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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Abstract

I use detailed data on bond and swap positions of pension funds and insurance companies (P&Is) in the Netherlands to study demand shifts and their causal effect on government bond yields. In particular, I exploit a reform in the regulatory discount curve that makes liabilities more sensitive to changes in the 20-year interest rate but less so to longer maturity rates. Following the reform, P&Is reduced their longest maturity holdings but increased those with maturities close to 20 years. The aggregate demand shift caused a substantial steepening of the long-end of the yield curve. Using the regulatory reform as an exogenous shock to estimate the demand elasticities of various investors in the government bond market, I show that the banking sector is most price elastic and primarily responsible for absorbing demand shocks. My findings indicate that the regulatory framework of long-term investors spills over to other sectors and directly affects the governments' cost of borrowing.

Keywords: demand shifts, insurance companies, pension funds, price elasticity of demand, regulatory constraints, yield curve.
JEL classifications: G12, G18, G22, G23, G28.

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I. Introduction

Recent literature shows that long-term investors, such as pension funds and insurance companies, affect yields (e.g., Greenwood and Vayanos 2010; Domanski et al. 2017; Greenwood and Vissing-Jorgensen 2018; Klinger and Sundaresan 2019). The findings in this literature are consistent with the preferred habitat view: demand for specific maturities creates price pressure on bond markets. Demand shocks by these investors can affect yields in case of inelastic demand (e.g., Koijen and Yogo 2019) that for instance arises in the presence of limits to arbitrage (e.g., Vayanos and Vila 2021).

Because of data limitations, the literature so far primarily uses only price data to study the implications of the preferred habitat view on yields. As a result, there are two important questions largely left unanswered. First, what is the *mechanism* through which demand affects yields, and, more importantly, what does that tell us about the arbitrageurs in government bond markets? Second, what *drives* the preferred habitat demand for long-term bonds in the first place? For instance, to what extent is this demand driven by economic versus regulatory incentives?

In order to answer these questions I focus on a regulatory reform in the Netherlands. As pointed out by Greenwood and Vissing-Jorgensen (2018), the reform affected long-term bond yields around the announcement day.[1] My first contribution is to study the underlying quantities and identify the causal effect of demand on government bond yields. More importantly, the unexpected nature of the reform allows for a precise estimation of price elasticities of demand for several investor types. These price elasticities give insight in the mechanism behind the observed yield effects because they show which investor demand responds to a larger or lesser degree to changes in yields, thereby shedding light on the question of who are the arbitrageurs in government bond markets. My second contribution is to provide micro evidence of the drivers of preferred habitat demand for long-term bonds. I show that regulation regarding the valuation of long-term investors' liabilities plays a key role in the demand for government bonds and swaps with specific maturities.

The Dutch pension and insurance market is a useful laboratory when studying the demand for long-dated assets and its effects on yields for three main reasons. First, the occurrence of an exogenous regulatory reform facilitates the clean identification of demand shifts and their effect on yields, which I will explain in detail in the following paragraphs. The second reason is the availability of detailed data on bond and derivative positions at

[1] The aspect of the regulatory reform that Greenwood and Vissing-Jorgensen (2018) focus on is the reduced reliance of liabilities on long-term interest rates. Their work abstracts away from the other two effects of the reform that I study in this paper: the reduction in the liability values and the increased reliance on the 20-year interest rate.

the institutional level on the one hand, and data about the investors' liabilities on the other hand. While data on bond holdings are widely available for various investor types, detailed data on derivative positions and liabilities are typically scarce.[2] Yet, pension funds and insurance companies (henceforth: P&Is) hedge a substantial amount of their interest rate risk with derivatives. In order to accurately estimate their demand for long-dated assets, data on both bond and derivative positions are necessary. To explain the drivers of demand for long-dated assets, data on the liability structure of P&Is is also key. Third, the Dutch P&I market is economically important because the pension sector alone already covers 58 percent of the total assets of pension funds in the euro area (OECD 2020).[3]

I exploit the regulatory reform that the Dutch regulator announced and directly implemented on July 2, 2012. This reform changed the regulatory discount curve at which P&Is had to value their liabilities. With the reform, the long-end of the curve became *more* dependent on the 20-year interest rate and *less* dependent on longer maturity rates. The new discount curve uses market interest rates for maturities up to 20 years, while the interest rates for maturities that exceed 20 years equal a weighted average between the 20-year rate and a fixed rate: the Ultimate Forward Rate (UFR). The UFR is substantially higher than market interest rates and as a result, the regulatory discount curve reduces the value of the liabilities. At the same time, liabilities became more sensitive to changes in the 20-year interest rate but less so to changes in longer maturity rates.

Why does a change in the regulatory discount curve affect demand for long-dated assets? I theoretically argue that this demand arises for two reasons: economic and regulatory hedging incentives. The long-term nature of P&Is' liabilities creates a natural preference for long-term bonds from a liability hedging perspective (Sharpe and Tint 1990; Campbell and Viceira 2002). Regulatory hedging incentives are particularly important when the regulatory framework does not fully reflect the economic state in which investors operate. For instance, the regulatory discount curve is important in solvency assessments, as the regulator uses it to estimate the solvency position of P&Is. In turn, solvency positions determine the amount pension funds can pay out to their retirees or insurance companies to their shareholders in terms of dividends. As a result, incentives to hedge the regulatory discount curve may increase if the curve diverges from the economic discount curve.

The reason to implement the regulatory reform was in anticipation of the European

[2] Detailed data on bond holdings, derivative positions, and liabilities are available for the US insurance sector and available for research, see e.g. Sen (2022), but these data do not (publicly) exist for US pension funds.

[3] In 2019, the assets under management (AUM) of pension funds equaled approximately €1.75 trillion or 192 percent of GDP and represented 58 percent of the total assets of pension funds in the euro area (OECD 2020). The AUM of insurance companies equaled €0.51 trillion and represented 6 percent of the total assets of insurance companies in the euro area (ECB 2021).

Union (EU) introducing a similar discount curve as part of the new Solvency II regulatory framework for insurance companies in 2016. In particular, the discussions at the time evolved around the convergence of regulatory discount rates to a stable level. Even though P&Is may have anticipated the regulatory reform as a result, they did not know the implementation date and the determinants of the shape of the UFR such as its level and slope. As such, how the reform would affect different maturities is unclear ex-ante and in particular the ex-post reliance of the curve on the 20-year interest rate. The less anticipated nature of the reform becomes evident by looking at the sudden increase in the 30-20 year yield spread on the announcement and implementation date of the UFR in Figure 1. The unexpected nature of the reform to the market is further motivated by the regulator prohibiting the P&I sector to trade on information discussed during meetings in the weeks leading up to the implementation of the reform.[4] That said, to the extent that P&Is anticipated a lower sensitivity of their liabilities to very long-term interest rates, the estimated changes in yields may understate the true effects and the price elasticities that I estimate provide an upper bound of the true elasticities.

Moving to the results, I report the following three main findings. First, consistent with the testable predictions of a mean-variance optimization problem in an asset-liability context with regulatory constraints, I find that the P&Is that are more exposed to the regulatory reform, that is, the ones with long-term liabilities, decrease their long-term bond holdings to a larger extent than less exposed ones. The aggregate decrease in long-term bond holdings is economically large: The total decline equals €9.42 billion which is equivalent to a decrease in demand of 30 percent relative to the pre-reform long-term bond holdings. At the same time, P&Is increase their aggregate bond holdings with maturities close to 20 years by €17.29 billion or 19 percent relative to the pre-reform 20-year bond holdings. Both effects are stronger for P&Is that are closer to their solvency constraints, because they have a stronger incentive to hedge the regulatory rather than the economic discount curve. Furthermore, the direct capital relief from the reduction in the liability values causes the P&Is to increase their allocation to equities and high yield government bonds. Overall, the results show that the regulatory reform leads to a reduction in economic hedges of interest rate risk and to a rise in risky asset exposures at the same time.[5]

Additionally, I find that my results on demand shifts in bond portfolios extend to derivative portfolios. In particular, I find a decline in the implied duration of swap portfolios at the time of the implementation of the regulatory reform. Further, I combine the data on

[4] One specific insurer, Delta Lloyd, did not comply and as a result, received a €22.7 million fine. For details, see the following link: Fine Delta Lloyd UFR.

[5] I perform several robustness checks to show that these findings cannot be explained by the ECB's asset purchasing programs (APP) or the chosen length of the pre and post period.

bond holdings with detailed data on derivative positions that became available as part of the European Market Infrastructure Regulation (EMIR) in 2017 to show a structural change in demand for long-dated assets with large exposures to the 20-year interest rate but small exposures to longer maturity rates, especially for constrained P&Is.

Second, I estimate the effect of the aggregate demand shift in long-term bond holdings on Dutch government bond yields. To cleanly identify the effect of demand on yields, I apply an instrumental variable approach that exploits the induced heterogeneous effect of the regulatory reform across maturities: P&Is suddenly sold 30-year bonds but simultaneously bought 20-year bonds instead. Based on the instrument, I find that the change in the regulatory discount curve resulted in an increase of the 30-year yield of approximately 20 basis points. Simultaneously, the reform led to a decrease in the 20-year yield of 10 basis points.

To gain further insight in the mechanism behind the price effect, I estimate demand curves as in Koijen and Yogo (2019) for the other institutions that hold Dutch debt, because the regulatory reform created an exogenous demand shift by the Dutch P&I sector that only affected the demand of other investor types through its effect on prices. The demand system gives further insight into the importance of various investor types in creating the observed yield effects. Consistent with banks being most price elastic along the maturity structure of debt, I show that after the reform banks substantially increased their 30-year bond holdings by 18 percent of the amount outstanding while at the same time they reduced their holdings towards 20-year ones by 9 percent of the amount outstanding. To better understand why banks are primarily responsible for absorbing demand shocks, I first show that the P&I sector predominantly trades swaps with banks as the counterparty. Moreover, banks hold the exact opposite exposures in the swap market compared to the P&I sector. These findings suggest that banks' detailed information about demand for long-dated assets by the P&I sector allows them to quickly react when this demand changes for reasons unrelated to economic fundamentals.

Third, to generalize my findings, I provide suggestive evidence for the effects of the regulatory reform on yields at the European level. The UFR is an important aspect of the EU Solvency II regulation that was announced in August 2015 and took effect on January 1, 2016. Relying on the home-bias found in euro area investors' portfolios (e.g., Koijen et al. 2017, 2021) and the fact that insurance companies in the Netherlands are subject to similar regulations as other insurers in Europe, similar yield effects should exist for other European countries with a sizeable insurance sector. I therefore investigate the effects of the UFR on a broad panel of 20 European countries and define the demand for long-term bonds by the size of the insurance sector relative to the total debt outstanding of a country.

My estimates suggest that for countries with a small insurance sector such as Hungary and Portugal changes in yields were negligible; while Ireland and Denmark with large insurance sectors experienced a drop of 13-32 basis points in the 20-10 year spread and an increase of 8-20 basis points in the 30-20 year spread.

My findings have important policy implications. First, they show that the regulatory framework of investors has direct consequences for the governments' costs of borrowing. Second, they show that the regulation of long-term investors spills over to the banking sector. As pointed out by Koijen and Yogo (2022), regulation of one sector is typically studied in isolation from other sectors by regulators. My findings however suggest that regulators should take the incentives of other sectors into account when analyzing the introduction of new regulatory policies targeted at long-term investors.

Related Literature

This study contributes to the preferred habitat theory proposed by Culbertson (1957) and Modigliani and Sutch (1966), and later formalized in Vayanos and Vila (2021). They argue that some investors prefer specific maturities and that their demand for bonds with those maturities influences the interest rates at those maturities. Greenwood and Vayanos (2014) study supply effects on yields. They find that supply shocks affect yields because they change the duration risk that arbitrageurs carry. Similarly, Guibaud et al. (2013) model an investor-based yield curve. They show that an increase in the relative importance of investors with a longer investment horizon, such as the young, has two related effects: it renders long-term bonds more expensive, and it increases their optimal supply by the government. I contribute to this literature by providing direct empirical evidence in favor of the preferred habitat theory by using a real world demand shock as well as showing the origin of such a shock.

My findings also contribute to the work that empirically tests the implications of the preferred habitat theory or the demand-based view. For instance, Domanski et al. (2017) argue that the "hunt-for-duration" of insurance companies might have amplified the decline in bond yields in the euro area.[6] Similarly, Klinger and Sundaresan (2019) explain that the negative 30-year US swap spreads are the result of underfunded pension plans optimally using swaps for duration hedging rather than long-term bonds. Additionally, Greenwood and Vayanos (2010) and Greenwood and Vissing-Jorgensen (2018) show that changes in regulation which increase the incentive to buy (sell) long-term bonds result in a decline (increase) in long-term yields around policy announcement days.[7] I contribute to this

[6] Ozdagli and Wang (2019) confirm that the tilt towards higher yield bonds in the portfolios of US life insurance companies when interest rates decline is driven by an increase in duration rather than credit risk.

[7] There is also a large body of literature that provides evidence of the demand-based view for stocks,

literature by using micro-data to study the underlying quantities that cause the price effects documented in these papers. Studying quantities together with prices is important to understand (i) the drivers of demand; (ii) the mechanism behind the price effects; (iii) the potential spillover effects; and (iv) the effects of future regulatory reforms on yields.

My study also contributes to the recent demand-based asset pricing literature. For instance, Koijen and Yogo (2019) propose an asset pricing model with flexible heterogeneity in the asset demand across investors. Koijen et al. (2017) and Koijen et al. (2021) apply this model to study the effects of quantitative easing on yields in the cross-section of euro area countries and Bretscher et al. (2020) study the implications of inelastic demand for corporate bond pricing. I contribute to this work in three ways. First, instead of focusing on yields across countries or in different bond markets, I show the implications of inelastic demand along the maturity structure of government bond debt. Second, a key challenge in demand-based asset pricing is to find clean instruments for prices. In this study, I make progress towards this direction by using an exogenous demand shock as an alternative instrument to establish a causal link between demand and asset prices. Third, I provide a micro-foundation of government bond demand for one particular sector, namely the P&I sector, and show that a substantial part of this demand is inelastic because of regulatory incentives.

Additionally, my study links to the intermediary asset pricing literature which directly models intermediaries and how they matter for asset prices, e.g., He and Krishnamurthy (2013); Adrian et al. (2014); Haddad and Muir (2021); Baron and Muir (2022). The focus in these studies has been primarily on the link between asset prices and constraints of (investment) banks, hedge funds, and broker dealers. Instead, in this paper, I provide micro evidence for the importance of regulatory constraints of the prime holders of government debt: the P&I sector.

Finally, my findings link to the literature on the effects of regulation on the investment behavior of long-term investors. Ellul et al. (2011) show that fire sales occur in corporate bond markets because of the regulatory constraints imposed on insurance companies. Becker and Ivashina (2015) study the "reaching for yield" behavior of US insurance companies and show that conditional on credit ratings, insurance companies are biased towards higher yielding bonds. Andonov et al. (2017) show that US public pension plans invest more in risky assets in order to report a better funding status. Sen (2022) finds distorted hedging incentives due to different regulatory treatments of interest rate risk for products with similar economic exposures. Becker et al. (2021) show that after a regulatory reform that eliminated capital requirements for MBS, US insurance companies have a reduced propensity to sell poorly-

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e.g., Shleifer (1986); Wurgler and Zhuravskaya (2002); Greenwood (2005); Chang et al. (2015); Pavlova and Sikorskaya (2022).

rated MBS investments. Ellul et al. (2022) show that variable annuities create incentives for insurers to hold more high risk and illiquid bonds. Consistent with these papers, my findings also show that regulation regarding capital requirements shapes the investment and hedging decisions of P&Is. Importantly, I contribute to this literature by linking permanent changes in hedging incentives to permanent effects on long-term government bond yields.

II. Institutional setting - Ultimate Forward Rate (UFR)

A. *Regulatory framework P&Is*

Pension funds and insurance companies are regulated by the Dutch Central Bank (DNB) and in this section I briefly describe both regulatory frameworks.

A pension fund's solvency position is assessed by computing its funding ratio, or its assets divided by its liabilities. The minimum funding requirement is a flat rate equal to a funding ratio of 104.2 percent. In contrast, the required funding ratio is based on a pension fund's risk profile and is calculated such that the probability that the funding ratio falls below 100 percent on a one-year horizon equals 2.5 percent. In case a pension fund is not compliant with funding requirements, it files a recovery plan to the supervisor. Additionally, pension funds are not allowed to index pension rights if the funding ratio is below the minimum funding requirement. If the funding ratio falls below 90 percent a reduction in accrued benefits may be required. Note that the regulatory framework of Dutch pension funds is very different from its US counterpart, where risk-based capital requirements are absent (Boon et al. 2018).

In addition to funding ratios, an insurance company's solvency position is also assessed by computing solvency ratios. Solvency ratios equal the available capital divided by the required capital. Prior to the introduction of Solvency II in 2016, the solvency ratios of insurance companies were not risk-based. Before 2016, the DNB required capital to equal 4 percent of the value of the liabilities. At the introduction of Solvency II, it required capital to be computed like for pension funds, except that it calculated capital such that the probability of the funding ratio falling below 100 percent on a one-year horizon equaled 0.5 percent, rather than the 2.5 percent for pension funds. In case an insurance company is not compliant with the minimum or required solvency requirements, it also files a recovery plan to the supervisor. Dividend policies are typically based on internal target solvency ratios. For instance, Allianz only pays out dividends if the solvency ratio exceeds 160 percent.[8]

[8]See https://www.allianz.com/en/investor_relations/share/dividend.html.

B. *Regulatory discount curve*

The regulator uses the regulatory discount curve to estimate the liability value and hence the solvency positions of P&Is. As highlighted in the previous section, P&Is make important decisions based on solvency positions, such as the amount of dividends paid to the shareholders or the ability to index and cut pension rights. Since 2007, the valuation of assets has been marked-to-market for both pension funds and insurance companies and the DNB constructs and publishes the regulatory discount curve to value the liabilities.[9]

Prior to the start of July 2012, the DNB based the regulatory discount curve on the euro swap curve for all maturities and used market interest rates up to a maturity of 50 years. Afterwards, it extrapolated the interest rates for maturities beyond 50 years from the last observed forward rate. Because it based the regulatory discount curve on market interest rates only, the curve equaled the economic discount curve.

The DNB announced and directly implemented a change in the regulatory discount curve on July 2, 2012 in anticipation of the EU introducing its Solvency II regulatory framework for insurance companies in 2016. The new curve is similar to the regulatory discount curve in Solvency II that would become applicable to all European insurers. The DNB announced a similar regulatory discount curve for pension funds on September 24, 2012.

The DNB's new regulatory discount curve uses an extrapolation method based on the UFR that is the convergence of long interest rates to a stable level. In essence, this new curve uses market interest rates up to a maturity of 20 years, and the DNB determines interest rates with maturities longer than 20 years by using a weighted average between the market interest rates and a fixed rate, the UFR. The main argument to justify the implementation of the UFR was that the market for long durations is less liquid and only a few securities with such long durations existed. As a result, the DNB regarded the implied market interest rates as unreliable: a discount curve purely based on market data was highly sensitive to liquidity shocks and therefore also the solvency positions of P&Is. A regulatory discount curve based on the UFR solved this issue by making the long-end of the curve less dependent on market interest rates.[10]

Formally, the DNB constructed the regulatory discount curve as follows:

1. The euro swap rates for maturities of 1 to 10, 12, 15, and 20 years are converted to zero-coupon interest rates by means of bootstrapping.[11] For non-observable swap rates,

[9] A marked-to-market valuation of the assets is in stark contrast with the life insurance industry in the US, where historical cost accounting is still commonly used across states (Ellul et al. 2015).

[10] Further details about the UFR are in Appendix A.

[11] Bloomberg also offers swap rates for all maturities from 1 to 20 years. However, the DNB refrained from using some of these interest rates because of less liquid markets.

the DNB estimates zero interest rates by assuming constant forward rates.

2. Forward rates exceeding maturities of 20 years are a weighted average between the 20-year forward rate and the UFR. The weight increases linearly in maturity, and the level of the UFR equals 4.2 percent. At a maturity of 60 years, forward rates equal the UFR:[12]

$$f_{t,h-1}^{h,*} \begin{cases} f_{t,h-1}^{h} & \text{if} \quad 1 \leq h \leq 20, \\ (1 - w^{UFR}(h)) \times f_{t,19}^{20} + w^{UFR}(h) \times \text{UFR} & \text{if} \quad 20 < h < 60, \\ \text{UFR} & \text{if} \quad h \geq 60. \end{cases} \tag{1}$$

3. The DNB computes the zero-coupon interest rates $y_t^{(h)}$ as follows:

$$(1 + y_t^{(h)})^h = \prod_{n=1}^{h} (1 + f_{t,n-1}^{n,*}) \qquad \text{for} \qquad h = 1, 2, ...120. \tag{2}$$

The regulatory discount curve with the UFR has three important effects. First, the UFR decreases current liability values as liabilities are discounted against higher rates. Second, the UFR makes the regulatory discount curve less sensitive to parallel shifts in interest rate changes. Figure 2 displays these two effects. The red solid line shows the economic discount curve, and the blue solid line shows the economic discount curve after a parallel shock in interest rates of −1 percent. The dashed green line and the dotted black line show the same discount curves with the UFR. Third, the UFR results in a higher exposure to changes in the 20-year interest rate. Figure 3 displays this effect. A localized negative shock in the 20-year market interest rate as reflected by the blue dashed line reduces all the regulatory discount rates for maturities beyond 20 years that makes the liabilities particularly sensitive to changes in the 20-year interest rate under the new regulatory framework.[13]

[Place Figure 2-3 about here]

C. Impact of the UFR on the liability value

In order to show the effects of the UFR on the liability value, I use the cash flows reported by pension funds in their quarterly filings (details in Section IV) and compute the corresponding

[12] For pension funds, the regulatory discount curve is slightly different and uses the corresponding market forward rate $f_{t,h-1}^{h}$ instead of the 20-year forward rate for maturities of 25, 30, 40, and 50 years.

[13] Note that a shock that affects the 20-year interest rate in isolation is not common and is only used for illustrative purposes.

liability values by using both the economic and the regulatory discount curve. As shown in Figure 4, for the average pension fund in my sample, the peak of the cash flow distribution of their liabilities is at a maturity of 20 years. This pattern reflects the importance of the UFR as half of the cash flows materialize at maturities beyond 20 years.[14] The cash flows allow me to compute the value of the liabilities both under the economic and regulatory discount curves. Formally, I compute $L_t = \sum_{h=0}^{120} CF(h)\exp(-hy_t^{(h)})$, where $CF(h)$ are the average projected pension payments for maturity h (in years) in which $y_t^{(h)} = y_{E,t}^{(h)}$ under the economic discount curve and $y_t^{(h)} = y_{R,t}^{(h)}$ under the regulatory discount curve.

In Table 1, I compute the liability values for the projected pension payments by using the discount curve with and without the UFR on July 2, 2012. Panel A shows that the liability value that uses the regulatory discount curve with the UFR declines by €664 million for the average pension fund, or a decrease of 4.23 percent. This decrease reflects the first effect of the UFR: a direct reduction in the regulatory liability values. The liability value after a -1 percent parallel shift in interest rates increases with €3,518 million when using the economic discount curve; while when using the regulatory discount curve, the increase equals €2,737 million, or a relative decline in interest rate sensitivity of 22.2 percent. This decline reflects the second effect of the UFR: a dampening effect of parallel changes in interest rates on liability values. Furthermore, this effect is particularly visible when looking at cash flows that materialize after 20 years in isolation. A parallel shock in interest rates of -1 percent increases the liability value by 31.7 percent less after the regulatory reform.

Panel B shows the third effect of the UFR: an increased sensitivity towards the 20-year market interest rate. A decrease in the 20-year interest rate increases the economic liability value by only 45 million, but the regulatory liability value increases by 1,222, or a relative increase of 2,615.6 percent. Again, this effect becomes even more apparent when looking in isolation at cash flows that materialize after 20 years.

[Place Table 1 about here]
[Place Figure 4 about here]

III. Model intuition

To better micro-found how P&Is changed their asset demand following the reform, I derive my main testable predictions from a partial equilibrium mean-variance optimization framework with assets and liabilities. The key driver of my predictions is the assumption that

[14]The data on cash flows that allow me to compute liability values is only available for the pension funds in my sample, so insurance companies are left out in this section's analysis.

P&Is care about both their economic and regulatory solvency positions. The full version of the model is in Appendix B, but I give a summary here to get the main intuition across.

For the assets, I assume that P&Is can invest in a risky asset S with corresponding return r^S_{t+1}, and in a set of bonds $B(h)$ with corresponding maturity h and return $r^{(h-1)}_{t+1}$. The vector of bond returns is denoted by $\mathbf{r}^B_{t+1}$. I assume throughout that the yield curve can be determined using this set of bonds. The risk-free rate is denoted by r_f and total assets by A_t. The assets therefore evolve as $A_{t+1} = \Big(1 + r_f + w^S_t(r^S_{t+1} - r_f) + \mathbf{w}^{B'}_t(\mathbf{r}^B_{t+1} - r_f\mathbf{1})\Big)A_t$.

For the liabilities, following the payout distribution introduced in Figure 4, I assume that P&Is have to pay out a fixed and promised set of cash flows for each maturity h, $\text{CF}(h)$.[15] The return on the liabilities is denoted by $\mathbf{r}^L_{t+1}$. Because of the promised nature of the cash flows, the economic value of the liabilities is determined using market interest rates, and hence $\mathbf{r}^L_{t+1} = \mathbf{r}^B_{t+1}$. The economic value of the liabilities therefore evolves as $L^E_{t+1} = \mathbf{a}'_t(\mathbf{1} + \mathbf{r}^B_{t+1})L^E_t$, where $\mathbf{a}_t$ is a vector that contains the cash flow distribution of the liabilities. Intuitively, $a_{it}(h)$ is the fraction of the liabilities that have to be paid in h years from now. The regulatory value of the liabilities evolves as $L^R_{t+1} = \mathbf{a}'_t(\mathbf{1} + \boldsymbol{\xi}'_L\mathbf{r}^B_{t+1})L^R_t$, where the sensitivity of the regulatory discount curve to market interest rates is defined by $\boldsymbol{\xi}_L$ and has the same length as the set of bonds. This sensitivity means that the economic and regulatory value of the liabilities are identical if $\xi_L(h) = 1$ for all h, which was the case prior to the regulatory reform. On the other hand, the regulatory value of the liabilities is insensitive to changes in the interest rate if $\xi_L(h) = 0$ for all h. An example is a regulatory discount curve that is based on a fixed rate for all maturities. The regulatory reform implied that $\xi_L(h)$ became larger than one for maturities close to 20 years, and $\xi_L(h)$ starts to converge to zero for maturities beyond 20 years.

I further assume that P&Is have mean-variance preferences over the assets minus liabilities, which is similar to Sharpe and Tint (1990) and Hoevenaars et al. (2008), and creates an incentive to reduce the volatility in the economic mismatch between assets and liabilities, or the volatility in the economic funding ratio. Following Koijen and Yogo (2015, 2016); Sen (2022), I also assume that P&Is care about the volatility in the regulatory mismatch between assets and liabilities, or their regulatory funding ratio. The reason is that P&Is have to make important decisions based on the regulatory funding ratio, such as the amount of dividends to pay to shareholders or the ability to index pension rights. The economic funding ratio is denoted by $F^E_t = A_t/L^E_t$ and the regulatory funding ratio by $F^R_t = A_t/L^R_t$. A simplified

[15] This assumption is realistic, because the pension funds are defined benefit in nature and insurance companies were not allowed to use variable annuities until 2016.

version of the optimization problem of assets over liabilities then equals:

$$\max_{\mathbf{w}_t} \mathbb{E}_t[\frac{A_{t+1}}{A_t}] - \frac{\gamma}{2}\text{Var}_t[\frac{A_{t+1}}{A_t} - \frac{L^E_{t+1}}{A_t}] - \frac{\lambda(F^R_t)}{2}\text{Var}_t[\frac{A_{t+1}}{A_t} - \frac{L^R_{t+1}}{A_t}],$$

where γ equals the risk-aversion parameter, and $\lambda'(F^R_t) < 0$; or in other words, P&Is care more about the regulatory funding ratio when its low as opposed to when its high.[16]

Solving for the optimal portfolio weights results in:

$$w^{S*}_t = \underbrace{\frac{\mathbb{E}_t[r^S_{t+1} - r_f]}{(\gamma + \lambda(F^R_t))\text{Var}_t[r^S_{t+1}]}}_{\text{speculative portfolio}}, \tag{3}$$

$$\mathbf{w}^{B*}_t = \underbrace{\frac{\mathbb{E}_t[\mathbf{r}^B_{t+1} - r_f\mathbf{1}]}{(\gamma + \lambda(F^R_t))\text{Var}_t[\mathbf{r}^B_{t+1}]}}_{\text{speculative portfolio}} + \underbrace{\frac{\gamma}{\gamma + \lambda(F^R_t)}\frac{1}{F^E_t}\mathbf{a}_t \circ \frac{\text{Cov}_t[\mathbf{r}^B_{t+1}, \mathbf{r}^L_{t+1}]}{\text{Var}_t[\mathbf{r}^B_{t+1}]}}_{\text{economic hedging portfolio}}$$
$$+ \underbrace{\frac{\lambda(F^R_t)}{\gamma + \lambda(F^R_t)}\frac{1}{F^R_t}(\mathbf{a}_t \circ \boldsymbol{\xi}_L \circ \frac{\text{Cov}_t[\mathbf{r}^B_{t+1}, \mathbf{r}^L_{t+1}]}{\text{Var}_t[\mathbf{r}^B_{t+1}]})}_{\text{regulatory hedging portfolio}}. \tag{4}$$

The optimal demand for the risky asset consists of speculative demand only, because the liabilities are valued using the yield curve, and the bonds are assumed to be independent of the risky asset. The bond portfolio consists of three components: the speculative demand, the economic hedging demand, and the regulatory hedging demand. The economic (regulatory) hedging demand equals the desired hedge against changes in the economic (regulatory) liability value. The heterogeneity in demand for long-term bonds across P&Is depends on two main factors. First, the demand for long-term bonds depends on the distribution of the cash flow payments: larger cash flows further away in the future, i.e. high $a_t(h)$, create a larger hedge demand for longer-term bonds. Second, the demand for long-term bonds depends on the weight assigned to the economic versus regulatory hedging demand. This weight depends on the relative magnitudes of $\lambda(F^R_t)$ and γ that is driven by solvency positions F^R_t: the closer P&Is are to the regulatory constraint, the stronger the desire to hedge the regulatory funding ratio and hence a higher weight is assigned to the regulatory hedge portfolio. For instance, if a large weight is assigned to the regulatory hedge portfolio (large $\lambda(F^R_t)$) and the regulatory discount curve is insensitive to changes in market interest rates, i.e. $\xi(h) = 0$, the demand for long-term bonds approaches zero.

[16] To keep the model tractable, the functional form of $\lambda(F^R_t)$ is a reduced form of the strict constraint that the funding ratio should be higher than a certain threshold (e.g. Leibowitz and Henriksson 1989).

In Appendix B, I formally derive the model implications of the regulatory reform by taking the difference between the model-implied optimal demand after and before the reform. This yields the following model implications:

Prediction 1 - *P&Is with long liability durations reduce their long-term bond holdings and increase those with maturities close to 20 years more compared to P&Is with short liability durations.*

Intuitively, the first prediction simply states that P&Is with long liability durations, so those that pay out in the far future, are more affected by the reform and hence have a stronger incentive to move away from long-term bond holdings towards 20 year ones.

Prediction 2 - *P&Is with long liability durations increase their risky asset holdings more compared to P&Is with short liability durations.*

P&Is with long liability durations saw a sharper decline in their liability values and hence experienced the largest capital relief. Because $\lambda(\cdot)$ is a convex and decreasing function of the regulatory funding ratio, those P&Is have the strongest incentive to increase their speculative portfolio.

Prediction 3 - *P&Is close to their solvency constraint reduce their long-term bond holdings and increase those with maturities close to 20 years more compared to unconstrained P&Is.*

The more constraint investors are, the stronger the incentive to hedge the regulatory discount curve which implies moving away from long-term bonds to those with a maturity of 20 years. Empirically, as suggested by the model, I take the inverse of the funding ratio to measure the solvency constraints of P&Is.

In Appendix B, I close the model by introducing an arbitrageur and impose market clearing to study the model-implied effects on the yield curve. I then calibrate the model and show the model-implied change in the yield curve because of the reform in Figure A1. The change in the model-implied shape of the yield curve corresponds to the observed change in the yield curve around the implementation date of the reform as shown in Figure A2. A detailed discussion of the empirical effects of the regulatory reform on government bond yields is in Section VI.

IV. Data

In this section, I describe the data sources that I use for my analysis (Subsection A) and provide summary statistics for the sample (Subsection B).

A. *Constructing the dataset*

I use data on Securities Holdings Statistics (SHS) for insurance companies and pension funds in the Netherlands over the period 2009q1-2019q4. All institutions that report are domiciled in the Netherlands and the regulator decides which institutions have to report in order to have sufficient coverage in terms of AUM for every sector. Institutions have to report their holdings of all securities, both foreign and domestic, to the regulator on a quarterly basis.[17]

DNB gathers holdings data to compute, among other things, the Dutch balance of payments, international investment positions, and the financial accounts.[18] Subsequently, it reports the holdings data to the ECB for the setup of the aforementioned statistics for the euro area. The data that I use are therefore also available for the euro area. I have two main reasons for using Dutch data for the main analysis. First, the UFR was introduced in 2012 but the holdings data that covers all countries and all securities became available only at the end of 2013. Moreover, the European data aggregates all institutions within a sector, while the Dutch data are at the institutional level. The institutional data therefore allow me to make use of the cross-sectional variations. For instance, measuring the effects of the solvency positions on holdings is only possible when data are available at the institutional level. Despite these arguments, I augment the Dutch holdings data with the ECB holdings data in Section VI to quantify the effect of the UFR on yields and to estimate the demand curves of various investor types.[19]

The data provide bond and stock holdings with International Securities Identification Numbers (ISIN). The holdings of stocks are available in the number of shares and market values. The holdings of bonds are available in both nominal and market values. The SHS database is then linked to the Centralised Securities Database (CSDB). The aim of this database is to hold accurate information on all individual securities relevant for the statistical purposes of the European System of Central Banks, ECB (2010). I obtain the following relevant market information from the CSDB database: debt type, maturity dates, coupon

[17] All institutions report their foreign holdings on a monthly basis, but this is not the case for domestic holdings. Because Dutch P&Is hold significant domestic fixed income securities, I use quarterly data to ensure consistency. See for details on reporting requirements `https://statistiek.dnb.nl/statistiek/index.aspx.`

[18] Another example that uses SHS data at the institutional level for Germany is Timmer (2018).

[19] The data on bond holdings that exceed one-year maturities are available as of 2009 for the euro area.

rates, coupon frequencies, coupon type (e.g., fixed, floating or zero-coupon), last coupon payment date, yield-to-maturity (YTM), prices, and total amount outstanding. I compute bond durations using YTMs and measure credit risk for corporate bonds using the distance to default (DTD) available from the Credit Research Initiative at the National University of Singapore. Credit risk for government bonds is measured using credit ratings from Fitch.

Next, I link the holdings data to the supervision databases. The supervision databases are from mandatory annual and quarterly statements that P&Is report to the DNB. P&Is have to report, among other things, solvency positions, liability durations, and asset allocations as well as the value of the assets and liabilities. For pension funds, I take the reported funding ratios directly from the files. For insurance companies, I convert the solvency ratios to funding ratios, because the model makes predictions based on funding ratios.[20] Formally, prior to Solvency II, solvency ratios equaled $SR = \frac{A-L}{0.04L}$ which meant that the funding ratio equaled $\frac{A}{L} = 0.04 * SR + 1$. The solvency ratios under Solvency II are more complex and hence I hand-collect data on the assets and the liabilities for each insurer to compute the funding ratios manually.

B. *The sample*

The total sample covers 42 pension funds, 12 life insurers, and 27 non-life insurers. This group of institutional investors represents around 80-90 percent of the AUM for all institutional investors domiciled in the Netherlands.

I only analyze investors' direct holdings, that is, investments that are not made via other investor types such as mutual funds. The data, unfortunately, do not allow for a linkage between the indirect holdings of investors to their direct holdings, except for the two largest pension funds and the two largest insurance companies. For these P&Is, I know their shares in mutual funds so I can use the reported holdings of mutual funds to obtain their indirect holdings. Table 2 shows that after correcting the holdings for these four P&Is, the fraction of assets that are incorporated in my analysis equals on average 85 percent of the total AUM (direct+indirect).

Table 2 also shows that life insurance companies are the largest in terms of average AUM, followed by pension funds.[21] The average allocation to government bonds is 49, 45, and 38 percent for life insurers, non-life insurers, and pension funds, respectively. Insurers have an allocation to corporate bonds of 34 percent and pension funds of 21 percent. Life insurers and pension funds also have the longest duration of their fixed income portfolios. The average bond durations are 8.4 and 7.3 years for life insurers and pension funds respectively; while the

[20]Notice that solvency ratios can be converted into funding ratios and vice versa.
[21]The extended summary statistics table is in the Appendix (Table A2).

duration equals 4.64 for non-life insurers. Pension funds have the largest equity allocation at 34 percent, while insurers invest on average 12 percent of their assets in equities.

Moving to the liability side of P&Is, life insurers and pension funds have the longest liability durations at 11.8 and 17.9 years respectively. The liability duration of non-life insurers is much shorter at 4.2 years. The average inverse of the funding ratio of pension funds equals 92.5 percent and 91.5 percent for insurers, which is equivalent to a funding ratio of 108% and 109%, respectively.[22]

[Place Table 2 about here]

V. Empirical methodology

I turn to the main tests of the empirical predictions from my theoretical framework next. For bond holdings, I use the *notional* amounts in all my analyses such that I capture active choices by investors and market prices are not driving the results. Moreover, in my main analysis, I focus on maturity buckets to take account of the fact that bonds with similar maturities are close substitutes. I therefore define *long-term* bonds as bonds with remaining time to maturities of 30 years or longer, and bonds with maturities close to 20 years as those with remaining times to maturities between 15 and 25 years.

A. Long-term bond holdings and the regulatory reform

Panel a of Figure 5 shows the average fraction of P&Is' total bond portfolio in long-term bonds over time. Likewise, Panel b shows the fraction of the bond portfolio with maturities close to 20 years.[23] Both graphs split the sample into P&Is with long (above the median) and short (below the median) liability durations. While both groups show similar trends prior to the reform, the P&Is with long liability durations sharply reduced their allocation to long-term bonds when the regulatory reform was announced (and implemented). The exact opposite pattern is visible for the allocation towards 20 year bonds, with a sudden and sharp increase in its allocation. Over the sample period, the allocation to 30 (20) year bonds remains substantially lower (higher) than the pre-UFR levels.

[Place Figure 5 about here]

[22]Notice that pension funds in the Netherlands are much better funded compared to pension funds in the US, potentially explained by the fact that Dutch pension funds are subject to risk-based capital requirements, whereas US pension funds are not (Boon et al. 2018).

[23]The bond portfolio contains investments in all type of bonds (e.g., government bonds, corporate bonds) and across all issuer countries.

To align the predictions of the model with the data, I use a difference-in-difference specification which compares long-term bond holdings before and after the implementation of the UFR. I conjecture that P&Is with long liability durations decrease long-term bond holdings more compared to investors with short liability durations:

$$\begin{aligned} w^B_{it} &= \alpha + \beta_1 D^L_{2011q2,i} \times \text{UFR}_t + \beta_2 \text{FR}^{-1}_{it-1} + \beta_3 \text{FR}^{-1}_{it-1} \times \text{PF}_i + \beta_4 D^L_{it-1} \\ &+ \beta_5 \text{AUM}_{it-1} + \nu_i + \lambda_t + \epsilon_{it}, \end{aligned} \tag{5}$$

where w^B_{it} is the bond allocation of P&I i at time t;[24] UFR_t equals one as of the announcement (and implementation) day of the UFR and zero otherwise; $D^L_{2011q2,i}$ is a time-invariant characteristic that equals the liability duration as of 2011q2; FR^{-1}_{it-1} is the lagged inverse of the funding ratio minus one; PF_i is a dummy variable that equals one if the investor is a pension fund; D^L_{it-1} is the lagged liability duration; AUM_{it-1} is the lagged total AUM; ν_i is the fund fixed effects; and λ_t is the time fixed effects.

I use the liability duration as of 2011q2 in the interaction term to ensure that the liabilities are not in any way affected by the regulatory reform, while at the same time ensuring representation of the liabilities as of the regulatory reform. An inverse of the funding ratio equal to one means that P&Is are neither funded or underfunded. Therefore, subtracting one from the inverse of the funding ratio has the advantage that the coefficient is easy to interpret with values above zero indicating underfunding. The regression specification also allows for differences in responses to a decline in funding positions across pension funds and insurers. Although size does not appear in the model, it is added as a control because empirical studies have shown that size is an important driver of investment decisions (e.g., Pollet and Wilson 2008).

The focus in the main specification is on the aggregate bond allocation to specific maturity buckets in order to easily interpret the total magnitude of demand shifts. I show that my results are robust to regressions at the security level in Section VII.A.3. Moreover, I also show that my results are not driven by QE (Section VII.A.1) or the fairly long pre and post period used in my main analysis (Section VII.A.2). Finally, in Section VII.B, I show similar shifts in exposures to long-term interest rates in P&Is swap portfolios.

Table 3 summarizes the results. P&Is with long liability durations decrease long-term holdings to a larger extent than the ones with short liability durations. At the same time, P&Is increased their bond holdings with maturities varying between 15 and 25 years, while they did not change their holdings of bonds with maturities less than 15 years. These results support the first prediction of my theoretical framework in Section III.

[24] Table A2 of the Appendix summarizes the dependent variables.

The effects are also economically significant. The total decline in long-term bond holdings approximately equals $\sum_{i=1}^{N} \hat{\beta}_1 \times D^L_{2011q2,i} \times AUM^B_{2012q1,i} =$ €9.42 billion, where $AUM^B_{2012q1,i}$ is the total AUM in bonds (nominal terms) for P&I i in the quarter before the regulatory reform was announced and implemented in 2012q2. The decline is equivalent to a decrease of 30 percent relative to the pre-reform long-term bond holdings. Similarly, P&Is increased their 20-year bond holdings by €17.29 billion or 19 percent relative to the pre-reform 20-year bond holdings.[25] To give additional support for the economic effects, I have reestimated the regression based on Dutch government bond holdings alone (Table A3 of the Appendix). The aggregate decline in 30-year Dutch bond holdings equals €2.61 billion. The corresponding amount outstanding equaled €12.13 billion at the implementation of the UFR, and hence, the total decline corresponded to 22 percent of its amount outstanding. Similarly, the aggregate increase in bond holdings with maturities between 15 and 25 years equaled €4.94 billion, or 26 percent of its amount outstanding.

[Place Table 3 about here]

My model also predicts that P&Is with long liability durations allocate more to risky assets after implementation of the UFR compared to those with short liability durations. To capture changes in risky asset allocations, I simultaneously study the asset allocation dynamics of stocks, corporate bonds, and government bonds. For corporate and government bonds, I also analyze the evolution of credit risk within both asset classes to distinguish between high risk or illiquid bonds (Ellul et al. 2022). Then, I use the following difference-in-difference specification to formally test the hypothesis:

$$\begin{aligned} w^S_{it} &= \alpha + \beta_1 D^L_{2011q2,i} \times \text{UFR}_t + \beta_2 \text{FR}^{-1}_{it-1} + \beta_3 \text{FR}^{-1}_{it-1} \times \text{PF}_i + \beta_4 D^L_{it-1} \\ &+ \beta_5 \text{AUM}_{it-1} + \nu_i + \lambda_t + \epsilon_{it}, \end{aligned} \tag{6}$$

where w^S_{it} is the risky asset allocation of P&I i at time t.[26]

Table 4 shows the results. The first column confirms that P&Is with long liability durations increase their equity allocation to a larger extent than the ones with short liability durations. A one standard deviation increase in the liability duration (6.49) expands the equity allocation by 1.25 percent but reduces the corporate bond allocation by 1.26 percent. The allocation to government bonds remains unaltered. Within corporate bonds, there is no evidence of a change in credit risk. On the other hand, a longer liability duration increases

[25] Because the regulatory discount curve is based on the euro swap curve, I have reestimated the regression specification using only investment grade European Union (EU) government bonds. The results do not change in sign and statistical significance, and if anything, increase in magnitude.

[26] Table A2 of the Appendix summarizes the dependent variables.

the fraction of government bonds allocated to countries with higher credit risk. Column 6 shows that a one standard deviation increase in the liability duration increases the fraction of high yield government bonds held by 1.64 percent. In sum, these findings show that P&Is move their assets away from corporate bonds to stocks and at the same time increase the riskiness of their government bond portfolios.

[Place Table 4 about here]

The final implication for the changes in holdings is that P&Is closer to their solvency constraint decrease (increase) long-term (20-year) bond holdings to a larger extent than unconstrained P&Is. I use a triple difference-in-difference to test this hypothesis:

$$\begin{aligned} w_{it}^B &= \alpha + \beta_1 D^L_{2011q2,i} \times \mathrm{FR}^{-1}_{2011q2,i} \times \mathrm{UFR}_t + \beta_2 D^L_{2011q2,i} \times \mathrm{UFR}_t \\ &+ \beta_3 \mathrm{FR}^{-1}_{2011q2,i} \times \mathrm{UFR}_t + \beta_4 \mathrm{FR}^{-1}_{it-1} + \beta_5 \mathrm{FR}^{-1}_{it-1} \times \mathrm{PF}_i + \beta_6 D^L_{it-1} \\ &+ \beta_7 \mathrm{AUM}_{it-1} + \nu_i + \lambda_t + \epsilon_{it}, \end{aligned} \tag{7}$$

where $FR^{-1}_{2011q2,i}$ is a time-invariant characteristic that equals the inverse of the funding ratio minus one in 2011q2.

Table 5 has a summary of the results. P&Is that are more constrained, that is, have a larger inverse of their funding ratio, decrease long-term bond holdings to a larger extent: A one standard deviation increase in the inverse of the funding ratio (0.08), increases the decline in long-term bond holdings by 1.3 percent for the P&Is with average liability duration and up to 2.8 percent for the ones with the longest liability durations, which equals a relative decline of 10-25 percent. Furthermore, consistent with the model's predictions, P&Is that are more constrained also increase their holdings of bonds with maturities close to 20 years to a larger extent than unconstrained ones.

[Place Table 5 about here]

VI. The effect of demand shifts on long-term yields

In this section, I estimate the effect of the regulatory reform on Dutch government bond yields by using the construction of the UFR as an exogenous shock to demand that affects yields differently at different maturities.[27] I then use this construction as an instrument to

[27] As opposed to the previous section, I focus here on Dutch government bonds in isolation, because the P&I sector holds a large fraction of the Dutch debt outstanding, allowing me to cleanly identify yield effects.

estimate the effect of yields on Dutch government bond holdings for various investor types by using the framework of Koijen and Yogo (2019). Finally, I provide suggestive evidence why some investor types are more price elastic in the government bond market than others.

A. Data

To estimate the demand curves, I extend the Dutch holdings data with the ECB holdings data to obtain a larger coverage of Dutch government bond holders. The euro area Securities Holdings Statistics by Sector (SHSS) data provides the sector-country holdings for each sector and country in the euro area over the period 2009q1-2019q4. Like for the Dutch SHS data, per country-sector, the data contains information on the quarter-end holdings at the ISIN level. For instance, the SHSS data reports the aggregate holdings of German banks in a specific security.[28] The euro area SHSS data, like the Dutch SHS data, is linked to the CSDB database to obtain market information about the securities held. The five distinct sectors that I incorporate in my analysis are banks, mutual funds, P&I sector (outside the Netherlands), other (households, non-financial institutions etc.), and the foreign sector. The investments of the foreign sector are defined as the difference between the total amount outstanding minus the holdings of all the euro area investors combined.

B. The connection between portfolio holdings and yields

As shown in Figure 1 (Panel a), the 30-20 year government bond spread increased significantly after the announcement and implementation of the UFR, and remained at a higher level thereafter. Figure A2 furthermore shows that the observed yield curve moved from being inverted at the longer end to become upward sloping after the reform.[29] These findings are consistent with the model-implied yields as laid out briefly in Section III and in detail in Appendix B, where I close the model by introducing an arbitrageur and impose market clearing.

Next to showing the effect on the yield curve, the goal of this section is to provide insight in the mechanism behind the yield effects. So even though the model gives suggestions about the change in the slope of the yield curve, it does not directly speak to the magnitude of the effects nor the investors that are driving it. In order to get more insight in the mechanism, I estimate the demand curves of the other investors that hold Dutch debt and thus have

[28] For more details on the euro area SHSS data, see for instance `https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R1011`, Koijen et al. (2017), and Koijen et al. (2021).

[29] Looking at yield spreads is a cleaner way to identify the effect of the regulatory reform, because movements in yields that are common across maturities cancel out. Nevertheless, both figures show an increase in the slope of the yield curve at the longer end.

to absorb the demand shock that is caused by the Dutch P&I sector. Using the demand curves, I can measure their price elasticities of demand which, in turn, allow me to study price effects as well as the importance of various investor types in creating price effects.

To estimate demand curves, I apply the asset demand system developed by Koijen and Yogo (2019). Formally, investor i's investment in Dutch government bonds within maturity bucket h is denoted by $B_{it}(h)$, and the investment in the outside asset is denoted by O_{it}.[30] I cannot observe what investors consider to be the outside asset, so I use the 10-year German yield as a proxy for the outside asset because German government bonds are good substitutes for Dutch ones.

The portfolio weight in the framework of Koijen and Yogo (2019) is then defined as:

$$w_{it}(h) = \frac{B_{it}(h)}{O_{it} + \sum_{h=1}^{H=7} B_{it}(h)} = \frac{\delta_{it}(h)}{1 + \sum_{h=1}^{H=7} \delta_{it}(h)}, \tag{8}$$

where $\delta_{it}(h) = w_{it}(h) w_{it}^{-1}(0) = B_{it}(h) O_{it}^{-1}$ and $w_{it}(0) = 1 - \sum_{h=1}^{H=7} w_{it}(h)$ equals the fraction invested in the outside asset. The demand of investor i for government bonds with maturity h is a function of bond yields and characteristics (Koijen et al. 2021):

$$\begin{aligned} \ln B_{it}(h) &= \ln \delta_{it}(h) + \ln O_{it} \\ &= \hat{\alpha}_i + \beta_{0i} y_t(h) + \beta_{1i}' \mathbf{x}_t(h) + \hat{\beta}_{2i} y_t^{DE} + \beta_{3i} \ln(B_{2009q1,i}(h)) + \epsilon_{it}(h), \end{aligned} \tag{9}$$

in which $\hat{\alpha}_i = \alpha_i + \ln O_i$, $\hat{\beta}_{2i} = \beta_{2i} + \psi_i$, $y_t(h)$ is the average yield for maturity bucket h, $\mathbf{x}_t(h)$ represents bond characteristics, and y_t^{DE} is the 10-year German yield and captures alternative investment opportunities outside of the Netherlands.[31] Moreover, the inclusion of the initial holdings, $\ln(B_{2009q1,i}(h))$, captures time-invariant omitted characteristics.

Koijen and Yogo (2019) show that (9) is consistent with a model in which investors have mean-variance preferences over returns, assume that returns follow a factor model, and assume that both the expected returns and factor loadings are affine in a set of characteristics. The component of demand that is not captured by prices, characteristics, and time-invariant characteristics, $\epsilon_{it}(h)$, is referred to as latent demand.

Moving to the bond characteristics, I assume that yields are primarily driven by duration

[30] Unfortunately, the data does not allow me to incorporate holdings of interest rate derivatives to estimate demand curves, because the instrument requires data before and after the reform and the detailed derivatives data only became available in 2017. However, as I will show in Section VII.B, the swaps are used in a similar way as bonds: P&Is use swaps to increase their exposure towards the 20-year interest rate, which provides suggestive evidence of similar estimates for the demand curves in case one would include derivative positions.

[31] The assumption that holdings of the outside asset move only due to changes in the German yield result in $O_{it} = O_i \exp(\psi_i y_t^{DE})$ and hence the natural logarithm results in the terms $\ln O_i$ and $\psi_i y_t^{DE}$ that can be placed on the right-hand side of Equation (9).

and convexity (measured as the duration squared), because Dutch government bonds are regarded as safe (long-term) assets.[32] I also add the average coupons and the total amount outstanding (TAO) for each maturity bucket as characteristics that drive demand for bonds. Investors who aim to match their cash flows might have a preference for coupon bonds and likewise, others may have a preference for more or less liquid bonds proxied by TAO. For the investors, I aggregate the holdings of all investors within a sector as in Koijen et al. (2021).[33]

In order to obtain consistent estimates of the parameters in (9) using OLS, one has to assume that characteristics are exogenous to latent demand. However, a positive latent demand for Dutch government bonds of a particular maturity may result in lower yields. The demand curves are therefore estimated using an instrumental variable approach. The instrument that is proposed in Koijen and Yogo (2019), which uses the investment mandates of other investors to construct an instrument that is related to yields but orthogonal to latent demand, is not ideal in government bond markets. The reason is that the investment universe for government bonds is not as restricted and pre-determined as for the equity (Koijen and Yogo 2019) and corporate bond market (Bretscher et al. 2020). Indeed, Table A5 of the Appendix shows that only 53 percent of the government bonds that are currently held in the portfolios of euro area investors were in the portfolio the previous quarter.

I therefore take advantage of the regulatory reform studied in this paper and use the weights assigned to the UFR as an instrument for changes in yields. Even though investors may have anticipated the UFR, they did not know the determinants of the shape of the UFR such as its level and the slope. In fact, in discussions between the regulator and the P&I sector about the UFR in the weeks before its implementation, the regulator prohibited P&Is to trade on this information. One specific insurer, Delta Lloyd, did not comply and as a result, received a €22.7 million fine.[34] As a result, the demand shift by the P&I sector is close to exogenous and can be used to estimate the demand curves of the other investors, because the demand shift only affects holdings of other investors through its effect on prices.

The instrument is constructed in such a way that its negative for the maturity buckets $(15, 20]$ and $(20, 25]$ because of the excess demand for 20-year bonds, whereas the instrument is positive for the maturity buckets $(25, 30]$ and $(30, \infty)$ because of the reduced demand for long-term maturities. Specifically, the instrument is constructed as the average weight assigned to the UFR for each maturity bucket summarized in Table A1 of the Appendix, minus the total weight assigned to the 20-year interest rate equally distributed over the $(15, 20]$ and $(20, 25]$ maturity buckets. The instrumental variable is then defined as $z_t(h) =$

[32]Indeed, the Fitch credit rating for the Netherlands is AAA over my entire sample period.
[33]Summary statistics on bond characteristics are provided in Table A4.
[34]For details, see the following link: Fine Delta Lloyd UFR.

$\xi(h)\text{UFR}_t$, where $\xi(h)$ is the average weight assigned to the UFR for maturity bucket h.

[Place Table 6 about here]

The first stage is summarized in Panel A of Table 7 for all sectors.[35] The first-stage coefficient estimates range from 0.28 to 0.33 and the corresponding t-statistic from 5.09 to 7.06, and are therefore higher than the proposed threshold of 4.05 by Stock and Yogo (2005) for rejecting the null of weak instruments at the 5 percent level. A coefficient of 0.30 means that government bond yields with maturities between 16 and 20 years decreased by 12 basis points and maturities between 21 and 25 years decreased by 5 basis points but maturities between 26 and 30-years went up by 17 basis points and maturities longer than 30-years went up by 27 basis points.

Columns 1-5 of Table 7 show the estimates of the demand system. The demand curves for all investors are downward sloping, except they are upward sloping for the P&I sector outside the Netherlands. Moreover, all investor types prefer bonds with large outstanding amounts (liquid bonds). The P&I sector prefers bonds with long durations, and the foreign investors and banks prefer bonds with strong convexity. Banks and the foreign sector move away from Dutch government bonds when the German yield goes up, whereas the P&I sector instead moves simultaneously towards Dutch government bonds.

[Place Table 7 about here]

I can use the demand system to connect prices to the elasticity of demand by taking the derivative of quantities with respect to price for all investor types (Koijen and Yogo 2019; Koijen et al. 2021):

$$\frac{\partial q_{it}(h)}{\partial p_{it}(h)} = 1 + 100\frac{\beta_{0i}}{T_t(h)}(1 - w_{it}(h)), \tag{11}$$

where lowercases are the logs of variables, and $T_t(h)$ is the average maturity for maturity bucket h. To compute $w_{it}(h)$, I take the weight of sector i in Dutch government bonds within maturity bucket h at time t, relative to the total investments in all government bonds at time t.

The demand elasticities with respect to price for each investor type are summarized

[35] The first-stage regression of the instrumental variable estimator equals:

$$y_t(h) = \gamma_{0i} + \gamma_{1i}z_t(h) + \gamma_{2i}'\mathbf{x}_t(h) + \gamma_{3i}y_t^{DE} + \gamma_{4i}\ln(B_{2009q1,i}(h)) + \epsilon_t(h). \tag{10}$$

in Table 8. A demand elasticity close to zero indicates that demand is inelastic, and a large value indicates that demand is sensitive to the price. Banks have the highest demand elasticity, followed by foreign investors. The market clearing condition means that the weighted average elasticity matters for deriving yield effects and equals 4.31. To the extent that P&Is anticipated a lower sensitivity of their liabilities to very long-term interest rates, the estimated changes in yields may understate the true effects and the price elasticities that I estimate provide an upper bound of the true elasticities.

In order to derive asset pricing effects from the demand system, I can perform a simple back-of-the-envelope calculation. Pension funds and insurers sold 22 percent of the amount outstanding of 30-year Dutch government bonds. This percentage means a price effect equal to $22\%/4.31 = 5.11\%$. For a bond with a maturity of 30-years, this percentage means an increase in long-term yields of 17 basis points, which is close to the price effect found for the first-stage regression.

[Place Figure 6 about here]
[Place Table 8 about here]

Despite the lower persistency of portfolio holdings in government bond markets on which the proposed instrument by Koijen and Yogo (2019) relies, I re-estimate the demand system using their instrument to benchmark my price elasticities. In order to adopt the investment universe as an instrument for yields, I use the holdings at the sector-country level (e.g., German banks) in each bond s. That is, I analyze the bond holdings $w_{it}(s)$ of sector-country i in Dutch government bond s at time t. To construct the instrument, I only aggregate over sector-country holdings for which I can plausibly assume fixed asset mandates. That is, I only aggregate over sector-country holdings for which at least 95 percent of the current bond holdings are included in the investment universe.[36]

The details of the estimation procedure are in Appendix C. Table A6 of the Appendix summarizes the demand system and Table A7 the corresponding price elasticities. Though the magnitudes do not map one-to-one, consistent with my earlier findings, banks are most price elastic with a median price elasticity of demand equal to 24.95.[37] Mutual funds are less

[36] Unfortunately, unlike my main analysis at the maturity-bucket level, I cannot estimate the aggregate price elasticity because the estimation of the demand curve for the foreign sector is inaccurate. The reason is that the foreign sector also includes the holdings of the ECB and the national banks and hence QE would bias my estimates. The foreign sector would appear to have upward sloping demand curves, because the central banks mainly bought bonds over my sample period when yields were declining. This problem is not a concern for my main analysis at the maturity-bucket level, because the ECB bought 'market neutral' across maturities, that is, they bought in proportion to the outstanding maturity distribution (Koijen et al. 2021).

[37] The magnitudes are not directly comparable because the price elasticities of demand that I derive based on the regulatory reform are at the maturity bucket level, whereas these estimates are at the bond level.

elastic with a price elasticity of demand that equals 2.71, and the P&I sector, both inside and outside of the Netherlands, have upward sloping demand curves with elasticities equal to -3.04 and -4.80, respectively.

As in Koijen et al. (2021), demand elasticities are substantially higher than the estimates for stock markets; for example, Chang et al. (2015) find an elasticity close to one. However, I find that banks are more elastic than mutual funds, while Koijen et al. (2021), who estimate price elasticities at the issuer-country level, find the opposite. In the next section, I discuss reasons why banks might be substantially more elastic along the maturity structure of debt relative to the other investor types.

C. Why are banks most price elastic?

Interestingly, as shown in Figure 5, banks substantially lowered their exposure to 20-year bonds after the regulatory reform while at the same time they increased their holdings of 30-year bonds, which is consistent with banks being most price elastic. The percentage of TAO held by each investor type is based on the average holdings the year prior and after the reform, however, the figures look similar irrespective of the specific quarter, which shows that banks are not just temporary liquidity providers. Quantitatively, banks moved from holding 9 percent of the total amount outstanding of bonds with maturities close to 20 years to zero percent after the regulatory reform. Likewise, they moved from holding 1 percent of the total amount outstanding of bonds with maturities exceeding 30 years to 18 percent after the reform.[38] This finding provides evidence that banks bought long-term bonds from the P&I sector, while at the same time they sold bonds with maturities close to 20 years to the P&I sector.

This finding raises the natural question of why banks absorb demand shocks by long-term investors, and not other investor types. Figure 6 shows that over 60 percent of the government bonds with maturities beyond 10 years are held by the P&I sector. This is a conservative estimate, because part of the foreign sector also consists of P&Is, such as those in the UK and Switzerland that are not part of my data set. These investors do not respond to prices, to the contrary, their (slightly) upward sloping demand curves show that they move in the same direction as prices. As theoretically shown by Domanski et al. (2017), demand for bonds by P&Is goes up when interest rates decline to match the duration of their liabilities.

Mutual funds hold another 11 percent of the Dutch debt outstanding. As shown in Table 8, their price elasticities of demand are downward sloping, but relatively small in

[38] Notice that these findings cannot be explained by QE, because QE was announced in 2014, while the comparison of the investor weights is based on data from 2011-2013.

magnitude. This implies that mutual funds are not elastic along the term-structure of interest rates. Mutual funds are typically evaluated against benchmarks (e.g. Pavlova and Sikorskaya 2022) and the duration of those benchmarks are therefore predetermined. As such, mutual funds may experience less room to alter the maturity structure of their bond holdings.

The final major sector in government bond markets is the banking sector. Banks, on the contrary, engage in maturity transformation. Their liabilities are short-term, but they have assets which are long-term. Maturity transformation does not expose them to interest rate risk per se, because their liabilities do not move one to one with interest rates because of banks' market power in deposit markets (Drechsler et al. 2021). As such, a change in the maturity structure of assets does not necessarily affect bank equity negatively. Additionally, a market dominated by the P&I sector may give banks an information advantage, because they are closely connected with the P&I sector through their derivative trades. Using derivative positions of all institutional investors established in the Netherlands that are reported as part of the EMIR regulation since 2017, Table 9 shows that over 85 percent of the derivative contracts of P&Is are with banks.[39] In particular, this pattern is consistent across maturities, and thus, P&Is perform the majority of their interest rate hedging activities with banks.

Furthermore, Figure 7 shows that Dutch banks are also on the opposite side of the swap positions of P&Is. The figure shows the net exposure towards different maturity buckets, computed as the total position in receiver swaps minus the total position in payer swaps.[40] I then report the results separately for the P&I sector and for the banks' positions with the P&I sector. Interestingly, banks have the exact opposite exposures compared to the P&I sector. In particular, they have the largest negative net exposure to the 20-year interest rate, whereas the P&I sector has the largest positive net exposure to this rate.[41] Based on these findings, it is plausible to assume that banks have detailed information about P&Is' demand for specific maturities, which in turn allows them to react quickly when demand shocks occur.

[Place Table 9 about here]
[Place Figure 7 about here]

[39] Appendix D has a detailed explanation of the data and the cleaning procedure.

[40] Throughout I assume that the floating leg of the swap has zero interest rate risk.

[41] Notice that in economic magnitude the total exposures of P&Is are substantially larger than the exposure of Dutch banks to the Dutch P&I sector. The reason is that the P&I sector also performs a substantial amount of their derivative trades with non-Dutch banks as shown in Table 9.

D. Supply side effects

Equation (9) holds under the assumption that supply is exogenously given or fixed (Koijen and Yogo 2019). However, based on the findings above, the government has an incentive to shift its issuance of debt away from very long-term bonds towards bonds with maturities close to 20 years to benefit from the reduced (increased) rate on 20 (30) year bonds. In order to investigate whether the government adjusted the maturity structure of its debt in response to the reform, Figure 8 shows the percentage of the debt outstanding for each maturity bucket relative to overall debt pre and post the reform. The figure shows no notable change in the maturity structure of its debt after the reform. Discussions with the Dutch State Treasury Agency reveal that the reason for not responding to the regulatory reform is twofold. First, the treasurer aims to be predictable and therefore does not alter the maturity structure of its debt frequently. Second, the treasurer also aspires to maintain a liquid nominal curve of its debt outstanding. Because the Dutch debt is relatively small, even if the treasurer wishes to alter the maturity structure of its debt, it does not have much scope to do so while maintaining liquidity at the same time. So, in sum, the underlying assumption that supply is fixed in estimating demand curves is realistic in my setting.

[Place Figure 8 about here]

VII. Robustness demand shifts

This section aims to provide robustness to the permanent change in demand for long-dated assets by the P&I sector. The first set of robustness checks in Section A ensure the validity of the shift in demand for long-term bonds at implementation of the UFR. The second set of robustness checks in Section B shows that a similar shifts in demand for specific maturities is observable in P&Is derivative positions.

A. Robustness main results

To ensure the validity of my findings, I perform three additional robustness checks. The first robustness check concerns the post period, the second one the number of observations used to estimate the pre and post period, and the third one concerns an analysis at the security level.

1. Post period

The post period of my sample covers the ECB's Expanded Asset Purchase Programme (EAPP) which has also affected the investment behavior of P&Is. Indeed, as shown by Domanski et al. (2017) and Koijen et al. (2021), P&Is increased their long-term bond holdings during QE that the widened duration gap between assets and liabilities when interest rates declined likely explains. However, the regulatory reform led to a decrease in long-term bond holdings as opposed to an increase which emphasizes that QE cannot explain my results, and if anything, the coefficient estimates underestimate the true effect of the regulatory reform on the decline in long-term bond holdings. To further corroborate that my findings are not driven by QE, I reestimate the regressions with a post period that ends in 2014q3 after which the ECB announced its EAPP on January 22, 2015. The results are in Appendix A8-A10 and both the signs and economic magnitudes remain similar.[42]

2. Standard error difference-in-difference estimation

Furthermore, I show that my results are not driven by the fairly long time series used in this study or autocorrelation in the dependent variable, which could severely understate the standard error of the coefficient on the difference-in-difference estimate (e.g. Bertrand et al. 2004). To address this issue, I first average the data in the pre and post period of the regulatory reform to take away the time series dimension of the data. Second, I zoom in on the quarter just before and after implementation of the reform. Table A11 of the Appendix shows that my results remain unchanged, both in statistical significance as in the economic magnitude of the effects.

3. Security level evidence

Finally, to ensure that my results are not driven by security characteristics other than a bond's maturity, I perform a similar regression as in Equation (5) at the security level. Formally, I run the following regression:

$$\begin{aligned} w_{sit} &= \beta_0 D^L_{2011q2,i} \times \mathbb{1}^{maturity \geq 30}_{st} \times \text{UFR}_t + \beta_1 D^L_{2011q2,i} \times \mathbb{1}^{maturity \in (15,25]}_{st} \times \text{UFR}_t \\ &+ \alpha_{is} + \gamma_{st} + \lambda_{it} + \epsilon_{sit}, \end{aligned} \tag{12}$$

where w_{sit} is the allocation to security s for P&I i at time t, $\mathbb{1}^{maturity \geq 30}_{st}$ is an indicator variable that equals one if the time to maturity of bond s is larger than or equal to 30 years

[42] Notice that even if other macro-events occurred at the same time the regulatory reform was implemented, it is difficult to think of macro developments that would lead to P&Is shedding long-term bonds, but specifically buying bonds with 20-year maturities instead.

at time t, and $\mathbb{1}_{st}^{maturity\in(15,25]}$ is an indicator variable that equals one if the time to maturity of bond s is between 15 and 25 years at time t. Fund-security fixed effects are denoted by α_{is} and capture time-invariant heterogeneity at the fund-security level, such as P&Is' differences in preferences for certain securities. Security-time fixed effects are denoted by γ_{st} and control for all time-variant and time-invariant security-specific characteristics that might correlate with maturity. Fund-time fixed effects are denoted by λ_{it} and control for time-variant and time-invariant P&I-specific characteristics.

Likewise, I show the regression in Equation (7) at the security level:

$$\begin{aligned} w_{sit} &= \beta_0 D^L_{2011q2,i} \times \text{FR}^{-1}_{2011q2,i} \times \mathbb{1}_{st}^{maturity\geq 30} \times \text{UFR}_t \\ &+ \beta_1 D^L_{2011q2,i} \times \text{FR}^{-1}_{2011q2,i} \times \mathbb{1}_{st}^{maturity\in(15,25]} \times \text{UFR}_t + \alpha_{is} + \gamma_{st} + \lambda_{it} + \epsilon_{sit}. \quad (13) \end{aligned}$$

Table A12 of the Appendix shows the results for (12) in Columns 1-3 and for (13) in Columns 4-6. In all specifications, the coefficient β_0 is negative and statistically significant, while the coefficient β_1 is positive and statistically significant which is consistent with the previous findings: P&Is with long liability durations reduced (increased) 30-year (20-year) bond holdings to a larger extent and the effect is stronger for constrained investors.

B. *Interest rate derivatives and the regulatory reform*

The empirical analysis thus far uses long-term bond holdings only, but investors can also use derivatives to manage interest rate risk, especially for very long maturities. Unfortunately, P&Is only started reporting their derivative holdings at the introduction of the EMIR regulation in 2017. However, as of the start of 2012, pension funds report derivative positions on an aggregate level. I will therefore first show evidence of the change in the aggregate swap portfolios for pension funds at implementation of the UFR. Second, I will use the EMIR database to test the model implications that should still persist as long as the regulatory reform is in place.

1. Evidence from the supervisory reports

As of 2012q1, pension funds report the market value of interest rate derivative contracts aggregated by different contract types. Moreover, they report the values of these positions after a parallel shock in interest rates of +1 percent (-1 percent) and +0.5 percent (-0.5 percent). These reporting requirements allow me to compute the dollar durations of the swap positions.[43] Because the data on swap positions only became available one quarter

[43] As the majority of the derivative positions consist of swaps, and swaps have a linear pay off function, I narrow down the analysis to the swap portfolio only.

prior to the regulatory reform, the time series is not long enough to statistically test whether pension funds changed their exposures to interest rates via swaps as well. However, using the time series of the cross-sectional average implied duration of the swap portfolios, I provide evidence that pension funds substantially decreased the duration of their swap positions after the regulatory reform.

Formally, I approximate the dollar duration of the swap position as follows:

$$D^{\$}_{p,t} \approx -\frac{dV_t}{dr} = \frac{V_t^{-dr} - V_t^{+dr}}{2|dr|} \tag{14}$$

where V_t^{-dr} (V_t^{+dr}) is the value of the swap portfolio after a negative (positive) change in interest rates; $D^{\$}_p$ is the dollar duration of the portfolio; and dr is the change in interest rates.

Figure 9 depicts the cross-sectional average implied duration of the swap portfolio over time, where the duration is computed as the dollar duration in (14) relative to the total AUM. The graph also shows the total balance sheet duration as the sum of the relative implied duration of the swap portfolio and the duration of the fixed income portfolio that is multiplied by the allocation to fixed income. On average, pension funds have a balance sheet duration of 9.5 years. As the duration of the liabilities equals 18 years on average, this duration means that pension funds hedge slightly over half of their interest rate risk. Importantly, the portfolio duration shows a decline at the implementation of the UFR, which is consistent with the predictions of the model and the empirical findings for long-term bond holdings.

[Place Figure 9 about here]

2. Evidence from the EMIR data

To further strengthen the robustness of my findings, I empirically validate the cross-sectional predictions of the model after the regulation had already been in place for some time by using the data on derivative positions introduced in Section VI. The model described in Section III indicates that as long as the regulation is in place, P&Is are incentivized to have a larger exposure to the 20-year interest rate and simultaneously a lower exposure to the 30-year rate. Likewise, the prediction that constrained P&Is hedge the regulatory discount curve more strongly as opposed to unconstrained P&Is should remain visible. Testing both these predictions allows me to draw more robust conclusions about the long-lasting effects of the UFR and to better understand the permanent price effects of the regulatory reform shown in the previous section.

In Panel A of Figure 10, I aggregate the bond and swap holdings to obtain the total exposure to each maturity bucket.[44] The figure shows some interesting patterns. First, interest rate derivatives across maturity buckets make up more than half of the total exposure for maturities beyond 15 years, which is consistent with Figure 9. Second, the exposure peaks for maturity buckets $(15, 20]$ and $(20, 25]$, but substantially lowers for the maturities beyond 30 years. More importantly, Figure 10 shows separate break downs of the P&Is into low versus high solvency positions, where high (low) is defined as those P&Is with a funding ratio above (below) the cross-sectional median funding ratio.[45] Interestingly, the P&Is with high solvency positions have much larger exposures to longer rates than the ones with low solvency positions. In particular, the aggregate amount invested in maturities beyond 30 years is €30 billion for P&Is that are unconstrained compared to approximately €5 billion for the ones that are constrained. This finding is consistent with the model and further corroborates the finding that constrained P&Is in particular hedge the regulatory rather than the economic discount curve.

[Place Figure 10 about here]

VIII. Effects of the UFR at the European level

The UFR is an important aspect of the EU Solvency II regulation that was announced in August 2015 and took effect as of January 1, 2016. Relying on the home-bias found in euro area investors' portfolios (e.g., Koijen et al. 2017, 2021) and the fact that insurance companies in the Netherlands are subject to similar regulations as other countries in Europe, one would expect effects on the yield curve in other European countries, too.[46] In order to test for the effect of the UFR on a broader scale, I construct a panel that comprises 20 European countries subject to Solvency II regulations and regress the yield spreads of these countries on a proxy for insurance demand in those countries that is interacted with a dummy that equals one after the announcement of the UFR.[47] Though, the results that follow should not

[44] The net swap position is computed as the total position in receiver swaps minus the total position in payer swaps for each maturity bucket. Throughout I assume that the floating leg of the swap has zero interest rate risk.

[45] The break down is separately computed for insurers and pension funds, so each group contains an equal number of pension funds and insurance companies.

[46] The level and the convergence of the regulatory discount curve to the UFR is identical for euro area countries but deviates for countries outside the euro area. In particular, the level of the UFR depends on the inflation level for non-euro area countries. For more details, see e.g. EIOPA (2017), page 8/135.

[47] The UFR dummy equals one as of the announcement of the UFR in August 2015, except for the countries Denmark, the Netherlands, and Sweden, because those countries implemented the UFR earlier, and hence,

be interpreted as causal, because the demand from the P&I sector may be correlated with unobservable factors that affect the yield curve for which I do not explicitly control.

The following countries are included in the panel: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, and the UK over the period from 2006-2020. The size of the insurance sector differs substantially in these countries (Scharfstein 2018; Greenwood and Vissing-Jorgensen 2018). Therefore, I use the size of the insurance sector in each country relative to its debt as a proxy for insurance demand for long-term bonds. The larger the size of the insurance sector relative to debt, the higher demand for long-term assets in that country. I obtain the sizes of the insurance sectors from EIOPA Insurance Statistics.[48]

In the regressions, I control for other variables that determine yield spreads: the 10-2 year government bond spread, the debt-to-GDP ratio, the CDS spread, and the age of the population (measured by the fraction of the elderly relative to the total population). The 10-2 year government bond spread controls for the slope of the term structure (Scholtens and Tol 1999). The debt-to-GDP ratio controls for the fact that countries with more debt, or a higher supply of bonds, likely have lower yields (e.g. Greenwood and Vayanos 2014). CDS spreads control for the effects of differences in default risk across countries on yield spreads. The age of the population controls for countries with older populations that have more government debt supply and larger term spreads (Guibaud et al. 2013). In some of the specifications, country fixed effects are also included to control for omitted persistent country characteristics that potentially affect yield spreads, such as differences in countries' financial systems.

I then run the following regression:

$$y_{c,t}(h) - y_{c,t}(s) = \alpha + \beta_0 \text{SIZEIC}_c^{2015} \times \text{UFR}_t + \beta_1 X_{c,t} + \lambda_t + \nu_c + \epsilon_{c,t}, \tag{15}$$

where $y_{c,t}(h) - y_{c,t}(s)$ is the h minus s year government bond spread in country c at time t; UFR_t equals one as of August 2015 and zero otherwise (except for Denmark, the Netherlands, and Sweden, where the dummy equals one as of June 2012, July 2012, and February 2013, respectively); SIZEIC_c^{2015} is the measure of the demand for long-term bonds by the insurance sector of country c in 2015; $X_{c,t}$ includes country controls: 10-2 year spread, debt-to-GDP, CDS spread, and age; λ_t are time fixed effects; and ν_c country fixed effects.

Table 10 has a summary of the results. Countries with larger demand for long-term bonds by the insurance sector have higher 30-20 year yield spreads but lower 20-10 year

the UFR dummy equals one as of June 2012, July 2012, and February 2013, respectively.

[48] See https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en

yield spreads, which is consistent with the findings for the Dutch P&I sector. A one standard deviation increase in insurance demand (0.715), increases the 30-20 year bond spread after the introduction of the UFR by 4.7 basis points and lowers the 20-10 year spread by 7.5 basis points. Countries with a small insurance sector such as Hungary and Portugal experienced negligible changes in yields, while Ireland and Denmark with large insurance sectors experienced a drop of 13-32 basis points in the 20-10 year spread and an increase of 8-20 basis points in the 30-20 year spread, respectively. Table A13 of the Appendix shows that similar effects occur when I use an alternative measure of insurance demand that multiples the size of the insurance sector with the aggregated liability duration of insurance companies. Multiplying the size of the insurance sector with the liability duration controls for differences in the liability structure of insurance companies across countries and thereby more accurately measures the demand for long-term bonds.

Overall, these findings show that the effects of the UFR on yields are visible beyond Netherlands, and that these effect are created through a shift in demand for long-term assets by the P&I sector. Though, as mentioned before, unlike the results for Dutch government debt, these results should be interpreted as correlations that are consistent with the findings in the rest of this study.

[**Place Table 10 about here**]

IX. Conclusion

In this study, I use holdings data and price data simultaneously to study demand shifts and their causal effect on yields. In particular, I exploit a change in the regulatory discount curve at which the liabilities of long-term investors are evaluated and find a structural change in demand for long-dated assets that led to a downward pressure on 20-year yields but to an upward pressure on longer maturity yields.

Exploiting the heterogeneity in demand shifts across long-term investors shows that constrained investors reacted more heavily to the regulatory reform compared to unconstrained ones which has important implications for the vulnerability of the pension and insurance sector going forward.

My results also show that regulation plays a nontrivial role in the demand for long-term bonds which in turn, affects the yields of these bonds. This finding has direct implications for the role of regulation in determining the government's cost of borrowing.

Finally, by estimating the price elasticities of investors in the government bond market, I show that the banking sector is most price elastic and primarily responsible for absorbing demand shocks by the P&I sector. My findings therefore suggest that regulators should take the spillover effects to other sectors into account when analyzing policies targeted at long-term investors.

Figure 1. **Dutch 30-20 year yield spread: UFR**

This graph shows the Dutch 30-20 year government bond yield spread around the announcement (and implementation) date of the UFR. The vertical lines are five days before and after the announcement (and implementation) of the UFR on July 2, 2012. Yields are in percentage points.

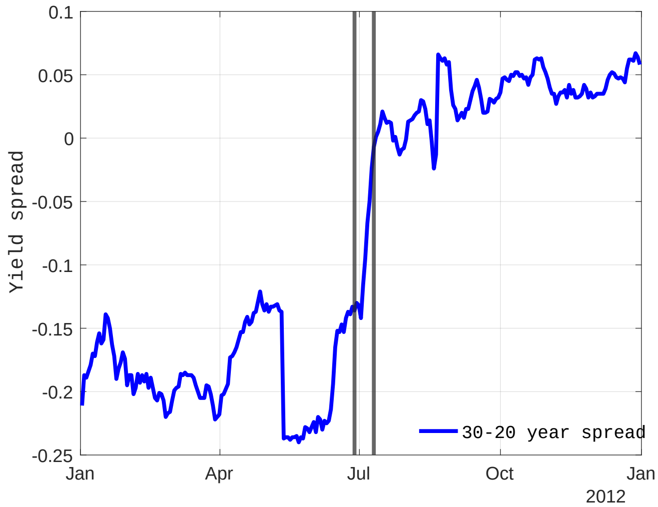


Figure 2. **Regulatory discount curve parallel shift interest rates**

This graph shows the economic discount curve (solid red line) and the regulatory discount curve (dashed green line) at implementation of the UFR on July 2, 2012. The graph also shows the economic (solid blue line) and regulatory (dotted black line) discount curve after a parallel shock in market interest rates of $\triangle y_t = -1\%$.

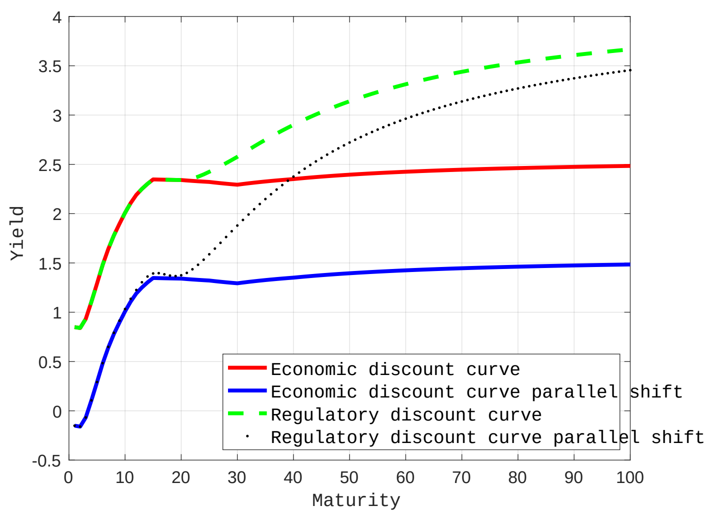


Figure 3. **Regulatory discount curve change 20-year interest rate**

This graph shows the economic discount curve (solid red line) and the regulatory discount curve (solid green line) at implementation of the UFR on July 2, 2012. The graph also shows the economic (dashed blue line) and regulatory (dotted black line) discount curve after a change in the 20-year market interest rate of $\triangle y_t^{(20)} = -0.5\%$.

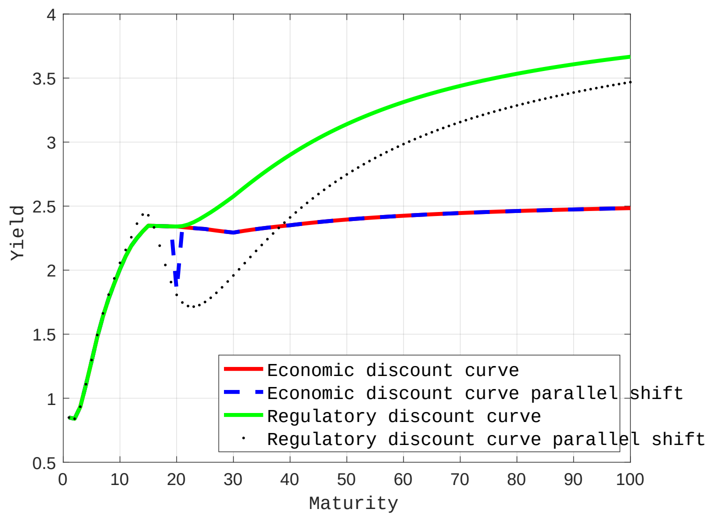


Figure 4. **Cash flow distribution of the liabilities**

This graph shows the (discounted) cash flow distribution of the liabilities for an average pension fund in million euros. The average is taken over all 42 pension funds in my dataset on 2012q1, the quarter before the announcement and implementation of the reform.

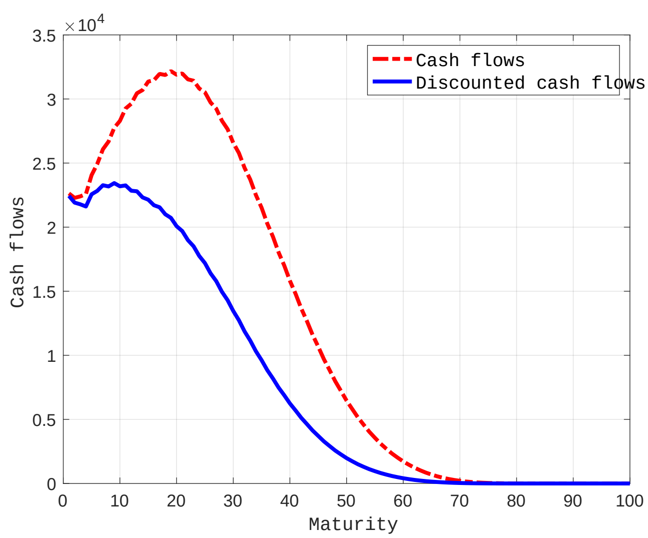
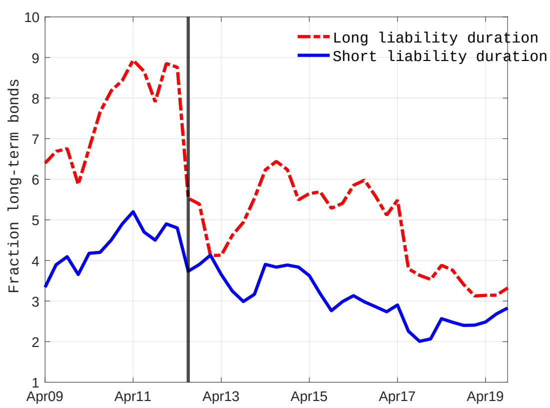
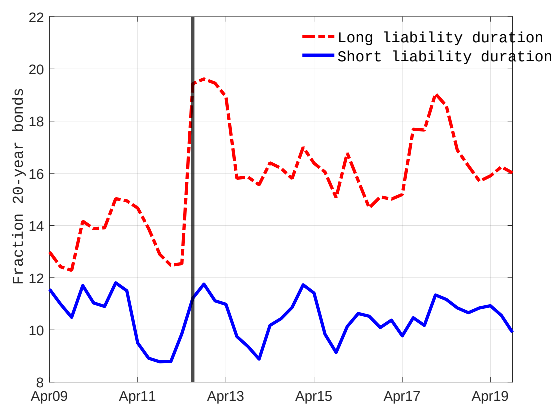


Figure 5. **Long-term bond holdings over time**

This graph shows the cross-sectional average fraction of the bond portfolio that is invested in long-term bonds, i.e., bonds with a maturity of 30 years or longer (Panel a), and for the fraction that is invested in bonds with maturities close to 20 years, i.e., between 15 and 25 years (Panel b). The sample of P&Is is split in those with long liability durations (higher than the median) and for those with short liability durations (lower than the median). The bond portfolio contains the investments in all type of bonds (e.g., corporate, government) and across all issuer countries. The fractions are in percentage points and the quarterly sample period is 2009q1-2019q4.



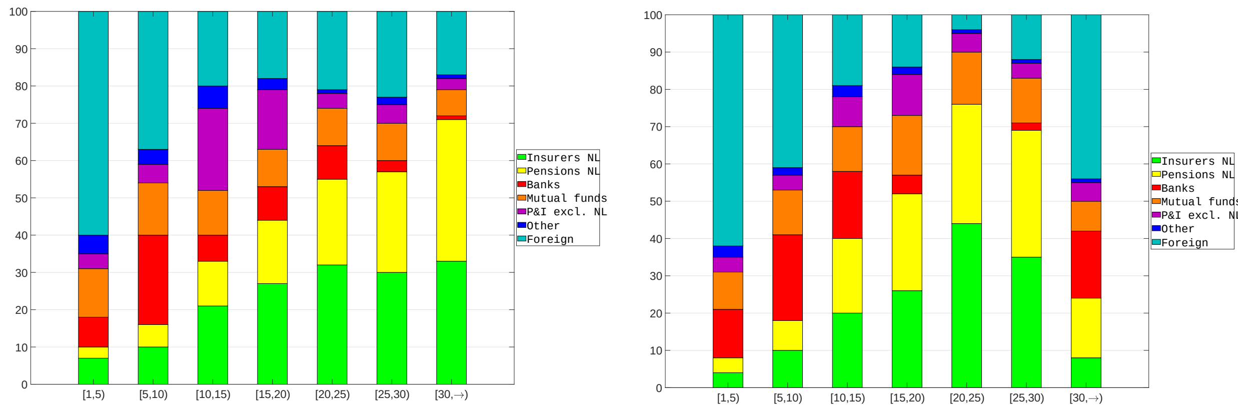
(a) Bond holdings maturity $T \geq 30$



(b) Bond holdings maturity $T \in (15, 25]$

Figure 6. **Weights of investor types within maturity buckets**

This figure displays the average weights of the investor types (banks, insurance companies, foreign investors, mutual funds, pension funds, and other investors) that held Dutch debt the year prior to the regulatory reform 2011q1-2012q1 (Panel a) and the year after the regulatory reform 2012q2-2013q2 (Panel b). The banks, mutual funds, an other investor types are at the euro area level. Dutch pension funds, Dutch insurance companies, and the P&I sector in the euro area excluding the Netherlands are separately reported. The foreign sector is determined as the fraction of total amount outstanding that is not held by euro area investors. The weights are in percentage points.



(a) Investor weights prior to the UFR

(b) Investor weights after the UFR

Figure 7. **Exposures to interest rates: P&Is versus banks**

This figure shows the net exposure of P&Is and banks' swap positions. For the Dutch P&I sector, I compute the aggregate net exposure of their swap positions per maturity bucket. For the Dutch banks, I compute the aggregate net exposures they have with the Dutch P&I sector. The notional amounts to compute the net exposures are based on Euribor plain vanilla swaps. The data is from EMIR and averaged over the period 2018q1-2019q4.

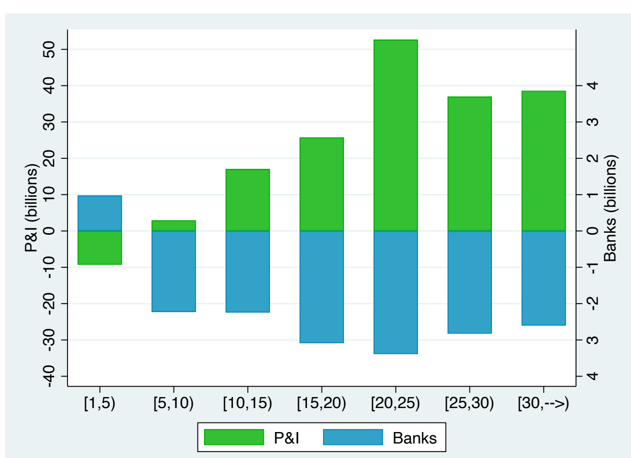


Figure 8. **Maturity structure Dutch debt pre and post UFR**

This figure shows the average maturity structure of the Dutch debt outstanding prior and after the regulatory reform was implemented. The weights are in percentage points and computed for each maturity bucket as the total debt outstanding within that maturity bucket relative to the total debt outstanding. The pre UFR period is from 2009q1 to 2012q1 and the post period is from 2012q2 to 2019q4.

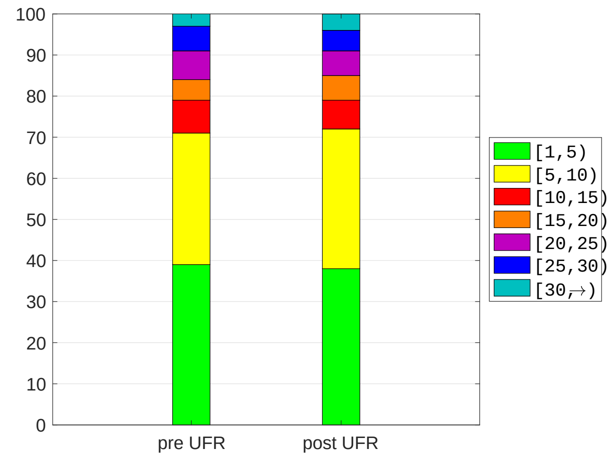


Figure 9. **Implied duration of pension funds' portfolios**

This graph shows the cross-sectional average implied duration of the swap portfolio and the duration of the total portfolio of the 42 pension funds in my sample over the period 2012q1-2017q1. The vertical line indicates the announcement and implementation date of the regulatory reform. The duration of the swap portfolio is determined as the implied dollar duration of the swaps divided by total pension assets. The duration of the total portfolio equals the sum of the implied duration of the swap portfolio and the duration of the fixed income portfolio times the allocation to fixed income.

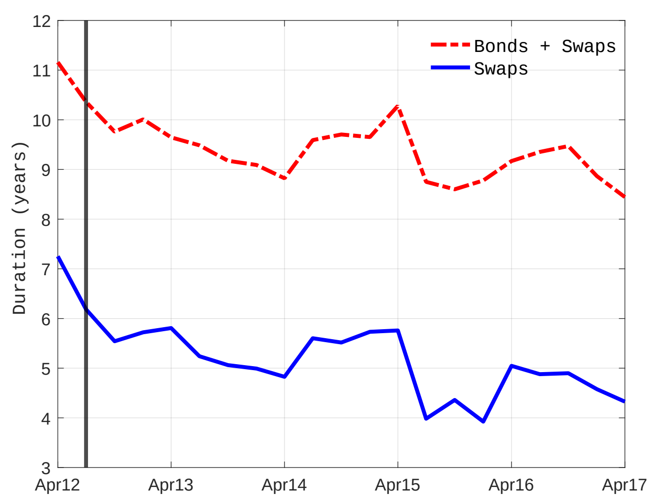
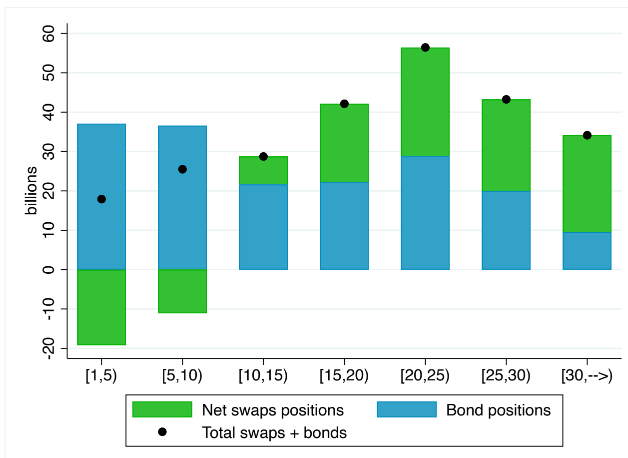
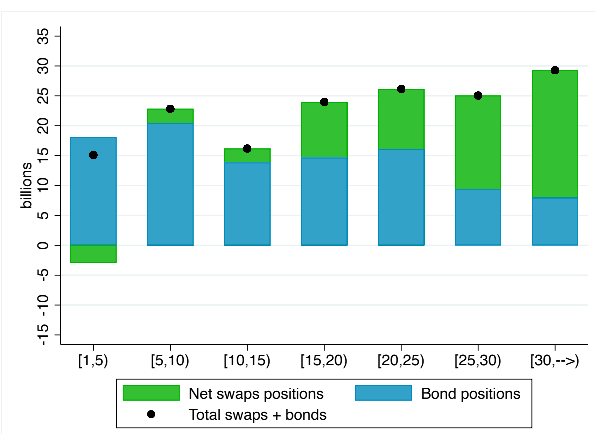


Figure 10. **Net notional maturity buckets: unconstrained versus constrained P&Is**

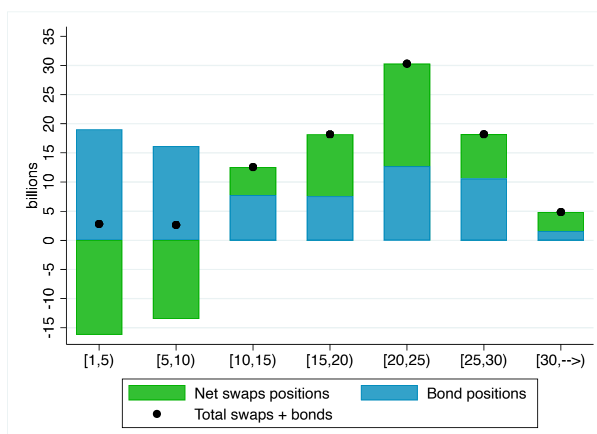
This graph shows the net notional exposure towards different maturity buckets for the bond portfolio (blue), swap portfolio (green), and swap and bond portfolio combined (black dot). Panel a shows the exposures aggregated across all P&Is, Panel b aggregates across all unconstrained investors, and Panel c aggregates across all constrained ones. Constrained (unconstrained) P&Is are defined as the ones with funding positions below (above) the median, measured separately for pension funds and insurance companies. For bonds, the aggregate exposure is based on safe (investment grade) EU government bonds. For swaps, the aggregate exposure is based on Euribor plain vanilla swaps. The data is from EMIR and averaged over the period 2018q1-2019q4.



(a) All P&Is



(b) Unconstrained P&Is



(c) Constrained P&Is

Table 1. **Economic versus regulatory value of the liabilities**: This table shows the value of the liabilities using the economic discount curve versus a discount curve based on the UFR on July 2, 2012. The liability value is the cross-sectional average of the 42 pension funds in my sample that report the projected cash flows of their liabilities at each maturity, starting from one year to 120 years into the future. The measurement date of the cash flows is 2012q1, the quarter before announcement and implementation of the reform. Panel A shows the sensitivity of the liabilities towards a parallel shift in interest rates and Panel B shows the sensitivity towards the 20 year interest rate. The liability values are computed for all projected cash flows and for cash flows with maturities beyond 20 years in isolation. The relative change computes the percentage point drop in the liability value as a result of the new regulatory discount curve based on the UFR. The values are in million euros.

Panel A: Sensitivity parallel shift interest rates

	economic	**UFR**	**relative change**
All maturities			
Discounted value liabilities	16,360	15,696	−4.23
Discounted value liabilities $\triangle y_t = -1$	19,878	18,433	−7.27
Change value liabilities $\triangle y_t = -1$	3,518	2,737	−22.20
Maturities beyond 20 years			
Discounted value liabilities	6,694	6,030	−9.92
Discounted value liabilities $\triangle y_t = -1$	9,155	7,711	−15.77
Change value liabilities $\triangle y_t = -1$	2,461	1,680	−31.74

Panel B: Sensitivity change 20 year interest rate

	economic	**UFR**	**relative change**
All maturities			
Discounted value liabilities	16,360	15,696	−4.23
Discounted value liabilities $\triangle y_t^{(20)} = -0.5$	16,405	16,918	+3.13
Change value liabilities $\triangle y_t^{(20)} = -0.5$	45	1,222	+2,615.56
Maturities beyond 20 years			
Discounted value liabilities	6,694	6,030	−9.92
Discounted value liabilities $\triangle y_t^{(20)} = -0.5$	6,694	7,164	+7.02
Change value liabilities $\triangle y_t^{(20)} = -0.5$	0	1,134	.

Table 2. **Summary statistics**: This table shows summary statistics on the AUM (Panel A), the asset allocation (Panel B), and the liability information (Panel C) of the P&I sector. In particular, I report the AUM of all assets, AUM of directly reported assets, allocation to government bonds, allocation to corporate bonds, allocation to stocks, bond duration, liability duration, and the solvency positions measured by the funding ratio. The asset allocation and funding ratios are in percentage points, AUM in million euro, bond and liability duration in years. The cross-sectional mean, standard deviation, and median are reported. The quarterly sample period is 2009q1-2019q4.

Panel A: AUM							
All assets	mean	std.dev.	p50	**Direct assets**	mean	std.dev.	p50
Life insurers	25,486	20,398	25,903	Life insurers	18,822	15,771	18,208
Non-life insurers	1,507	1,380	957	Non-life insurers	1,322	1,359	741
Pension funds	17,578	43,918	6,244	Pension funds	14,761	40,265	3,964
Panel B: Asset allocation							
Government bonds	mean	std.dev.	p50	**Corporate bonds**	mean	std.dev.	p50
Life insurers	49.41	12.53	50.00	Life insurers	33.00	11.70	30.67
Non-life insurers	45.32	19.75	44.84	Non-life insurers	34.44	22.95	34.94
Pension funds	37.73	17.20	34.58	Pension funds	20.93	13.33	19.75
Stocks	mean	std.dev.	p50	**Bond duration**	mean	std.dev.	p50
Life insurers	10.08	9.92	6.71	Life insurers	8.72	2.61	8.74
Non-life insurers	13.75	20.26	3.77	Non-life insurers	4.47	1.66	4.59
Pension funds	34.13	16.86	36.49	Pension funds	7.29	2.22	7.02
Panel C: Liability information							
Liability duration	mean	std.dev.	p50	**Inverse funding ratio**	mean	std.dev.	p50
Life insurers	11.77	3.95	12.56	Life insurers	91.60	3.42	92.26
Non-life insurers	4.20	2.62	3.47	Non-life insurers	91.37	4.01	92.48
Pension funds	17.94	2.96	17.70	Pension funds	92.53	9.43	92.59

Table 3. **Long-term bond holdings and the regulatory discount curve**: This table presents the results of the main regression described in Equation (5): $w_{it}^{B} = \alpha + \beta_1 D_{2011q2,i}^{L} \times \text{UFR}_t + \cdots + \epsilon_{it}$, with the dependent variable equal to the fraction of the P&I's bond portfolio invested in a certain maturity bucket, UFR equal to 1 as of 2012q2 and zero otherwise, D_{2011q2}^{L} the duration of the liabilities as of 2011q2, and controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). Column (1) and (2) show the results for bond holdings with a maturity of 30 years or longer, column (3) and (4) for maturities between 15 and 25 years, and column (5) and (6) for maturities shorter than 15 years. The bond holdings contain the investments in all type of bonds (e.g., corporate, government) and across all issuer countries. The quarterly sample period is 2009q1-2019q4. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Holdings $\boldsymbol{T \geq 30}$		Holdings $\boldsymbol{15 < T \leq 25}$		Holdings $\boldsymbol{T \leq 15}$	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	0.1243		-0.879		1.2495	
	[0.33]		[-1.19]		[0.73]	
D_{2011q2}^{L}	0.3590***		0.224		-0.3561	
	[5.19]		[1.36]		[-1.46]	
UFR$\times D_{2011q2}^{L}$	-0.1480***	-0.1462***	0.1966***	0.2682***	0.0543	0.0062
	[-4.20]	[-5.32]	[3.45]	[6.29]	[0.44]	[0.07]
D_{t-1}^{L}	-0.1655***	0.3511***	0.0452	0.4288**	0.4777**	-1.6988***
	[-2.63]	[4.59]	[0.27]	[2.00]	[2.22]	[-7.31]
FR_{t-1}^{-1}	2.4389	3.6919	-3.237	-3.7669	-19.3991**	-11.7107*
	[0.87]	[1.50]	[-0.67]	[-0.93]	[-2.54]	[-1.83]
$FR_{t-1}^{-1}\times$ Pension funds	-2.4942	1.6782	-7.2747	-0.9908	15.5057*	2.6138
	[-0.77]	[0.53]	[-1.46]	[-0.22]	[1.86]	[0.37]
Log AUM	0.8553***	-1.3306	0.7818**	-1.8976	-2.7454***	6.0522**
	[3.57]	[-1.15]	[2.12]	[-1.57]	[-3.78]	[2.03]
Life insurance	4.6759***		5.6288***		-10.5670***	
	[10.05]		[6.78]		[-6.88]	
Pension funds	3.531		8.1097*		-22.8325***	
	[1.19]		[1.72]		[-2.96]	
Fund FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	2437	2437	2437	2437	2437	2437
adj. R-squared	0.1562	0.6203	0.1422	0.6601	0.0692	0.7085

Table 4. **Asset allocation and the regulatory discount curve**: This table presents the results of the regression described in Equation (6): $w_{it}^S = \alpha + \beta_1 D^L_{2011q2,i} \times \text{UFR}_t + \cdots + \epsilon_{it}$, with the dependent variable equal to a measure of P&I's risky asset allocation, UFR equal to 1 as of 2012q2 and zero otherwise, D^L_{2011q2} the duration of the liabilities as of 2011q2, and controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). Column (1) shows the results for the equity allocation, column (2) for the corporate bond allocation, column (3) for the corporate bond distance-to-default measure (DTD), column (4) for the government bond allocation, column (5) for government bond credit risk, and column (6) for the high yield government bond allocation. The quarterly sample period is 2009q1-2019q4. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Equity	**Corporate bonds**		**Government bonds**		
	Allocation	Allocation	DTD	Allocation	Credit rating	High yield
	(1)	(2)	(3)	(4)	(5)	(6)
UFR$\times D^L_{2011q2}$	0.1922**	-0.1934**	-0.0165	-0.0005	-0.0411**	0.2530***
	[2.07]	[-2.31]	[-1.17]	[-0.01]	[-2.29]	[2.68]
D^L_{t-1}	0.0699	-0.0035	-0.0158	-0.0943	0.034	0.4308***
	[0.41]	[-0.02]	[-0.46]	[-0.42]	[0.89]	[4.01]
FR^{-1}_{t-1}	1.7577	21.2057***	0.9999	-24.6881***	-0.7155	-7.2278***
	[0.30]	[3.05]	[0.85]	[-3.89]	[-0.51]	[-2.62]
$FR^{-1}_{t-1}\times$ Pension funds	-5.1877	-5.2714	-4.9214***	13.7891*	-4.0653***	0.772
	[-0.78]	[-0.70]	[-3.63]	[1.83]	[-2.67]	[0.23]
Log AUM	12.6684***	-2.9602	1.2548***	-3.0628	2.0870***	-5.6426
	[4.28]	[-1.14]	[2.74]	[-0.93]	[3.31]	[-1.57]
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2437	2437	2437	2437	2432	2432
adj. R-squared	0.8336	0.7706	0.6487	0.7229	0.5867	0.3722

Table 5. **Long-term bond holdings and constraints**: This table present the results of the regression described in Equation (7): $w^B_{it} = \alpha + \beta_1 D^L_{2011q2,i} \times \text{FR}^{-1}_{2011q2,i} \times \text{UFR}_t + \cdots + \epsilon_{it}$, with the dependent variable equal to the fraction of the P&I's bond portfolio invested in a certain maturity bucket, UFR equal to 1 as of 2012q2 and zero otherwise, D^L_{2011q2} the duration of the liabilities as of 2011q2, and FR^{-1}_{2011q2} the inverse of the funding ratio minus 1 as of 2011q2. Controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). P&I type fixed effects include dummies indicating pension funds, life insurers, or non-life insurers. Column (1) and (2) show the results for bond holdings with a maturity of 30 years or longer, column (3) and (4) for maturities between 15 and 25 years, and column (5) and (6) for maturities shorter than 15 years. The bond holdings contain the investments in all type of bonds (e.g., corporate, government) and across all issuer countries. The quarterly sample period is 2009q1-2019q4. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Holdings $\boldsymbol{T \geq 30}$		Holdings $\boldsymbol{15 < T \leq 25}$		Holdings $\boldsymbol{T \leq 15}$	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	-0.4777		-3.9728**		1.3001	
	[-0.38]		[-2.28]		[0.29]	
D^L_{2011q2}	0.5097***		0.3974**		-0.5698	
	[4.50]		[2.12]		[-1.64]	
FR^{-1}_{2011q2}	-16.6552		-43.6699***		35.1294	
	[-1.52]		[-2.62]		[1.04]	
$D^L_{2011q2} \times FR^{-1}_{2011q4}$	2.3404**		2.3488**		-4.8019**	
	[2.57]		[2.19]		[-2.02]	
UFR $\times D^L_{2011q2}$	-0.2022*	-0.2620***	0.4719***	0.3973***	0.0746	0.0646
	[-1.80]	[-3.68]	[3.95]	[4.53]	[0.24]	[0.37]
UFR $\times FR^{-1}_{2011q2}$	-4.9203	13.2797	-30.3373	0.1148	4.4775	-30.6946
	[-0.42]	[1.61]	[-1.59]	[0.01]	[0.12]	[-1.41]
UFR$\times D^L_{2011q2} \times FR^{-1}_{2011q4}$	-0.4487	-1.1770**	2.8008**	1.2628**	-0.4038	0.6716
	[-0.47]	[-2.03]	[2.25]	[1.98]	[-0.16]	[0.49]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
P&I type FE	Yes	No	Yes	No	Yes	No
Fund FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	2433	2433	2433	2433	2433	2433
adj. R-squared	0.1809	0.6209	0.1603	0.6632	0.0891	0.7096

Table 6. **Instrument for every maturity bucket**: This table shows the value of the instrument for each maturity bucket used in the instrumental variable approach. The instrument is constructed as the average weight assigned to the UFR for each maturity bucket, minus the average weight assigned to the 20-year interest rate equally distributed over the $(15, 20]$ and $(20, 25]$ maturity buckets. An overview of the weights for each separate maturity is given in Table A1.

	$(1, 5]$	$(5, 10]$	$(10, 15]$	$(15, 20]$	$(20, 25]$	$(25, 30]$	$(30, \infty)$
$\xi(h)$	0	0	0	-0.41	-0.15	0.58	0.91

Table 7. **Demand system - regulatory reform as instrument**: This table shows the regression results of the demand system described in Equation (9): $\ln B_{it}(h) = \hat{\alpha}_i + \beta_{0i} y_t(h) + \beta_{1i}' \mathbf{x}_t(h) + \hat{\beta}_{2i} y_t^{DE} + \beta_{3i} \ln(B_{2009q1,i}(h)) + \epsilon_{it}(h)$. Panel A shows the first stage of the IV and Panel B the second stage. The instrument $z_t(h)$ equals the weights assigned to the UFR for each maturity bucket h interacted with a dummy that equals one after implementation of the UFR. Bond characteristics include the average bond duration, convexity, coupon, and the log of AUM outstanding. The outside asset O_{it} is proxied by the 10-year German yield and initial holdings are added as control to capture time-invariant omitted characteristics. The quarterly sample period is 2009q1-2019q4. The standard errors are clustered by quarter and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Panel A: First Stage IV

	Foreign $y_t(m)$	**Bank** $y_t(m)$	**MF** $y_t(m)$	**P&I excl. NL** $y_t(m)$	**Other** $y_t(m)$
$z_t(m)$	0.2806***	0.3287***	0.2766***	0.2824***	0.2902***
	[5.87]	[5.09]	[6.55]	[7.06]	[6.30]
Bond Controls	Yes	Yes	Yes	Yes	Yes
Initial holdings	Yes	Yes	Yes	Yes	Yes
Observations	260	213	260	260	245
adj. R-squared	0.9719	0.9726	0.9719	0.972	0.9729

Panel B: Second Stage IV

	Foreign Holdings	**Bank** Holdings	**MF** Holdings	**P&I excl. NL** Holdings	**Other** Holdings
$y_t(m)$	0.5395*	2.3526**	0.0184	-0.5533**	0.2419
	[1.68]	[2.05]	[0.08]	[-1.98]	[0.84]
Duration	-0.3421***	-0.7946**	0.0179	0.1333**	-0.1675
	[-3.21]	[-2.34]	[0.28]	[1.97]	[-0.81]
Convexity	0.0095***	0.0217**	-0.0004	-0.0048**	-0.0031
	[3.26]	[2.37]	[-0.25]	[-2.35]	[-0.52]
Coupon	-0.0950***	0.0098	-0.1095***	0.0055	0.0311
	[-3.67]	[0.15]	[-5.45]	[0.20]	[0.76]
AUM outstanding	1.3936***	0.9013***	0.7376***	0.2178***	0.3216**
	[20.55]	[3.07]	[11.92]	[4.85]	[2.18]
10-year German yield	-0.7984**	-2.9318*	0.1724	0.5812*	0.0835
	[-2.28]	[-1.86]	[0.65]	[1.90]	[0.10]
Initial holdings	-0.3312***	0.6789***	0.2102***	0.4873***	0.2465**
	[-4.58]	[3.63]	[2.92]	[6.05]	[2.29]
Observations	260	213	260	260	245
adj. R-squared	0.9241	0.7637	0.9211	0.8697	0.9192

Table 8. **Price elasticity of demand**: This table shows the price elasticity of demand, computed as in Equation (11): $\frac{\partial q_{it}(h)}{\partial p_{it}(h)} = 1 + 100\frac{\beta_{0i}}{T_t(h)}(1 - w_{it}(h))$ for each investor type, maturity bucket h, and quarter t. The median, standard deviation, 5th percentile, and 95th percentile are provided. The total elasticity is the weighted median elasticity, using the weights of each sector defined in the last column. The quarterly sample period is 2009q1-2019q4.

	obs	median	std.dev.	p5	p95	weights
Banks euro	213	14.95	12.58	8.61	47.99	15
Foreign investors	260	3.53	2.21	2.11	9.35	55
Mutual funds euro	260	1.11	0.11	1.06	1.41	16
P&I euro (non-NL)	260	-2.07	4.21	-14.22	-0.75	10
Other euro	245	1.63	1.23	1.03	4.78	4
Total		**4.31**				100

Table 9. **Separation of P&I swap portfolio by counterparty**: This table divides the total notional amount of P&Is' swap positions by counterparty types in percentage points. The sectors considered are banks in the euro area, mutual funds in the euro area, P&Is in the euro area except those in the Netherlands, pension funds in the Netherlands, insurance companies in the Netherlands, other euro area investors, and foreign investors. Foreign investors are all investors that reside outside of the euro area. The last two rows break up the foreign investors into banks and non-banks. The results are reported for all swaps and broken down by maturity buckets. The notional amounts are based on Euribor plain vanilla swaps. The data is from EMIR and averaged over the period 2018q1-2019q4.

	All	$(1,5]$	$(5,10]$	$(10,15]$	$(15,20]$	$(20,25]$	$(25,30]$	$(30,\infty)$
Banks euro	34.96	28.67	39.09	35.07	37.01	33.68	40.08	36.94
Mutual funds euro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P&I euro (except NL)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Pension funds NL	8.47	6.02	9.65	9.18	6.56	10.92	12.15	5.25
Insurance companies NL	3.80	3.32	2.33	4.11	4.69	3.29	6.61	5.52
Other euro	0.54	0.26	0.47	0.49	1.40	0.56	0.94	4.18
Foreign investors:	52.23	61.73	48.45	51.14	50.34	51.56	40.23	48.10
Banks	51.42	61.01	47.91	50.83	49.76	50.54	37.96	46.77
Non-banks	0.81	0.72	0.54	0.31	0.59	1.02	2.27	1.32

Table 10. **Effects of the UFR at the European level**: This table shows the effects of the UFR on yield spreads for a panel of European countries over the period 2006-2020 (annual). The UFR equals one as of the announcement of the UFR as part of the Solvency II regulation in August, 2015, except for the countries Denmark, the Netherlands, and Sweden where the dummy equals one as of June 2012, July 2012, and February 2013, respectively. Size IC market equals the size of the insurance market relative to debt in 2015. Controls include the 10-2y government bond spread, debt-to-GDP ratio, CDS spread, and age of the population. Standard errors are clustered at the country level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Spread 30-20y		**Spread 20-10y**		**Spread 30-10y**	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	0.1278***		0.1879***		0.3157***	
	[3.34]		[2.60]		[3.56]	
size IC market	-0.0596***		0.0744		0.0148	
	[-2.62]		[1.50]		[0.26]	
size IC market × UFR	0.0511*	0.0656***	-0.1043*	-0.1052**	-0.0532	-0.0396
	[1.81]	[2.63]	[-1.71]	[-2.27]	[-0.75]	[-0.71]
10-2y spread	0.0477***	0.0508***	-0.012	-0.0216	0.0357	0.0291
	[7.06]	[9.36]	[-0.66]	[-0.94]	[1.54]	[1.05]
Debt to GDP	0.0007	0.0017	0.0031***	0.0027	0.0038***	0.0045
	[1.55]	[1.60]	[4.00]	[1.22]	[3.61]	[1.60]
CDS	-0.0005***	-0.0004***	-0.0009***	-0.0009**	-0.0013***	-0.0013***
	[-4.23]	[-4.09]	[-3.38]	[-2.57]	[-3.79]	[-2.93]
Age	-0.0019	-0.0336	0.011	0.0234	0.0091	-0.0102
	[-0.37]	[-1.50]	[1.09]	[0.82]	[0.84]	[-0.32]
Country FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	286	286	286	286	286	286
adj. R-squared	0.829	0.865	0.416	0.525	0.705	0.752

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Appendix A Further details on the UFR

The UFR was initially discussed as part of the Long-Term Guarantee Assessment (LTGA) of the Solvency II regulation. EIOPA proposed the regulatory discount curve based on the UFR method in 2010 and the official announcement of the adoption of the UFR was made in August 2015. There are three important decisions that policymakers have to make when introducing the UFR: the level of the UFR, the point on the curve at which the UFR method starts, and the interpolation method or the convergence path. The initial EIOPA proposals are first discussed in detail.

The UFR was initially set at 4.2 percent which is based on 2 percent expected inflation and a 2.2 percent historical average of the real short interest rate. The expected inflation rate aligns with the ECB's target inflation. The real interest rate is based on a study by Dimson et al. (2002). The point of the curve at which the UFR method starts was set at 20 years and the convergence period at 40 years. The extrapolation method proposed by EIOPA is the Smith-Wilson technique. The Smith-Wilson technique uses the forward rate for the time-to-maturity of 19 to 20 years and the UFR to compute the yield curve. This technique assumes that the convergence parameter that defines how quickly the discount curve converges to the UFR equals $\alpha = 0.1$. Table A1 shows the weights assigned to the UFR that follow from the Smith-Wilson technique, where the weights are fixed and increase in h. Formally the weights equal:

$$w_h = \frac{f_{h-1}^{h,SW} - f_{19}^{20}}{f_{60}^{61,SW} - f_{19}^{20}} \qquad \text{for} \qquad h = 21, ..., 60, \tag{A.1}$$

where $f_{h-1}^{h,SW}$ are the one year forward rates that follow from the Smith-Wilson method.[49]

[49] The Smith-Wilson technique is described in an EIOPA paper: 'QIS 5 Risk-free interest rates – Extrapolation method': EIOPA UFR.

Appendix B Model

In this section, I derive my main testable predictions described in Section III for the full model. I then close the model by introducing an arbitrageur and perform a simple calibration of the model to study the model-implied effects of the regulatory reform on the yield curve.

The financial market

The financial market consists of a risky asset and a set of bonds. The risky asset is denoted by S_t and its corresponding return by r^S_{t+1}. The set of bonds is denoted by B_t, and each bond is characterized by its maturity h and corresponding yield $y_t^{(h)}$. The return on each bond is defined as:

$$r_{t+1}^{(h-1)} = \ln(\frac{P_{t+1}^{(h-1)}}{P_t^{(h)}}) = y_t^{(h)} - (h-1)[y_{t+1}^{(h-1)} - y_t^{(h)}]. \tag{A.2}$$

The vector of maturities is denoted by $\mathbf{h}$, the vector of bond yields is denoted by $\mathbf{y}_t$, bond returns by $\mathbf{r}^B_{t+1}$, the return expectations by $\mathbb{E}_{it}[\mathbf{r}^B_{t+1}]$, and the covariance matrix by $\text{Var}_{it}[\mathbf{r}^B_{t+1}]$. I assume that the bond returns are imperfectly correlated,[50] while the risky asset and the set of bonds are uncorrelated. Furthermore, I assume throughout that the yield curve can be determined using this set of bonds.

Long-term investors

The wealth of the long-term investor evolves as follows:

$$A_{i,t+1} = \Big(1 + r_f + w^S_{it}(r^S_{t+1} - r_f) + \mathbf{w}^{B\prime}_{it}(\mathbf{r}^B_{t+1} - r_f\mathbf{1})\Big)A_{it}, \tag{A.3}$$

where r_f equals the risk-free interest rate, w^S_{it} equals the portfolio weight to risky assets, and $\mathbf{w}^B_{it}$ equals the vector of portfolio weights to bonds for investor $i = 1, ..., N$.

For the liabilities, I assume that P&Is have to pay out a fixed set of time-invariant cash flows each period that is characterized by the vector $\mathbf{CF}_i$ and its elements $\text{CF}_i(h)$, that is, the cash flows for maturity h. A high cash flow $\text{CF}_i(h)$ relative to the sum of the total cash flows $\sum_{h=1}\text{CF}_i(h)$ means that a large fraction of the liabilities are due at maturity h.[51]

[50] In Section B, I estimate the variance-covariance matrix by taking a set of government bonds and assuming that yields follow a VAR(1) model.

[51] This assumption is realistic, because the pension funds are defined benefit in nature and insurance companies were not allowed to use variable annuities until 2016.

Hence, the economic value of the liabilities at time t equals:

$$L_{it}^E = \sum_{h=0} \mathrm{CF}_i(h) \exp(-hy_t^{(h)}). \tag{A.4}$$

A first-order Taylor expansion in $hy_t^{(h)}$ results in the following economic value of the liabilities at time $t+1$:

$$\begin{aligned} L_{i,t+1}^E &\approx \sum_{h=1} \mathrm{CF}_i(h) \exp(-hy_t^{(h)}) \Big(1 + y_t^{(h)} - (h-1)(y_{t+1}^{(h-1)} - y_t^{(h)})\Big) \\ &= \mathbf{a}_{it}'(\mathbf{1} + \mathbf{r}_{t+1}^B) L_{it}^E, \end{aligned} \tag{A.5}$$

where

$$a_{it}(h) = \frac{\mathrm{CF}_i(h) \exp(-hy_t^{(h)})}{L_{it}^E}. \tag{A.6}$$

The regulatory discount curve diverges from its economic counterpart in that its sensitivity to the market interest rate changes is different. The sensitivity of the regulatory discount curve to market interest rates is defined by $\boldsymbol{\xi}_L$, where $\boldsymbol{\xi}_L$ has the same length as the set of bonds. This sensitivity means that the economic and regulatory value of the liabilities are identical if $\xi_L(h) = 1$ for all h, which was the case prior to the regulatory reform. The regulatory reform that is the focus of this study indicates $\xi_L(h) = 1$ for $h < 20$, $\xi_L(h) > 1$ for $h = 20$, and $\xi_L(h) < 1$ for $h > 20$. Specifically, for the 20-year maturity, the sensitivity increases with the total sum of one minus the weights assigned to the UFR: $\xi_L(20) = \sum_{h=21}^{60} 1 - w^{UFR}(h)$, with the weights assigned to the UFR as described in Section II. For maturities beyond 20 years, $\xi_L(h) = 1 - w^{UFR}(h)$. Moreover, the market interest rate in (A.5) is replaced with the 20-year interest rate for maturities beyond 20 years. Thus, for the regulatory value of the liabilities we have:

$$L_{it}^R = \sum_{h=0} \mathrm{CF}_i(h) \exp\Big(-h\big(\mathbb{1}_{h<20} y_t^{(h)} + \mathbb{1}_{h\geq 20}\{\xi_L(h) y_t^{(20)} + (1 - \xi_L(h))UFR\}\big)\Big), \tag{A.7}$$

where UFR is a constant. A first-order Taylor expansion in $hy_t^{(h)}$ for maturities below 20 years and in $hy_t^{(20)}$ for maturities as of 20 years results in the following evolution of the regulatory liability value over time:

$$L_{i,t+1}^R \approx \Big(\mathbb{1}_{h<20} \mathbf{a}_{it}'(\mathbf{1} + \mathbf{r}_{t+1}^B) + \mathbb{1}_{h\geq 20} \mathbf{a}_{it}'(\mathbf{1} + \boldsymbol{\xi}_L r_{t+1}^{20})\Big) L_{it}^R. \tag{A.8}$$

Further, I assume P&Is have mean-variance preferences over the assets minus liabilities or the surplus, which is similar to Sharpe and Tint (1990) and Hoevenaars et al. (2008). Following Koijen and Yogo (2015), I also assume P&Is care about the volatility in the regulatory funding ratio. P&Is have to make important decisions that are based on their funding positions, such as the amount of dividends to pay to shareholders or the ability to index pension rights. The optimization problem of P&Is then equals:

$$\begin{aligned} \max_{\mathbf{w}_{it}} \quad & V(\mathbf{w}_{it}) \\ = \quad & \max_{\mathbf{w}_{it}} \mathbb{E}_{it}[\frac{A_{i,t+1}}{A_{it}}] - \frac{\gamma}{2}\text{Var}_{it}[\frac{A_{i,t+1}}{A_{it}} - \frac{L^E_{i,t+1}}{A_{it}}] - \frac{\lambda(F^R_{it})}{2}\text{Var}_{it}[\frac{A_{i,t+1}}{A_{it}} - \frac{L^R_{i,t+1}}{A_{it}}], \end{aligned} \tag{A.9}$$

where γ equals the risk-aversion parameter, $F^R_{it} = \frac{A_{it}}{L^R_{it}}$, and $\lambda(F^R_{it})$ defines the importance of the regulatory funding ratio. As in Koijen and Yogo (2016) and Sen (2022), I assume that the variance of the regulatory funding ratio is proportional to $\lambda(F^R_{it})$ where $\lambda'(F^R_{it}) < 0$; or in other words P&Is care more about the regulatory funding ratio when its low. To keep the model tractable, the functional form of $\lambda(F^R_{it})$ is a reduced form of the strict constraint that the funding ratio should be higher than a certain threshold (e.g. Leibowitz and Henriksson 1989).

Solution to the optimization problem of long-term investors

For ease of notation, the proof of the optimization problem (A.9) is based on a more general form of the regulatory value of the liabilities in Equation (A.8): $L^R_{i,t+1} = \mathbf{a}'_{it}(\mathbf{1} + \boldsymbol{\xi}'_L \mathbf{r}^L_{t+1})L^R_{it}$, where $\mathbf{r}^L_{t+1}$ is a vector of liability returns that is uncorrelated with the risky asset S and the same length as the set of bonds B. Following the proof below and substituting other forms of the regulatory value of the liabilities automatically leads to the correct specification of the optimal portfolio holdings.

The objective equals:

$$\begin{aligned} V(\mathbf{w}_{it}) \quad = \quad & 1 + r_f + \mathbf{w}'_{it}\mathbb{E}_{it}[\mathbf{r}_{t+1} - r_f\mathbf{1}] \\ - \quad & \frac{\gamma}{2}\Big(\mathbf{w}'_{it}\text{Var}_{it}[\mathbf{r}_{t+1}]\mathbf{w}_{it} + \mathbf{a}'_{it}\text{Var}_{it}[\mathbf{r}^L_{t+1}]\mathbf{a}_{it}\frac{1}{F^E_{it}} - 2\mathbf{w}'_{it}(\mathbf{a}_{it} \circ \text{Cov}_{it}[\mathbf{r}^L_{t+1}, \mathbf{r}_{t+1}])\frac{1}{F^E_{it}}\Big) \\ - \quad & \frac{\lambda(F^R_{it})}{2}\Big(\mathbf{w}'_{it}\text{Var}_{it}[\mathbf{r}_{t+1}]\mathbf{w}_{it} + (\mathbf{a}_{it} \circ \boldsymbol{\xi}_L)'\text{Var}_{it}[\mathbf{r}^L_{t+1}](\mathbf{a}_{it} \circ \boldsymbol{\xi}_L)\frac{1}{F^R_{it}} \\ - \quad & 2\mathbf{w}'_{it}(\mathbf{a}_{it} \circ \boldsymbol{\xi}_L \circ \text{Cov}_{it}[\mathbf{r}^L_{t+1}, \mathbf{r}_{t+1}])\frac{1}{F^R_{it}}\Big). \end{aligned} \tag{A.10}$$

Taking the derivative with respect to w_t^S and w_t^B gives:

$$\frac{\partial V(w_{it}^S)}{\partial w_{it}^S} = \mathbb{E}_{it}[r_{t+1}^S - r_f] - (\gamma + \lambda(F_{it}^R))\text{Var}_{it}[r_{t+1}^S]w_{it}^S = 0, \tag{A.11}$$

$$\begin{aligned}\frac{\partial V(\mathbf{w}_{it}^B)}{\partial \mathbf{w}_{it}^B} &= \mathbb{E}_{it}[\mathbf{r}_{t+1}^B - r_f\mathbf{1}] - (\gamma + \lambda(F_{it}^R))\text{Var}_{it}[\mathbf{r}_{t+1}^B]\mathbf{w}_{it}^B - \gamma\mathbf{a}_{it} \circ \text{Cov}_{it}[\mathbf{r}_{t+1}^L, \mathbf{r}_{t+1}^B]\frac{1}{F_{it}^E} \\ &- \lambda(F_{it}^R)(\mathbf{a}_{it} \circ \boldsymbol{\xi}_L \circ \text{Cov}_{it}[\mathbf{r}_{t+1}^L, , \mathbf{r}_{t+1}^B])\frac{1}{F_{it}^R} = 0. \end{aligned} \tag{A.12}$$

This results in the optimal weights:

$$w_{it}^{S*} = \underbrace{\frac{\mathbb{E}_{it}[r_{t+1}^S - r_f]}{(\gamma + \lambda(F_{it}^R))\text{Var}_{it}[r_{t+1}^S]}}_{\text{speculative portfolio}}, \tag{A.13}$$

$$\begin{aligned}\mathbf{w}_{it}^{B*} &= \underbrace{\frac{\mathbb{E}_{it}[\mathbf{r}_{t+1}^B - r_f\mathbf{1}]}{(\gamma + \lambda(F_{it}^R))\text{Var}_{it}[\mathbf{r}_{t+1}^B]}}_{\text{speculative portfolio}} + \underbrace{\frac{\gamma}{\gamma + \lambda(F_{it}^R)}\frac{1}{F_{it}^E}\mathbf{a}_{it} \circ \frac{\text{Cov}_{it}[\mathbf{r}_{t+1}^B, \mathbf{r}_{t+1}^L]}{\text{Var}_{it}[\mathbf{r}_{t+1}^B]}}_{\text{economic hedging portfolio}} \\ &+ \underbrace{\frac{\lambda(F_{it}^R)}{\gamma + \lambda(F_{it}^R)}\frac{1}{F_{it}^R}(\mathbf{a}_{it} \circ \boldsymbol{\xi}_L \circ \frac{\text{Cov}_{it}[\mathbf{r}_{t+1}^B, \mathbf{r}_{t+1}^L]}{\text{Var}_{it}[\mathbf{r}_{t+1}^B]})}_{\text{regulatory hedging portfolio}}, \end{aligned} \tag{A.14}$$

where ($\circ$) equals the Hadamard product.

Using the regulatory value of the liabilities in Equation (A.8), we get:

$$w_{it}^{S*} = \underbrace{\frac{\mathbb{E}_{it}[r_{t+1}^S - r_f]}{(\gamma + \lambda(F_{it}^R))\text{Var}_{it}[r_{t+1}^S]}}_{\text{speculative portfolio}}, \tag{A.15}$$

$$\begin{aligned}\mathbf{w}_{it}^{B*} &= \underbrace{\frac{\mathbb{E}_{it}[\mathbf{r}_{t+1}^B - r_f\mathbf{1}]}{(\gamma + \lambda(F_{it}^R))\text{Var}_{it}[\mathbf{r}_{t+1}^B]}}_{\text{speculative portfolio}} + \underbrace{\frac{\gamma}{\gamma + \lambda(F_{it}^R)}}_{\text{economic hedge portfolio}}\mathbf{a}_{it}\frac{1}{F_{it}^E} \\ &+ \underbrace{\frac{\lambda(F_{it}^R)}{\gamma + \lambda(F_{it}^R)}\mathbf{a}_{it}\frac{1}{F_{it}^R} \circ \left(\mathbb{1}_{h<20}\mathbf{1} + \mathbb{1}_{h\geq 20}\,\boldsymbol{\xi}_L \circ \frac{\text{Cov}_{it}[r_{t+1}^{20}\mathbf{1}, \mathbf{r}_{t+1}^B]}{\text{Var}_{it}[\mathbf{r}_{t+1}^B]}\right)}_{\text{regulatory hedge portfolio}}. \end{aligned} \tag{A.16}$$

Prior to the UFR, the regulatory funding ratio exactly equaled the economic funding ratio, that is, $F^E_{it} = F^R_{it}$, and the optimal weights were a simpler version of (A.16):

$$\mathbf{w}^{B*}_{it} = \underbrace{\frac{\mathbb{E}_{it}[\mathbf{r}^B_{t+1} - r_f \mathbf{1}]}{(\gamma + \lambda(F^E_{it}))\mathrm{Var}_{it}[\mathbf{r}^B_{t+1}]}}_{\text{speculative portfolio}} + \underbrace{\mathbf{a}_{it}\frac{1}{F^E_{it}}}_{\text{hedging portfolio}}. \tag{A.17}$$

I now move on to characterize the change in demand. Throughout I indicate variables after implementation of the UFR with a plus sign ($^+$). Subtracting the optimal weights prior to the UFR (A.17) from (A.16), the change in bond holdings due to the the regulatory reform becomes:

$$\begin{aligned}\mathbf{c}_{it} = \mathbf{w}^{B*+}_{it} - \mathbf{w}^{B*}_{it} &= \underbrace{\frac{\mathbb{E}_{it}[\mathbf{r}^B_{t+1} - r_f \mathbf{1}]}{\mathrm{Var}_{it}[\mathbf{r}^B_{t+1}]}\left(\frac{1}{\gamma + \lambda(F^R_{it})} - \frac{1}{\gamma + \lambda(F^E_{it})}\right)}_{\Delta \text{ in speculative demand}} \\ &+ \underbrace{\frac{\lambda(F^R_{it})}{\gamma + \lambda(F^R_{it})}\left(\mathbf{a}_{it}\frac{1}{F^R_{it}} \circ \left(\mathbb{1}_{h<20}\mathbf{1} + \mathbb{1}_{h\geq 20}\,\boldsymbol{\xi}_L \circ \frac{\mathrm{Cov}_{it}[r^{20}_{t+1}\mathbf{1}, \mathbf{r}^B_{t+1}]}{\mathrm{Var}_{it}[\mathbf{r}^B_{t+1}]}\right) - \mathbf{a}_{it}\frac{1}{F^E_{it}}\right)}_{\Delta \text{ in liability hedge demand}}.\end{aligned} \tag{A.18}$$

The speculative demand increases at all maturities, because $F^E_{it} < F^R_{it}$. For long maturities, $\lim_{h\to 60} \xi_L(h) \to 0$, and thus liability hedging demand declines with $\frac{\lambda(F^R_{it})}{\gamma+\lambda(F^R_{it})} a_{it}(h)\frac{1}{F^E_{it}}$. As shown in Section II, the regulatory reform decreases the liability values by 4 percent on average, and thus increases the regulatory funding ratio by approximately the same amount. However, the sensitivity to long-term interest rates declines by 22 percent (Table 1). As such, the decline in the liability hedging demand is much stronger than the increase in speculative demand. On the other hand, for maturities that are close to 20 years, $\lim_{h\to 20} \xi_L(h) \to \sum_{h=21}^{60} 1 - w^{UFR}(h) = 8.421$ (using the weights in Table A1), and therefore the liability hedging demand increases by $\frac{\lambda(F^R_{it})}{\gamma+\lambda(F^R_{it})} a_{it}(h)\left(\frac{1}{F^R_{it}}\xi_L(h) - \frac{1}{F^E_{it}}\right) > 0.$[52]

Finally, the model predicts a positive change in the risky asset holdings, because the regulatory reform led to a direct capital relief ($\lambda(F^R_{it}) < \lambda(F^E_{it})$):

$$c^S_{it} = w^{S*+}_{it} - w^{S*}_{it} = \frac{\mathbb{E}_{it}[r^S_{t+1} - r_f]}{\mathrm{Var}_{it}[r^S_{t+1}]}\left(\frac{1}{\gamma + \lambda(F^R_{it})} - \frac{1}{\gamma + \lambda(F^E_{it})}\right) > 0. \tag{A.19}$$

[52]The regulatory funding ratio for the average P&I goes from 0.99 to 1.03, and as such the inverse of the regulatory funding ratio decreases from 1.01 to 0.96. Thus, $\frac{1}{F^R_{it}}\xi_L(h) - \frac{1}{F^E_{it}} >> 0$.

Testable model implications

I now move on to derive the model predictions stated in Section III.

Prediction 1 - *P&Is with long liability durations reduce their long-term bond holdings and increase those with maturities close to 20 years more compared to P&Is with short liability durations.*

We have that:

$$\lim_{h \to 60} \xi_L(h) \to 0,$$

and hence P&Is with large projected cash flows $a_{it}(h)$ in the distant future decrease long-term bond holdings to a larger extent than those with little distant cash flows, because of a stronger reduction in interest rate sensitivities of the liabilities for the former group. Formally, we have that:

$$\lim_{h \to 60, a_{it}(60) \to 1} c_{it}(h) = -\frac{\lambda(F_{it}^R)}{\gamma + \lambda(F_{it}^R)} \frac{1}{F_{it}^E} < \lim_{h \to 60, a_{it}(60) \to 0} c_{it}(h) = 0.$$

Empirically, the distribution of cash flow payments is measured by the liability duration. Hence, my model predicts that P&Is with long liability durations decrease long-term bond holdings more than the ones with short liability durations.

At the same time,

$$\lim_{h \to 20} \xi_L(h) \to 8.41,$$

and hence the demand for bonds with maturities close to 20 years increases more for P&Is with long liability durations specifically because of a larger increase in sensitivity to the 20 year interest rate for those P&Is. Formally, we have that:

$$\lim_{h \to 20, a_{it}(20) > 0} c_{it}(h) = \frac{\lambda(F_{it}^R)}{\gamma + \lambda(F_{it}^R)} a_{it}(h) \Big(\frac{1}{F_{it}^R} \xi_L(h) - \frac{1}{F_{it}^E} \Big) > \lim_{h \to 20, a_{it}(20) \to 0} c_{it}(h) = 0.$$

Prediction 2 - *P&Is with long liability durations increase their risky asset holdings more compared to P&Is with short liability durations.*

Because of a larger capital relief for P&Is with long liability durations as opposed to those with short liability durations, the weight that is assigned to the regulatory hedging demand, $\lambda(F_{it}^R)$, decreases more rapidly for the former group. Formally, the change in the regulatory interest rates is ($UFR = 4.2$ percent):

$$\begin{aligned}
&\lim_{h\to 0} \quad \Big(\xi_L(h)y_t^{(h)} + \big(1-\xi_L(h)\big)UFR\Big) - y_t^{(h)} = 0,\\
&\lim_{h\to 60} \quad \Big(\xi_L(h)y_t^{(h)} + \big(1-\xi_L(h)\big)UFR\Big) - y_t^{(h)} = UFR - y_t^{(h)} > 0.
\end{aligned}$$

Hence, the P&Is with cash flows in the more distant future have a stronger capital relief which, in turn, leads to a higher allocation of risky assets. Formally, if $a_{it}(h)$ is large for $h > 20$, then $F_{it}^R > F_{it}^E$; but if $a_{it}(h)$ is small for $h > 20$, then $F_{it}^R \approx F_{it}^E$. Therefore, following Equation (A.19), the change in risky asset holdings is:

$$\lim_{h\to 60, a_{it}(h)\to 1} c_{it}^S = \frac{\mathbb{E}_{it}[r_{t+1}^S - r_f]}{\text{Var}_{it}[r_{t+1}^S]}\Big(\frac{1}{\gamma + \lambda(F_{it}^R)} - \frac{1}{\gamma + \lambda(F_{it}^E)}\Big) > \lim_{h\to 60, a_{it}(h)\to 0} c_{it}^S = 0.$$

Prediction 3 - *P&Is close to their solvency constraint reduce their long-term bond holdings and increase those with maturities close to 20 years more compared to unconstrained P&Is.*

Constrained P&Is put a larger weight on the regulatory hedge demand compared to unconstrained ones, and only the regulatory hedging demand is affected by the UFR. Formally, the change in demand for unconstrained investors converges to zero at all maturities:

$$\lim_{\lambda(F_{it}^R)\to 0} \mathbf{c}_{it} = 0.$$

Constrained investors have for their long-term holdings the following:

$$\lim_{h\to 60, \lambda(F_{it}^R)\to\infty} c_{it}(h) = -a_{it}(h)\frac{1}{F_{it}^E} < 0.$$

At the same time, the assets with maturities close to 20 years have ($\lim_{h\to 20}\xi_L(h) \to 8.41$):

$$\lim_{h\to 20, \lambda(F_{it}^R)\to\infty} c_{it}(h) \quad = \quad a_{it}(h)\Big(\frac{1}{F_{it}^R}\xi_L(h) - \frac{1}{F_{it}^E}\Big) > 0.$$

At the limit, unconstrained investors do not decrease long-term bond holdings nor increase those with maturities close to 20 years, but constrained P&Is do.

Model implied term structure of interest rates

So far, I have shown the implications of the regulatory reform for demand. The final step is to close the model by imposing market clearing and derive the effect of the regulatory reform on yields. In order to achieve this goal, I introduce a representative myopic investor, or an arbitrageur, and impose market clearing as in Vayanos and Vila (2021). This approach means that the change in holdings by the long-term investors has to be absorbed by a representative myopic investor. As for the long-term investors, I assume that the myopic investor has mean-variance preferences over excess returns. Moreover, the investors do not face borrowing or short-sale constraints. Therefore, the optimal portfolio equals:

$$\boldsymbol{\alpha}_t^{B*} = \frac{\mathbb{E}_t[\mathbf{r}_{t+1}^B - r_f\mathbf{1}]}{\gamma \text{Var}_t[\mathbf{r}_{t+1}^B]} \tag{A.20}$$

First, the two set of investors in the market have to clear, and thus the market clearing condition implies:

$$\boldsymbol{\alpha}_t^{B*} B_t + \sum_{i=1}^{N} \mathbf{w}_{it}^{B*} A_{it} = \mathbf{Q}_t, \tag{A.21}$$

where B_t denotes the total wealth of the myopic investors and $\mathbf{Q}_t$ denotes the vector of total supply, whereby $Q_t(h)$ indicates total supply for maturity h.

Plugging in the optimal solution of the myopic investor in Equation (A.20), solving for $\mathbf{y}_t$, and using Equation (A.2) results in:

$$\mathbf{y}_t - r_f = \frac{(\mathbf{h}-\mathbf{1})\mathbb{E}_t[\mathbf{y}_{t+1}^B - r_f]}{\mathbf{h}} + \frac{\mathbf{Q}_t - \sum_{i=1}^{N} \mathbf{w}_{it}^{B*} A_{it}}{B_t} \frac{\gamma \text{Var}_t[\mathbf{y}_{t+1}](\mathbf{h}-\mathbf{1})(\mathbf{h}-\mathbf{1})'}{\mathbf{h}}. \tag{A.22}$$

For the changes in yields that result from the implementation of the UFR we get:

$$\mathbf{y}_t^{+} - \mathbf{y}_t = \underbrace{\frac{(\mathbf{h}-\mathbf{1})(\mathbb{E}_t^{+}[\mathbf{y}_{t+1}^B] - \mathbb{E}_t[\mathbf{y}_{t+1}^B])}{\mathbf{h}}}_{\text{change expectations}} + \underbrace{\frac{1}{B_t} \frac{\gamma \text{Var}_t[\mathbf{y}_{t+1}](\mathbf{h}-\mathbf{1})(\mathbf{h}-\mathbf{1})'}{\mathbf{h}} \sum_{i=1}^{N} \mathbf{c}_{it} A_{it}}_{\text{change risk-bearing capacity}} \tag{A.23}$$

Assuming that interest rate expectations did not change because of the implementation of the UFR[53], the change in yields equals:

$$\mathbf{y}_t^{+} - \mathbf{y}_t \;=\; -\frac{1}{B_t}\frac{\gamma \mathrm{Var}_t[\mathbf{y}_{t+1}](\mathbf{h}-\mathbf{1})(\mathbf{h}-\mathbf{1})'}{\mathbf{h}}\sum_{i=1}^{N}\mathbf{c}_{it}A_{it}, \tag{A.24}$$

where B_t is the aggregate wealth of the arbitrageurs and the other variables are as defined in Section III.

I calibrate the effect on the yield curve by making the following assumptions. First, as is common in the asset pricing literature, I set $\gamma = 3$. I estimate the covariance matrix by using a VAR(1) model.[54] For the VAR(1) model, I use the daily 1, 3, 5, 10, 15, 20, and 30-year Dutch zero-coupon bond yields obtained from Bloomberg over the period 1998 to June 30, 2012, when the UFR was implemented.

For the calibration of the model implied term structure of interest rates, I assume that yields only change because of a change in risk-bearing capacity. Further, I estimate the covariance matrix using a VAR(1) model that uses the 1, 3, 5, 10, 15, 20 and 30-year Dutch zero-coupon bond yields over the period 1998 to June 30, 2012, when the UFR was implemented. I also assume the off-diagonals of the VAR(1) are zero, because the off-diagonal elements have a negligible effect on the conditional variances. Therefore, the VAR(1) looks as follows:

$$\begin{bmatrix} y_{t+1}^{(1)} \\ y_{t+1}^{(3)} \\ \vdots \\ y_{t+1}^{(30)} \end{bmatrix} = \begin{bmatrix} \alpha^{(1)} \\ \alpha^{(3)} \\ \vdots \\ \alpha^{(30)} \end{bmatrix} + \begin{bmatrix} \rho^{(1)} & 0 & \dots & 0 \\ 0 & \rho^{(3)} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \rho^{(30)} \end{bmatrix} \begin{bmatrix} y_t^{(1)} \\ y_t^{(3)} \\ \vdots \\ y_t^{(30)} \end{bmatrix} + \begin{bmatrix} \epsilon_{t+1}^{(1)} \\ \epsilon_{t+1}^{(3)} \\ \vdots \\ \epsilon_{t+1}^{(30)} \end{bmatrix}. \tag{A.25}$$

The conditional covariance matrix $\mathrm{Var}_t[\mathbf{y}_{t+1}]$ is then determined by the covariance matrix of the error terms, multiplied by 252 to convert daily covariances to yearly ones.

The aggregate demand shock $\sum_{i=1}^{N}\mathbf{c}_{it}A_{it}$ and the wealth of the arbitrageurs B_t is taken relative to total Dutch debt. Therefore, the demand shock $\sum_{i=1}^{N}\mathbf{c}_{it}A_{it}$ is equal to the total increase (decline) in 20 (30) year bond holdings as estimated in Section V relative to the total amount outstanding. These estimates consider $\sum_{i=1}^{N}A_{it}\mathbf{c}_{it}(20) = 26\%$ and $\sum_{i=1}^{N}A_{it}\mathbf{c}_{it}(30) = -22\%$, while $\sum_{i=1}^{N}A_{it}\mathbf{c}_{it}(h) = 0$ for $h = 1, 3, 5, 10, 15$. For the wealth of the arbitrageurs, suppose, as in Vayanos and Vila (2021), that the arbitrageurs are the hedge funds. Their wealth equaled 19.8 billion and total Dutch debt equaled 280 billion in 2012. These values

[53] If anything, changes in expectations would amplify the yield effects that I calibrate.

[54] I leave to future research a full calibration of the model where yields are derived endogenously as in Vayanos and Vila (2021).

mean that the arbitrageurs' wealth equals 7.07% of the total Dutch debt.[55]

Figure A1 shows the actual yield curve prior to the regulatory reform and the calibrated yield curve after the change. Yields at shorter maturities went up, because the negative shock to the 30-year yield outweighs the positive shock to the 20-year yield at shorter maturities due to a higher conditional covariance of short maturity bond returns with the 30-year bond return than with the 20-year one (i.e., longer maturity bonds are riskier). For maturities beyond 20 years, the yield curve moves from a hump-shaped pattern to an upward sloping pattern. Because the data do not allow for precisely pinning down the fraction of arbitrageurs, I also estimate the change in the yield curve using the upper bound for the fraction of arbitrageurs equal to 29.5% as used in Vayanos and Vila (2021). In that case, the yield effects are substantially smaller, but the change from an inverted yield curve to an upward sloping one remains visible. As Figure A2 shows, the model-implied change in the shape of the yield curve is consistent with the observed change in the shape of the yield curve after the implementation of the regulatory reform.

[**Place Figure A1-A2 about here**]

[55] For the total wealth of hedge funds in 2012 in the Netherlands, see, for instance, https://www.bnr.nl/nieuws/beurs/10167851/pensioenbeheerders-spekken-hedgefondsen and https://financieel-management.nl/artikelen/cijfers-dnb-vermogen-hedgefondsen-stijgt-opnieuw/.

Appendix C Derivation demand-based asset pricing model

This section derives the characteristics-based demand system in the traditional Koijen and Yogo (2019) framework.

As for the analysis at the maturity bucket level, the portfolio weight of investor i in bond s is denoted by $w_{it}(s)$:

$$w_{it}(s) = \frac{\delta_{it}(s)}{1 + \sum_{m \in N_{it}} \delta_{it}(m)}, \tag{A.26}$$

where N_{it} is the investment universe of investor i, $\delta_{it}(s) = w_{it}(s) w_{it}^{-1}(0)$ and $w_{it}(0) = 1 - \sum_{m \in N_{it}} w_{it}(m)$ equals the fraction invested in the outside asset. An investor i in my setting is a sector-country pair (e.g., German banks, Italian mutual funds).

Likewise, under the same assumptions as outlined in Section VI, the portfolio weights can be written as a logit function of yields and bond characteristics:

$$\ln \frac{w_{it}(s)}{w_{it}(0)} \quad = \quad \alpha_i + \beta_{0i} y_t(s) + \beta_{1i}' \mathbf{x}_t(s) + \epsilon_{it}(s). \tag{A.27}$$

The bond characteristics are the same as the bond characteristics used in Section VI: bond duration, convexity, coupon, and amount outstanding. In also include investor fixed effects to exploit the variation in holdings across bonds for the same investor.

The instrument proposed by Koijen and Yogo (2019) makes use of the investment mandates at the institutional level. Unfortunately, investment mandates are typically not observable, so one has to infer the universe from portfolio holdings. Persistent portfolio holdings are consistent with investors having investment mandates, i.e. investors stay away from certain bonds because they are not part of the index, have too low credit ratings, and so on. As pointed out in Section VI, the persistency in government bond holdings is not nearly as high as for equities (Koijen and Yogo 2019) and corporate bonds (Bretscher et al. 2020). Nevertheless, to benchmark the price elasticities found in Section VI, I apply this definition and aggregate over sector-country holdings for which I can plausibly assume fixed asset mandates. That is, I only aggregate over sector-country holdings for which at least 95 percent of the current bond holdings are included in the investment universe.

The instrument therefore equals:

$$z_{i,t}(s) = \ln \Big(\sum_{j \neq i} A_{jt} \frac{\mathbb{1}_{jt}(s)}{1 + \sum_{m=1}^{N} \mathbb{1}_{jt}(s)} \Big), \tag{A.28}$$

where A_{jt} equals the assets under management of investor j and the indicator function equals one if bond s at time t belongs to the investment universe of investor j. Differently put, if a bond is included in the investment universe of many investors and/or large investors, the bond has a large component of exogenous demand that's orthogonal to latent demand, but does generate higher (lower) prices (bond yields). Indeed, Table A6 confirms the negative relationship between the instrument and bond yields.

Appendix D Cleaning EMIR data

The EMIR, which is similar to the Dodd-Frank Act, introduced reporting requirements to make derivative markets more transparent.[56] The EMIR contains the derivative positions at the contract level of all counterparties for which at least one institution is established in Europe. Institutions report, among other things, the contract type (e.g., swaps, options, futures) and the details on the transaction such as notional, effective date, maturity date, information on price, payment frequencies, currencies, and the contract's counterparty.[57] The Dutch regulator receives data on those derivative contracts for which at least one counterparty is established in the Netherlands. The database allows me to study derivative positions and connect the derivative holdings of P&Is to their bond holdings by means of name matching.

For the purpose of this analysis, I focus on Euribor plain vanilla swaps for two main reasons. First, the regulatory discount curve is based on the euro swap curve; this basis means the best way to hedge liabilities is to buy into a receiver swap contract with underlying Euribor rates. Second, Euribor swaps represent over 70 percent of the total use of interest rate derivatives across P&Is which indeed indicates that P&Is primarily hedge their liabilities with swaps that use the Euribor as the underlying interest rate.

The EMIR database contains some quality issues with the data as acknowledged by, for instance, Perez-Duarte and Skrzypczynski (2019). Most importantly, I compute the market values of the swap contracts using the information available on each contract and compare these to the reported market values to correct for potential misreporting on the side of the swap contract (payer or receiver). A detailed explanation follows now.

1. EMIR contains double reporting. This reporting means that both counterparties of a derivative contract, counterparties A and B, have to report the trade. I assume that the perspective of counterparty A is always the correct one, so potential divergences in trade reports between counterparties A and B are ignored.

2. For the purpose of the analysis in this study, swaps based on Euribor are selected.

3. Exclude swap contracts with missing swap rates or floating rates (approximately 0.8 percent).

4. Exclude float-for-float swap contracts (approximately 0.7 percent).

[56]In response to the aftermath of the global financial crisis, regulators aimed to reduce risks and increase transparency in OTC derivative markets.

[57]For details on reporting requirement, see, for instance: https://www.esma.europa.eu/policy-rules/post-trading/trade-reporting.

5. Exclude swap contracts that start in the future (approximately 0.4 percent).
6. Exclude duplicate trades (approximately 0.24 percent).
7. Exclude the payment frequency of the swap contract if missing (approximately 0.01 percent).
8. Exclude swap contracts with negative notionals, notionals smaller than 1,000, and notionals larger than 10 billion (approximately 0.01 percent).
9. Exclude swap contracts for which the maturity date is missing or is prior to the reporting date (less than 0.005 percent).
10. Exclude swap contracts for which it is unclear if it is a receiver or payer swap (less than 0.005 percent).
11. Exclude inflation swap contracts (less than 0.005 percent).
12. Exclude swap contracts for which the effective date is missing (less than 0.005 percent).
13. Swap rates should be reported as percentages, so swap rates with an absolute value larger than 10 are divided by 100.

After conducting the cleaning steps above, I have a large database containing the swap contracts of all Dutch counterparties. I then assign the sector of each counterparty based on a list of LEI codes available through the DNB.

Institutions have to indicate whether they entered a receiver or payer swap by means of a variable that indicates if they receive the fixed rate or the floating rate. However, some institutions consistently report the opposite of the contract they actually entered. I can detect these mistakes, because institutions also report the market value of the derivative from their perspective. Hence, by computing the price of the swap contract based on the available data in EMIR and by comparing that with the reported market values, I can detect these errors. To do so, I compute the price of each swap contract in the following way:

$$V(t, r^{SW}, T_M) = wN\big(P_{r^{SW}}(t, T_M) - P_{FR}(t, T_M)\big), \tag{A.29}$$

where r^{SW} equals the swap rate; w indicates a receiver or payer swap: $w = 1(-1)$ receiver (payer) swap; $P_{r^{SW}}(t, T)$ is the price of the fixed-coupon bond at time t with maturity T_M; $P_{FR}(t, T)$ is the price of a floating rate bond at time t with maturity T; and N is the notional value.

The value of the floating rate bond at time t is calculated as:

$$\begin{cases} P_{FR}(t,T) = 1 & \text{for } t = T_i, T_{i+1} \\ P_{FR}(t,T) = (1 + \Delta^{FR} r_{1/\Delta^{FR}}(T_i))DF(t,T_{i+1}) & \text{for } T_i < t < T_{i+1} \end{cases} \tag{A.30}$$

where T_i is the payment date of the floating leg; T is the maturity date; Δ^{FR} is the payment frequency of the floating rate; $r_{1/\Delta^{FR}}(T_i)$ is the corresponding floating rate at time T_i; and $DF(t, T_{i+1})$ is the discount rate at time t with maturity T_{i+1}. The discount rate is based on the euro OIS zero curve from Bloomberg.

The value of the fixed-coupon bond at time t is calculated similarly:

$$P_{r^{SW}}(t,T) = (\Delta^{FI} r^{SW} \sum_{j=1}^{M} DF(t,T_j) + DF(t,T_M)), \tag{A.31}$$

where T_j indicates the payment date of the fixed leg and Δ^{FI} the payment frequency of the fixed leg.

If the sign of the market price that is calculated in Equation (A.29) differs from the reported market value by the institutions themselves in more than 85 percent of the total trades reported in one day, I assume that the reported market values by the institution are correct, and flip receiver (payer) swaps into payer (receiver) swaps.

Appendix E Additional Figures

Figure A1. **Calibration of the effect of the regulatory reform on the yield curve**

This graph depicts the actual yield curve prior to the regulatory reform (black line), the calibrated yield curve at the implementation of the UFR when arbitrageur wealth is assumed to be 7.07% of total Dutch debt (red dashed line), and the same calibrated yield curve when arbitrageur wealth is assumed to be 29.5% of total Dutch debt (blue dotted line). Yields are in percentages.

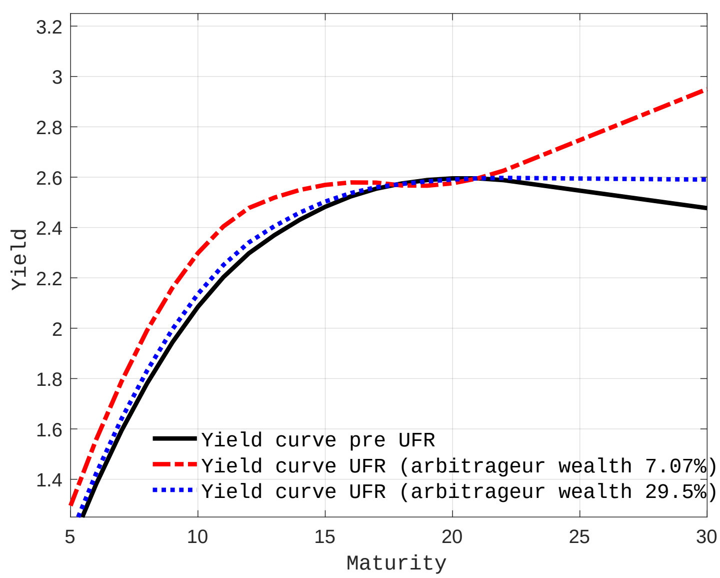
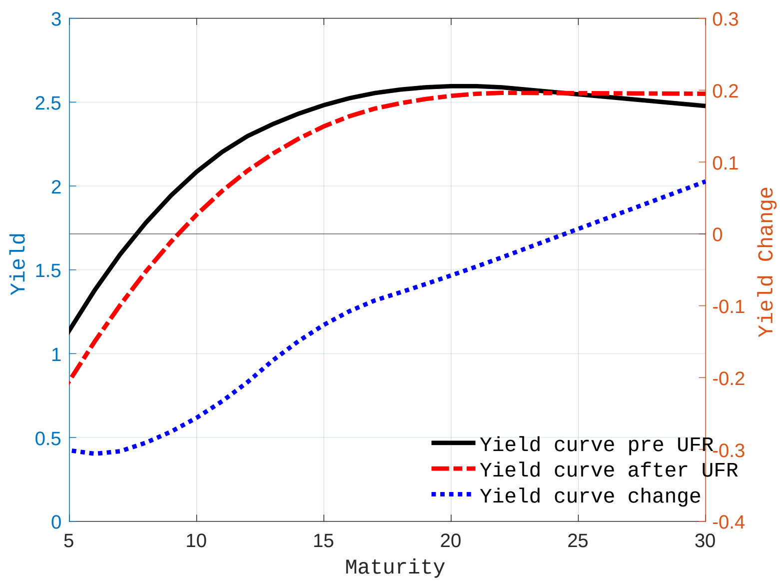


Figure A2. **Yield curve before and after the regulatory reform**

This graph depicts the observed yield curve five days prior to the announcement and implementation of the regulatory reform (black line) and five days after (red dashed line). The reform was announced and implemented on Monday July 2, 2022. The blue dotted line shows the difference in the two yield curves (right y-axis). Yields are in percentages.



Appendix F Additional tables

Table A1. **Weights UFR for the regulatory discount curve**: This table shows the weights assigned to the UFR to compute the regulatory discount curve. The weights beyond 60 years are equal to 1. The weights are fixed, derived using the Smith-Wilson technique, and set by the regulator: https://eerstekamer.nl/9370000/1/j4nvjlhjvvt9eu4_j9vvksvji1pf4wd/vj41egqaz5ze.

time-to-maturity	weight	time-to-maturity	weight
21	0.086	41	0.903
22	0.186	42	0.914
23	0.274	43	0.923
24	0.351	44	0.932
25	0.420	45	0.940
26	0.481	46	0.947
27	0.536	47	0.954
28	0.584	48	0.960
29	0.628	49	0.965
30	0.666	50	0.970
31	0.701	51	0.974
32	0.732	52	0.978
33	0.760	53	0.982
34	0.785	54	0.985
35	0.808	55	0.988
36	0.828	56	0.990
37	0.846	57	0.993
38	0.863	58	0.995
39	0.878	59	0.997
40	0.891	60	0.998

Table A2. **Summary statistics - extended**: This table extends the summary statistics table in the main text. I report the fraction of P&Is' total bond portfolios in bonds with maturities $T \geq 30$, those with maturities $15 < T \leq 25$, and those with $T \leq 15$, all in percentage points. Furthermore, I report the corporate bond portfolio distance-to-default measure (DTD; higher number implies further away from default), the government bond portfolio credit risk (CR; higher number implies higher credit rating), and the fraction of the government bond portfolio that is allocated to high yield (HY) government bonds. The cross-sectional mean, standard deviation, and median are reported. The quarterly sample period is 2009q1-2019q4.

% bonds $T \geq 30$	mean	std.dev.	p50	**% bonds $15 < T \leq 25$**	mean	std.dev.	p50
Life insurers	8.20	6.29	6.91	Life insurers	17.23	8.85	15.46
Non-life insurers	2.19	2.64	1.07	Non-life insurers	7.47	6.99	5.46
Pension funds	5.20	5.50	3.44	Pension funds	15.43	10.11	13.30
% bonds $T \leq 15$	mean	std.dev.	p50	**DTD corporate bonds**	mean	std.dev.	p50
Life insurers	56.94	15.89	56.17	Life insurers	17.98	1.20	18.13
Non-life insurers	68.80	15.00	71.35	Non-life insurers	16.34	2.70	17.05
Pension funds	60.32	17.58	64.35	Pension funds	17.15	2.70	17.90
CR government bonds	mean	std.dev.	p50	**% HY government bonds**	mean	std.dev.	p50
Life insurers	19.24	1.22	19.52	Life insurers	0.37	0.90	0.02
Non-life insurers	17.66	3.05	18.36	Non-life insurers	0.69	5.00	0.00
Pension funds	18.21	2.57	18.88	Pension funds	2.74	5.27	0.03

Table A3. **Long-term bond holdings and the regulatory discount curve - Dutch government bonds**: This table presents the results of the main regression described in Equation (5): $w_{it}^B = \alpha + \beta_1 D^L_{2011q2,i} \times \text{UFR}_t + \cdots + \epsilon_{it}$ focusing on Dutch government bond holdings only, with the dependent variable equal to the fraction of the P&I's bond portfolio invested in a certain maturity bucket, UFR equal to 1 as of 2012q2 and zero otherwise, D^L_{2011q2} the duration of the liabilities as of 2011q2, and controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). Column (1) and (2) show the results for bond holdings with a maturity of 30 years or longer, column (3) and (4) for maturities between 15 and 25 years, and column (5) and (6) for maturities shorter than 15 years. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Holdings $\boldsymbol{T \geq 30}$		Holdings $\boldsymbol{15 < T \leq 25}$		Holdings $\boldsymbol{T \leq 15}$	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	-0.2416		-1.0166		2.527	
	[-0.40]		[-0.53]		[0.85]	
D^L_{2011q2}	-0.4418***		-0.7355		1.1425**	
	[-3.34]		[-1.62]		[2.43]	
UFR$\times D^L_{2011q2}$	-0.3635***	-0.3019***	0.6884***	0.7282***	-0.4866**	-0.3708*
	[-5.81]	[-4.67]	[4.57]	[5.04]	[-2.32]	[-1.89]
D^L_{t-1}	0.6950***	0.4177**	1.5605***	2.8983***	-1.3976***	-2.8083***
	[5.74]	[2.07]	[3.55]	[6.09]	[-3.25]	[-5.39]
FR^{-1}_{t-1}	-4.2462	-4.3697	17.798	11.1834	-23.4788*	-12.0455
	[-0.80]	[-0.70]	[1.40]	[0.92]	[-1.72]	[-0.89]
$FR^{-1}_{t-1}\times$ Pension funds	16.4155***	15.8986**	0.1748	-4.0958	-22.8225	-12.3394
	[2.81]	[2.20]	[0.01]	[-0.29]	[-1.55]	[-0.80]
Log size	0.1268	-4.5869**	0.8522	-0.6183	-2.9894**	5.0266
	[0.27]	[-2.03]	[0.68]	[-0.11]	[-2.21]	[0.74]
Life insurance	2.7477***		13.8217***		-8.0323***	
	[3.56]		[5.91]		[-3.18]	
Pension funds	-10.4152**		4.599		15.946	
	[-1.97]		[0.36]		[1.17]	
Fund FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	2325	2325	2325	2325	2325	2325
adj. R-squared	0.1018	0.3345	0.1845	0.6467	0.0941	0.5892

Table A4. **Summary statistics demand system**: This table provides summary statistics on the inputs in the estimated demand systems in Table 7. I provide statistics on $y_t(h)$ (in percentage points), which equals the yield on Dutch government debt that belongs to maturity bucket h, bond characteristics at the maturity bucket level: average bond duration (in years), convexity (in years), coupon (in percentage points), and the log AUM outstanding, and the 10-year German yield (in percentage points). I report the mean, standard deviation, minimum, and maximum.

	mean	std.dev.	min	max
$y_t(h)$	1.44	1.28	-0.78	4.38
Duration	12.35	6.70	2.28	31.28
Convexity	197.44	180.50	5.19	978.28
Coupon	3.44	1.05	1.28	6.38
log AUM outstanding	17.07	1.00	15.13	18.91
10-year German yield	1.25	1.18	-0.58	3.51

Table A5. **Persistence of government bond holdings**: This table reports the percentage of government bonds that are held in the current quarter and that were also held in the previous one to eleven quarters for euro area investors based on AUM percentiles. Panel A shows the results for all government bonds and Panel B for Dutch government bonds only. The percentages are taken over the time-series and the cross-section of sector-country pairs within each percentile. The quarterly sample period is from 2009q1-2019q4.

Panel A: All government bonds

AUM	Previous Quarters										
percentile	1	2	3	4	5	6	7	8	9	10	11
1	52	59	64	68	72	74	77	79	81	83	84
2	54	59	64	68	72	75	77	79	81	83	85
3	53	58	63	67	70	73	75	78	80	82	83
4	51	56	61	65	68	71	74	76	78	80	82
5	53	58	62	66	69	72	74	77	79	80	82
6	50	55	60	63	67	69	72	74	77	78	80
7	51	56	61	65	68	71	73	75	77	79	81
8	52	57	61	65	68	71	73	76	78	79	81
9	51	56	60	64	67	70	73	75	77	79	81
10	54	59	63	67	70	73	76	78	80	82	83

Panel B: Dutch government bonds

AUM	Previous Quarters										
percentile	1	2	3	4	5	6	7	8	9	10	11
1	54	60	65	69	73	76	79	81	83	85	86
2	53	58	62	66	69	72	75	77	80	82	84
3	55	60	65	69	72	74	77	79	81	83	85
4	51	56	60	64	67	70	73	75	78	80	82
5	50	55	60	63	67	70	72	75	77	79	81
6	53	57	61	65	68	71	73	75	77	79	81
7	52	56	60	63	66	69	71	74	76	78	80
8	52	57	61	65	68	71	74	76	79	81	82
9	53	58	62	66	69	71	73	76	78	80	81
10	53	57	62	65	69	72	74	76	78	80	82

Table A6. **Demand system - KY (2019) instrument**: This table shows the regression results of the demand system described in Equation (9): $\ln \frac{w_{it}(s)}{w_{it}(0)} = \alpha_i + \beta_{0i} y_t(s) + \beta'_{1i}\mathbf{x}_t(s) + \epsilon_{it}(s)$, using instead the instrument introduced by Koijen and Yogo (2019) (the instrument, z_t^s, uses the investment mandates of investors to construct an instrument that's related to yields but orthogonal to latent demand). The dependent variable is the log of the portfolio weight of holder sector-country i for bond s at time t, relative to the portfolio weight of the outside asset. Panel A shows the first stage of the IV, Panel B the second stage. Bond characteristics include the average bond duration, convexity, coupon, and the log of AUM outstanding. The sample period is 2009q1-2019q4. The standard errors are clustered by holder area and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Panel A: First Stage IV

	Bank	**MF**	**P&I excl. NL**	**P&I NL**	**Other**
	y_t^s	y_t^s	y_t^s	y_t^s	y_t^s
z_t^s	-0.4902***	-0.7170***	-1.6510***	-1.7014***	-2.3310***
	[-7.95]	[-5.64]	[-15.48]	[-10.03]	[-12.31]
Bond Controls	Yes	Yes	Yes	Yes	Yes
Holder area FE	Yes	Yes	Yes	Yes	Yes
Observations	7,638	13,240	15,005	1,971	8,570
adj. R-squared	0.5067	0.533	0.5638	0.574	0.6003

Panel B: Second Stage IV

	Bank	**MF**	**P&I excl. NL**	**P&I NL**	**Other**
	Holdings	Holdings	Holdings	Holdings	Holdings
y_t^s	1.3883***	0.0871	-0.3384***	-0.2351**	0.1828**
	[6.03]	[0.94]	[-7.78]	[-2.10]	[2.01]
Duration	-0.1895***	0.0256	0.1530***	0.2051***	-0.0817***
	[-5.82]	[1.36]	[15.96]	[8.92]	[-3.71]
Convexity	-0.5506***	-0.0813***	0.0624***	0.1267***	-0.1785***
	[-8.70]	[-3.92]	[4.50]	[4.42]	[-8.78]
Coupon	-0.0006	-0.0002	-0.0051***	-0.0031***	0.0014*
	[-0.60]	[-0.38]	[-13.41]	[-4.58]	[1.76]
AUM outstanding	0.9377***	0.7388***	0.2849***	0.9667***	0.5508***
	[21.56]	[33.43]	[9.19]	[23.08]	[9.78]
German yield	-1.2593***	0.2483**	0.5186***	-0.0199	0.0264
	[-4.92]	[2.35]	[8.04]	[-0.18]	[0.30]]
Holder area FE	Yes	Yes	Yes	Yes	Yes
Observations	7,638	13,240	15,005	1,971	8,570
adj. R-squared	0.382	0.3037	0.3419	0.5983	0.4557

Table A7. **Price elasticity of demand - KY (2019) instrument**: This table shows the price elasticity of demand, computed as in Equation (11): $\frac{\partial q_{it}(h)}{\partial p_{it}(h)} = 1 + 100\frac{\beta_{0i}}{T_t(h)}(1 - w_{it}(h))$ for each holder sector-country i, bond b, and quarter t, based on estimates that use the instrument introduced by Koijen and Yogo (2019). The median, standard deviation, 5th percentile, and 95th percentile over time are given. The total elasticity is the weighted median elasticity, using the weights of each sector defined in the last column. The sample period is 2009q1-2019q4.

	obs	median	std.dev.	p5	p95
Banks euro	7,638	24.95	22.36	6.65	78.48
Mutual funds euro	13,240	2.71	5.87	1.35	16.95
P&I euro (non-NL)	15,005	-4.80	12.52	-41.48	-0.32
P&I NL	1,971	-3.04	14.34	-41.82	0.14
Other euro	8,570	4.62	11.28	1.88	34.15

Table A8. **Long-term bond holdings and the regulatory discount curve 2009q1-2014q3**: This table presents the results of the main regression described in Equation (5): $w_{it}^B = \alpha + \beta_1 D^L_{2011q2,i} \times \text{UFR}_t + \cdots + \epsilon_{it}$ for the sample period 2009q1-2014q3, with the dependent variable equal to the fraction of the P&I's bond portfolio invested in a certain maturity bucket, UFR equal to 1 as of 2012q2 and zero otherwise, D^L_{2011q2} the duration of the liabilities as of 2011q2, and controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). Column (1) and (2) show the results for bond holdings with a maturity of 30 years or longer, column (3) and (4) for maturities between 15 and 25 years, and column (5) and (6) for maturities shorter than 15 years. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Holdings **$T \geq 30$**		Holdings **$15 < T \leq 25$**		Holdings **$T \leq 15$**	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	0.6798		-1.7387**		1.8994	
	[1.51]		[-2.00]		[0.90]	
D^L_{2011q2}	-0.1822		0.2591		-0.4009	
	[-1.32]		[0.73]		[-0.82]	
UFR$\times D^L_{2011q2}$	-0.1665***	-0.1563***	0.2626***	0.2941***	-0.0088	-0.0906
	[-4.10]	[-5.71]	[3.76]	[7.60]	[-0.06]	[-1.07]
D^L_{t-1}	0.4144***	0.3434***	-0.002	0.2174	0.3442	-1.2464***
	[2.85]	[2.67]	[-0.01]	[0.63]	[0.72]	[-4.21]
FR^{-1}_{t-1}	5.8205	-0.7063	-4.9608	0.4306	-18.2143*	1.6546
	[1.58]	[-0.21]	[-0.89]	[0.08]	[-1.91]	[0.22]
$FR^{-1}_{t-1}\times$ Pension funds	-3.0611	-0.2461	-6.8308	-2.5964	8.6781	-3.7261
	[-0.66]	[-0.05]	[-1.12]	[-0.45]	[0.79]	[-0.44]
Log AUM	1.2471***	-2.311	1.9282***	-0.742	-4.1812***	7.4288*
	[2.96]	[-1.31]	[3.33]	[-0.47]	[-3.51]	[1.80]
Life insurance	4.2086***		3.5517***		-5.9197***	
	[6.04]		[3.14]		[-2.73]	
Pension funds	3.502		6.9657		-12.3289	
	[0.83]		[1.21]		[-1.21]	
Fund FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	1300	1300	1300	1300	1300	1300
adj. R-squared	0.1421	0.669	0.1316	0.7058	0.0598	0.771

Table A9. **Asset allocation and the regulatory discount curve 2009q1-2014q3**: This table presents the results of the regression described in Equation (6): $w_{it}^S = \alpha + \beta_1 D^L_{2011q2,i} \times \text{UFR}_t + \cdots + \epsilon_{it}$ for the sample period 2009q1-2014q3, with the dependent variable equal to a measure of P&I's risky asset allocation, UFR equal to 1 as of 2012q2 and zero otherwise, D^L_{2011q2} the duration of the liabilities as of 2011q2, and controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). Column (1) shows the results for the equity allocation, column (2) for the corporate bond allocation, column (3) for the corporate bond distance-to-default measure (DTD), column (4) for the government bond allocation, column (5) for government bond credit risk, and column (6) for the high yield government bond allocation. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Equity	**Corporate bonds**		**Government bonds**		
	Allocation	Allocation	DTD	Allocation	Credit rating	High yield
	(1)	(2)	(3)	(4)	(5)	(6)
UFR$\times D^L_{2011q2}$	0.2921***	-0.2171***	-0.0122	-0.1359	-0.0268*	0.1598**
	[3.63]	[-2.69]	[-0.92]	[-1.50]	[-1.78]	[2.11]
D^L_{t-1}	0.1228	-0.5714	-0.0983**	0.0526	0.0689	-0.0214
	[0.61]	[-1.42]	[-2.12]	[0.14]	[1.18]	[-0.17]
FR^{-1}_{t-1}	-4.5251	20.8533***	0.4125	-16.1207**	-1.7422	-4.3831
	[-0.80]	[2.60]	[0.33]	[-2.11]	[-1.14]	[-1.21]
$FR^{-1}_{t-1}\times$ Pension funds	2.6727	-3.0887	-2.8945*	-3.5528	-3.8271**	3.1273
	[0.41]	[-0.36]	[-1.96]	[-0.40]	[-2.11]	[0.73]
Log AUM	-1.9055	-3.6785	1.6759***	10.0204**	4.0878***	-14.6911***
	[-0.52]	[-1.09]	[2.75]	[2.11]	[3.65]	[-2.91]
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1300	1300	1300	1300	1295	1295
adj. R-squared	0.8997	0.7944	0.7239	0.7933	0.6458	0.3482

Table A10. **Long-term bond holdings and constraints 2009q1-2014q3**: This table presents the results of the regression described in Equation (7): $w_{it}^B = \alpha + \beta_1 D_{2011q2,i}^L \times \text{FR}_{2011q2,i}^{-1} \times \text{UFR}_t + \cdots + \epsilon_{it}$ for the sample period 2009q1-2014q3, with the dependent variable equal to the fraction of the P&I's bond portfolio invested in a certain maturity bucket, UFR equal to 1 as of 2012q2 and zero otherwise, D_{2011q2}^L the duration of the liabilities as of 2011q2, and FR_{2011q2}^{-1} the inverse of the funding ratio minus 1 as of 2011q2. Controls include the lagged liability duration, the lagged inverse of the funding ratio, the lagged inverse of the funding ratio interacted with a dummy that indicates pension funds, and the log of size (AUM). P&I type fixed effects include dummies indicating pension funds, life insurers, or non-life insurers. Column (1) and (2) show the results for bond holdings with a maturity of 30 years or longer, column (3) and (4) for maturities between 15 and 25 years, and column (5) and (6) for maturities shorter than 15 years. Standard errors are clustered at the investor level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Holdings $\boldsymbol{T \geq 30}$		Holdings $\boldsymbol{15 < T \leq 25}$		Holdings $\boldsymbol{T \leq 15}$	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	0.2555		-5.0767**		5.4692	
	[0.17]		[-2.31]		[0.93]	
D_{2011q2}^L	-0.003		0.4421		-0.6854	
	[-0.02]		[1.23]		[-1.26]	
FR_{2011q2}^{-1}	-23.4755**		-52.0165***		44.6007	
	[-2.03]		[-3.10]		[1.26]	
$D_{2011q2}^L \times FR_{2011q4}^{-1}$	2.7735***		2.4058**		-4.6687*	
	[2.94]		[2.22]		[-1.88]	
UFR $\times D_{2011q2}^L$	-0.2317*	-0.2581***	0.5092***	0.4708***	-0.1868	-0.1935
	[-1.76]	[-3.52]	[3.32]	[5.15]	[-0.47]	[-1.02]
UFR $\times FR_{2011q2}^{-1}$	-3.4259	7.3372	-31.4663	-19.7461	35.9548	14.1919
	[-0.25]	[0.99]	[-1.35]	[-1.49]	[0.77]	[0.61]
UFR $\times D_{2011q2}^L \times FR_{2011q4}^{-1}$	-0.5363	-1.0262*	2.4313*	1.7870**	-2.1074	-1.0441
	[-0.48]	[-1.71]	[1.65]	[2.09]	[-0.65]	[-0.73]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
P&I type FE	Yes	No	Yes	No	Yes	No
Fund FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	1300	1300	1300	1300	1300	1300
adj. R-squared	0.1619	0.6711	0.1442	0.7066	0.0675	0.7707

Table A11. **Long-term bond holdings and the regulatory discount curve - cross-sectional regressions**: This table presents the results of the regression described in Equation (5): $w_{it}^B = \alpha + \beta_1 D_{2011q2,i}^L \times \text{UFR}_t + \cdots + \epsilon_{it}$, where the observations are either averaged before and after the implementation of the regulatory reform (column 1 and 2), or the observations only include the quarter before and after the implementation of the reform (column 3 and 4). The dependent variable is equal to the fraction of the P&Is bond portfolio invested in the corresponding maturity bucket, UFR equal to 1 as of 2012q2 and zero otherwise, and D_{2011q2}^L the duration of the liabilities as of 2011q2. Column (1) and (3) show the results for bond holdings with a maturity of 30 years or longer, column (2) and (4) for maturities between 15 and 25 years, and column (3) and (6) for maturities below 15 years. Standard errors are clustered at the fund level and the corresponding t-statistics are in brackets; $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Obs. averaged			**Obs. 2012q1-2012q3**		
	Holdings $\boldsymbol{T \geq 30}$	Holdings $\boldsymbol{15 < T \leq 25}$	Holdings $\boldsymbol{T \leq 15}$	Holdings $\boldsymbol{T \geq 30}$	Holdings $\boldsymbol{15 < T \leq 25}$	Holdings $\boldsymbol{T \leq 15}$
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	0.3404	-1.1481	-0.49	0.8534**	0.7693*	0.5751
	[0.59]	[-0.73]	[-0.19]	[2.36]	[1.90]	[0.21]
UFR$\times D_{2011q2}^L$	-0.1461**	0.2506**	0.1072	-0.1349***	0.1453***	-0.0407
	[-2.57]	[2.17]	[0.57]	[-3.75]	[3.05]	[-0.25]
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	132	132	132	132	132	132
adj. R-squared	0.7106	0.6169	0.7232	0.9531	0.9298	0.9327

Table A12. **Long-term bond holdings and the regulatory discount curve at the security level**: This table presents the results of the regression described in Equation (12): $w_{sit} = \beta_0 D^L_{2011q2,i} \times \mathbb{1}^{maturity \geq 30}_{st} \times \text{UFR}_t + \cdots + \epsilon_{sit}$, and (13): $w_{sit} = \beta_0 D^L_{2011q2,i} \times \text{FR}^{-1}_{2011q2,i} \times \mathbb{1}^{maturity \geq 30}_{st} \times \text{UFR}_t + \cdots + \epsilon_{sit}$, where the dependent variable is the weight assigned to bond s for fund i at time t, with UFR equal to 1 as of 2012q2 and zero otherwise, D^L_{2011q2} the duration of the liabilities as of 2011q2, FR^{-1}_{2011q2} the inverse of the funding ratio minus 1 as of 2011q2, $\mathbb{1}^{maturity \geq 30}$ an indicator variable that equals one if the time to maturity of bond s at time t is larger or equal to 30 years, and $\mathbb{1}^{maturity \in (15,25]}$ an indicator variable that equals one if the time to maturity of bond s at time t is between 15 and 25 years. The first three columns show the results for Equation (12) and the last three columns for Equation (13). The quarterly sample period is 2009q1-2019q4. Standard errors are clustered at the fund-security level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Main			**Constraints**		
	(1)	(2)	(3)	(4)	(5)	(6)
UFR $\times D^L_{2011q2} \times \mathbb{1}^{maturity \geq 30}$	-0.0007***	-0.0027***	-0.0019**			
	[-3.52]	[-2.66]	[-1.97]			
UFR $\times D^L_{2011q2} \times \mathbb{1}^{maturity \in (15,25]}$	0.0003*	0.0015*	0.0019**			
	[1.75]	[1.71]	[2.20]			
UFR $\times D^L_{2011q2} \times \text{FR}^{-1}_{2011q2} \times \mathbb{1}^{maturity \geq 30}$				-0.0008***	-0.0019**	-0.0011*
				[-3.64]	[-2.02]	[-1.90]
UFR $\times D^L_{2011q2} \times \text{FR}^{-1}_{2011q2} \times \mathbb{1}^{maturity \in (15,25]}$				0.0003*	0.0018**	0.0022***
				[1.81]	[2.30]	[2.81]
Time FE	Yes	No	No	Yes	No	No
Fund-security FE	Yes	Yes	Yes	Yes	Yes	Yes
Security-time FE	No	Yes	Yes	No	Yes	Yes
Fund-time FE	No	No	Yes	No	No	Yes
Observations	2134615	1887256	1887256	2096034	1848685	1848685
R-squared	0.852	0.8376	0.847	0.8502	0.8354	0.8445

Table A13. **Effects of the UFR at the European level - alternative measure**: This table shows the effects of the UFR on yield spreads for a panel of European countries over the period 2006-2020 (annual). The countries included are: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, and the UK. The UFR equals one as of the announcement of the UFR as part of the Solvency II regulation in August, 2015, except for the countries Denmark, the Netherlands, and Sweden where the dummy equals one as of June 2012, July 2012, and February 2013, respectively. Size IC market equals the size of the insurance market relative to debt in 2015, multiplied by the liability duration. Controls include the 10-2y government bond spread, the debt-to-GDP ratio, the CDS spread, and the age of the population measured by the fraction of the elderly relative to the total population. Standard errors are clustered at the country level and the corresponding t-statistics are in brackets; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

	Spread 30-20y		**Spread 20-10y**		**Spread 30-10y**	
	(1)	(2)	(3)	(4)	(5)	(6)
UFR	0.1291***		0.1801***		0.3092***	
	[3.55]		[2.63]		[3.66]	
size IC market	-0.0039***		0.0042		0.0003	
	[-2.82]		[1.41]		[0.09]	
size IC market × UFR	0.0032**	0.0038***	-0.0060*	-0.0066**	-0.0027	-0.0028
	[1.97]	[2.63]	[-1.72]	[-2.42]	[-0.69]	[-0.87]
10-2y spread	0.0477***	0.0507***	-0.012	-0.0215	0.0357	0.0292
	[7.02]	[9.27]	[-0.66]	[-0.94]	[1.54]	[1.05]
Debt to GDP	0.0006	0.0018	0.0031***	0.0026	0.0037***	0.0044
	[1.37]	[1.60]	[4.00]	[1.17]	[3.55]	[1.55]
CDS	-0.0005***	-0.0004***	-0.0009***	-0.0009**	-0.0013***	-0.0013***
	[-4.20]	[-4.06]	[-3.39]	[-2.57]	[-3.79]	[-2.93]
Age	-0.0006	-0.0333	0.0099	0.0227	0.0093	-0.0106
	[-0.11]	[-1.49]	[0.96]	[0.80]	[0.84]	[-0.34]
Country FE	No	Yes	No	Yes	No	Yes
Time FE	No	Yes	No	Yes	No	Yes
Observations	286	286	286	286	286	286
adj. R-squared	0.829	0.865	0.416	0.526	0.705	0.752

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