The Impact of Pensions and Insurance on Global Yield Curves

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Abstract: We document a strong effect of pension and insurance company (P&I) assets on the long end of the yield curve. Using data from 26 countries, the yield spread between 30-year and 10-year government bond yields is negatively related to the ratio of pension assets (in funded and private pension and life insurance arrangements) to GDP, suggesting that preferred-habitat demand by the P&I sector for long-dated assets drives the long end of the yield curve. We draw on changes in regulations in several European countries between 2008 and 2013 to provide well-identified evidence on the effect of the P&I sector on yields and to show that P&I demand is in part driven by hedging linked to the regulatory discount curve. When regulators reduce the dependence of the regulatory discount curve on a particular security, P&I demand for the security falls and its yield increases. These effects extend beyond long government bonds. Our results suggest that pension discount rules can have a destabilizing impact on bond markets that reverses once rules are changed.

I. Introduction

The global financial crisis and its aftermath had a dramatic impact on the solvency of pension funds and insurance companies around the world. During the crisis, pension funds and insurance companies lost capital as global asset prices fell (Koijen and Yogo 2015; National Association of State Retirement Administrators Survey 2017). In the aftermath of the crisis, despite recovering stock markets, the financial position of pension funds was further worsened by reductions in short- and long-term interest rates, which increased the present value of pension and insurance liabilities.

While it is well understood that interest rates drive changes in pension funding status, over recent years researchers have uncovered suggestive evidence that the causality may also run in the other direction: pension fund demand may drive interest rates at the long end of the yield curve. Greenwood and Vayanos (2010) suggest that demand from pension funds may have driven yield spreads on long bonds in the UK negative in 2005 and 2006; Klingler and Sundaresan (2018) show that US pension fund demand for long-dated interest-rate swaps can explain why swap rates fell below rates on US Treasuries during the 2008-2015 period. These authors interpret their findings as being consistent with a preferred habitat theory of the yield curve in the spirit of Modigliani and Sutch (1966) and Vayanos and Vila (1999). Under a preferred habitat interpretation, pension funds are large buyers of long maturity bonds, and shifts in their demand are thus important for understanding bond prices and yields.

In this paper, we show that these previous findings are part of a much broader global phenomenon of pension and insurance demand driving the long end of the yield curve. Namely, drawing on a large cross-section of countries, we show that countries with larger private pension systems tend to have lower yield spreads on long maturity bonds, measured as the spread between the yield on 30-year and 10-year government debt. These findings hold despite vast differences in the structure of pension systems around the world – such as recently documented by Scharfstein (2018)—including the proportion of defined benefit and defined contribution plans, or whether contributions are voluntary or mandated.

We show corresponding results on the impact of the *supply* of government debt on yield spreads. Namely, countries with a larger supply of government debt tend to have larger 30-10 yield spreads. Supply (measured as debt-to-GDP) and demand (pension and life insurance assets-to-GDP) impact yield spreads with approximately equal magnitude but opposite signs. We combine demand and supply into a variable "*NETDEMAND*" – which measures demand for long-term bonds net of available government supply – and show that this variable has a correlation of -0.69 with 30-10 yield spreads in the 26 countries we study. These results hold both pre- and post-crisis and are robust to controls such as the shorter maturity 10-2 yield spread, country credit risk, and measures of demographics.

The most natural interpretation of these findings is that pension funds have a large preferred-habitat allocation to long maturity bonds (perhaps because of asset liability matching, and in part driven by regulation) and therefore that countries with large pension assets on average demand more bonds, driving down yields for the longest maturity bonds. But, as with any correlation between demand and prices, interpreting the evidence as causal is potentially problematic. For example, pension funds may choose to allocate less to bonds if yields are low, attenuating the correlation we observe. And the size of the pension system may reflect factors such as demographics, that influence the yield curve through other channels.

In the second part of the paper, we conduct a series of event studies to provide better identified evidence that pension and insurance demand causes lower yields on long-term bonds. These event studies also shed additional light on why pension funds demand long maturity bonds. The event studies are all based on changes in the statutory discount rate by which pensions (and in some cases insurance companies too) value their liabilities for regulatory purposes. Drawing on a series of reforms in northern Europe in recent years, we show that when regulators decrease the P&I sector's demand for a given asset by changing the regulatory discount curve methodology, this drives up yields and yield spreads.

Consider the case of the Danish reform in late 2011. As the European sovereign debt crisis intensified, the Danish Krone became perceived as a safe haven, and yields on Danish government debt plummeted by 139 basis points over a five-month period. Regulators expressed concern that pension funds were hoarding Danish government bonds on the fear that rates would continue to fall which would worsen their funding (solvency) status further. On December 2, to alleviate the pressure on pensions, the regulator announced that pensions and insurance companies would be allowed to increase the rate used to discount long maturity liabilities, specifically moving the discount rate closer to the yield on euro interest rate swaps than the yield on Danish government bonds. Within two days of the announcement, the Danish 10-year government bond yield had increased by 20 basis points, and 10-year Danish Kroner interest rate swap yields by 21 basis points.

We consider six such regulatory reforms occurring between 2008 and 2013 in Denmark, the Netherlands, and Sweden. In each of the events that we study, we show that prices of the new reference asset for the liability discount curve significantly increase, and prices of the old reference asset for the liability discount curve fall. All of this begs the question of why pension and insurance company asset allocation is so closely tied to the regulated discount curve for their *liabilities*? The simplest and most widely recognized explanation has to do with a form of tracking error minimization. Namely, if the regulatory discount curve is based on, say, the Danish bond yield curve, then holding Danish bonds naturally hedges the pension fund against changes in interest rates, in a way that holding German bonds do not.

In most of the regulatory episodes that we study, the impetus for the change in regulation in the first place was to limit pension funds from feeling forced to buy or sell assets. Put differently, a common theme in the timing of the events is that they were preceded by procylical behavior by the P&I sector. In the 2011 Danish case, this behavior took the form of pensions buying Danish government bonds relative to German government bonds, further driving down Danish bond yields and worsening their funding position. This activity was ostensibly curtailed by regulators' announcement of the change in discount curve. Thissuggests that when designing pension fund regulations, regulators face a trade-off. On the one hand, stopping pro-cyclical behavior by intermediaries is useful for avoiding asset price spirals that hurt the sector's solvency and destabilize markets. On the other hand, being more lenient in how pensions mark their liabilities increases the risk that the pensions will not ultimately be able to meet their obligations.

Our paper contributes to accumulating evidence that preferred habitat demand can drive the long end of the yield curve. A number of papers study bond yields around policy events that shift demand or supply of these securities (Modigliani and Sutch 1966; Ross 1966; Garbade and Rutherford 2007; Greenwood and Vayanos 2010; Krishnamurthy and Vissing-Jorgensen 2011 and 2013). More closely related to our study is Guibaud, Nosbusch, and Vayanos (2013) who show that countries with older populations have lower term premiums. Our event-study results on regulatory incentives are also a close cousin of an older literature on stock market index inclusions (Shleifer 1986; Lynch and Mendenhall 1997; Kaul, Mehrotra, Morck 2002). These studies showed that when stocks were added to an index such as the S&P 500, index funds are induced to buy them (presumably to avoid future tracking error), and in doing so drive the price of these securities up. Our findings are analogous to these, because pension and insurance demand for bonds is in part driven by the reference securities used in the regulatory discount curve.

Our paper joins a large literature on pension and insurance company behavior. Rauh (2009) suggests that poorly funded corporate pension funds shift asset allocations to low-risk assets. Andonov, Beuer and Cremers (2017) show that US public pension funds increase risk taking following losses, compared to either private pension funds in the US or public or private pension funds in Europe and argue that this is due to US public pension funds being allowed to discount liabilities using the expected return on their assets. Koijen and Yogo (2015) show that during the financial crisis, life insurers sold long-term policies at discounts to comply with statutory reserve regulations. Boubaker, Gounopoulus, Nguyen, and Paltalidis (2015) show that changes in Treasury yields following central bank quantitative easing led US public pension funds to allocate more capital towards equities. More recently, researchers have built on these findings to suggest that pension and insurance company behavior may explain features of asset prices.[1] Domanski, Shin and Sushko (2015) suggest that European pension funds may have amplified the impact of quantitative easing policies by the European Central Bank. Klingler and Sundaresan (2018) argue that the more pronounced effect of US pension demand on swaps than Treasuries is due to a preference among US pension funds for hedging duration risk using swaps because swaps require

[1] These papers join a broader emerging literature on the role of financial intermediaries for asset pricing (e.g., Adrian, Etula and Muir (2014), and He, Kelly and Manela (2017)). Compared to this work, an advantage of studying the asset pricing impact of regulatory changes is that it provides econometrically straightforward evidence on the role of intermediaries for price setting as well as highlighting regulation as a driver of intermediary asset demand.

only a modest investment to cover margins. Unlike the US case, we show that P&I demand in Europe affects bond markets as much as swap markets.[2]

II. Cross-country evidence on pension and insurance systems and long-term government bond yields

We start in this section by presenting some basic facts on the size of pension and insurance systems around the world, and then document the strong correlation between the size of the P&I sector and global yield curves.

Table 1 summarizes our data on the pension system, obtained from the OECD Global Pension Statistics, OECD Insurance Statistics, OECD Public Pension Reserve Funds' Statistics and other sources. Averages are shown for each country time-series. Private pension assets are the sum of assets held by pension funds and pension insurance contracts. Pension funds are funds that support the claims of defined benefit and defined contribution plans. Pension insurance contracts work similarly to a defined benefit plan, where the pensioner and his or her employer make fixed amounts of contributions during the working years, and received fixed amounts of pension income at retirement. Such contracts are important in countries such as Denmark and Sweden.

A broader measure of total pension-system demand for long-term assets, and one that we use as a benchmark for our analysis, would allow for the fact that in many countries, vehicles other than private pension funds accumulate long-term fixed income assets to make subsequent payouts to pensioners. These include the public pension reserve funds, which holds assets in reserve funds that governments build up to support public pension schemes (and typically have a sizeable allocation to long-term fixed income assets [Blundell-Wignall 2008]). Insurance assets include life insurance assets and "composite" insurance assets, and are obtained from the OECD Global

[2] The narrower effects in the US than Europe may be due to US pension regulations allowing public pension plans to discount their *liabilities* at a higher rate if they have riskier *assets*.

Insurance Statistics.[3] Like pension funds, insurance companies allocate a sizeable percentage of their assets to long-maturity bonds.[4]

We supplement our data on pensions and insurance companies with information on government debt stocks, CDS spreads and demographics (median age, collected every five years). Government debt data are taken from the OECD National Accounts Database, except for that of Korea and New Zealand, which are taken from IMF World Economic Outlook Database, Government CDS spreads are from Capital IQ and are based on 5-year government bonds. To avoid picking up variation in credit spreads, we exclude country-years in which the CDS spread exceeds 200 basis points; furthermore, in some specifications we control for the CDS spread directly. Overall, we limit our sample to countries for which we have complete data on pension size, government bond yields, and CDS spreads.

Figure 1 Panel A shows averages over the 2009-2016 period of private pension plus insurance assets to GDP. The P&I sector is the largest relative to GDP in Denmark at around 300%, with Canada, US, UK, Netherlands, Sweden and Switzerland around 200%.

Table 1 provides further detail. Consistent with Scharfstein (2018), there is remarkable variation between countries in the amount of pension assets. Denmark, with a forced private saving system, reports average pension assets of 157% of GDP. By contrast, Germany, whose pension system is mostly pay-as-you-go, reports average pension assets of 5% of GDP. Scharfstein (2018) shows that pension assets to GDP are in large part driven by the public pension replacement rate.

Of course, pension fund assets are driven by a host of other factors, including the age of the private pension system (systems set up earlier tend to be larger), regulations on mandatory contributions, and demographics. Surprisingly, the correlation between pension assets and average age is only 19% in the panel.

Figure 1 Panel B shows that NETDEMAND, computed as (pension and insurance assets minus government debt)/GDP, is highly correlated with pension assets-to-GDP, reflecting the low

[3] We include "composite" insurance companies because for many countries, we do not have a good way to differentiate between life- and other forms of insurance.
[4] http://www.naic.org/capital_markets_archive/150622.htm. GSAM Insurance Survey https://www.gsam.com/content/dam/gsam/direct-links/us/en/institutions/2016-gsam-insurance-survey.pdf?sa=n&rd=n.

correlation between pension assets and country debt levels. The outlier is Japan, which has a government debt-to-GDP ratio over 230%.The OECD data does not contain information about the maturity distribution of the P&I sector's holdings. However, drawing on proprietary data on pensions in the euro area, the Committee on the Global Financial System (2018), Chart 2, shows that the P&I sector disproportionately holds longer maturity bonds than other sectors of the economy. In Appendix Table 1, drawing on public data from the Danish central bank, we show that Danish P&I sector has a disproportionate ownership share of long bonds. While this sector owns 33.7% of all bonds held by Danish investors, it owns 53.1% of bonds in the segment of bonds with more than 20 years of remaining maturity. This contrasts sharply with holdings of monetary financial institutions (banks) who hold 70.9% of bonds in the under one -year segment but only 6.3% of bonds in the greater than 20-year segment.

Cross-sectional Results

In this section, we describe the relationship between pension fund size and the long-end of the yield curve, drawing on the OECD data described above and yields on government debt obtained from Bloomberg and supplemented by Datastream and Global Financial Data. Our working hypothesis is that in countries with larger private pension systems, there is greater demand for long-term assets, depressing the long end of the yield curve. This effect should be attenuated in countries with large stocks of government debt, which can help satisfy pension and insurance demand.

Our approach is to run cross sectional regressions of the form:

$$y_{30} - y_{10} = a + b^{*}P\&I\ Assets/GDP + c^{*}GovtDebt/GDP + d^{*}z + u_{it}, \quad (1)$$

where i denotes country, *P&I Assets/GDP* denotes the size of the pension and insurance assets as a percentage of GDP, *GovtDebt* denotes central government debt-to-GDP, and z represents a suite of control variables, including the yield spread between the 10- and 2-year government bond, and the 5-year CDS spread on government debt. All variables are measured in percentage terms, except CDS spreads, which are measured in basis points.

In essence, equation (1) estimates the yield curve slope as a function of both the *supply* and *demand* for long duration assets. We use total P&I assets as opposed to P&I assets invested in long-maturity bonds because pension funds may endogenously choose to hold more or less long duration assets making total P&I assets more exogenous (notably, the overall size of the pension system is largely driven by pensioner contribution rates which are in turn affected by the country's choice of public pension replacement rate). Similarly, we use total government debt to GDP rather than long government debt to GDP because the government may endogenously choose to issue more or less long-term debt.

We also estimate regressions of the form:

$$y_{30} - y_{10} = a + b*NETDEMAND/GDP + d*z + u_{it}, \qquad (2)$$

where *NETDEMAND* is *P&I Assets/GDP* minus *GovtDebt/GDP*.

The main analysis is conducted on the 2009-2016 sample for which we have the most data. Our primary source of variation is *between* countries. In estimating (1), one issue that arises is that yield spreads, government debt, and to some extent pension assets fluctuate according to the business cycle, potentially causing a spurious correlation driven by the time-series, and therefore limiting our ability to make statements about the supply or demand elasticity. For example, during business cycle troughs, governments may run deficits, increasing debt-to-GDP, while yield spreads might be low because the central bank is expected to keep interest rates low, an effect that would attenuate any regression results. Our preferred approach, therefore, is to present pooled cross-sectional regressions that average both right and left-hand side variables over a long enough period to reduce concerns about the business cycle. For the 2009-2016 period, this allows us to include 26 countries in the regression; prior to 2009, we have data on 16 countries. An alternative approach that we present below is to estimate panel regressions with year fixed effects.

In estimating (1), we use two definitions of the size of the P&I sector. We begin by using the broadest measure, which includes all assets in private pensions, public pension reserve funds, and all insurance assets. As a robustness check, we also show results for a narrower measure that includes only pensions.

Columns (1) and (2) of Table 2 shows our primary result. Larger P&I systems are associated with lower yield spreads on long-term bonds. The coefficient on (P&I Assets)/GDP is coefficient of -0.0022 The economic magnitude is large: Increasing (P&I Assets)/GDP by 150 percentage points of GDP (about two standard deviations in the cross-section of countries) reduces yield spreads by 33 basis points, more than its cross-sectional standard deviation of 29 basis points.

Column (2) shows that an important offset to this effect is the supply of government debt, which enters the regression with a similar coefficient (0.0031) of the opposite sign. Because P&I demand and government supply enter with opposite signs, for convenience we combine them into a "net demand" variable, *NETDEMAND*, by taking the difference of the two.

In column (3), we include the CDS spread, median age, and the yield spread between 10-year and 2-year government bonds as control variables. CDS spread we include to account for country credit risk (Scholtens 1999), although this variable is only marginally significant in the regression. The yield spread between the 10- and 2-year measures the overall slope of the term structure. But this variable runs the risk of over controlling, as preferred habitat demand for pension funds may drive 10-year yields as well as 30-year yields. Vayanos and Vila (2009) and Greenwood and Vayanos (2014) show, for example, that in a single factor model, an increase in preferred habitat for 30-year debt would also raise yields on 10-year debt. Guibaud, Nosbusch, and Vayanos (2013) show in a smaller sample of 10 countries that countries with older populations have larger government debt supply and greater term spreads; we control for median age but (P&I assets-Gov debt)/GDP remains highly significant suggesting it is a more direct measure of net demand for long-term bonds. Excluding these control variables, the regression coefficient on *NETDEMAND* is almost unchanged (coef = -0.0025, *t*-stat = -5.53, not shown). Litterman, Scheinkman, and Weiss (1991) show that the volatility of interest rates influences the long end of the yield curve. We measure the volatility of interest rates by taking the standard deviation of the two-year yield in daily data over our sample period of 2009-2016 and including it as a control in column (4), although it does not enter significantly.

Figure 2 shows graphically the result described in column (3). Countries with high net demand from private pensions and insurance – such as Denmark, Sweden, the Netherlands and Switzerland, have low yield spreads. Countries with low net demand – coming from relatively modest private pensions and insurance assets combined with large supply of government debt – such as Japan, Italy, and Belgium, have much higher yield spreads. Overall, the correlation between *NETDEMAND* and the 30-10 yield spread is -69 percent.

In columns (5)-(8) of Table 2, we repeat our estimations from (1)-(4), using a narrower definition of pension demand that excludes insurance assets and the public pension reserve fund.

The coefficient in column (5) is slightly larger in magnitude to that in column (1), but the regression fit is slightly worse, perhaps because we are measuring demand for long-term assets with less precision.

Robustness

Panel B of Table 2 presents a number of robustness tests. One concern is how exactly to draw the boundaries of fixed income markets, whether by country (as we have just done) or by currency. The first two columns collapse the Euro countries into a single observation, weighting them by GDP. This reduces the sample to only 15 observations, but the coefficient estimates are similar. These regressions should be interpreted as the impact of pension and insurance demand in a particular currency on yield spreads on bonds in that currency.

In columns (3) and (4) we show panel regressions using year fixed effects. Again, the coefficients on demand and net demand are nearly identical to those that we showed earlier.

In columns (5) and (6), we show results from 1999-2008. Since data on insurance company assets is not available for the earlier period, we are restricted to our narrower measure of pension demand. Thus, these results are comparable to the results shown in columns (4) – (6) of Panel A. Although we have data on only 16 countries for the 2001-2008 period, the coefficients on net pension demand is significant, with and without controls.

III. Event studies of regulatory reforms in northern Europe

In the previous section, we showed that the size of the P&I sector is correlated with the slope of the long end of the yield curve. But, as we cautioned, these results are hard to interpret as being causal, in part because pensions and insurance companies have flexibility to own other assets, and also because the size of the P&I system may be correlated with other factors that influence the yield curve.

Conceptual background

To obtain well-identified evidence of the impact of pension and insurance company demand on asset prices we turn to a series of regulatory changes in northern Europe. By way of background, northern Europe is home to several countries with large private pension systems, whether measured per capita or as a percentage of GDP. And, beginning in 2008, regulators in Denmark, Sweden, and the Netherlands made a series of changes to the way that pensions were mandated to discount their liabilities. In large part, these reforms were conducted in the face of unprecedented low interest rates in those countries.

To understand the impact of the regulatory discount rate, consider the funding position of a pension fund at time t:

$$F_t = A_t - L_{Tt} / (1+R_t)^T, \qquad (3)$$

where A_t is the current value of the assets, L_{Tt} is the face value of time-T liabilities known as of t, and R_t is the statutory discount rate.

Countries vary enormously in how they approach the discounting of pension and liabilities (R_t in equation (1) above), with an overall trend towards market-based riskless yield curves, as advocated by Novy-Marx and Rauh (2011). Within countries, statutory discount rates can vary depending on the type of pension plan or insurance company. Langejan et al. (2013) classify Denmark, Netherlands, Sweden and Switzerland as using market-based discounting of liabilities, and the UK as discounting liabilities using an "expected return" on investments, much like public pension plans do in the United States. As of the start of 2008 the discount curves of Denmark, Netherlands, Sweden and Switzerland were all based on swap or government bond yields.[5]

The choice of regulatory discount curve creates an incentive for the P&I sector to hold as assets the securities whose yields enter the regulatory discount curve used to discount the sector's liabilities. By doing this, when yields on securities used in the discount curve move and the regulatory value of liabilities changes, the P&I sector's assets change in value in the same direction, thus insolating solvency from yield curve moves.

[5] US private pension funds and Canadian private and public pension funds also used market-based discounting, but with discount curves that were based on corporate yields. US public funds are allowed to discount liabilities using the expected return on investments.

All the events we study involve changes in the statutory discount rate from R_t to R_t*, where R_t* denotes a new reference rate. To understand our empirical design, we note that this has two effects. First, there is the direct effect on the funding position of the pension: if $R_t^*>R_t$, then post-reform, the statutory funding position is improved and conversely if $R_t^*<R_t$, the funding position deteriorates. The second—and more important from our perspective—effect of changing R_t to R_t*, is on the future *volatility* of the funding gap, analogous to a form of "tracking error". To see this, consider the simple case in which the pension is fully funded at time t (F_t=0) and also fully hedged with respect to changes in its current discount rate R_t. Fully hedged means a perfect correlation between the present value of its liabilities and changes in the value of its assets, which can be achieved by holding a portfolio directly correlated with the reference discount rate. In this case, moving the statutory discount rate to R_t* opens the pension fund up to tracking error ($Var(F_t)$), which can be undone only by shifting the asset portfolio towards assets that deliver returns of R_t*.

In practice, pension funds hedge the risk in their future liabilities in two ways. First, they can buy assets that mimic changes in the value of their liability. For example, if the liability is a bullet payment of $1 billion in twenty years, and the reference rate is the 20-year zero-coupon yield on US government bonds, the liability can be perfectly hedged by owning 20-year zero coupon bonds. Second, many pensions engage in hedging programs (often managed by an investment bank such as Goldman Sachs) which hedge changes in the liability using derivatives. Either way in which the hedge is implemented, regulation induces demand for the asset that delivers the reference return.

The testable prediction of this simple framework is that if the market yield (or spread) of a particular asset is added to the regulatory discount rate, this will increase pensions' tracking error with respect to this discount rate and induce demand for the asset tied to the new reference rate. Conversely, if a given market yield is removed from the regulatory discount curve, pensions no longer need to own the asset to minimize tracking error. Press coverage of the events we list below is broadly consistent with this assumption. Following a change to the regulatory discount rate in Denmark in 2011, for example, the main Danish financial newspaper Børsen quotes a pension company executive who says “"Danish government bonds are no longer linked to the method for calculating liabilities and therefore become risky to hold. From being gold-plated they become risky. We have sold everything we could get rid of" [our translation].

The events

We identified six reforms in Denmark, the Netherlands, and Sweden, all of which take the form of *increasing* regulatory discount rates relative to the market yield curve for some sets of maturities. For each event, we discuss how we expect the reform to impact P&I asset demand, under the assumption that P&Is seek to minimize future tracking error.[6] The complete set of events and their estimated impact on the regulatory discount curve is summarized in Table 3.

Reform 1. Denmark, October 31, 2008: Change to "2008 curve"

In the fall of 2008 falling prices on stocks and mortgage-backed securities resulted in solvency problems for the P&I sector. At the time, the statutory discount curve did not include MBS yields. As a result, increasing spreads on MBS over government bonds implied that asset values fell relative to the value of liabilities. A large fraction of the Danish P&I sector's assets were in MBS (32% for insurance companies and 23% for pensions, as of the end of 2007, see Finanstilsynet (2009)). If the Danish P&I sector had started to sell MBS and buy more Danish government bonds in order to further align its assets with the statutory discount curve, this could have generated a self-reinforcing spiral, destabilizing the Danish MBS market and further worsening the solvency of the P&I sector. Danmarks Nationalbank (2016) describes the Danish reforms and events leading up to them.

On October 31, 2008, the Danish government and the Danish P&I sector agreed to change the statutory discount curve. The new curve would decrease P&I liabilities by around 60 Billion Danish Kroner, approximately 8 Billion Euro, compared to total P&I assets of around 600 Billion Euro.[7] Using τ to denote maturity in years, the curve was changed from being the Euro swap rate plus the government bond spread to Germany

[6] We identified but excluded a seventh event in Sweden in November 2008 (similar to the first Danish event) due to lack of daily MBS data for Sweden for this period and an eight even in Switzerland in September 2011 (the introduction of the ultimate forward rate) because it coincided with a major US Federal Reserve announcement.
[7] The announcement is available only in Danish at https://virksomhed.pension.dk/documents/Om%20PensionDanmark/Nyheder/Aftaletekst.pdf

$R_{Pre}(\tau)$ = Euro swap(τ)+[Danish govt.(τ)-German govt.(τ)]

for all maturities (except that [Danish govt.(10)-German govt.(10)] was used for all maturities 10 years and longer), to

R_{Post} =

- 0-2 years: Weighted average of rates on variable-rate mortgage bonds
- 7 years and longer:
  Euro swap(τ)+(Danish govt.(10)-German govt.(10))
  + 0.5*max(0, [OAS+DK swap(10)]-[Euro swap(10) +(Danish govt.(10)-German govt.(10))])
- Short and long segments are linked by linear interpolation.

"OAS" denotes the option-adjusted spread between Danish mortgage bonds and the Danish Kroner interest rate swap rate. "DK swap" denotes the swap interest rate for Danish Kroner interest rate swaps. Since the swap spread between Danish Kroner and Euro was similar to the government bond spread between Denmark and Germany, the change to the curve from 7 years and longer was approximately to add 0.5*OAS, i.e., half of the OAS spread.[8]

Using yields the day before the announcement, the impact of the reform on the discount curve on the long end was an increase of 52 basis points, with smaller increases for maturities between 2 and 7 years.

Predicted asset price effects of reform:

We expect this reform to increase the P&I sector's demand for Danish MBS relative to Danish Kroner interest rate swaps. Therefore, we expect the OAS on Danish MBS relative to Danish Kroner interest rate swaps to fall.

Reform 2. Denmark, December 2, 2011: Change to "2011 curve"

As the European sovereign debt crisis intensified in the second half of 2011, negative stock returns and falling interest rates in northern European countries led to renewed solvency problems in the

[8] On February 7, 2012 the OAS adjustment was simplified to 0.5*max(0,OASswap).

P&I sector. From July 1 to December 1, 2011 the MSCI EMU stock market index fell by 19% and the Danish 10-year government bond yield fell by 139 bps. The spread between the Danish 10-year government bond yield and the German government bond yield fell sharply at the end of November 2011 to equal -32 bps on December 1, 2011. Concerns about further spread narrowing led to an increased incentive for the P&I sector to align assets with the regulatory discount curve. This would imply selling German government bonds and buying Danish government bonds, again implying a risk of a self-reinforcing spiral and in this case potentially also strengthening the Danish Kroner, an outcome that would run counter to the fixed-exchange rate policy maintained by the central bank. On December 2, 2011 it was announced that the Danish P&I sector would be allowed to change the discount curve used to discount liabilities occurring 7 years and longer from

$$R_{Pre}(\tau) = \text{Euro swap}(\tau)+(\text{Danish govt.}(10)-\text{German govt.}(10)) + 0.5*\max(0,[\text{OAS+DK swap}(10)] -[\text{Euro swap}(10) +(\text{Danish govt.}(10)-\text{German govt.}(10))])$$

to

$$R_{Post}(\tau) = \text{Euro swap}(\tau)+\max(0, \text{250 day moving avg of }(\text{Danish govt.}(10)-\text{German govt.}(10))) + 0.5*\max(0,[\text{OAS+DK swap}(10)]-[\text{Euro swap}(10) +(\text{Danish govt.}(10)-\text{German govt.}(10))]).$$

Using data from the 250 days leading up to the announcement we estimate that this reform shifted the regulatory discount curve up by 40 bps from 7 years and longer with smaller effects in the 2 to 7-year segment due to linear interpolation between the 2- and 7-year points.

Predicted asset price effects of reform:

a. Direct asset price effects of changes to P&I asset demand:
   We expect this reform to decrease the P&I sector's demand for Danish government bonds relative to German government bonds because decreases in the Danish-German government bond spread no longer increase the value of liabilities for regulatory purposes. As a result, we expect the spread between Danish and German government bonds to increase.
b. Indirect asset price effects of changes to P&I asset demand via spillovers to closely related markets:

We expect reduced demand for Danish government bonds to spill over into reduced demand for other low-risk Danish fixed-income investments such as Danish swap rates. This would be expected to increase Danish swap yields relative to German government bond yields.

Reform 3. Denmark, June 12, 2012: Introduction of ultimate forward rate (UFR) in Danish discount curve

As the European sovereign debt crisis intensified in 2012, yields on long-term bonds in Denmark and other northern European countries fell to unprecedented low levels. Appendix Figure 1 shows the evolution of northern European 10-year government bond yields from 2008 to 2013. Falling rates increased the duration of the P&I sector's liabilities (the duration of a given set of cash flows is higher for a lower interest rate). Furthermore, mortgage-related assets with pre-payment options shortened in duration as rates fell. Both factors implied a need for longer asset duration for risk-management purposes. Once again, regulators became concerned that procyclical trading would lead to a spiral of falling long bond yields.

On June 12, 2012 the Danish regulator (the Danish Financial Supervisory Authority) announced an increase in the discount curve, moving to be based on the "ultimate forward rate" (UFR) for longer maturities. For maturities less than 20 years, the discount curve would be calculated as before, but for longer maturities, a model of the forward curve was to be used under which the forward rate converges smoothly from the market forward rate at year 20 to the UFR. In the Danish reform the UFR was set to 4.2% and the convergence point for the forward rates to the 30-year point (with forward rates beyond maturity 30 also equal to 4.2%). Discount rates from year 20 and longer were to be calculated based on the value of the discount rate at the 20-year point and the forward rates past this point. Calculations are done by the Danish FSA. Using the spreadsheet provided by the Danish FSA, we estimate that based on data as of the day before the reform, the upward shift of on the regulatory discount curve was zero at the 20-year point, 28 bps at the 25-

year point, 56 bps at the 30-year point and as large as 103 bps at the 50-year point.[9] Appendix Figure 2 shows the Danish regulatory curve (the spot curve) as of June 13, 2012.**Predicted asset price effects of reform:**

a. Direct asset price effects of changes to P&I asset demand:

   We expect this reform to reduce the P&I sector's demand for euro interest rate swaps with maturities longer than 20 years relative to euro interest rate swaps with shorter maturities, because decreases in the value of market yields beyond the 20 year point no longer increase the value of liabilities for regulatory purposes. As a result, we expect the corresponding euro interest rate swap yield spreads to narrow. Note that the direct asset price effect is on the euro swap curve because the currency adjustment to the yield curve – the term max(0, 250 day moving average of (Danish govt.(10)-German govt.(10)) – is the same for all maturities (beyond the 7-year maturity).

b. Indirect asset price effects of changes to P&I asset demand via spillovers to closely related markets:

   We expect reduced demand from the Danish P&I sector for long euro interest rate swaps to spill over into demand for safe euro-denominated government bonds and (given the currency peg) also to demand for Danish Krone interest rate swaps and government bonds.[10]

Reform 4. The Netherlands, July 2, 2012: Introduction of ultimate forward rate (UFR) in Dutch discount curve

Prior to July 2, 2012 the Dutch discount curve for the P&I sector was based on the euro swap curve. Due to the adverse effects of declining interest rates in the spring of 2012 on the solvency

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[9] The use of the UFR is one of the components of the Solvency II regulatory framework which took effect in the EU on January 1, 2016. We do not study announcement dates related to Solvency II because this reform has been repeatedly delayed making it difficult to isolate the most important dates. To the extent that the Danish, Dutch and Swedish UFR reforms simply moved the implementation of Solvency II to an earlier date the effects should be interpreted as such, with the full effect of moving to a UFR framework larger than those estimated here.

[10] The Danish Krone is pegged to the Euro and allowed to fluctuate in a band of +/- 2.25 percentage points around a value of 7.46 Danish Krone per Euro. Historically the central bank has intervened to keep the exchange rate close to the middle of the band.

of the P&I sector, the Dutch central bank announced on July 2, 2012 that the Netherlands would, like Denmark, reform its discount curve for the P&I sector to use the UFR.[11]

The Dutch also chose 20 years as the last liquid point and an ultimate forward rate of 4.2% but chose 60 years as the convergence point for the forward rate. The switch to the UFR methodology shifted up the Dutch regulatory discount curve by 32 bps at the 30-year maturity with larger effects at longer maturities (Table 3).

Predicted asset price effects of reform:

a. Direct asset price effects of changes to P&I asset demand:
We expect this reform to decrease the P&I sector's demand for euro interest rate swaps with maturities longer than 20 years relative to euro interest rate swaps with shorter maturities because increases in the value of market yields beyond the 20 year point no longer reduce the value of liabilities for regulatory purposes. As a result, we expect the corresponding yield euro interest rate swap yield spreads to narrow.
b. Indirect asset price effects of changes to P&I asset demand via spillovers to closely related markets:
We expect reduced demand from the Dutch P&I sector for long euro interest rate swaps to spill over into demand for safe euro-denominated government bonds (and Danish bonds given the Danish currency peg).

Reform 5. Sweden June 7, 2012: Floor under discount curve

Prior to 2012, the Swedish regulatory discount curve was an average of the yield curves on Swedish government bonds and Swedish Kroner interest rate swap rates or Swedish covered bonds (with the P&I company choosing to use either swaps or covered bonds). Following reduced northern European bond yields in the spring of 2012, the Swedish FSA (Finansinspektionen)

[11] Initially the reform applied only to the insurance sector. However, at the time of the July announcement, it was widely anticipated that UFR would be extended to pensions, and in fact that was announced on September 24, 2012.

announced on June 7, 2012 that the regulatory discount curve would be capped from below based on its values on May 31, 2012. Yields had been falling sharply leading up to the announcement.[12]

Comparing yields as of the day before the reform to yields on May 31, 2012, the reform implied an upward shift of yields of 7 bps at the 2-year point, 13 bps at the 10-year point and 12 bps at the 20-year point. Perhaps equally important, by putting a floor under the regulatory discount curve, the reform removed the risk of further increases to P&I regulatory liabilities in the event that market interest rates would fall further.

Predicted asset price effects of reform:

a. Direct asset price effects of changes to P&I asset demand:
   We expect this reform to decrease the P&I sector's demand for Swedish government bonds of all maturities because downward shifts in the Swedish government bonds do not increase the regulatory value of liabilities as long as the floor is binding.
   Therefore, we expect Swedish government bond yields to increase.
b. Indirect asset price effects of changes to P&I asset demand via spillovers to closely related markets:
   We expect reduced demand for Swedish government bonds to spill over into reduced demand for other low-risk Swedish fixed-income yields such as Swedish swap rates.

Reform 6. Sweden, February 18, 2013: Introduction of ultimate forward rate (UFR) in Swedish discount curve

The floor for the Swedish discount curve was initially announced to be in place until June 15, 2013. On February 18, 2013, the Swedish FSA announced that the floor would be in place until the end of 2013 at which point a new discount curve would be introduced which would be based on the UFR. The details of the method used for the new curve were announced on May 20, 2013. We use February 18, 2013 as our event date. We do not yet have an estimate of the exact switch of the Swedish curve

[12] On the same date as the Swedish announcement (June 7), the Danish government announced that it had started negotiations with the P&I sector about potential changes to the Danish regulatory discount curve, perhaps anticipating the formal announcement on June 12 that we already described above.

but Swedish yields in February 2013 were quite similar to Dutch yields at the time of the Dutch UFR announcement the shift is likely to be of a similar magnitude. An industry newsletter cites a Swedish insurance company executive for stating that "the proposals would improve the company's capital requirements by 3-4% and would reduce the overall interest rate sensitivity of liabilities by 35-45%, reducing the need for hedges"[13]

The predicted effects of this reform are as for the Danish and Dutch UFR reforms, with effects predicted for Swedish government bonds and Swedish Kroner interest rate swaps.

IV. Results

Reform 1: Denmark, October 31, 2008

Figure 3 shows the option-adjusted spread (OAS) on Danish MBS over Danish interest rate swaps (Bloomberg ticker NYKDOAS Index). The vertical line shows the date of the reform, which added approximately half of the OAS to the discount curve. As can be seen, the OAS drops by an impressive 37 bps from the trading day before the announcement to the trading day after, consistent with the hypothesis that the reform increased P&I demand for MBS relative to Danish Kroner interest rate swaps.

To assess the statistical significance of the drop in the Danish OAS we regress the daily change in the OAS on a dummy for the reform announcement, a regression design we also adopt in studying the other reforms.[14] The dummy is turned on the day of the announcement and the following day to allow a test of whether the daily change in the OAS on the day of the reform and the following day is significantly different from the daily change on other days. For ease of interpretation we divide the dummy variable by two (i.e., use D(Date=October 31, 2008 or Date=November 3, 2008)/2) so the regression coefficient can be interpreted as the abnormal two-day change in the OAS. We estimate all regressions over the 2008-2013 period which contains all

[13] http://www.investmenteurope.net/regions/swedendenmarkfinlandnorway/swedish-insurers-warn-of-manipulation-threat-to-new-discount-curve/

[14] For simplicity we present separate results for each reform. Omitting dates of the other reforms from regression results for a given reform has almost no effect on the results.

our events. The result is shown in Table 4. The abnormal two-day change in the OAS is 37 bps with a t-statistic of -11.68. In the second column, we show that a similar drop can be discerned in the Danish MBS index (Bloomberg ticker NYKDYTM Index), ensuring that the finding in column (1) is not driven by a change in the expected pattern of mortgage prepayments. In a robustness check, we also compare the change in OAS to moves in the yields of MBS spreads in the United States, where we see no meaningful changes.[15]

Reform 2: Denmark, December 2, 2011

Figure 4 graphs the spread between Danish and German 10-year government bond yields. Following a drop of about 50 bps in the weeks leading up the reform on December 2, 2011, the spread stops falling and increases by 17 bps from the day before the reform to the day after the reform.

Table 5 shows the results of regressing various daily changes in yield or yield spreads on a dummy for the 2011 reform. The abnormal two-day change in the Danish 10-year government bond yield is 19.5 bps, compared to 2.8 bps for the change in the German 10-year government bond yield. The abnormal change in the Danish-German 10-year government bond yield spread around this event is thus around 17 bps (column (4)) with a *t*-statistic of 6.75. The effect of the reform on the Danish Krone 10-year interest rate swap yield (column (2) and (5)) is similar to that of the Danish 10-year government bond yield.

Reform 3: Denmark, June 12, 2012

The third reform is perhaps the most interesting because it allows us to assess the extent to which the Danish P&I sector drives yields not only on Danish fixed-income securities but potentially also on euro swaps and other northern European government bond yields.

Table 6 Panel A documents large effects of this reform on the euro swap curve. The reform increased the 50-year and 30-year rates by around 26 bps in the 2 days around the reform; 10-year rates increased also, by 17 bps, perhaps because the because the reform also reduced P&I demand

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[15] Appendix Figure 2 shows OAS for US MBS. The reduction in the US OAS a few days after the reform on November 4 is the day Barack Obama was elected president. Controlling for daily changes in the US OAS in the regression has no impact on the results above.

for hedging duration risk more generally. As predicted, the 50-10 and the 30-10 spreads increase, with an effect around 9 bps, significant at the 5% level or better.

Figure 5 shows these effects graphically. Panel A illustrates the jump in the 30-10 spread for the euro interest rate swap curve, with the first vertical line denoting the date of the Danish UFR reform. For comparison, and to rule out confounding world-wide events, the graph also shows the 30-10 spread for US dollar interest rate swaps at the same time; interest rate swaps do not jump around the event.

Panel B of Table 6 shows that effects on the euro swap curve carry over to safe euro-denominated government bonds. The reform increases the 30-10 spread for German government bonds by 10 bps and that for Dutch government bonds by 8 bps. No significant effect is found for Italian and Spanish government bonds which in the summer of 2012 were much higher risk and apparently not integrated with safer markets in Northern Europe markets at the time.

Turning to effects on Danish yields, Panel C of Table 6 shows that Danish Krone interest rate swaps moved a bit more than euro interest rate swaps, with an abnormal increase in the Danish Krone 30-10 interest rate swap spread of 12.5 bps in the 2 days around the reform and an even larger effect of 20 bps on the 30-2 Danish Krone interest rate swap spread. Effects on Danish government bond yields in Table 6 Panel D are similar to those for Danish Krone interest rate swaps. Figure 5 Panel C illustrates the jump in the Danish government 30-10 spread due to the reform.

The results above suggest that Danish P&I demand impacts long-maturity interest rates for safe assets denominated in *both* Euro and Danish Kroner. This is not surprising given the combination of large Danish P&I assets (345% of GDP in 2016), modest Danish government debt, and the fact that the Krone is pegged to the Euro, making safe euro assets a reasonable substitute for Danish investors.[16] Moreover, as can be seen from Appendix Table 2, the Danish P&I sector (and the Dutch P&I sector the impact of which we study next) is a substantial fraction of all euro zone + Denmark P&I assets.

[16] See Liao (2016) and Maggiori, Neiman, and Schreger (2017) who suggest that capital markets may be segmented along currency lines.

Reform 4: Netherlands, July 2, 2012

Panel A of Table 7 documents the effect of the Dutch reform on euro interest rate swap rates. The abnormal changes implied by the regression dummies are a 12 bps increase in the 30-10 spread and a 16 bps increase in the 50-10 spread in the 2 days around the reform, both changes significant at the 1% level. These imply a substantial effect of the Dutch P&I sector on the euro interest rate swap curve. The effect on Dutch government bonds documented in Panel B is similar with a 15 bps increase of the 30-10 spread, illustrated in Figure 5 Panel D. Table 7 Panel C shows that, as predicted, effects carry over to 30-10 spreads on German and Danish government bonds (both low credit risk and denominated in euro or in a currency pegged to the euro) but do not carry over with statistically significant effects to higher credit-risk Italian and Spanish bonds. The effect on the Danish 30-10 spread is visible in Figure 5 Panel C.

Reform 5: Sweden, June 7, 2012

Figure 6 illustrates the impressive reversal of Swedish interest rates following the announcement that the regulatory discount curve would be bounded from below at May 31, 2012 values. The announcement date for this reform is indicated by the first vertical line. Panel A of Table 8 shows that the abnormal two-day returns around the reform for Swedish government bonds an Swedish Krone interest rate swaps is almost 30 bps from the 10-year point and longer, with 2-year rates moving by about half of that. All changes are statistically significant at the 10% level or better.

Given the strong reversal of rates caused by the reform, rates on June 8, 2012, the day after the reform was announced, are back to where they were a few days before the reform and higher than rates on May 31, 2012. The floor ultimately ended up not binding -- likely due to the endogenous response of the P&I sector to the floor which made Swedish government bonds and Swedish Kroner interest rate swaps less attractive by removing the need to hedge fluctuations in Swedish government bond yields.

Indirect effects

Given that the Swedish regulatory discount curve is based only on Swedish government bonds and Swedish Kroner interest rate swaps the Swedish 2012 reform did not have a direct effect on the Swedish P&I sectors' demand for fixed income securities denominated in other currencies. If sufficiently correlated with Swedish bonds, the Swedish P&I sector could have used e.g. Danish or euro-denominated bonds to hedge fluctuations in the regulatory discount curve before the reform. In that case it may have reduced its demand for these bonds following reforms. We find little evidence of this. Panels B and C or Table 8 document that the Swedish 2012 reform had no significant effect on euro interest rate swap rates or government bonds yields in northern or southern Europe. Similarly, we do not find any effects of the Danish or Dutch reforms on Swedish yields (omitted from the tables for brevity) consistent with markets being somewhat disconnected due to exchange rate risk given that Sweden (unlike Denmark) follows a floating exchange rate policy. This is consistent with Maggiori, Neiman, and Schreger (2017) who suggest that fixed income investors focus on investments denominated in their own currency.

Reform 6: Sweden, February 18, 2013

Table 9 Panel A confirms that long Swedish rates fell relative to shorter rates. The only significant effect is for the 20-10 spread for Swedish government bonds, which falls by about 7 bps. As for the first Swedish reform there is no effect on euro interest rates swap rates of rates on other northern European bonds. The modest effect of this reform may be due to uncertainty about when and precisely how it would be implemented. From Figure 6 Panel A it is can be seen that Swedish 30-year swaps increase relative to Swedish 2-year swaps in the period leading up to the second announcement on May 20, 2013 regarding this reform. Some of this increase may be related to the reform.

V. Conclusion

In this paper, we showed the importance of pension and insurance companies in determining the yields on long maturity bonds around the world. Our analysis was in two parts. First, using data from 26 countries, we showed that the yield spread between 30-year and 10-year government bond yields is negatively related to the ratio of pension and insurance assets (in funded and private pension arrangements) to GDP, suggesting that preferred-habitat demand by the pension and insurance sector for long-dated assets drives the long end of the yield curve.

We then drew on changes in pension regulations in several European countries between 2008 and 2013 to show that the pension and insurance sector's demand is in part driven by the statutory discount curve used for regulatory purposes. In particular, pension and insurance companies can hedge future statutory underfunding by buying assets with returns tied to the rate used to discount their liabilities. When regulators move to change the reference curve by which pensions discount their liabilities, this results in changes in hedging demand, and as we show, changes in the prices of fixed income assets.

We have noted throughout that the timing of these events was by no means exogenous. As interest rates in Europe fell during and after the 2008-2009 financial crisis, regulators became increasingly concerned that in seeking to reduce the volatility of their funding gap, the pension and insurance sector would act procyclically, selling assets whose prices were falling or buying assets whose prices were increasing. Changing the reference curve for marking liabilities reduced this pressure, but with long-term implications for solvency that remain unclear.

References

Abad, Jorge, Inaki Aldasoro, Christoph Aymanns, Marco D'Errico, Linda Fache Rousová, Peter Hoffman, Sam Langfield, Martin, Neychev, and Tarik Roukny, 2016, "Shedding light on dark markets: First insights from the new EU-wide OTC derivatives dataset," European Systemic Risk Board.

Adrian, T., E. Etula, and T. Muir, 2014, "Financial Intermediaries and the Cross-Section of Asset Returns", *Journal of Finance*, 69, 6, 2557-2596.

Andonov, Aleksander, Rob Bayer, and Martijn Cremers, 2017, "Pension fund asset allocation and liability discount rates," *Review of Financial Studies* 30, 2555-2595.

Ang, Andrew, Bingxu Chen, and Suresh Sundaresan, 2013, "Liability-driven investment with downside risk," *Journal of Portfolio Management* 40, 71-87.

Barr, Nicholas, and Peter Diamond, 2006, "The economics of pensions," *Oxford Review of Economic Policy* 22, 15-39.

Blundell-Wignall, Adrian, Yu-Wei Hu, and Juan Yermo, 2008, "Sovereign wealth and pension reserve fund issues," *Financial Market Trends* 2008/1, 117-132.

Boubaker Sabri, Dimitrios Gounopoulus, Duc Khuong Nguyen, and Nikos Paltalidis, 2017, "Assessing the effects of unconventional monetary policy and low interest rates on pension fund risk incentives," *Journal of Banking and Finance* 77, 35-52.

Committee on the Global Financial System, 2018, "Financial stability implications of a prolonged period of low interest rates", CGFS Papers No 61.

Danmarks Nationalbank, 2016, "Financial Stability, 2nd Half, 2016".

Domanski, Dietrich, Hyun Song Shin, and Vladyslav Sushok, 2017, "The hunt for duration: not waving but drowning?" *IMF Economic Review* 65, 113-153.

Finanstilsynet, 2009, "Markedsudvikling 2008 for livsforsikringsselskaber og tværgående pensionskasser".

Fuchita, Yasuyuki, Richard Herring and Robert Litan, *Growing old: Paying for retirement and institutional money management after the financial crisis,* (Brookings Institution Press: Washington, DC) 2011.

Garbade, Kennth, and Matthew Rutherford, 2007, "Buybacks in Treasury Cash and Debt Management", Federal Reserve Bank of New York Staff Report No. 304.

Giannetti, Mariassunta, and Luc Laeven, 2008, "Pension reform, ownership structure, and corporate governance: Evidence from a natural experiment," *Review of Financial Studies* 22, 4091-4127.

Greenwood, Robin, and Dimitri Vayanos, 2010, "Price pressure in the government bond market," *American Economic Review: Papers and Proceedings* 100, 585-590.

Greenwood, Robin, and Dimitri Vayanos, 2014, "Bond supply and excess bond returns," *Review of Financial Studies* 27, 663-713.

Guibaud, Stéphane, Yves Nosbusch, and Dimitri Vayanos, 2013, "Bond market clienteles, the yield curve and the optimal maturity structure of government debt,"*Review of Financial Studies* 26, 1914-1961.

He, Z., B. Kelly, and A. Manela, 2017, "Intermediary Asset Pricing: New Evidence from Many Asset Classes", *Journal of Financial Economics*, 126, 1, 1-35

Kaul, Aditya, Vikas Mehrotra, and Randall Morck, 2000, "Demand curves for stocks *do* slope down: New evidence from an index weights adjustment," *Journal of Finance* 55, 893-912.

Klingler, Sven, and Suresh Sundaresan, 2018, "An explanation of negative swap spreads: Demand for duration from underfunded pension plans," BIS Working paper 705.

Koijen, Ralph, and Motohiro Yogo, 2015, "The cost of financial frictions for life insurers," *American Economic Review* 105, 445-475.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen, 2012, "The aggregate demand for treasury debt," *Journal of Political Economy* 120, 233-267.

Krishnamurthy, Arvind, and Annette Vissing-Jorgensen, "The ins and outs of large scale asset purchases," Kansas City Federal Reserve Symposium on Global Dimensions of Unconventional Monetary Policy, 2013

Langejan, T. W., T.E. Nijman, A. A. J. Pelsser, O.C.H.M. Sleijpen, O.W. Steenbeek, and C. van Ewijk, "Advisory Report of the UFR Committee," 2013.

Lewin, Christopher, *Pensions and Insurance Before 1800: A Social History* (Tuckwell Press, East Lothian, Scotland), 2004.

Liao, Gordon, 2016, "Credit migration and covered interest rate parity," Project on Behavioral Finance and Financial Stability Working Paper Series No. 2016-07.

Litterman, R., J. Scheinkman, and L. Weiss, 1991, "Volatility and the Yield Curve", Journal of Fixed Income 49, 49-53.

Lynch, Anthony, and Richard Mendenhall, 1997, "New evidence on stock price effects associated with changes in the S&P 500 Index," *Journal of Business* 70, 351-383.

Maggiori, Matteo, Brent Neiman, and Jesse Schreger, 2018, "International currencies and capital allocation," Working paper.

Modigliani, Franco, and Richard Sutch, 1966, "Innovations in interest-rate policy," *American Economic Review* 56, 178-197.

Novy-Marx, Robert, and Joshua Rauh, 2011, "The crisis in local government pensions in the United States," Working paper.

OECD, "Pensions at a glance," Technical report, 2015.

OECD, "OECD and G20 indicators," Technical report, 2015.

OECD, "Annual survey of large pension funds and public pension reserve funds," Technical report, 2016.

Rauh, Joshua, 2009, "Risk shifting versus risk management: Investment policy in corporate pension plans," *Review of Financial Studies* 22, 2687-2733,

Scharfstein, David, "Pension policy and the financial system," forthcoming, *Journal of Finance*.

Scholtens, Bert, and Ramon Tol, 1999, "On the comovement of bond yield spreads and country risk ratings," *Journal of Fixed Income* 8, 100-103.

Shleifer, Andrei, 1986, "Do demand curves for stocks slope down?" *Journal of Finance* 41, 579-590.

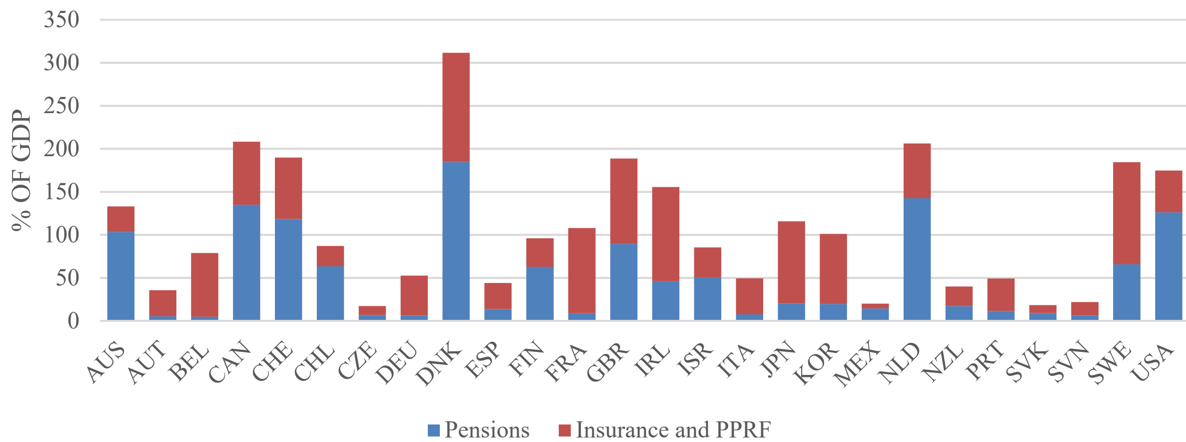
Treynor, Jack, 1977, "The principles of corporate pension finance," *Journal of Finance* 32, 627-638.

Vayanos, Dimitri, and Jean Luc Vila, 2009, "A preferred-habitat model of the term structure of interest rates," Working paper.

World Bank, *Averting the Old Age Crisis,* (Washington, DC), 1994.

Figure 1. Pension and insurance assets

Panel A. (P&I Assets)/GDP (%), mean 2009-2016



Panel B. (P&I Assets-GovDebt)/GDP vs. (P&I Assets)/GDP

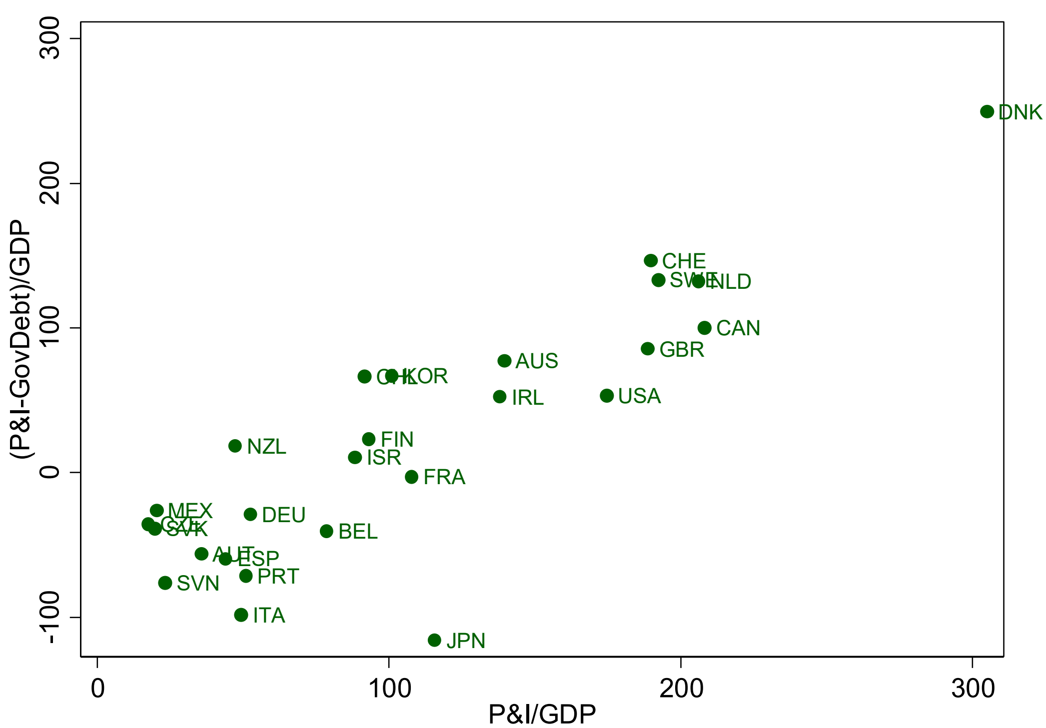


Figure 2. Pensions and global yield curves

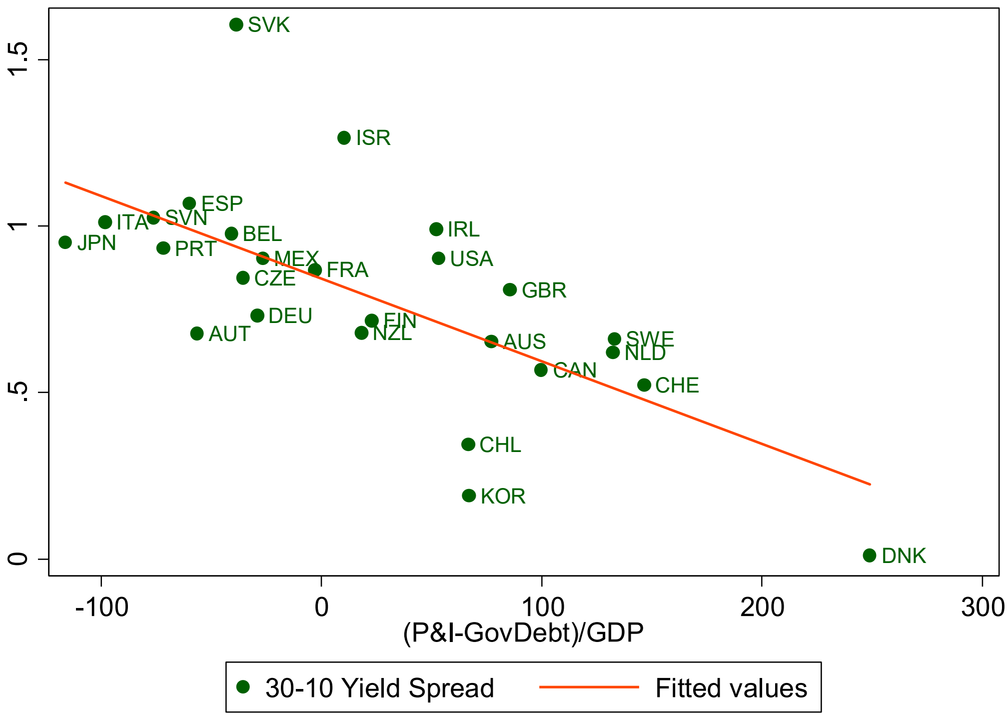


Figure 3. Option-adjusted spread on Danish MBS over Danish interest rate swaps

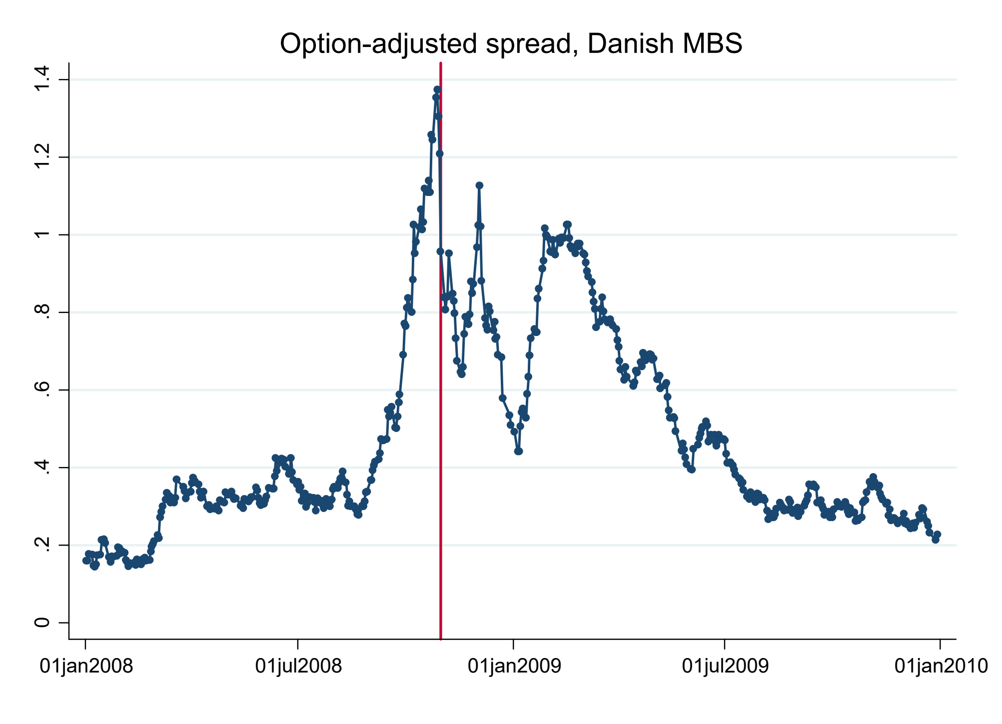


Figure 4. Spread between Danish and German 10-year government bond yields

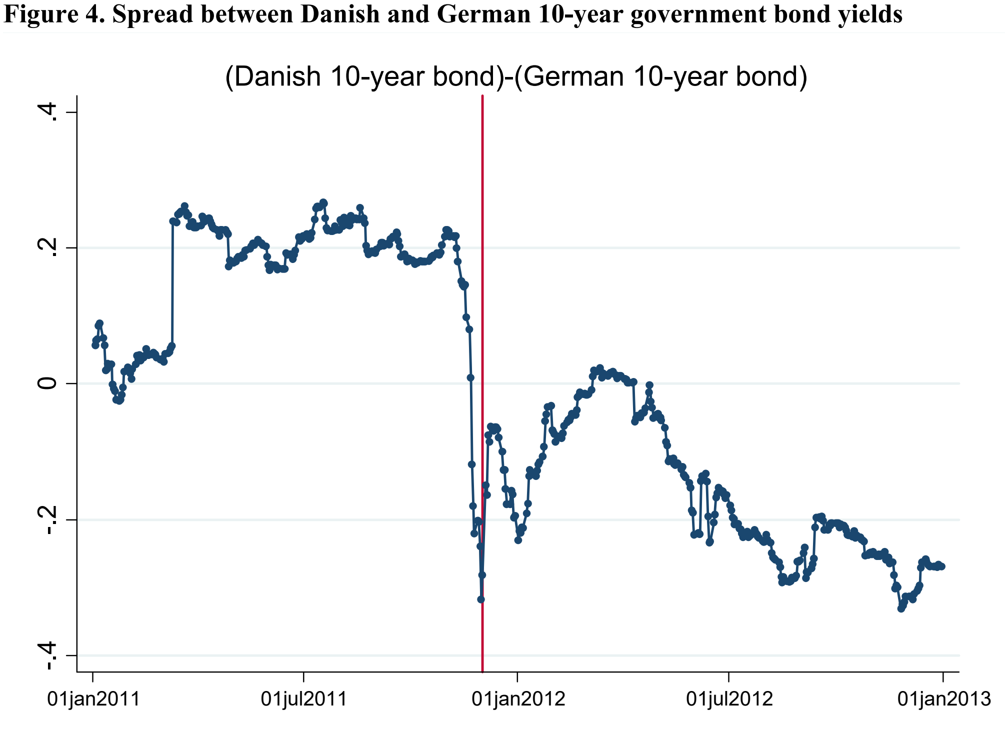
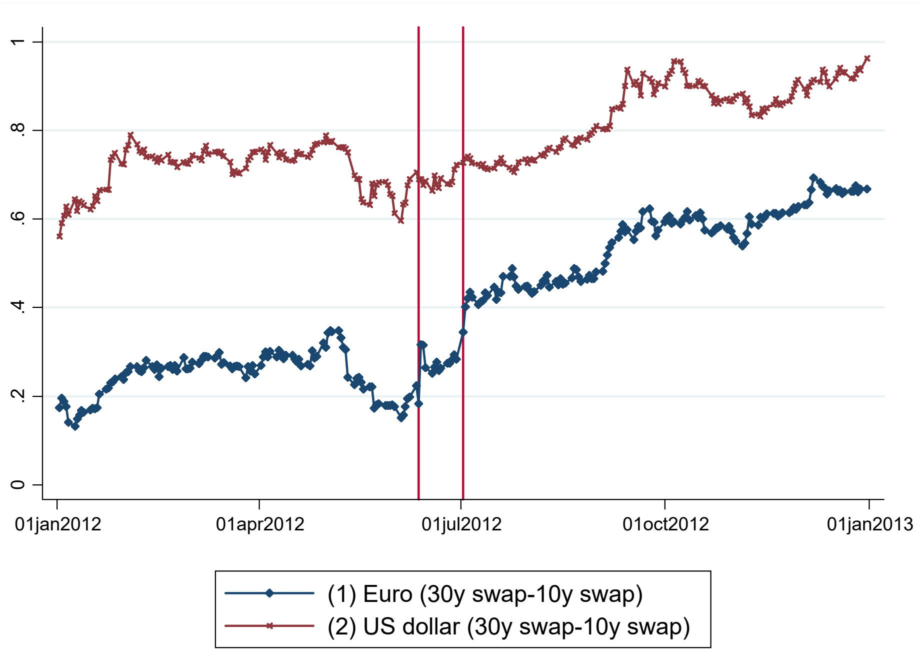


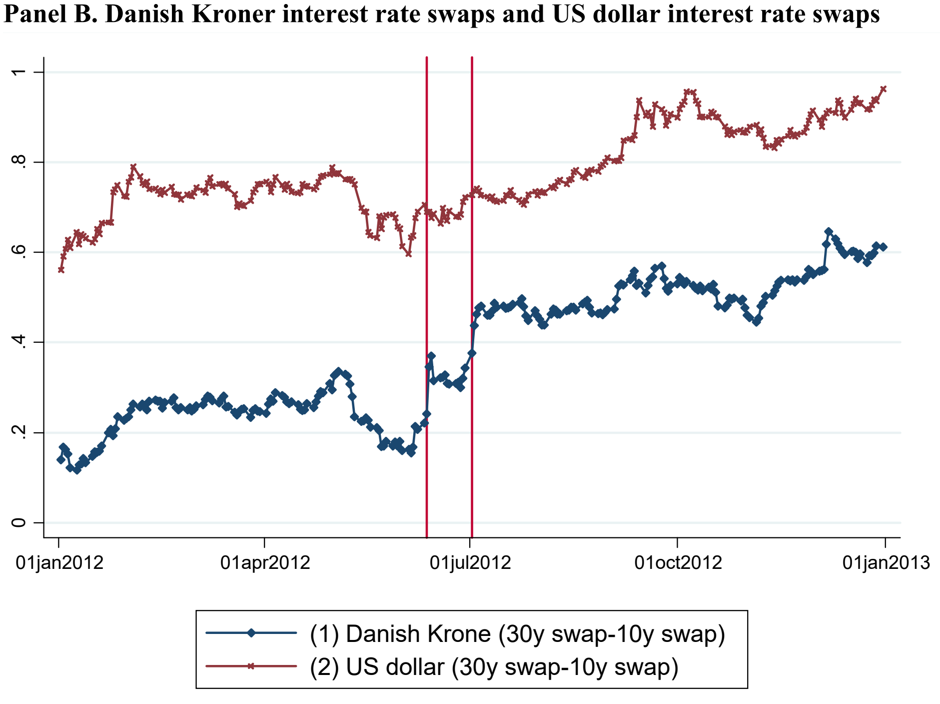
Figure 5. Spread between 30 and 10 year yields

The first vertical line indicates the June 12, 2012 Danish reform. The second vertical line indicates the Dutch July 2, 2012 reform.

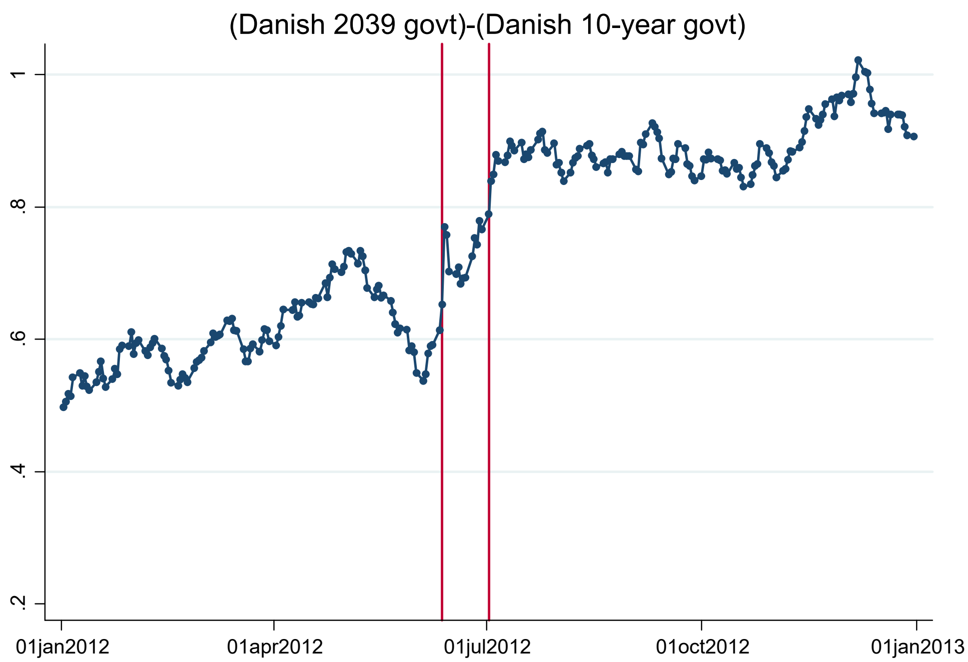
Panel A. Euro interest rate swaps and US dollar interest rate swaps



Panel B. Danish Kroner interest rate swaps and US dollar interest rate swaps



Panel C. Danish government bonds



Panel D. Dutch government bonds

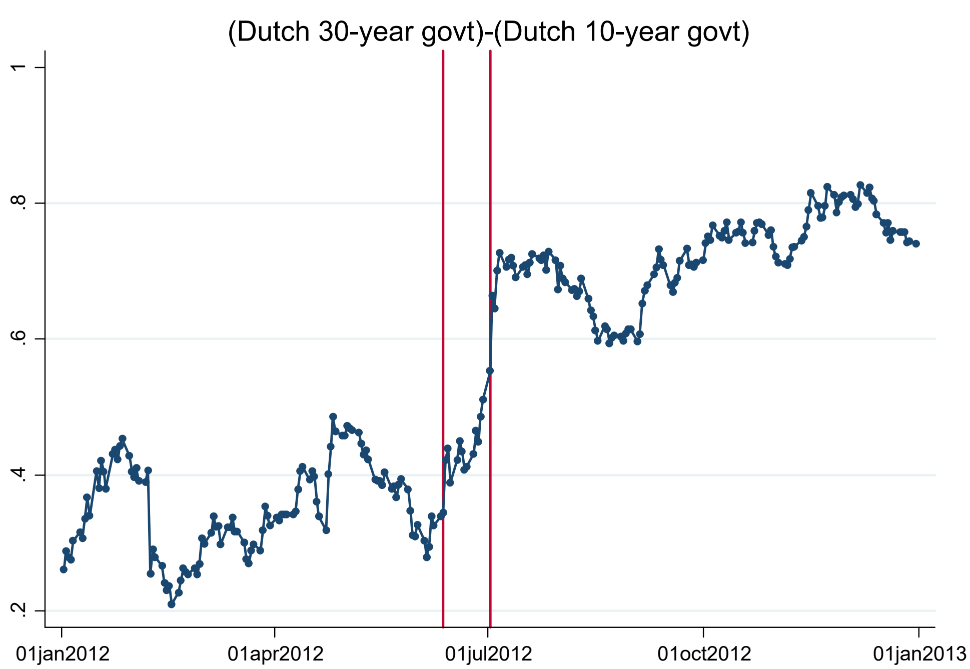
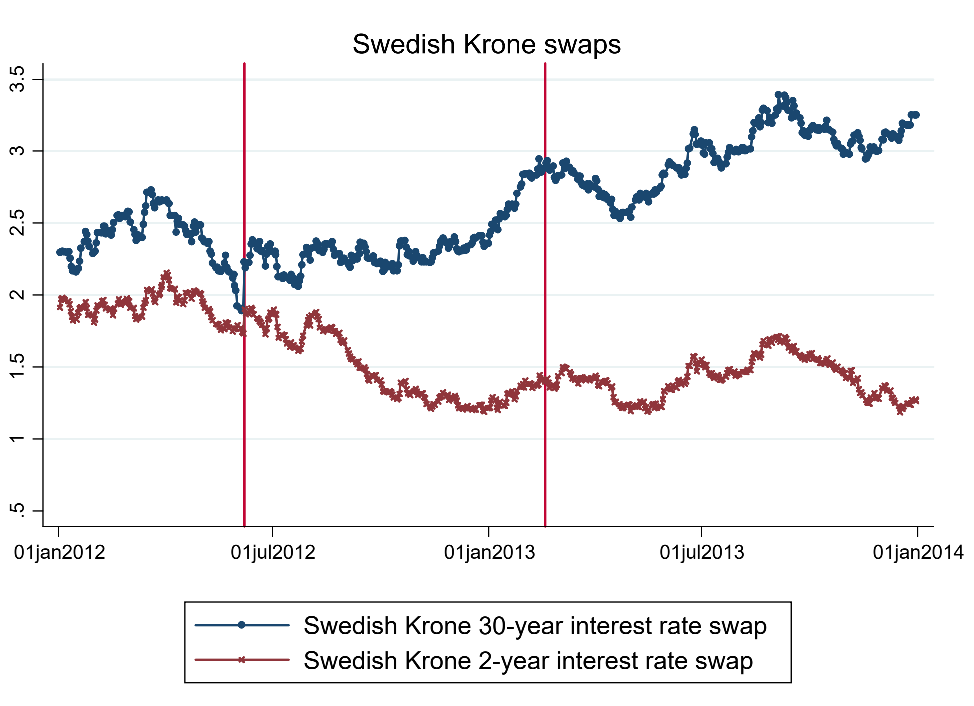
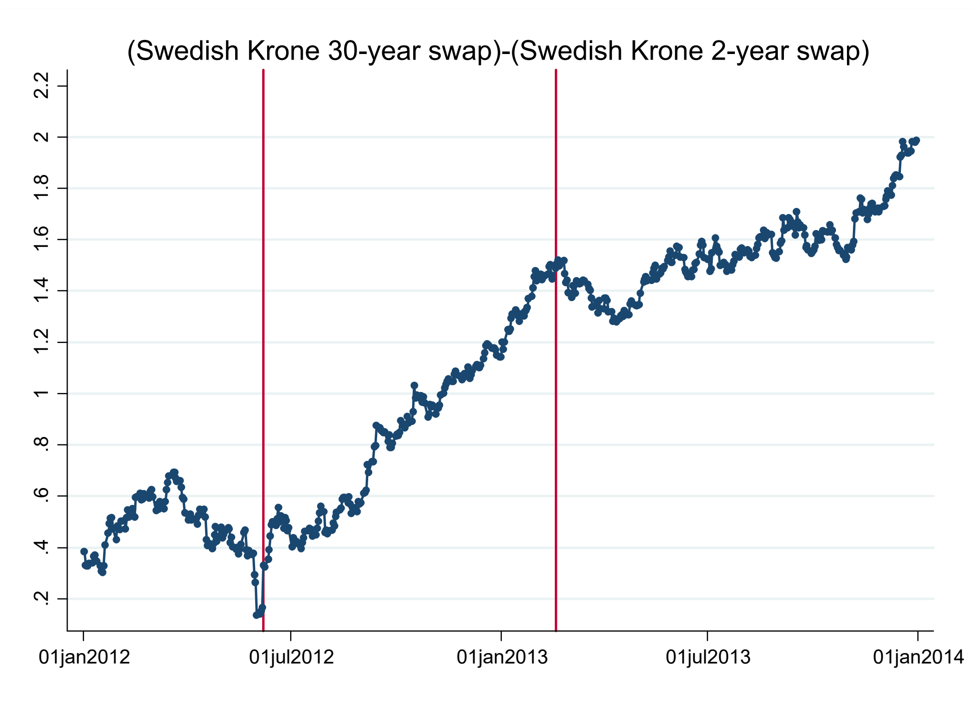


Figure 6. Yields on Swedish government bonds and Swedish Krone interest rate swaps

The vertical lines denote the announcement dates of the two Swedish reforms, June 7, 2012 and February 18, 2013.

Panel A. Swedish Kroner interest rate swaps





Panel B. Swedish government bonds

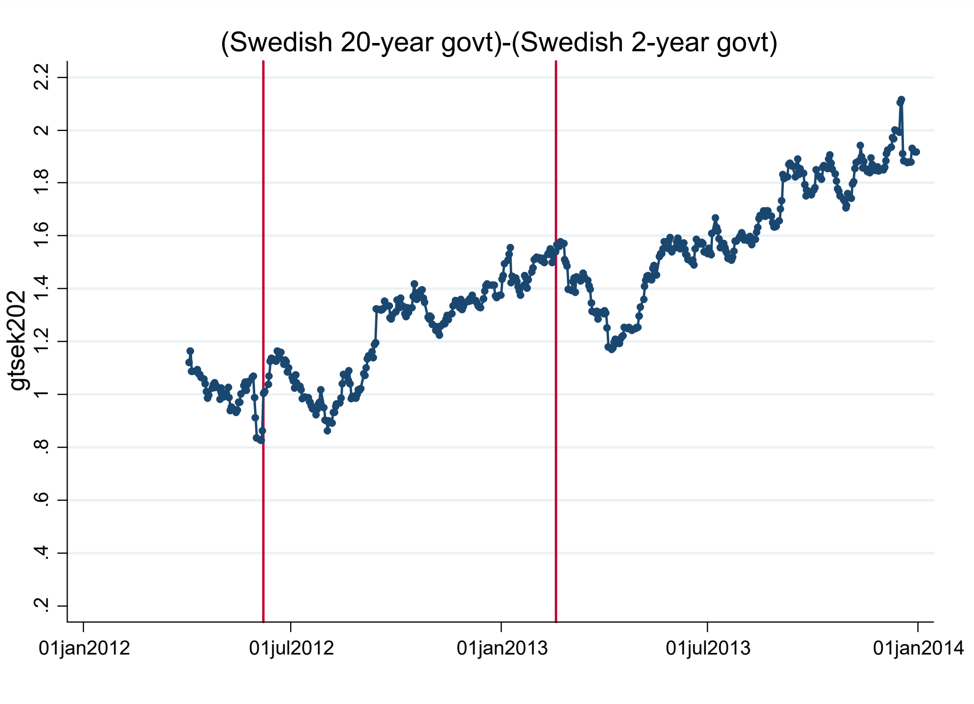


Table 1. Summary statistics

Country	First Year	Last Year	Pensions Assets/GDP	(Pensions + Insurance Assets)/GDP	Gov Debt/GDP	*NETDEMAND* (col. (4)-(5))	Replacement Rate	Allocation to Bonds (for pensions)	30-10 Spread	10-2 Spread	Sovereign CDS Spread
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
AUS	2013	2016	94.9	133.1	43.7	78.7	13.5	8.5	0.67	0.60	41.58
AUT	2001	2013	4.7	35.7	80.2	-56.3	78.1	50.2	0.61	1.21	49.06
BEL	2001	2014	4.5	78.8	111.9	-40.7	46.6	38.5	0.66	1.23	34.74
CAN	2000	2016	122.7	208.2	102.7	99.8	36.7	35.4	0.41	1.03	25.97
CHE	2007	2016	105.0	189.7	49.2	146.5	23.3	36.2	0.47	0.96	35.01
CHL	2014	2016	61.1	87.1	18.8	67.2	0.0	53.8	0.34	0.80	68.56
CZE	2014	2016	5.2	17.2	41.5	-34.1	49.0	84.6	0.75	1.45	62.83
DEU	1995	2016	4.6	52.5	69.4	-29.2	37.5	48.7	0.63	1.20	27.18
DNK	2001	2016	156.8	311.6	52.0	255.9	21.5	63.3	0.31	1.18	39.08
ESP	2001	2016	12.4	44.0	71.6	-59.7	82.1	63.1	0.69	1.27	78.72
FIN	2012	2016	65.7	95.9	54.7	31.7	55.8	31.4	0.72	1.30	28.40
FRA	2001	2016	7.3	107.9	93.0	-2.8	55.4	Missing	0.65	1.29	40.12
GBR	2001	2016	77.3	188.7	77.0	85.6	21.6	29.1	0.21	0.77	44.28
IRL	2001	2016	43.7	155.6	58.5	57.0	34.7	Missing	0.65	1.32	72.91
ISR	2012	2015	38.0	85.4	85.3	5.1	11.8	79.5	1.27	1.98	89.71
ITA	2001	2016	4.9	49.4	127.6	-98.2	69.5	44.6	0.73	1.44	90.58
JPN	2001	2016	15.2	115.7	198.7	-116.1	35.1	34.8	0.84	1.00	46.34
KOR	2006	2016	14.3	101.0	29.9	67.0	39.3	6.9	0.15	0.53	61.57
MEX	2011	2016	10.9	19.9	38.9	-22.9	3.9	80.6	0.81	1.54	111.66
NLD	1999	2016	117.4	206.2	67.9	132.3	27.1	42.1	0.51	1.26	39.04
NZL	2016	2016	14.2	39.8	23.8	11.7	40.1	Missing	0.61	0.42	36.80
PRT	2006	2015	12.4	49.2	86.1	-82.9	73.8	49.3	0.63	1.39	76.31
SVK	2012	2012	5.0	18.4	48.8	-37.3	38.9	67.6	1.45	0.95	55.71
SVN	2015	2016	4.2	21.9	53.9	-56.0	38.4	71.3	1.06	1.35	77.52
SWE	2012	2016	45.1	184.4	63.5	127.2	37.0	68.7	0.67	1.15	33.11
USA	1995	2016	114.4	174.7	91.8	53.3	35.2	35.1	0.57	1.19	29.67
Mean			50.0	112.3	69.1	34.4	37.2	50.2	0.59	1.12	53.93
SD			47.0	76.1	37.4	87.8	21.4	21.2	0.29	0.34	23.23

Notes: Columns (2)-(11) show time series means for each country for the years listed in columns (1) and (2). AUS=Australia, AUT=Austria, BEL=Belgium, CAN=Canada, CHE=Switzerland, CHL=Chile, CZE=Czech Republic, DEU=Germany, DNK=Denmark, ESP=Spain, FIN=Finland, FRA=France, GBR=Great Brittain, IRL=Ireland, ISR=Israel, ITA=Italy, JPN=Japan, KOR=South Korea, MEX=Mexico, NLD=The Netherlands, NZL=New Zealand, PRT=Portugal, SVK=Slovakia, SVN=Slovenia, SWE=Sweden, USA=United States.

Table 2. Pensions and global yield curves

Panel A. Baseline estimation

	Baseline Results 2009-2016				Exclude Insurance & PPRF			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(P&I Assets)/GDP	-0.0022***	-0.0022***			-0.0031***	-0.0027***		
	[-3.66]	[-4.37]			[-3.52]	[-3.14]		
GovDebt/GDP		0.0031**				0.0025*		
		[2.67]				[1.89]		
(P&I Assets-GovDebt)/GDP			-0.0027***	-0.0024***			-0.0028***	-0.0026***
			[-4.56]	[-6.27]			[-4.45]	[-4.92]
CDS			-0.0022				-0.0011	
			[-1.53]				[-0.76]	
10-2 Yield Spread			0.2599**				0.2412	
			[2.09]				[1.62]	
Age			-0.0148				-0.0192*	
			[-1.41]				[-1.78]	
$\sigma(y_2)$				-0.4449				0.0530
				[-0.83]				[0.10]
Constant	1.0195***	0.7642***	1.1983**	0.9331***	0.9449***	0.7192***	1.1744**	0.6892***
	[11.06]	[5.29]	[2.50]	[7.49]	[12.26]	[4.47]	[2.56]	[5.59]
Year FE?	No	No	No	No	No	No	No	No
Observations	26	26	26	26	26	26	26	26
R-squared	0.288	0.490	0.600	0.491	0.281	0.408	0.547	0.408

Notes: The dependent variable is the average spread between the yields of 30- and 10-year government bonds. All variables are averaged over the 2009-2016 period.

[Table 2 Continued]

Panel B. Robustness

	Collapse Euro area		Panel Estimation		Pre-2009	
	(1)	(2)	(3)	(4)	(5)	(6)
(P&I Assets-GovDebt)/GDP	-0.0023***	-0.0028***	-0.0022***	-0.0025***	-0.0020**	-0.0017**
	[-3.22]	[-3.97]	[-9.14]	[-8.28]	[-2.65]	[-2.58]
CDS		-0.0040		-0.0027***		
		[-1.34]		[-3.84]		
10-2 Yield Spread		0.3461**		0.2486***		0.4505***
		[2.96]		[5.40]		[3.29]
Age		-0.0151		-0.0119*		-0.0182
		[-0.91]		[-1.79]		[-0.69]
Constant	0.7785***	1.1722	0.8091***	1.0944***	0.3012***	0.6237
	[10.96]	[1.42]	[33.77]	[3.86]	[6.07]	[0.67]
Year FE?	No	No	Yes	Yes	No	No
Observations	15	15	128	121	16	15
R-squared	0.443	0.739	0.420	0.570	0.367	0.718

Table 3. Overview of regulatory reforms studied

Reform	Change to regulatory discount curve	Date announced	Upward shift in regulatory discount curve	Using day t-1 data	Using day t+1 data
Danish 2008 reform	Including half of OAS in curve	October 31, 2008	Maturities 7 years or longer: None for maturities 0 to 2 years. Linear interpolation from 2 to7 years.	52 bps	34 bps
Danish 2011 reform	Floor and averaging for Danish-German 10-year spread	December 2, 2011	Maturities 7 years or longer: None for maturities 0 to 2 years. Linear interpolation from 2 to7 years.	40 bps	24 bps
Danish 2012 reform	UFR introduced, LLP=20y, convergence of forward rate to 4.2% at 30y	June 12, 2012	Maturity 50 years Maturity 30 years Maturity 25 years None for maturities 0-20 years.	103 bps 56 bps 28 bps	88 bps 47 bps 24 bps
Dutch 2012 reform	UFR introduced, LLP=20y, convergence of forward rate to 4.2% at 60y	July 2, 2012	Maturity 50 years Maturity 30 years Maturity 25 years None for maturities 0-20 years.	78 bps 32 bps 12 bps	72 bps 32 bps 15 bps
Swedish 2012 reform	Floor introduced. Rates bounded below at May 31, 2012 values	June 7, 2012	At 20 year maturity: At 10 year maturity: At 2 year maturity:	12 bps 13 bps 5 bps	-17 bps -15 bps -9 bps
Swedish 2013 reform	UFR introduced, LLP=10y, convergence of forward rate to 4.2% at 20y	February 18, 2013	Maturity 50 years Maturity 30 years Maturity 25 years None for maturities 0-20 years.	TBD	TBD

Notes: We calculate the shifts in the regulatory yield curve using data for the relevant inputs from Bloomberg and in the case of the Danish and Dutch reforms in 2012 using spreadsheets from the Danish FSA and the Dutch central bank with data on the curves that use the UFR methodology. The Dutch central bank posts monthly regulatory yield curves so for the Dutch 2012 reform column (5) shows the results based on data from 6/30/2012 and column (6) based on data from 7/31/2012. The shift in the regulatory yield curve for pension funds following the Dutch extension of the UFR method to pension funds on 9/24/2012 is of similar magnitude.

Table 4. Effects of Danish 2008 reform

	(1)	(2)
	OAS on Danish MBS	Yield on Danish MBS
Dummy for 2008 change to Danish discount curve	-0.369***	-0.302***
(including half of OAS in curve)	[-11.68]	[-7.93]
Constant	0.000316	-0.00138*
	[0.53]	[-1.96]
N	1435	1460

Notes: The dependent variable is the daily change in the variable stated. The dummy variable on the right-hand side is turned on for the day of the announcement and the following day. The dummy is divided by two so that the coefficient has the interpretation of the abnormal 2-day change in the dependent variable. Data are for 2008-2013. ***/**/* indicate significance at the 1%/5%/10% level.

Table 5. Effects of Danish 2011 reform

	(1)	(2)	(3)	(4)	(5)
	A. Danish 10-year govt bond yield	B. Danish Krone 10-year interest rate swap yield	C. German 10-year govt bond yield	A-C	B-C
Dummy for 2011 change to Danish discount curve (floor and averaging for Danish-German 10-year spread)	0.195*** [2.72]	0.211*** [3.12]	0.0281 [0.38]	0.169*** [6.75]	0.183*** [4.05]
Constant	-0.00117	-0.00169	-0.00154	-0.000444	-0.000152
	[-0.87]	[-1.40]	[-1.16]	[-0.95]	[-0.19]
N	1428	1566	1566	1428	1566

Notes: The dependent variable is the daily change in the variable stated. The dummy variable on the right-hand side is turned on for the day of the announcement and the following day. The dummy is divided by two so the coefficient has the interpretation of the abnormal 2-day change in the dependent variable. Data are for 2008-2013. ***/**/* indicate significance at the 1%/5%/10% level.

Table 6. Effects of Danish 2012 reform

In each panel the dependent variable is the daily change in the variable stated for the particular column. The dummy variable on the right-hand side is turned on for the day of the announcement and the following day. The dummy is divided by two so the coefficient has the interpretation of the abnormal 2-day change in the dependent variable. Data are for 2008-2013. ***/**/* indicate significance at the 1%/5%/10% level.

Panel A. Euro interest rate swaps

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Euro interest rates swaps						
	50-year	30-year	10-year	2-year	50-10	30-10	30-2
Dummy for 2012 change to Danish discount curve (UFR introduced, LLP=20y)	0.254***	0.264***	0.171**	0.0782	0.0824**	0.0926***	0.186***
	[3.26]	[3.44]	[2.52]	[1.27]	[1.98]	[2.62]	[2.70]
Constant	-0.00147	-0.00154	-0.00175	-0.00262**	0.000280	0.000206	0.00107
	[-1.06]	[-1.13]	[-1.44]	[-2.37]	[0.38]	[0.33]	[0.87]
N	1,566	1566	1566	1566	1566	1566	1566

Panel B. Yields on euro-denominated government bonds

	(1)	(2)	(3)	(4)
	30-10 year govt bond spreads			
	Germany	Netherlands	Italy	Spain
Dummy for 2012 change to Danish discount curve (UFR introduced, LLP=20y)	0.0984***	0.0826**	0.0315	-0.0747
	[2.96]	[2.30]	[0.53]	[-1.39]
Constant	0.000277	0.000202	0.000249	0.000356
	[0.47]	[0.31]	[0.23]	[0.37]
N	1566	1566	1566	1566

Panel C. Danish Krone interest rate swaps

	(1)	(2)	(3)	(4)	(5)
	Danish Krone interest rates swaps				
	30-year	10-year	2-year	30-10 year	30-2 year
Dummy for 2012 change to Danish discount curve (UFR introduced, LLP=20y)	0.291***	0.166**	0.0882	0.125***	0.203***
	[3.84]	[2.45]	[1.36]	[3.21]	[2.76]
Constant	-0.00152	-0.00166	-0.00262**	0.000142	0.0011
	[-1.12]	[-1.37]	[-2.26]	[0.20]	[0.84]
N	1566	1566	1566	1566	1566

Table 6. Effects of Danish 2012 reform [Continued]

Panel D. Danish government bonds

	(1)	(2)	(3)	(4)	(5)
	Danish government bonds				
	2039 bond	10-year	2-year	(2039 bond) - 10 year	(2039 bond) - 2 year
Dummy for 2012 change to Danish discount curve (UFR introduced, LLP=20y)	0.279***	0.122*	0.0652	0.155***	0.214***
	[3.98]	[1.70]	[0.92]	[4.79]	[3.31]
Constant	-0.0017	-0.00112	-0.00259**	0.000402	0.0009
	[-1.25]	[-0.83]	[-2.04]	[0.63]	[0.72]
N	1331	1428	1566	1281	1331

Note: No 30-year generic government bond yield is available for Denmark. We use the Danish government bond maturing in 2039 instead.

Table 7. Effects of Dutch 2012 reform

In each panel the dependent variable is the daily change in the variable stated for the particular column. The dummy variable on the right-hand side is turned on for the day of the announcement and the following day. The dummy is divided by two so the coefficient has the interpretation of the abnormal 2-day change in the dependent variable. Data are for 2008-2013. ***/**/* indicate significance at the 1%/5%/10% level.

Panel A. Euro interest rate swaps

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Euro interest rates swaps						
	50-year	30-year	10-year	2-year	50-10	30-10	30-2
Dummy for 2012 change to Dutch discount curve (UFR introduced, LLP=20y)	0.106	0.0613	-0.0578	-0.0474	0.164***	0.119***	0.109
	[1.35]	[0.80]	[-0.85]	[-0.77]	[3.94]	[3.38]	[1.58]
Constant	-0.00137	-0.00141	-0.0016	-0.00254**	0.000229	0.000189	0.00112
	[-0.98]	[-1.03]	[-1.32]	[-2.30]	[0.31]	[0.30]	[0.91]
N	1566	1566	1566	1566	1566	1566	1566

Panel B. Dutch government bonds

	(1)	(2)	(3)	(4)	(5)
	Dutch government bonds				
	30-year	10-year	2-year	30-10	30-2
Dummy for 2012 change to Dutch discount curve (UFR introduced, LLP=20y)	0.0523	-0.100	-0.0341	0.153***	0.0864
	[0.74]	[-1.45]	[-0.49]	[4.26]	[1.24]
Constant	-0.00117	-0.00133	-0.00245**	0.000157	0.00128
	[-0.93]	[-1.07]	[-1.96]	[0.25]	[1.03]
N	1566	1566	1566	1566	1566

Panel C. Various government bond yields

	(1)	(2)	(3)	(4)
	30-10 year govt bonds			
	Germany	Denmark	Italy	Spain
Dummy for 2012 change to Dutch discount curve (UFR introduced, LLP=20y)	0.0854**	0.0724**	0.0555	0.0725
	[2.56]	[2.22]	[0.93]	[1.35]
Constant	0.000286	0.000467	0.000233	0.000262
	[0.48]	[0.72]	[0.22]	[0.27]
N	1566	1281	1566	1566

Table 8. Effects of Swedish 2012 reform

In each panel the dependent variable is the daily change in the variable stated for the particular column. The dummy variable on the right-hand side is turned on for the day of the announcement and the following day. The dummy is divided by two so the coefficient has the interpretation of the abnormal 2-day change in the dependent variable. Data are for 2008-2013. ***/**/* indicate significance at the 1%/5%/10% level.

Panel A. Swedish government bonds and Swedish Krone interest rate swaps

	(1)	(2)	(3)	(4)	(5)	(6)
	Swedish government bonds			Swedish Krone interest rate swaps		
	20-year	10-year	2-year	30-year	10-year	2-year
Dummy for 2012 change to Swedish discount curve (lower floor introduced)	0.291***	0.283***	0.149*	0.295***	0.277***	0.138**
	[4.83]	[4.05]	[1.81]	[4.20]	[4.14]	[2.25]
Constant	0.00068	-0.00136	-0.00204	-0.00121	-0.00148	-0.00226**
	[0.34]	[-1.09]	[-1.39]	[-0.97]	[-1.24]	[-2.07]
N	455	1566	1566	1566	1566	1566

Note: No 30-year government bond yield is available for Sweden. We use the 20-year yield in column 1.

Panel B. Euro interest rate swaps

	(1)	(2)	(3)
	Euro interest rates swaps		
	30-year	10-year	2-year
Dummy for 2012 change to Swedish discount curve (lower floor introduced)	0.0603	0.0393	-0.0199
	[0.78]	[0.58]	[-0.32]
Constant	-0.00141	-0.00166	-0.00255**
	[-1.03]	[-1.37]	[-2.31]
N	1566	1566	1566

Panel C. Various European government bond yields

	(1)	(2)	(3)	(5)	(6)
	10-year government bonds				
	Denmark	Germany	Netherlands	Italy	Spain
Dummy for 2012 change to Swedish discount curve (lower floor introduced)	0.0812	-0.00296	0.0679	0.105	-0.0617
	[1.13]	[-0.04]	[0.98]	[0.91]	[-0.49]
Constant	-0.00109	-0.00152	-0.00143	-0.00043	-0.000153
	[-0.81]	[-1.15]	[-1.16]	[-0.21]	[-0.07]
N	1428	1566	1566	1566	1566

Table 9. Effects of Swedish 2013 reform

In each panel the dependent variable is the daily change in the variable stated for the particular column. The dummy variable on the right-hand side is turned on for the day of the announcement and the following day. The dummy is divided by two so the coefficient has the interpretation of the abnormal 2-day change in the dependent variable. Data are for 2008-2013. ***/**/* indicate significance at the 1%/5%/10% level.

Panel A. Swedish government bonds

	(1)	(2)	(3)	(4)	(5)	(6)
	Swedish government bonds					
	20-year	10-year	2-year	20-10 year	10-2 year	20-2 year
Dummy for 2013 change to Swedish discount curve (UFR introduced, LLP=10y)	0.0918	0.0274	0.0289	0.0690***	-0.00153	0.0658
	[1.49]	[0.39]	[0.35]	[3.58]	[-0.02]	[1.51]
Constant	0.00112	-0.0012	-0.00196	0.00000221	0.000767	0.0016
	[0.55]	[-0.96]	[-1.34]	[0.00]	[0.61]	[1.11]
N	455	1566	1566	455	1566	455

Panel B. Swedish interest rate swaps

	(1)	(2)	(3)	(4)	(5)	(6)
	Swedish Krone interest rates swaps					
	30-year	10-year	2-year	30-10 year	10-2 year	30-2 year
Dummy for 2013 change to Swedish discount curve (UFR introduced, LLP=10y)	0.0647	0.0276	0.00526	0.0371	0.0224	0.0595
	[0.92]	[0.41]	[0.09]	[1.11]	[0.43]	[1.10]
Constant	-0.00107	-0.00132	-0.00218**	0.000256	0.000854	0.00111
	[-0.85]	[-1.10]	[-1.99]	[0.43]	[0.93]	[1.15]
N	1566	1566	1566	1566	1566	1566

Panel C. Euro interest rate swaps

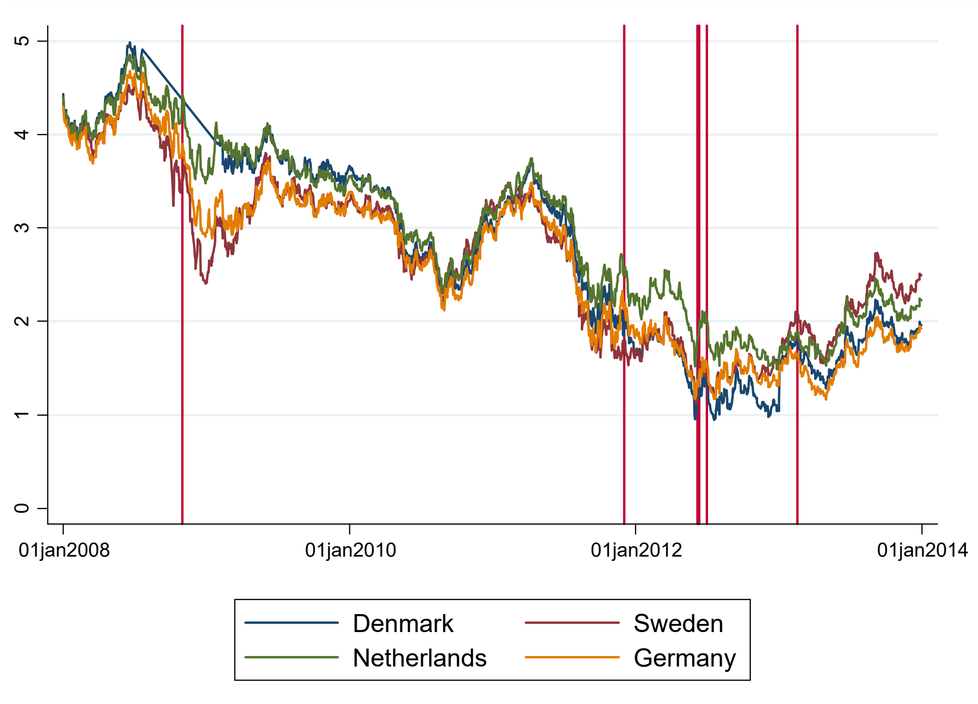
	(1)	(2)	(3)	(4)	(5)	(6)
	Euro interest rates swaps					
	30-year	10-year	2-year	30-10 year	10-2 year	30-2 year
Dummy for 2013 change to Swedish discount curve (UFR introduced, LLP=10y)	-0.00826	-0.0177	0.00113	0.00948	-0.0189	-0.0094
	[-0.11]	[-0.26]	[0.02]	[0.27]	[-0.36]	[-0.14]
Constant	-0.00137	-0.00163	-0.00257**	0.000259	0.000939	0.0012
	[-1.00]	[-1.34]	[-2.32]	[0.41]	[1.00]	[0.97]
N	1566	1566	1566	1566	1566	1566

Table 9. Effects of Swedish 2013 reform [Continued]

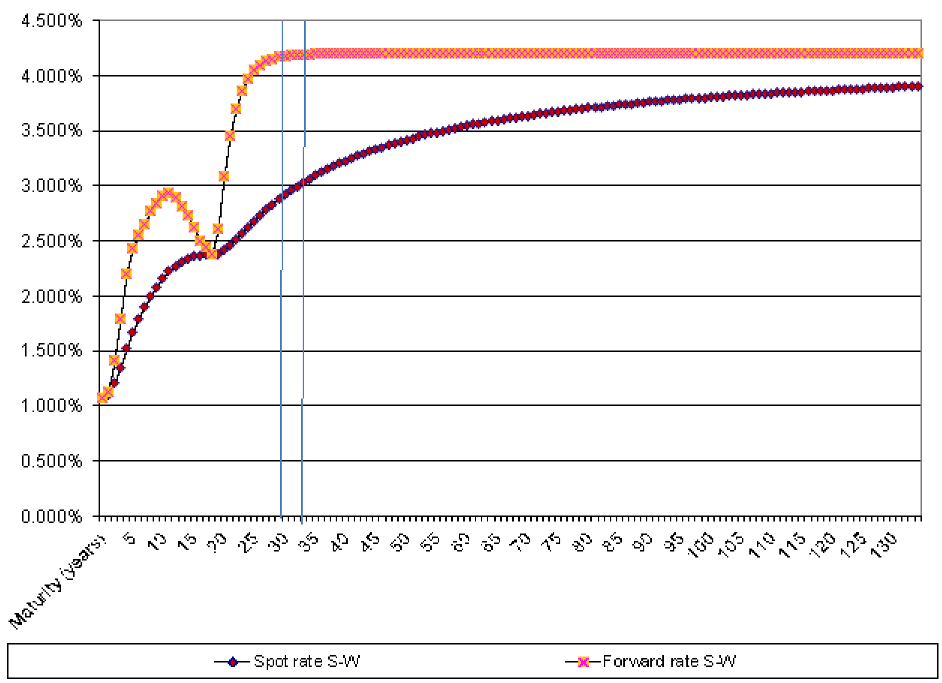
Panel D. Various European government bond yields

	(1)	(2)	(3)	(4)	(5)
	30-10 year govt bonds				
	Denmark	Germany	Netherlands	Italy	Spain
Dummy for 2013 change to Swedish discount curve (UFR introduced, LLP=10y)	0.0142	0.0173	0.0275	0.00447	-0.0116
	[0.43]	[0.52]	[0.76]	[0.07]	[-0.22]
Constant	0.000512	0.000329	0.000237	0.000266	0.000316
	[0.79]	[0.55]	[0.37]	[0.25]	[0.33]
N	1281	1566	1566	1566	1566

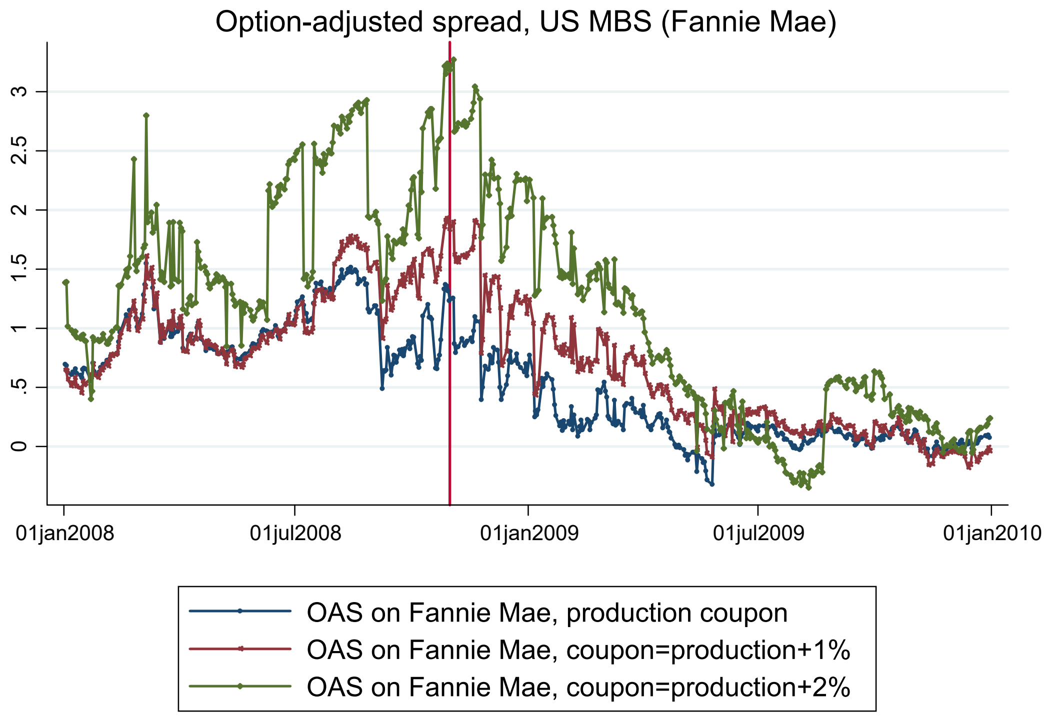
Appendix Figure 1. Yields on 10-year government bonds in northern Europe



Appendix Figure 2. Danish regulatory discount curve (spot and forward), June 13, 2012



Appendix Figure 3. Option-adjusted spread on US MBS over US Treasuries



Appendix Table 1. Maturity distribution of bond holdings of Danish investors, end of 2017

The table states the percent of each maturity segments that is owned by each Danish investor sector. All types of bonds are included (government, MBS, corporate etc.).

	Remaining maturity					
	All	≤1y	1 to 5	5 to 10	10 to 20	>20
	2017M12					
Bonds owned by Danish investors (DKr Billion)	3082	481	1307	288	195	806
Percent of Danish inv. holdings owned by sector:						
Insurance corporations and pension funds	33.7%	17.6%	28.7%	37.8%	21.1%	53.1%
Monetary financial institutions	35.1%	70.9%	47.0%	15.0%	16.5%	6.3%
Other financial intermediaries	21.9%	6.3%	15.0%	28.5%	48.2%	33.5%
General government	4.1%	1.8%	4.4%	12.8%	4.6%	1.9%
Non-financial corporations	3.4%	2.3%	3.7%	3.7%	6.0%	2.8%
Households	1.8%	1.1%	1.2%	2.2%	3.6%	2.5%
	100%	100%	100%	100%	100%	100%

Appendix Table 2. P&I Sector in Europe and Elsewhere, 2011

Country	Private pension assets (€B)	Life insurance assets (€B)	Life+non-life insurance assets (€B)	Private pension +Insurance Assets (€B)	Fraction of total private pension assets	Fraction of total private pension+ insurance assets
Eurozone or pegged to Euro						
Netherlands	1,056	462	545	1,518	0.399	0.177
Denmark	581	357	388	939	0.220	0.109
France	224	519	2,370	2,316	0.085	0.270
Germany	193	1,098	1,578	1,290	0.073	0.150
Spain	173	104	331	471	0.065	0.055
Finland	129	50	66	179	0.049	0.021
Italy	120	189	758	853	0.045	0.099
Ireland	94	199	244	293	0.035	0.034
Belgium	20	12	331	337	0.008	0.039
Austria	20	6	119	128	0.007	0.015
Portugal	19	33	67	80	0.007	0.009
Slovak Republic	8	1	8	16	0.003	0.002
Slovenia	3	1	7	10	0.001	0.001
Latvia	2	0	0	2	0.001	0.000
Estonia	2	1	2	3	0.001	0.000
Luxembourg	1	132	144	133	0.000	0.016
Greece	0	8	19	16	0.000	0.002
Sum:	2,643	3,173	6,978	8,584		
Other European Union countries						
Sweden	322	361	434	683		
Poland	68	26	43	94		
Czech Republic	12	2	22	33		
Hungary	4	3	10	14		
Non-EU OECD countries						
United States	18,000	3,579	5,035	21,579		
United Kingdom	2,233	1,824	2,434	4,413		
Canada	2,178	4	1,234	3,295		
Australia	1,438	228	332	1,665		
Japan	1,069	4,207	4,568	5,275		
Switzerland	665	303	435	967		
Korea, Rep.	192	384	485	577		
Mexico	143	12	54	193		
Chile	135	41	45	176		
Israel	113	0	109	216		
Norway	34	151	182	185		
Turkey	28	13	22	41		
New Zealand	24	10	29	34		
Iceland	19	0	1	19		

Source: OECD