G11, G22

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1 Introduction

Life insurers assume interest rate risk, which means the firm value changes as interest rates fluctuate. The reason is that life insurers offer long-term savings products with minimum return guarantees. In doing so, they have to deliver on their promise of fixed interest payments irrespective of their interest income from investments. Matching the maturities of interest-bearing assets and liabilities reduces the 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 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. Life insurers therefore tend to benefit from rises in interest rates but lose if interest rates fall.

While 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 examines the reasons why life insurers assume interest rate risk. In a nutshell, the theoretical idea is that risk management is at odds with value-enhancing investment strategies. Insurers have specific expertise in managing interest rate 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. A typical investment strategy involves the holding of illiquid and long-term assets to maturity. By contrast, interest rate risk management involves the holding of liquid assets and regular asset sales and reinvestment, and therefore the realization of short-term value fluctuations. This illustrates that life insurers’ asset managers face a trade-off.

To reconcile this trade-off with data, this paper develops a new accounting-based method to estimate interest rate risk at an insurer level. The measure allows me to quantify interest rate risks for the entire industry within a country. This was not possible with the previous approaches, which only work with limited samples. My top-down approach to measuring interest rate risk is based on a comparison of fair value accounting and historical cost accounting data. The basic idea is to use two valuations that only differ in the underlying discount rates. To estimate the sensitivity, I relate the difference between the two observed valuations to the change in the discount rate. This results in estimates of (modified) duration of assets and liabilities. In portfolio management, duration is a simple and generally 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.

In the literature so 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, though owing to data constraints it is not feasible for most research purposes. Furthermore, there is a lack of replicability and transparency because researchers cannot observe the calibrations and assumptions of insurers’ internal models. *Second*, Brewer et al. (2007), Berends et al. (2013) and Hartley et al. (2016) use a top-down approach estimating 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. *Third*, Kirti (2017) and Domanski et al. (2017) estimate the duration of investments on an asset-by-asset basis whereas on the liabilities 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.

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 of life insurers. First of all, it is one of the largest insurance markets in the world. Second, owing to their traditional business models with a focus on long-term endowment and annuity policies1 with minimum return guarantees, German life insurers’ liabilities are highly sensitive to interest rates. This is shown by EIOPA (2014), whose estimate for the duration gap - the duration of liabilities minus the duration of assets - of Germany’s life insurance sector is one of the widest of all the countries included in its analysis. While the exact number and EIOPA’s methodology has been scrutinized by some (Wagner and Lazic 2016), the high interest rate risk of German life insurers as such is undisputed. Typical characteristics of long-duration insurance policies are vehicles to save for retirement which provide fixed minimum returns that are independent of the underlying investment returns. Alternative popular life insurance products with less or no fixed interest rate guarantees such as unit-linked policies have been rarely sold in Germany. The tax system has also contributed to long-duration policies, because very long-term annuity policies 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.2

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1Simply put, an endowment life insurance 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 life insurance provides life-long annuity payments after either a large one-time payment or as a savings vehicle following the payment of regular monthly premiums.

2EIOPA (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 IMF, which
The high interest rate risk of German life insurers attracts widespread interest, e.g. regarding potential risks to financial stability, from the IMF (2015a) and IMF (2016). The association between the high duration gap and capital investment behavior has been greatly discussed, e.g. by Domanski et al. (2017) who show that the objective of German life insurers of narrowing an existing duration gap puts downward pressure on long-term interest rates. Recent studies such as Kablau and Weiß (2014) and Berdin and Gründl (2015) illustrate that German life insurers are particularly vulnerable to low interest rates. In addition to the interesting market characteristics, it is also worthwhile investigating the German case because I have special, unique data at hand. I exploit data from a recently enacted piece of legislation, which makes it possible to observe detailed information on valuations with different underlying discount rates. In some other countries, the market value and historical cost value are also observed, but not the underlying discount rates.

In line with the high interest rate risk of German life insurers, 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.

Using a 2014-16 panel, I study factors associated with interest rate risk. The relationship between asset duration and typical investment features implies that the interest rate risk could at least be explained to a certain extent by profitable investment strategies. First, I observe that duration matching is related to proxy of asset turnover. A regular adjustment of investment portfolios is a typical feature of duration matching. However, it is at odds with typical value-enhancing investment strategies. Furthermore, I observe that insurers with a higher asset duration tend to hold more government bonds and less real estate. Public sector bonds are a typical choice for duration matching, because they are often the only available ultra-long bonds. Profitable investment strategies, by contrast, require a preference for illiquid and high-transaction-cost securities such as real estate.

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

assumes a duration gap of two based on expert judgment and discussion with market participants (IMF, 2015b, 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). By contrast, empirical studies such as Berends et al. (2013) show considerable interest rate risk for U.S. insurers. An estimate for the U.K. is included in EIOPA (2014).

Note that this analysis uses aggregated bond portfolios of the sector; it does not allow the researcher to investigate differences between insurers.
empirical analysis. Section 6 concludes the paper.

2 Why do life insurers bear interest rate risk

2.1 Initial thoughts

This section deals with possible explanations for the interest rate risk exposure of life insurers. Households demand life insurance policies as long-term savings schemes for various reasons, including the benefits of compulsory saving, tax advantages, and because of insurers’ expertise in managing long-term capital market risks. Because customers seek such policies, the long-term horizon on the liability side of insurers’ balance sheets is a business feature. Therefore, I take the long duration on the liability side as a given.

It is the duration on the asset side, then, which determines the interest rate risk exposure. The research question therefore is, given the long duration on the liability side, why do managers of insurance companies 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 which studies the optimal amount of interest rate risk that life insurers should bear.

I see three possible kinds of explanations. First of all, interest rate risk could be a deliberate choice, i.e. there are more benefits for the firm associated with interest rate risk than costs. Besides that, it could also be the result of inaccurate measurement of interest rate risk, i.e. actual interest rate risk might be lower than initially thought. Finally, interest rate risk could be accidental, in the sense that life insurers have a liability side that they cannot purchase in capital markets. In the following, I focus on the explanation that interest rate risk is a deliberate choice, and after that I comment on the other two possible explanations.

2.2 Interest rate risk exposure as a deliberate choice

Firm perspective: Interest rate risk comes with costs and benefits. Regarding costs, a duration mismatch gives rise to reinvestment risk because future interest income is uncertain and, as a consequence of falling interest rates, it may fall short of interest expenses (French et al. 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, because it increases the common exposure to market risk within the insurance sector. Finally, with a short asset duration one may miss out on additional yield potential because the term structure of interest rates tends to increase with maturity.
There are also important benefits associated with investment strategies which have the side effect of increased interest rate risk. Insurers have specific expertise in managing interest rate risk, and compared to other intermediaries they can anticipate to hold investments for the long term. Chodorow-Reich et al. (2016) argue and provide empirical evidence that life insurers are asset insulators, i.e. 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 involatile and illiquid liabilities. However, an asset insulation strategy is contrary to a duration-matching strategy, because the two strategies require completely different investment management. 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.

**Policyholder perspective:** Firm and policyholder interests regarding duration-matching are not aligned if policies offer a high minimum return that is irrespective of investment returns. In an unregulated insurance industry, policyholders recognize the incentive problem and they could use contracts to limit risk taking (Mayers and 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 a way of specific reserve requirements or less transparent due to historical cost valuation on the balance sheet (Moody’s, 2015). Fleuriet and Lubochinsky (2005) demonstrate the effect of accounting methods using the example of a reform in Denmark: following a stipulated change in the discount rates used for premium reserves, Danish life insurers substantially increased the duration of their investments. Koijen and Yogo (2015) and Ellul et al. (2014) highlight that non-economic valuation in external accounting can distort managerial decisions.

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 of for assets and liabilities. With Solvency II, capital requirements take interest rate risk into account with due emphasis. Simply put, the higher an insurer’s interest rate risk, the higher the capital requirements.\(^4\) Hence, with Solvency II interest rate risk management is a

\(^4\)Capital requirements in Solvency II are based on a balance sheet with market-consistent valuation. It measures interest rate risk based on a stress test approach as the decrease of asset over liability value given a shift in the yield curve. Hence, the duration gap - the difference in interest rate sensitivity between
key factor in the optimization of investment portfolios (Braun et al. 2017). However, in the past and in particular in Germany, this was not quite so. The previous Solvency I regime determined capital requirements using a simplistic factor-based approach. Capital requirements were independent of the duration of the asset portfolio and asset-liability management.\textsuperscript{5} This suggests that regulatory constraints varied over time. Before 2016 the constraints of regulation addressing interest rate risk had a limited effect in Germany.

Taking all this into account, the degree of interest rate risk ultimately depends on 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 asset insulation and risk management, i.e. I examine features of investment management that are necessary for duration matching, but contradict an asset insulation strategy.

These are in particular the asset turnover and the holding of specific investment classes. In a world with a limited supply of ultra-long bonds, say 30-year bonds, a simple buy-and-hold strategy is not the way to achieve duration matching. Instead, duration matching requires a high asset turnover – one must sell securities as they approach their maturity date and reinvest in newly issued securities with a long time to maturity. This situation is due to the fact that even the longest-term bonds available have an asset duration that exceeds the liability duration only at the time of issue and after that for a few years. Regular portfolio adjustments are necessary to keep asset duration close to the duration of newly issued ultra-long bonds. By contrast, an asset insulation strategy is not consistent with the realization of short-term asset value fluctuations. Instead of a high asset turnover, an asset insulation strategy is related to a buy-and-hold strategy - holding assets for the long run with only minimal turnover.

In addition, if duration matching is the aim, then public sector bonds are the investment object of choice, because these bonds are often the only available ultra-long bonds. Asset insulation, on the other hand, requires a preference for illiquid and high-transaction-cost securities, for example investment in real estate.

Based on this, one derives testable hypotheses about the cross-section of insurers. Insurers with only a high asset duration should be those that (1) regularly adjust their portfolios, (2) buy many public sector bonds, and (3) have little real estate investment. In this way, I indirectly investigate whether the trade-off between profitable investment strategies and risk management can to a certain extent explain the observed interest rate liabilities and assets - is a key indicator within the Solvency II framework.

\textsuperscript{5}To be precise, with Solvency I the regulatory landscape differed between countries. For instance, the United Kingdom supplemented Solvency I with further requirements, which were sensitive to duration matching (Swain and Swallow 2015).
risk. It is difficult to establish an opinion about the influence of firm characteristics. Although I examine the relationship with firm characteristics in this paper, I do not formulate any directional hypotheses.

### 2.3 Explanations as an inaccurate measure

Some insurance experts are critical about the use of the duration measure for insurance liabilities. Interest rate risk exposure may be less material where it is viewed from a different perspective. The measure in this paper concentrates on the interest rate sensitivity of fixed future cash flows that follow from the minimum return guarantees and therefore views the total amount of liabilities as predictable. Variability of future cash flows is disregarded in my setting, two sources of which are meaningful in the specific institutional context of Germany. Typical contracts in Germany pay a higher benefit to customers for investment income that significantly exceeds the contract-specific minimum guarantee (future discretionary benefits). This is allocated to customers a few years later and cannot be revoked at this time in years with low investment income. Second, typical contracts include a surrender option, which gives policyholders a choice to reduce the term of their policy.

There is no consensus on how to incorporate future discretionary benefits into measuring interest rate risk of insurers. EIOPA (2016) proposes, in addition to its Macaulay duration measure, the concept of effective duration. This measure takes into account that future profit participation moves in parallel to the future path of interest rates. The effective duration is therefore lower than the Macaulay / modified duration (Briys and De Varenne, 1997, EIOPA, 2016). One approach to approximate the effective duration is the definition of scenarios: first, the present values of future cash flows are calculated for the baseline and a stress scenario. This calculation must contain behavioral assumptions as to how future cash flows respond to market interest rates. Then, one simulates the profit statements and profit sharing for the relevant future years. After that, the change in the present value is expressed in relation to the change in interest rates. The effective duration estimate should be judged in the context of the two compared scenarios. In EIOPA (2016) these are a baseline scenario (which assumes that interest rates rise in the long run as the yield curve is upward sloping)\(^6\) and a low-for-long scenario. Related to the assumption of a flattening of the yield curve, one predicts a significant drop in future discretionary benefits, which has a risk-dampening effect.

The difference between the modified and effective duration depends on the scenarios

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\(^6\)One key element here is what is known as the ultimate forward rate. Solvency II stipulates the use of discount rates for liabilities with a maturity of over 20 years calculated on its basis, which was set at 4.2%.
compared. I believe that interest rate risk from fixed benefits is not materially reduced by the argument that in future, in some scenarios, there are additional variable benefits that one could reduce in other scenarios. Therefore, I see modified duration as the more intuitive and more useful measure. Furthermore, it needs to be noted that effective duration can ultimately only be calculated by insurance companies themselves, because of the behavioral assumptions and complex calibrations required. An approach like the one taken in this paper is not possible with regard to effective duration.

Another source of variability of future cash flows is the policyholder option to surrender contracts, mostly involving additional surrender fees. From a purely financial view, the option to lapse becomes more valuable when interest rates rise. The reason for this is that variable benefits of life insurance policies are very slow to reflect the interest rate level, while alternative investments immediately provide a higher yield. Therefore, the surrender option has an influence on the interest rate sensitivity of insurance liabilities (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 significantly if interest rates rose sharply (Fürstemann, 2018). Therefore, future cash flows are most likely not influenced much by lapse behavior, at least in the context of a persistent low interest rate environment or a moderate rise in interest rates.

Besides, empirical studies indicate many other, non-financial reasons why policyholders lapse their contracts (Eling and Kochanski, 2013, Nolte and Schneider, 2017). Insurers can therefore calculate that a significant proportion of their obligations for a distant future will be incurred much earlier. For this reason, lapses are likely to lead to a lower duration of liabilities than initially planned. However, incorporating the influence of the surrender would also require the assumption of scenarios, and estimates are restricted to internal calculations of insurers.

To sum up, there are several concepts for calculating duration. One alternative is effective duration, which is lower than modified duration. However, effective duration can only be interpreted with respect to the scenarios compared. Different measures of interest rate risk have different interpretations, and these should always be kept in mind. This paper focuses on the interest rate risk which is based on minimum return guarantees and should therefore be interpreted accordingly.

2.4 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. Indeed, some argue that there is a shortage of long-term bonds (e.g. Frey, 2012). In addition, a dearth
of long-term bonds puts pressure on yields at the long end of the maturity spectrum (Greenwood and Vayanos, 2010). Besides, 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 et al., 2017). Ultra-long bonds usually belong to the safe assets category. Against this background, it seems a natural explanation that the supply of suitable long-term bonds alone is not sufficient to fully immunize life insurers against interest rate risk.

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. In addition, 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). On the basis of these empirical observations, a shortage of long-term bonds and their unattractive yields may be a challenge for investment managers. However, it is not plausible that a shortage of long-term bonds alone can explain limited duration matching.

3 Measuring interest rate sensitivity with accounting data

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

$$Dur \equiv -\frac{\partial MV}{\partial r} \frac{1}{MV} \tag{1}$$

In principle, modified duration is defined if the market value is continuous and differentiable with respect to the yield. As a more strict version of the duration measure, I specify two further assumptions: first, the underlying cash flow is not contingent on interest rate $r$. Second, interest rate $r$ is not contingent on the time horizon, i.e. the yield curve is flat.

Consider $MV$ as the observed market value of an insurer’s assets or its liabilities, and $r_0$ and $r_0 + \Delta r$ as two interest rate levels. I relate the change between two market values for the two interest rate levels $MV_{r_0}$ and $MV_{r_0+\Delta r}$ to a change in interest rates from $r_0$ to $r_0 + \Delta r$. This means modified duration is determined by linear approximation:

$$Dur_{r_0} \approx -\frac{MV_{r_0+\Delta r} - MV_{r_0}}{\Delta r} \frac{1}{MV_{r_0}} \tag{2}$$
With discretization, the accuracy of the duration measure depends on the curvature of the relationship between the market value and interest rates. The relationship is convex – the sensitivity increases when interest rates fall. Equation (2) measures the slope of the secant line between the market values for two interest rate levels, which lies between the interest rate sensitivity at the lower market value (higher interest rate) and the interest rate sensitivity at the higher market value (lower interest rate). The further analysis rests on the concept that the measure is a sufficiently accurate measure of interest rate sensitivity. Further, the comparison implies the assumption that changes observed in the market value are predominantly attributable to a change in the level of interest rates. This is valid because life insurers invest primarily in fixed-income securities, and liabilities are calculated as the present value of guaranteed future payments.

I now 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 those conditions are met. First, the book value and market value were identical when rates are $r_0$. And second, 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. Third, the use of accounting data implies the assumption that balance sheet items provide a meaningful picture of interest rate risk. This is reasonable, because the balance sheets of insurers change very little over time, and securities outside the balance sheet and short-term holdings of derivatives play only a minor role.\(^7\)

I transform Equation (2) with a view to deriving an equation that can be calculated with the available information. I set $r_0$ such that assets and liabilities were recognized on the balance sheet at this interest rate level. Therefore, at interest rate level $r_0$, the book value equals the market value. That way, the modified duration can be approximated by the standardized amount by which the market value differs from the book value relative to the underlying change in interest rates.

$$Dur_{r_0} \approx - \frac{MV_{r_0+\Delta r} - BV_{r_0}}{\Delta r} \frac{1}{BV_{r_0}}$$

Equation (3) only considers the value effect of a change in interest rates. I set the current year as $v_0 + \Delta v$ and the time of interest rate change in the past as $v_0$ with $\Delta v > 0$. $\Delta v$ represents the number of years that have passed. The following holds:

$$Dur_{r_0,v_0} \approx - \frac{MV_{r_0+\Delta r,v_0} - BV_{r_0,v_0}}{\Delta r} \frac{1}{BV_{r_0,v_0}} + Inc_{v_0 + \Delta v}$$

Equation (4) is similar to Equation (3), apart from the stipulation that the interest

\(^7\)German insurers hold derivatives only to a very small extent, i.e. EIOPA (2018) p. 45.
rate change takes place without any passage of time. Furthermore, accounting for time differences requires an adjustment, because some items with a difference between market and book value disappear from the balance sheet. First, there is gains trading - insurers sell their winners, assets with a significant difference between their market value and book value, and hold on to other assets, and in doing so they generate profits by realizing capital gains (Ellul et al., 2015). The corresponding effect on liabilities is that some policyholders lapse their insurance contracts. In this case, the policyholders receive approximately the book value of the provisions. The difference between the book value and market value generates a profit for the insurer. This profit can be regarded as a lapse gain. To consider the gains trading and the lapse gain effect, I add the profit generated back to the observed book market difference. Consider the relevant profit added back $Inc_{r_0 + \Delta v}$ as the sum over the years $\Delta v$ of the yearly realized capital gains. On top of that adjustment I assume that portfolios are constant over time.

Because I observe neither $MV_{r_0 + \Delta r, r_0}$ nor $BV_{r_0 + \Delta r, r_0}$, I need an approximation based on $MV_{r_0 + \Delta r, r_0 + \Delta v}$ nor $BV_{r_0 + \Delta r, r_0 + \Delta v}$, which I observe. I approximate the change in book and market values for a change in observation time. Any present value is sensitive to the passing of time and the sensitivity to the passing of time increases in the discount rate. Therefore, the interest-rate-induced difference between the market and book value decreases over 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 interest 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 interest 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 pre-change interest rate $r_0$ is the discount rate. Note that it is necessary to also consider the time passing effect of the book value even in a historical cost accounting regime. In such a regime, the book value changes when the time value changes because of a later observation time. Book and market values conditional on observation year $z \in \mathbb{N}$ can be written as:

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

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

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:

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\[ \frac{\partial MV_{r_0 + \Delta r}}{\partial z} \frac{1}{MV_{r_0 + \Delta r}} = \frac{\ln(1 + r_0 + \Delta r) a}{(1 + r_0 + \Delta r)^{\frac{r}{z}}} \frac{1}{MV_{r_0 + \Delta r}} = \ln(1 + r_0 + \Delta r) \quad (6a) \]

\[ \frac{\partial BV_{r_0}}{\partial z} \frac{1}{BV_{r_0}} = \frac{\ln(1 + r_0) a}{(1 + r_0)^{\frac{r}{z}}} \frac{1}{BV_{r_0}} = \ln(1 + r_0) \quad (6b) \]

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 gives the following relationship between the market and book values at year \( v_0 + \Delta v \) and year \( v_0 \):

\[ MV_{r_0 + \Delta r, v_0 + \Delta v} \approx (1 + \ln(1 + r_0 + \Delta r))^{\Delta v} MV_{r_0 + \Delta r, v_0} \quad (7a) \]
\[ BV_{r_0, v_0 + \Delta v} \approx (1 + \ln(1 + r_0))^{\Delta v} BV_{r_0, v_0} \quad (7b) \]

The later the interest 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 interest rates first and time passage afterwards. Instead, I take half of the time period of \( \Delta v \) in the exponent. This roughly approximates that interest rate uniformly decreased over time. It gives the following approximate relationship:

\[ MV_{r_0 + \Delta r, v_0 + \Delta v} \approx (1 + \ln(1 + r_0 + \Delta r))^{0.5\Delta v} MV_{r_0 + \Delta r, v_0} \quad (8a) \]
\[ BV_{r_0, v_0 + \Delta v} \approx (1 + \ln(1 + r_0))^{0.5\Delta v} BV_{r_0, v_0} \quad (8b) \]

Then, I derive the following estimate of the book market difference which considers the time passing effect.

\[ MV_{r_0 + \Delta r, v_0} - BV_{r_0, v_0} \approx \frac{MV_{r_0 + \Delta r, v_0 + \Delta v}}{(1 + \ln(1 + r_0 + \Delta r))^{0.5\Delta v}} - \frac{BV_{r_0, v_0 + \Delta v}}{(1 + \ln(1 + r_0))^{0.5\Delta v}} + Inc_{v_0 + \Delta v} \quad (9) \]

This gives the following approximation of the duration prior to the change in interest rate level and time:

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

The duration estimate is therefore the relative change in the valuation of market over book value divided by the interest 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 for gains on the sale of securities and for lapses to cover portfolio changes.

Using Equation (10) one can, in principle, separately calculate the duration of liabilities \( \text{Dur}_{r_0,v_0}^{\text{Liabilities}} \) and the duration of assets \( \text{Dur}_{r_0,v_0}^{\text{Assets}} \). The duration gap is defined as the difference between the two.

\[
\text{Duration gap} = \text{Dur}_{r_0,v_0}^{\text{Liabilities}} - \text{Dur}_{r_0,v_0}^{\text{Assets}}
\]  

(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.
The sensitivity of own funds is approximated by:

\[
\text{Sensitivity Own Funds} = \frac{\text{BV}_{r_0,v_0}^{\text{Assets}} \frac{\text{Dur}_{r_0,v_0}^{\text{Assets}}}{100} - \text{BV}_{r_0,v_0}^{\text{Liabilities}} \frac{\text{Dur}_{r_0,v_0}^{\text{Liabilities}}}{100}}{\text{Own Funds}}
\]  

(12)

with \text{Own Funds} being the national GAAP own funds.

4 Application to German life insurers

4.1 German life insurance sector

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

Life insurance within Germany is always regulated as a standalone entity and conse-
quentially organized and managed as a separate subsidiary. In 2014, there are 86 German
life insurers, which are subsidiaries of 54 insurance groups. Among the groups, 15 are
listed on the stock exchange, 4 are non-listed private corporations, 28 are mutual insur-
ance companies, 6 are public sector firms, and one is the policyholder protection scheme,
a corporation with German life insurers being 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 life insurance industry with life insurance policies being important
long-term saving vehicles. Total financial assets of the life insurance sector are 818 billion
euro (year 2014), which corresponds to about 28% of 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 with 750 billion euros. Life insurers create this provision to provide for future net benefit obligations that are guaranteed and attributed to individual policies. The fixed interest liabilities arose from minimum return guarantees, which are applied on a year-by-year basis to the policyholders’ savings (for more details see Eling and Holder, 2013). The minimum return is set at the inception of the contract and cannot be changed afterwards. All insurance contracts entered into within the same period have the same minimum return. For example, all insurance contracts entered into between July 1986 and June 1994 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 policies were sold. The industry average in 2014 is 3.1%. 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 not usually binding (Hombert and Lyonnet, 2017).

4.2 Basics of German insurance accounting

This paper uses insurance data taken from single-entity balance sheets. Therefore, it is useful to briefly describe the basics of German insurance accounting. Life insurers prepare their single-entity financial statements in accordance with German national GAAP, 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 most investments - the vast majority of which are fixed-income securities - are carried at par value. Insurers also report their valuation reserves, the difference between market and book values. For this reason, the financial statements disclose two valuations for investments that differ only in terms of the discount rate.

On the liability side, the premium reserve is valued at the present value of expected cash flows. It consists of 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, in principle, of adjusting the level of reserves towards the market value. The reasoning is to increase provisions for under-provisioned policies. However, the adjustment is only partial, and there remains a significant portion of hidden losses. It recently became possible to observe 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 on the hidden losses carried on the liability side. The hidden losses of the premium reserve are approximated by the safeguard amount. Therefore, I effectively have two valuations of the premium reserve which differ only in terms of their discount rate. The difference between
the two valuations, the book value and the market value, is the sum of the safeguard amount and the additional interest provision.

4.3 Data set

The data set I use is the extended forecast collected by the Federal Financial Supervisory Authority (BaFin). The publicly unavailable cross-sectional data set includes detailed reports from the financial reporting systems of all German life insurers. The data are based on company business plans as at 30 September 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 do not end up being published.

The data set includes information on the market value of German life insurers’ liabilities based on an industry-wide discount rate as well as on the book value and its 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 which are mostly not observed. The data set has the main advantage that I observe both.

Regarding financial assets, the data set includes information on the book value of investments as well as on the valuation reserves, which are the difference between market and book values. Here, both discount rates need to 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. To adjust extreme values, I replace observations with the mean plus/minus 2.5 times the standard deviation if the observation exceeds this value. Regarding the discount rate for the market value, I estimate the current yield of the fixed-income portfolio. I consider the insurer-specific portfolio split between investment grade bonds and high yield bonds.\footnote{Bonds with a rating of BB or lower and unrated bonds.} For the share of investment-grade bonds I use the average current yield of debt securities in Germany.\footnote{Yields on debt securities outstanding issued by German residents, Bundesbank time series BBK01.WU0017.} 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.

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 a premium reserve of around 0.25 billion euro compared to an average premium reserve of 9 billion euro. This leaves me with a sample of 83 German life insurers. To give an overview of the data, Table 1 presents the key balance sheet items and the underlying...
Table 1: Descriptive statistics of key balance sheet items for the year 2014 [bn euro]

<table>
<thead>
<tr>
<th>Balance sheet item</th>
<th>Mean</th>
<th>SD</th>
<th>Median</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book value investments</td>
<td>9.9</td>
<td>20.8</td>
<td>2.9</td>
<td>818</td>
</tr>
<tr>
<td>Underlying discount rate</td>
<td>3.7%</td>
<td>0.5%</td>
<td>3.6%</td>
<td></td>
</tr>
<tr>
<td>Market value investments</td>
<td>11.5</td>
<td>25.4</td>
<td>3.4</td>
<td>954</td>
</tr>
<tr>
<td>Underlying discount rate</td>
<td>1.0%</td>
<td>0.2%</td>
<td>1.0%</td>
<td></td>
</tr>
<tr>
<td>Book value premium reserve</td>
<td>9.0</td>
<td>18.6</td>
<td>3.0</td>
<td>750</td>
</tr>
<tr>
<td>Underlying discount rate</td>
<td>3.1%</td>
<td>0.3%</td>
<td>3.2%</td>
<td></td>
</tr>
<tr>
<td>Market value premium reserve</td>
<td>11.1</td>
<td>22.9</td>
<td>3.5</td>
<td>923</td>
</tr>
<tr>
<td>Underlying discount rate</td>
<td>1.2%</td>
<td>0.0%</td>
<td>1.2%</td>
<td></td>
</tr>
</tbody>
</table>

The table shows descriptive statistics of key balance sheet items for 83 German life insurers in the year 2014 based on German national GAAP. The book value of the premium reserve displayed here excludes the additional interest provision. The market value of the premium reserve is approximated by adding 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 investments is based on average yearly coupon payments. Regarding the discount rate for the market value, an estimate based on the portfolio composition is used. 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 the premium reserve is the market rate used for calculating the safeguard amount, which is the same for all insurers.

discount rates for the year 2014. The total market value of investments is 17% 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 the premium reserve is 23% 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, the descriptive statistics suggest that liabilities are more sensitive to interest rate changes than assets.

Measured in terms of book value, the discount rates of investments are higher than the discount rates of liabilities. This reflects that insurers can finance their current expenses out of their current investment income. Due to a different age structure of contracts and investments, the average discount rate of the book value differs widely between insurers. Simply put, older contract and investment portfolios have a higher discount rate than younger ones. The discount rate on the asset side differs even more widely between insurers than it does on the liability side (Figure 1).

There is a strong relationship between discount rates and book-market differences. This illustrates that cross-sectional variation in the discount rate used in the books is the main determinant of the cross-sectional variation in the book value.

4.4 Estimate of time passed since recognition on the balance sheet

I derive an estimate of $\Delta v$, which is the time period between today and the point of time when the average investment was purchased or the average contract was concluded.

For the liability side, I estimate $\Delta v$ at an insurer level by using the policy structure
Figure 1: Histogram of the underlying discount rates for the book value of assets and liabilities

![Histogram of the underlying discount rates](image)

The histogram shows the distribution of the discount rates $r_0$ in Equation (10) used to estimate the asset and liability durations. For assets, the discount rate corresponds to the average yearly coupon payments for the year 2014. For liabilities, insurers report this discount rate. The sample is 83 German life insurers. Each bin illustrates the number of insurers with a discount rate within the interval.

set out in the yearly industry report from the rating agency Assekurata. This includes a contract breakdown by guaranteed interest rate for 64 life insurers (89% market share). This breakdown can be used to derive a contract breakdown by starting year, because each observed guarantee rate was only valid for a few years. For the few life insurers with no contract split I estimate $\Delta v$ based on the average guaranteed rate. For the year 2014 this approach gives me an average contract age estimate of 12 years with a standard deviation of 2.6.

For the investment side, I base my estimate on the current return on investments, which excludes valuation effects and is a good proxy for the average yield at the time of investment. I adjust the observed return for portfolio risk, because more investment risk would generally transfer into higher coupon payments which maps into this measure. I match, at an insurer level, the current return on investment and the investment yield of a typical investment by year in the past.\textsuperscript{11} For the year 2014 this approach results in an average asset age of 6.2 years with a standard deviation of 0.9.

The time passing effect of the market value of the premium reserve cannot be estimated with the general approach outlined above because of measurement specifics: the safeguard

\textsuperscript{11}For this purpose, I use yields on German mortgage covered bonds outstanding with ten years maturity (Bundesbank time series BBK01.WX4260). Mostly, interest rates decreased over time. If they did not for a certain year, I would interpolate.
amount, which is used to approximate the book-market difference, covers exactly the next 15 years. If the observation year were to move forward, the time period of 15 years would remain constant, but the years included would change. For example, if one measures the hidden losses in year \( n + 1 \) rather than in year \( n \), one then observes hidden losses from year \( n + 1 \) until \( n + 15 \), rather than from year \( n \) to \( n + 14 \). Therefore, the hidden losses measure keeps itself up to date. For this reason, in the specific case of German insurance accounting, one needs not account for the time passing effect of the difference between market and book value.

4.5 Estimate of the effect of gains trading and lapses

Insurers generate accounting profits from the sale of assets (realization of capital gains) and from lapses (realization of book-market differences on the liability side). I calculate the relevant profit \( Inc_{v_0 + \Delta v} \) for the period between \( v_0 \) and \( v_0 + \Delta v \).

Each insurer reports the investment income from gains trading each year in their profit and loss statement. This information permits me to calculate the relevant profit. On aggregate, the valuation reserves disappeared due to the realization of capital gains are 30 billion euro or 22% of today’s observed book-market difference. On the liability side, I cannot directly observe the profit generated through lapses. Instead, I use the individual yearly lapse rate of insurers and multiply it for each year by the observed book-market difference. On aggregate, the hidden losses disappeared due to lapses are 24 billion euro, or 14% of today’s observed book-market difference.

Figure 2 displays the distribution between insurers for the year 2014, with both the asset and liability side standardized by the observed book-market difference. It illustrates that most insurers have made only moderate use of profit generation from realized capitals gains; however, the effect on the book-market difference is considerable larger on the asset side than on the liability side. One observes long tails on the asset side as some insurers generated considerably more profit than the median insurer.

4.6 Time series dimension

The data set is available yearly. The 2014 edition is the first one that includes data on the market value on the liability side. So far, two more recent versions have been available which include this information, the 2015 and 2016 editions. The annual cross-sections are merged on the basis of a unique identification number for the insurers. Adding the 2015 and 2016 data sets reduces the sample to 78 insurers. This is due to five insurers either going out of business, being converted to a pension fund, or reporting missing data. These five insurers are relatively small, with an average premium reserve of below 0.5
The histograms show the distribution of book-market difference disappeared from the balance sheet during the time passed \( \Delta t \), which is used in Equation (9), standardized by division with the book-market difference of the year 2014. The left-hand side displays capital gains realized through the sale of assets with a market value that exceeds the book value. The right-hand side displays the gains realized through lapses, as policyholders who lapse their contracts receive the book value. The sample is 83 German life insurers. Each bin illustrates the number of insurers with a yearly income from realized capital gains within the interval.

billion euro, compared to an average premium reserve of 9 billion euro.

5 Results

5.1 Estimation of the duration gap

On the basis of the data discussed in the previous section I calculate for German life insurers the duration of the assets and liabilities as well as the difference between the two, the duration gap. In the aggregate, the sector has an estimated asset duration of 11 and a liability duration of 17 in 2014 (Table 2). The resulting duration gap amounts to 6. This means 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 estimate, which implies 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. Looking at the time series, it is noticeable that both asset and liability duration grow over time. The asset duration grows more strongly and the duration gap narrows. This result is largely in line with the development described by Domanski et al. (2017). The duration gap estimate is highly correlated between years.

The estimated duration gap can be compared with estimates of other studies. The
Table 2: Interest rate sensitivity estimate of German life insurers (2014-16)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Total</th>
<th>Mean</th>
<th>SD</th>
<th>p25</th>
<th>p50</th>
<th>p75</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2014</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset duration</td>
<td>83</td>
<td>11.3</td>
<td>10.0</td>
<td>1.8</td>
<td>8.8</td>
<td>10.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Liability duration</td>
<td>83</td>
<td>16.8</td>
<td>17.6</td>
<td>4.7</td>
<td>14.0</td>
<td>16.6</td>
<td>20.2</td>
</tr>
<tr>
<td>Duration gap</td>
<td>83</td>
<td>5.5</td>
<td>7.7</td>
<td>4.9</td>
<td>4.2</td>
<td>6.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Sensitivity own funds</td>
<td>83</td>
<td>27%</td>
<td>39%</td>
<td>34%</td>
<td>15%</td>
<td>35%</td>
<td>55%</td>
</tr>
<tr>
<td><strong>2015</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset duration</td>
<td>80</td>
<td>12.8</td>
<td>11.7</td>
<td>3.1</td>
<td>9.8</td>
<td>11.5</td>
<td>12.8</td>
</tr>
<tr>
<td>Liability duration</td>
<td>80</td>
<td>17.2</td>
<td>18.5</td>
<td>5.4</td>
<td>15.1</td>
<td>17.7</td>
<td>20.4</td>
</tr>
<tr>
<td>Duration gap</td>
<td>80</td>
<td>4.4</td>
<td>6.8</td>
<td>5.5</td>
<td>3.4</td>
<td>5.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Sensitivity own funds</td>
<td>80</td>
<td>23%</td>
<td>36%</td>
<td>37%</td>
<td>10%</td>
<td>31%</td>
<td>56%</td>
</tr>
<tr>
<td><strong>2016</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset duration</td>
<td>78</td>
<td>14.9</td>
<td>13.0</td>
<td>2.4</td>
<td>11.3</td>
<td>12.9</td>
<td>14.6</td>
</tr>
<tr>
<td>Liability duration</td>
<td>78</td>
<td>17.3</td>
<td>19.1</td>
<td>6.7</td>
<td>15.6</td>
<td>17.7</td>
<td>20.4</td>
</tr>
<tr>
<td>Duration gap</td>
<td>78</td>
<td>2.4</td>
<td>6.1</td>
<td>7.2</td>
<td>2.2</td>
<td>4.5</td>
<td>8.3</td>
</tr>
<tr>
<td>Sensitivity own funds</td>
<td>78</td>
<td>1%</td>
<td>20%</td>
<td>31%</td>
<td>1%</td>
<td>16%</td>
<td>40%</td>
</tr>
</tbody>
</table>

The table shows descriptive statistics of the modified durations estimated in Equation (10), the duration gap estimated in Equation (11) and the sensitivity of own funds estimated in Equation (12). 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.

results are in a similar range. EIOPA (2014) derives a (Macaulay) duration of German life insurers for assets at 10 and for liabilities at 21. Assekurata (2015) estimates the modified duration for fixed-income investments at 8 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 7 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.

I use the duration result to calculate the sensitivity of the residual claim, the own funds. In analogy to the previous definition of the book value, I use the reported own funds to which the additional interest reserve has been added. Because German life insurers operate with little reported own funds, their sensitivity to interest rate changes is quite high. The estimate for the year 2014 implies that, on aggregate, a one percentage point decrease in interest rates results in a 27 percent decrease in own funds (Table 2). The sensitivity of balance sheet own funds is higher than stock market value sensitivity. Hartley et al. (2016) observe, based on stock market data, that a one percentage point decrease in yield in mid 2015 is associated with an nine percent drop in the stock market value of U.S. life insurers. The sensitivity was lower before that date. For U.K. life insurers the effect is not significantly different from zero. Domanski et al. (2017) replicate the analysis using a German life insurance stock market index. They find that a one percentage point decrease in yield is associated with a seven percent drop in the stock market value. That the book value of own funds is more sensitive than the stock market value is in line with the asset insulator view of Chodorow-Reich et al. (2016). It is also in
Figure 3: Scatterplots: Duration gap estimate between years

The scatterplots show the association between the duration gaps estimated in Equation (11) across different years. The dots displayed are averages between three randomly selected insurers to comply with data confidentiality. The left-hand side compares the years 2014 and 2015, while the right-hand side compares the years 2014 and 2016. The mid-line indicates combinations for which the duration gap is identical in both years.

This line with the fact that listed insurance companies are diversified companies and therefore less sensitive to interest rate risk than pure life insurance companies.

To get 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 the years 2015 and 2016, respectively (Figure 3). It can be seen that there is a relatively close correlation between the duration gaps of the individual years.

5.2 Variation in interest rate risk between insurers

Figure 4 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. While the asset duration is approaching a normal distribution, the distribution of the liability duration is relatively broad with a long tail. The cross-insurer standard deviation of the gap is 4.7 for the year 2014, which is 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.

Asset-liability management implies that insurers with a higher liability duration should have a 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. Given complete matching, all the dots would be on the mid-line. However, this requires only low degrees of freedom for investment management and only limited opportunities
Figure 4: Histograms: Estimated asset and liability duration

The histograms show the distribution of the modified durations estimated in Equation (10) for 83 German life insurers for the year 2014. The left-hand side shows the distribution of asset durations, while the right-hand side shows the distribution of liability durations. Each bin illustrates the number of insurers with a duration within the interval. The wider the duration, the more sensitive is the value of the balance sheet side to a change in interest rates.

to achieve excess returns on the basis of an asset insulator strategy. Figure 5 directly compares asset and liability durations for the year 2014. I observe only a weak relationship between asset and liability durations. The scatterplot suggests that the two sides of the balance sheet are barely related. This implies limited liability-driven investment and insurers giving low priority to duration matching compared with other investment objectives.

To use panel regression to investigate the asset-liability correlation of investment duration with liability duration, I estimate

\[
\left( D^{\text{Assets}}_{r_0,v_0} \right)_{i,t} = \alpha + \beta \left( D^{\text{Liabilities}}_{r_0,v_0} \right)_{i,t} + \epsilon_{i,t}
\] (13)

I cluster standard errors by group to address the potential correlation of insurers’ durations across the firms in a group. Extreme values of the duration measures were 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 duration on the liabilities side of the balance sheet cannot be influenced by the insurer, while the duration of the assets side 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 asset and liabilities, one would expect \( \beta = 1 \). Where asset-liability management takes place, but duration matching is only done partly, one would expect \( \beta \) to be substantially larger than zero, but below one.

Table 3 displays the results. The relationship between asset and liability duration
Figure 5: Distribution of asset and liability duration of German life insurers (2014)

The scatterplot shows the relationship between the asset duration on the x-axis and the liability duration on the y-axis, both estimated in Equation (10), for 83 German life insurers for the year 2014. The dots displayed are averages between three randomly selected insurers to comply with data confidentiality. The greater the duration, the more sensitive is the value of the balance sheet side to a change in interest rates. The mid-line indicates combinations for which the asset duration equals the liability duration. The distance to the mid-line indicates the duration gap.

Table 3: Association between investment and liability duration

<table>
<thead>
<tr>
<th>Variable</th>
<th>Column (1)</th>
<th>Column (2)</th>
<th>Column (3)</th>
<th>Column (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fixed-effects</td>
<td>random-effects</td>
<td>pooled</td>
<td>pooled, lagged</td>
</tr>
<tr>
<td>Liability duration</td>
<td>-.020 (.030)</td>
<td>-.006 (0.024)</td>
<td>.038 (.052)</td>
<td>.051 (.065)</td>
</tr>
<tr>
<td>Year fixed-effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>23%</td>
<td>24%</td>
<td>25%</td>
<td>9%</td>
</tr>
</tbody>
</table>

The table shows results from panel regression (13). The sample consists of 78 life insurers for the three years 2014-16. The dependent variable is the investment duration and the variable is the liability duration, both estimated in Equation (10). Extreme values are set to the mean plus/minus the 2.5 standard deviations if they exceed this value. Column (1) displays results of a fixed-effects regression, column (2) of a random-effects regression, column (3) of a pooled-model, and column (4) a pooled model with a lagged liability duration as the variable. Standard errors are clustered by group and displayed in brackets. *, ** and *** show a significance level of 0.1, 0.05 and 0.01, respectively.

is not significantly different from zero. In addition, the coefficient is far from 1. This is contrary to liability-driven investment; it suggests that insurers do not attach much priority to duration matching.

5.3 Duration matching as a deliberate choice

According to Chodorow-Reich et al. (2016) life insurers act as asset insulators: they create value by holding bonds for long intervals instead of exposing their balance sheets to market fluctuations through a turnover of assets. This results in a trade-off for asset managers. On the one hand, illiquid and risky securities need to be purchased for the asset insulation strategy and held to maturity, and on the other hand long-term securities need to be purchased for duration matching, which must be traded regularly in order to keep a wide duration in the investment portfolio. It is not possible to tell which strategy
is preferred in each individual case. This depends on the characteristics and calculations of the respective decision-makers.

From the trade-off, the theoretical idea is deduced that some insurers assume interest rate risk as a deliberate choice, whereas others mainly strive for duration matching. For the empirical analysis, typical properties of asset management are identified that suggest the prevalence of one of the two strategies. With regard to suitable data, the background is as follows: firstly, characteristics from the past must be used, because the interest rate risk calculated in this paper is the result of investment strategies from the past. Secondly, for the past, detailed data on pre-defined categories of investments are available for the German market, but not on an asset-by-asset basis.

On this basis, I use three variables whose values can be assigned to the two strategies. The first variable covers the holding period of investments. I use the average yearly income from realized capital gains between 2006 (the first available year) and 2013 (the last year before I calculate the interest rate risk). The income is set in relation to the assets, the market value of total investments in 2014. The higher the measure, the higher the share of securities sold by the insurers before the maturity date. This approximates the 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 zero. The more an insurer pursues a duration-matching strategy, the higher I expect this variable to be. The more an insurer pursues an asset insulation strategy, the lower I expect this variable to be. Of course, insurers sell securities for many other reasons, too, and one cannot know for sure why securities are being sold. However, it is evident that duration matching requires regular asset sales, whereas asset insulation is based on little or no sales of securities. A histogram illustrates some heterogeneity between insurers, with the median insurer having a yearly income from gains trading of 0.3% relative to total investments (top-left side of Figure 6).

The second variable covers the type of investments. The theory of asset insulation implies that insurers miss out on 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. By contrast, public sector bonds are essential for duration matching because they are often the only bonds available with very long-term maturities. I use company reports to calculate a variable at an insurer level which approximates the degree of holding public bonds. The extended forecast, the data set used in this study, includes information on the holdings of public sector bonds. This information is available from year end 2013 onwards. I use data from 2013, one year before the period used for the remaining analysis (2014-16). I use the share of public sector bonds compared to total investments. The more insurers pursue a duration-matching strategy,
the higher I expect this variable to be. 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 having a holding of 23% relative to total investments (top-right side of Figure 6).

The third variable also covers the type of investment. Real estate is an attractive investment class with an asset insulation strategy, because real estate investments are illiquid and have high transaction costs. By contrast, real estate is of limited use for duration matching, because the duration of real estate is significantly lower than the duration of long-term bonds (e.g. Constantinescu, 2010) and at the same time, high transaction costs do not permit a regular adjustment of portfolios. I use company reports to calculate a variable at an insurer level which approximates the degree of real estate investments. The extended forecast, the data set used in this study, has this information available from year-end 2013 onward. The variable covers the following investments: direct investment in land and land rights, direct investment in real estate, shares of real estate companies, real estate investment trusts, shares in closed-end real estate funds and shareholder loans to real estate companies. I use the share of real estate investments compared to total investments (bottom-left side of Figure 6).

I interpret the described correlations with asset duration as an indication of a trade-off and that pursuing an asset insulation strategy goes some way towards explaining why insurers have not increased their asset duration in order to reduce their interest rate risk. On the other hand, I do not expect any correlations between liability duration and one of the three variables because liability duration is the result of the business model and customer demand, and can hardly be influenced by insurers’ management. I estimate regressions of the following form

\[ Dur_{i,t} = \beta_0 + \beta_1 AssetTurnover_i + \beta_2 PublSector_i + \beta_3 RealEstate_i + \beta_4 X_{i,t} + \epsilon_{i,t} \]  

where the dependent variable is either asset or liability duration of insurers \(i\) at year \(t\) and \(AssetTurnover_i\) is the average realized capital gain of insurer \(i\), \(PublSector_i\) is the share of public sector bonds of insurer \(i\) and \(RealEstate_i\) is the share of real estate investments of insurer \(i\). While I observe changes of the dependent variables over time, the variables on the right-hand side are historical and therefore time constant. Theory predicts estimates of coefficients \(\beta_1\) and \(\beta_2\) that are significantly larger than zero for regressions with asset duration as the dependent variable. For \(\beta_3\) I predict estimates that are significantly lower than zero.\(^{12}\)

\(^{12}\)Note that, in principle, one could also calculate a yearly estimate of asset turnover and government bond holdings and estimate a fixed-effects model. However, I do not consider that approach to be meaningful, because the theory about the behavior of insurers followed here is about a feature of investment
Figure 6: Histograms: Typical investment features that suggest a prevalence of either a duration-matching or asset insulation strategy

The top-left histogram shows the distribution of asset turnover, measured in percent as average yearly income from realized capital gains between 2006 and 2013 divided by total investments for the year 2014. The higher the income, the higher the asset turnover. A high level indicates a duration-matching strategy. The top-right histogram shows the distribution of public sector bond holdings, measured in percent as average holdings of public sector bonds divided by total investments for the year 2013. A high level indicates a duration-matching strategy. The bottom-left histogram shows the distribution of real estate investments, measured in percent as average holdings of real estate investments divided by total investments for the year 2013. A low level indicates a duration-matching strategy. The sample is 83 German life insurers. Each bin illustrates the number of insurers with a level within the interval.
Table 4: Descriptive statistics of life insurer attributes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p25</th>
<th>Median</th>
<th>p75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned premium growth</td>
<td>-0.23</td>
<td>5.39</td>
<td>-2.19</td>
<td>0.29</td>
<td>1.72</td>
</tr>
<tr>
<td>Run-off</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Size (log premium reserve)</td>
<td>14.9</td>
<td>1.7</td>
<td>13.9</td>
<td>15.0</td>
<td>16.3</td>
</tr>
<tr>
<td>Final shareholder listed group</td>
<td>0.38</td>
<td>0.49</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Final shareholder mutual insurer</td>
<td>0.44</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Final shareholder public</td>
<td>0.10</td>
<td>0.30</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct insurer</td>
<td>0.09</td>
<td>0.28</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Interest rate derivatives</td>
<td>0.42</td>
<td>0.49</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

The table shows descriptive statistics of company attributes used as variables in regression (14). There are two continuous variables: projected premium growth for the next three years, measured in percent, and size, measured as the natural logarithm of the book value of the premium reserve. Further, it includes the following dummies: being in run-off, being a direct insurer 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 which is not listed or the policyholder protection scheme. Finally, it includes as a dummy variable the use of derivatives as a hedging instrument in the years 2010-2013.

I cluster standard errors by group to address potential correlation of insurers’ durations across the firms in a group. To address a small number of extreme values in the dependent variable, extreme values were set to the mean plus/minus the 2.5 standard deviations if they exceeded this value.

In some specifications I also include firm characteristics $X_{i,t}$. The first one is size, measured by the natural logarithm of the book value of the premium reserve. 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 three years. I take this information from the respective company forecasts in the extended forecasts data sets for the years 2014, 2015 and 2016. 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. Further, I control for direct insurers. These are insurers that do not work with brokers or insurance agents. Instead, they sell policies mostly through their websites. This is also a proxy for age because these companies have been established more recently. Finally, I control whether an insurer used interest rate derivatives as a hedging instrument during the years 2010-2013. The derivatives data are taken from regulatory reporting. Table 4 displays detailed descriptive statistics of these firm characteristics. I expect asset and liability duration to differ between insurers with different attributes, though, I do not have directional hypotheses.

First, I estimate a random-effects model with firm characteristics included. This spec-
Table 5: Panel regression: Relationship between duration, asset turnover and public sector bond holdings

<table>
<thead>
<tr>
<th>Variable:</th>
<th>Column (1)</th>
<th>Column (2)</th>
<th>Column (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random-effects</td>
<td>Pooled</td>
<td></td>
</tr>
<tr>
<td>Dependent variable: Asset duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset turnover</td>
<td>3.703*** (.506)</td>
<td>3.540*** (.525)</td>
<td>3.749*** (.509)</td>
</tr>
<tr>
<td>Public sector bond</td>
<td>.029* (.016)</td>
<td>.052*** (.017)</td>
<td>.030* (.016)</td>
</tr>
<tr>
<td>Real estate investment</td>
<td>-.188*** (.062)</td>
<td>-.064 (.057)</td>
<td>-.191*** (.062)</td>
</tr>
<tr>
<td>Firm characteristics</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Year fixed-effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Adj. R-Squared</td>
<td>65%</td>
<td>52%</td>
<td>65%</td>
</tr>
</tbody>
</table>

| Variable:                      | Column (2) | Column (3) |
| Dependent variable: Liability duration |          |           |
| Asset turnover                 | 3.278* (1.695) | 4.367** (1.983) | 2.920 (1.820) |
| Public sector bond             | .024 (.041)   | .007 (.033)    | .023 (.040)    |
| Real estate investment         | -.395*** (.139) | -.448*** (.159) | -.372** (.140) |
| Firm characteristics           | Yes        | No         | Yes         |
| Adj. R-Squared                 | 25%        | 15%        | 26%         |

The table shows results from panel regression (14). The panel covers 78 German life insurers for the years 2014-16. The dependent variable is the asset duration (upper part of the table) or the liability duration (lower part of the table) estimated in Equation (11). Extreme values are set to the mean plus/minus the 2.5 standard deviations if they exceed this value. The first variable is the average yearly realized capital gain between 2006 and 2013 relative to total investment. The second variable is the average holding of public sector bonds relative to total investment in 2013. The third variable is the investment in real estate relative to total investment in 2013. Column (1) displays the results of random-effects regression, which include the control variables displayed in Table 4. Column (2) displays the results of a pooled model with no other variables. Column (3) displays the same model with the control variables displayed in Table 4 included. Standard errors are clustered by group and displayed in brackets. *, ** and *** show a significance level of 0.1, 0.05 and 0.01, respectively.

The result is in line with a trade-off between asset insulation and duration matching. I find for asset duration as the dependent variable in all specifications (random and between effects, with and without control variables) that the coefficient of asset turnover is highly significantly positive. The effect of public sector bond holdings on asset duration is also significantly larger than zero. The effect of real estate investment on asset duration is significantly negative, as expected.

As an alternative analysis, I use a common factor calculated with principal component analysis instead of the three variables asset turnover, public sector bond holdings and real estate investments. The estimated effect of common factor on asset duration is significantly positive and on liability duration it is not significantly different from zero.

In summary, the result indicates a trade-off and that pursuing an asset insulation...
strategy goes some way towards explaining why insurers have not increased their asset duration in order to reduce their interest rate risk. Hence, the result suggests that interest rate risk is a deliberate choice influenced by the advantages of trading strategies with the side-effect of a shorter asset duration.

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 result should be interpreted carefully.

6 Conclusion

This paper sheds light on the still-incomplete picture of why insurers assume interest rate risk. The analysis indicates that many insurers assume interest rate risk as a deliberate choice with the goal of following profitable investment strategies rather than pursuing a strict duration-matching strategy.

Life insurance policies compete with other intermediaries’ products. Insurers might be able to generate extra returns for their clients through profitable investment strategies such as asset insulation. Results of this paper imply that value creation is limited by interest rate risk. A prolonged low-interest-rate environment could lead to solvency problems and a sector-wide interest rate risk increases the common exposure to market risk within the insurance sector. It is therefore necessary to compare value creation through profitable investment strategies with related private and social costs.

References


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