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Domestic bond portfolio adjustments during duration jumps

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Abstract

Increases in long-term interest rates such as in 2021 entail a jump in the duration of Danish long-term mortgage bonds via an embedded prepayment option.

The jump in duration may lower the demand for duration and thus long-term bonds. This may lead to self-reinforcing effects. Jumps in duration in fact appear correlated with increases in yield spreads on long-term Danish bonds.

We show that key Danish domestic institutional investor segments as a whole remain net buyers of Danish mortgage bonds during episodes of duration jumps and seem to buy more than they do on average.

Thus, during the episodes considered, key domestic investors acted in a way that supported the market and limited a potential self-reinforcing mechanism of duration jumps. Thus, the effects on mortgage bond rates of duration jumps have overall been relatively contained, benefitting economic and macrofinancial stability.

We also show that some segments of domestic investors with a need to rebalance their duration exposure due to their liabilities appear to lower their demand for Danish government bonds. This can contribute to explaining the observed spillover of duration jumps to a higher Danish-German government bond yield spread.

Introduction

The Danish covered bond market is the largest in Europe and among the largest in the world. There is around DKK 3,000bn of Danish covered bonds outstanding, which corresponds to around 125 percent of the Danish GDP. As a unique characteristic in an international context, the size of the covered bond market is many times larger than the market for domestic government bonds. Therefore, developments in the covered bond market are highly important for the broader Danish financial markets and the real economy.

A major segment of the covered bond market is the market for fixed-rate callable mortgage bonds with a maturity of typically 30 years. Callable mortgage bonds have an embedded option that gives rise to particular price dynamics for these bonds, cf. annex 1. When interest rates rise, it becomes less likely that mortgage borrowers will exercise their right to repay their loan early at par, see also Hensch (2021).[1] In that case, the expected time to maturity of the mortgage bond increases, and the interest rate sensitivity of the bond, i.e. the duration, increases. Jumps in duration for Danish callable mortgage bonds are a recurring phenomenon and have, for example, occurred at least once a year since 2015.

One of those episodes took place in spring 2021, where interest rates in developed countries increased in response to increases in inflation and inflation expectations in the fairly strong post-Covid-19 recovery. Danish government bond yields increased slightly more than German government bond yields, even though Danish yields usually follow these closely due to the fixed exchange rate regime

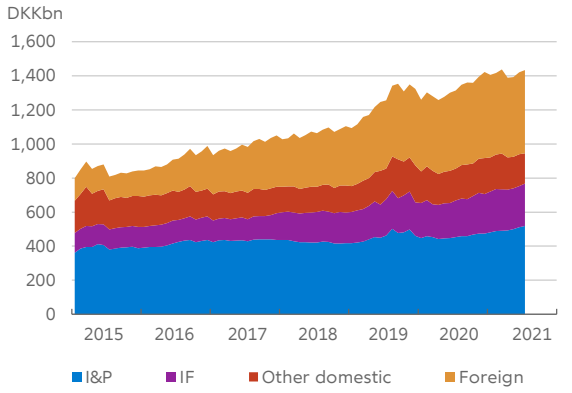
[1] Jonas Ladegaard Hensch (2021), The role of refinancing in the interest rate pass-through to fixed-rate mortgage contracts, *Danmarks Nationalbank Working Paper*, No. 174, April 2021.

toward the euro, see also Jensen, Mikkelsen, and Spange (2017).[2] The extra increases in Danish government bond yields appear unrelated to fundamental economic developments, e.g. affecting debt levels, over the periods. In addition, the yield spread between covered bonds and government bonds increased. Both are close to credit-risk free and thus triple-A rated. Also, for that yield spread there are no clear links with underlying credit fundamentals.

Episodes with duration jumps have typically been associated with a widening of the Danish-German government bond spread and the option-adjusted spread (OAS)[3] on callable mortgage bonds. An increase in the duration of callable mortgage bonds may, in isolation, lead to an increase in the duration of the investors' assets, i.e. their krone duration.[4] The resulting potential reaction of the key domestic investors, namely the Danish insurance and pension (I&P) sector and the investment fund (IF) sector, may have implications for the markets for Danish government and mortgage bonds, and thus for the evolution of financing costs for the Danish government, Danish homeowners, and businesses.

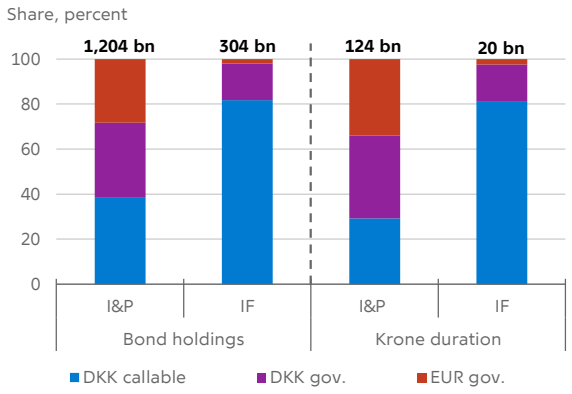
I&P and IF are large investors in Danish long-term callable mortgage bonds. The two sectors own about half of all Danish fixed-rate callable mortgage bonds, cf. chart 1. Looking at the bond holdings of the two sectors, long-term callable mortgage bonds make up almost one half of the combined investments in Danish and euro-denominated government bonds as well as Danish callable mortgage bonds for the I&P sector and the majority of the bond holdings of the IF sector, cf. chart 2.[5]

Investor distribution for long-term fixed-rate mortgage bonds Chart 1



Note: Excludes MFI holdings of own bonds.
Source: Danmarks Nationalbank.

I&P portfolios are balanced between bond classes, whereas IF portfolios are skewed toward callable bonds Chart 2



Note: Holdings at July 2021. Krone duration is the market value sensitivity for a 1 basis point interest rate change for the total outstanding stock of long-term fixed-rate mortgage bonds.
Source: Danmarks Nationalbank.

[2] Jensen, Jakob Roager, Jakob Guldbæk Mikkelsen and Morten Spange (2017), The ECB's unconventional monetary policy and the role of exchange rate regimes in cross-country spillovers, *Danmarks Nationalbank Working Paper*, No. 119, October 2017.

[3] The option-adjusted spread (OAS) relative to government bonds can be interpreted as the yield to maturity of the bonds less the same-maturity government bond yield less the value of the prepayment option of the callable bond. Hence, OAS reflects the additional return that a bond investor requires for buying the expected cash flow of a mortgage bond as opposed to government bonds.

[4] Duration is measured in years for each bond and can be interpreted as the price change in percentage for that bond. Krone duration is the total duration risk of a portfolio and can be interpreted as the krone change in the value of a portfolio when interest rates change. To follow market standards, the unit is expressed per basis point change. For our purpose, the unit is measured in DKK million per basis point change.

[5] The share of bonds to total assets in the pension sector's balance sheets has been decreasing during the last couple of years, reflecting particularly large purchases of and large returns on holdings of foreign stocks.

This Economic Memo examines how the I&P and IF sectors adjust their bond portfolios in reaction to duration jumps. It further assesses the role of these adjustments in explaining the observed market price dynamics in both the mortgage bond and government bond markets. To our knowledge, this has not been investigated in depth before. The analysis is based on new, detailed holdings data at instrument and company level for the sectors since 2015 (2018 for IF).[6] A large part of I&P's holdings are indirect holdings through investment funds, i.e. their capital funds. These funds are therefore included as part of the I&P sector, cf. annex 2.

A priori, there is no clear expectation as to how the I&Ps and IFs react to duration jumps. On the one hand, and for given market prices, some investors might tend to reduce their demand for duration, which can lead to sales of, for example, mortgage bonds or government bonds. In particular, some I&P companies use bonds with long duration to lock in or predict their future return. This is particularly relevant for companies aiming either at explicitly matching a promise to their customers, i.e. companies with guarantees managing their net duration tightly as mismatches between the duration on assets and liabilities create a risk to their capital reserves, or companies aiming at providing customers with stable long-term returns. On the other hand, the cheapening of bonds may provide an attractive buying opportunity.

In the Economic Memo, we use information on the liability side of the institutional investors to analyze to what extent differences in the obligations to the companies' clients influence the investment reactions of the companies. The heterogeneity in the sectoral groups is potentially very important in order to understand reactions to future events where the financial market shock that they react to or the economic backdrop may be of a different nature. Furthermore, there might be structural trends in the sector compositions, such as the shift toward market rate products, that can change the total reaction of the sector.

In the next section, we explain the special market dynamics for callable mortgage bonds when interest rates increase. In section 2, we identify the episodes of jumps in duration for callable mortgage bonds since 2015 and further asses the bond market developments during those episodes. In sections 3 and 4, we investigate how the two sectors react to the jumps in duration. In section 5, we interpret the findings and assess how the findings can contribute to understanding the developments observed in the Danish bond markets since 2015 during episodes of sudden interest rate increases, and the potential macrofinancial implications.

1. Increasing rates may be self-reinforcing

Theoretically, the case of a lower demand for Danish bonds by the domestic institutional investors in response to duration jumps may lead to a self-reinforcing behavior in the pricing of Danish bonds as illustrated in chart 3. Hence, higher duration might lead investors to sell Danish bonds, which reduces their prices and thus leads to a further increase in duration etc.

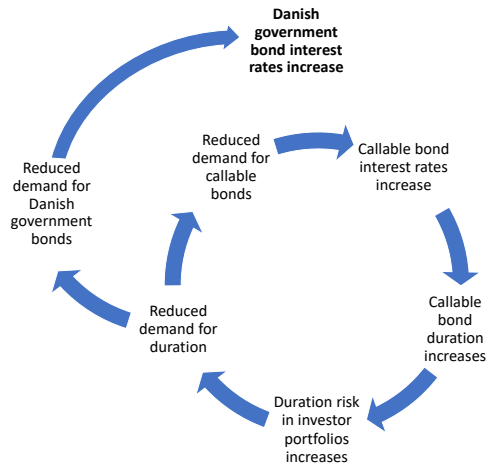
Investors may rebalance their portfolios in response to jumps in the duration of callable mortgage bonds by selling those mortgage bonds that increased in duration or, for example, by selling other assets or buying less than otherwise, such as government bonds in Danish kroner or euro. They might also adjust the duration by means of interest rate derivatives.[7] Thus, an increase in duration in one market segment might give rise to spillovers into other markets. Ultimately, the relative market pricing

[6] We restrict the analysis to these bond types as they are the most obvious bonds used to provide duration to hedge the interest rate risk on the liabilities in kroner. Bond holdings of I&P companies through investment funds only reside with the I&P companies in the analysis (look through principle), cf. annex 2.

[7] For the I&P sector (and some investment funds) in particular, adjustments to the duration of the portfolios likely takes place via derivatives. However, analyzing transactions in derivatives is not possible since data is unavailable. See annex 2.

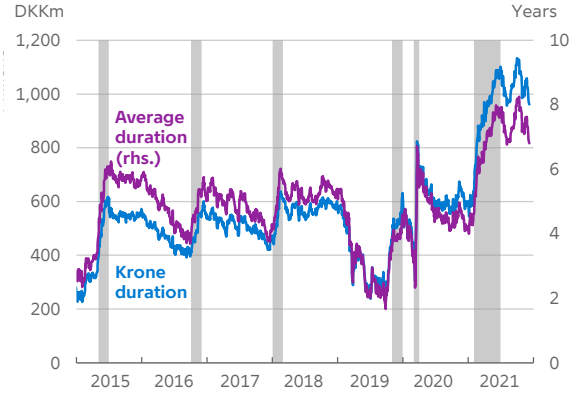
between bonds and between bonds and swaps, measured by yield spreads, may be affected.

Self-reinforcing interest rate increases Chart 3



Source: Danmarks Nationalbank.

Duration developments for long-term fixed-rate mortgage bonds Chart 4

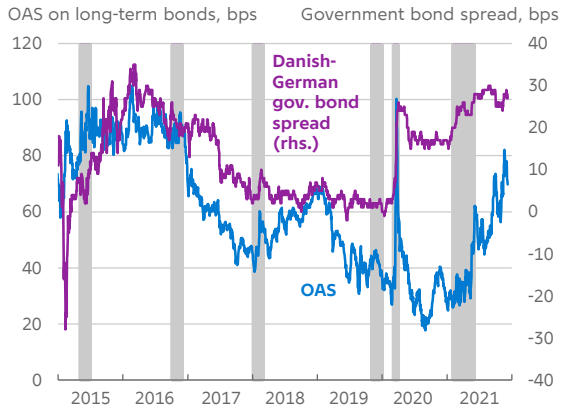


Note: Krone duration is the market value sensitivity for a 1 basis point interest rate change for the total outstanding stock of long-term fixed-rate mortgage bonds. Average duration denotes the Macaulay duration, which is a weighted average term to maturity of the cash flows from the bonds measured in years.
Source: Rio Scanrate and Danmarks Nationalbank.

2. Identification of episodes of duration jumps and methodology for determining investor reactions

The episodes with sudden jumps in duration for long-term fixed-rate mortgage bonds are identified based on the developments in chart 4 and are listed in annex 3. In the episodes considered, the yields on the long-term fixed-rate mortgage bonds increase in the range between 20 to 40 bps over short periods of usually 1-2 months. Furthermore, the episodes are characterized by a widening in the spread between Danish and German government bond yields and by a widening of the OAS (option-adjusted spread) to the government bond curve, cf. chart 5.

Widening yield spreads during duration jumps Chart 5



Note: Periods of duration jumps are reported in annex 3.
Source: Nordea Analytics, Nykredit Markets and Danmarks Nationalbank.

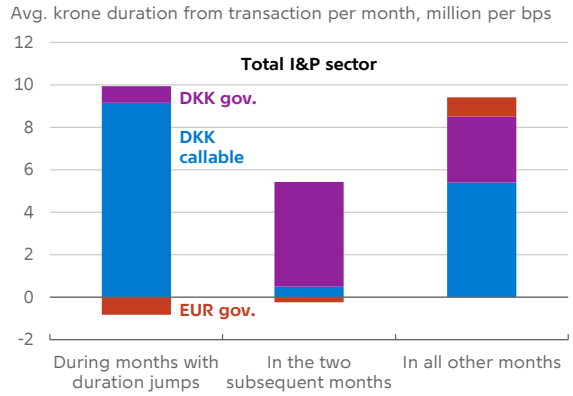
The most recent episode being investigated covers the period from February to June 2021, which exhibits the largest increase in krone duration of the considered periods.[8] All considered episodes differ in terms of the macrofinancial backdrop and the magnitude of the widening of interest rate spreads, cf. chart 5. That can naturally lead to differences in investor behavior between episodes. Still, looking at

[8] We do not consider the episode during fall this year (August to September) due to data limitations.

common reactions in more periods is valuable in order to understand normal behavior.

In the following section, we examine how insurance and pension companies (I&P) and investment funds (IF) react to duration jumps through changes in their bond portfolio allocation. This is done in order to identify whether changes in portfolio duration are a result of market changes or active choices of the investors. Therefore, we compare the factual krone duration of the investors' portfolios to a measure of the counterfactual krone duration. The latter is determined as the current duration of the investors' portfolios using the bond holdings of the previous month. In other words, it is the current krone duration from the investors' bond holdings before any net transactions take place during the month. We denote this as the pre-transaction duration. Thus, the difference between the factual krone duration and the pre-transaction krone duration shows the change in krone duration from portfolio rebalancing through net transactions.[9]

The I&P sector as a whole purchases callable bond duration when it jumps Chart 6



Note: Zoom-in on the months identified as episodes of duration jumps for callable mortgage bonds from annex 3. Krone duration is the market value sensitivity for a 1 basis point interest rate change for the total outstanding stock of long-term fixed-rate mortgage bonds. EUR gov. includes government bonds issued by a euro area government and denominated in euro.
Source: Danmarks Nationalbank.

3. Insurance and pension companies and their reaction to duration jumps

The I&P sector as a whole purchases callable bond duration during episodes of duration jumps

We start off by considering the I&P sector as a whole. The I&P sector reacts to episodes of jumps in duration for callable mortgage bonds by purchasing duration in callable mortgage bonds, cf. chart 6. In fact, the sector as a whole purchases even more callable bond duration than it does in all other periods. The I&P sector reduces its purchases of duration from euro and Danish government bonds to close to zero on average during callable bond duration jumps.

How do different pension companies react to duration jumps?

The Danish I&P sector as a whole is characterized by a large degree of heterogeneity due to a large variety of product types offered to customers. The heterogeneity implies that the companies' exposure and reaction to jumps in duration for Danish callable mortgage bonds might differ significantly depending on the business models.

We therefore divide the pension companies into three groups according to an, a priori, qualitative assessment of their predominant economic nature. Specifically, the split is based on how the companies' business models and their dominant pension product type may affect their need to rebalance portfolio duration. Annex 5 explains in technical terms how the Solvency II regulation of pension funds impact the duration hedge of different types of pension companies. The three groups are:

- *Balance sheet hedge companies* that offer a large degree of guaranteed benefits, and hence need to maintain a stable interest rate hedge on their total portfolios, also in cases of duration jumps and associated market volatility.
- *Flexible hedge companies* that offer long-term conditional guarantees. They are less constrained

[9] Net transactions, however, would include the repayment of the principal of mortgage bonds that are called by the issuer, which is outside the control of the investor. However, the duration of bonds that are called is typically low.

than the former companies due to a higher degree of freely investible capital.

- *No fixed income hedge companies.* The group has the most flexible investment strategy and has no interest rate hedge since they only offer market rate benefits to their customers.

Further details on the groups are available in box 1.

Balance sheet hedge companies buy more duration in callable bonds in periods with duration jumps

When duration for callable mortgage bonds jumps, companies with a stable balance sheet hedge increase their purchases of duration of callable mortgage bonds compared to other periods, cf. chart 7. These companies as a group also reduce their purchase of government bond duration, as

Dividing I&P companies into three groups based on expected duration hedge behavior Box 1

The Danish insurance and pension companies (I&P) as a group exhibit a large degree of heterogeneity, which to a large extent is due to the differences in business models and product types offered to their customers. As a result, some companies need to manage their duration closely and may thus be required to hedge their interest rate risk in periods with increases in duration for Danish callable mortgage bonds, whereas others will not. For this reason, we construct three groups of I&P companies depending on the predominant economic nature of the companies, i.e. companies with i) a balance sheet hedge, with ii) a flexible hedge, and with iii) no fixed income hedge.

Balance sheet hedge companies need to actively manage and maintain a dynamic interest rate hedge in order to protect their solvency ratio from movements in the option-adjusted spread (OAS) and interest rates. Net duration is tightly hedged to protect the balance sheet. These companies offer guaranteed average rate products to their customers, of which guaranteed benefits make up over 90 percent of the reserves. This product type implies that the companies' investment strategies are more constrained relative to the other groups.

As an example, during episodes of duration jumps for callable mortgage bonds, these companies continue their purchases of callable mortgage bonds and thus add further duration to their overall portfolio. Furthermore, the duration of their government bond holdings declines. Both developments affect the duration of guaranteed liabilities via the Solvency II discount curve.[2] In order to maintain their duration hedge, these companies need to balance the duration of their total balance sheet, i.e. assets and liabilities.

Flexible hedge companies offer long-term conditionally guaranteed benefits to their customers, of which guaranteed benefits make up around 30 to 60 percent of the reserves, whereas the remaining 40 to 70 percent are freely investible. This makes the investment strategy less constrained relative to the balance sheet hedge companies. The focus of the flexible hedge is to achieve return targets in the medium to long term, and these companies' solvency is not sensitive to market volatility in the same manner as companies with a tight balance sheet hedge.[3]

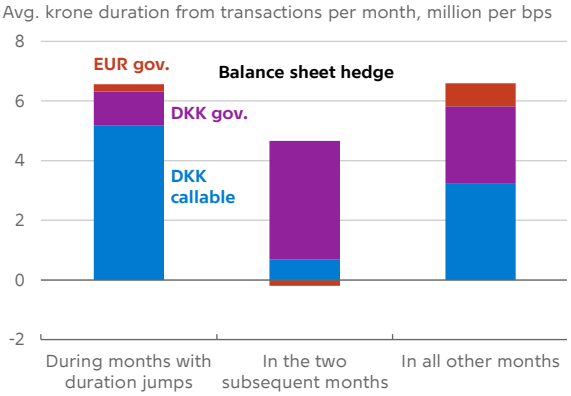
The **no fixed income hedge** group mainly comprises companies with market rate portfolios. Some of the companies will have small average rate portfolios, but their investment behavior is largely influenced by their larger market rate investment portfolios. These companies focus on both short and longer-term market returns. Companies' solvency ratios are not adversely affected when interest rates or OAS move around.[4] This provides them with a lot of flexibility, which has implications for their ability to react to duration jumps for callable mortgage bonds.

The remaining part of the I&P companies are categorized as non-life insurance companies. Their bond holdings are very small relative to the larger companies. We disregard this group of companies given that their effect on the overall results is insignificant.

1. The Solvency II solvency ratio is the ratio of a company's Eligible Own Funds (equity capital) to the Solvency Capital Requirement.
2. See annex 5 for a technical discussion of duration and discounting effects of regulation and the Solvency II discount curve.
3. For companies with conditional guarantees, the present value of guaranteed benefits is sensitive to changes in the OAS via the Solvency II Volatility Adjustment (VA). However, the 40 to 70 percent in freely investible reserves acts as a buffer for asset losses. The companies' ability to write down the conditional guarantees to protect solvency acts as an additional buffer in very extreme situations. These companies' solvency ratios are high and stable and do not change materially due to changes in the OAS.
4. Under Solvency II, all insurance and pension companies may choose whether to use the Solvency II discount curve with or without the VA. The VA is most often used for long-term guaranteed benefits where some of the underlying assets are invested in credit risky assets. For companies with market rate portfolios, the Solvency II discount curve is without the VA. Hence, the present value of liabilities is not affected by changes in the OAS. Moreover, as the customer bears the investment risks, these companies' solvency ratios are not materially affected by market volatility.

some companies in the group respond by selling government bond duration outright. Furthermore, the companies will most likely also react by selling interest rate futures or reducing the net notional amounts of interest rate swaps in order to rebalance their net duration. This is, however, not captured in the data used in this Economic Memo, see annex 2.

Balance sheet hedge companies shift duration purchases towards callable bonds during duration jumps Chart 7



Note: Same as Chart 6.
Source: Danmarks Nationalbank.

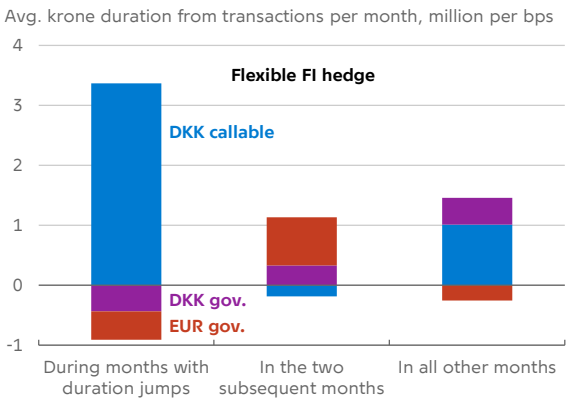
The companies may purchase less government bond duration to reduce overall duration in the bond portfolio, which, ceteris paribus, increased from the duration jump and the larger purchases of duration in callable mortgage bonds. The shift from government bonds to callable bonds may be due to the concurrent increase in the yield spread between mortgage bonds and government bonds, cf. chart 5. Liquidity consideration in specific bonds or market segments may also play a role. In the two months following the jump in duration, the companies tend to rebalance their fixed income duration back toward a desired portfolio mix with less from mortgage bonds and more from government bonds.

Companies with a flexible hedge ramp up purchases of callable bond duration in periods with duration jumps

The business models of flexible hedge companies provide them with more flexibility in deciding how much and by which speed they prefer to rebalance the duration either using bonds or derivates, cf. box 1. Compared to the balance sheet hedge group, the flexible hedge group seem to take even more advantage of the cheapening of callable mortgage bonds relative to government bonds during duration jumps by increasing their purchases of callable bonds significantly relatively to other periods, cf. chart 8.

As a group, the flexible hedge companies sell Danish government bond duration possibly to counter the purchases of callable bonds. They also sell duration in euro area government bonds. In the two subsequent months, they reverse positions rather quickly to get back toward their pre-duration jump portfolio mix. To that end, the group as a whole sells mortgage bond duration. This reversing of positions might reflect an opportunistic fund management strategy and more investment freedom compared to the balance sheet hedge group.

Flexible fixed income hedge group ramps up purchases of callable bond duration Chart 8



Note: Same as chart 6.
Source: Danmarks Nationalbank.

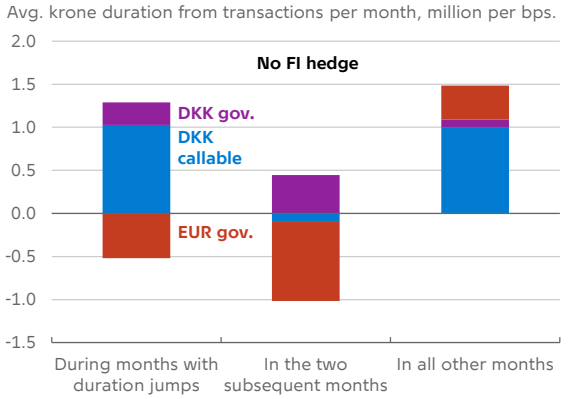
Companies without a fixed income hedge adhere to a stable long-term strategy and buy slightly more mortgages

Compared to the other groups, the group without a fixed income hedge can invest most freely due to a high degree of market rate portfolios, cf. box 1. The

group is not constrained by guarantees or solvency; hence, they do not have to react to market movements such as OAS widenings and duration jumps.

The group's purchases of callable mortgage bond duration during episodes of duration jumps are largely in line with the purchases in all other months, cf. chart 9. On the other hand, the group appears to be buying slightly more Danish government bond duration during these episodes. In the two months following the jumps in duration, these companies purchase even more Danish government bond duration and sell callable bond duration. Thus, there are some signs of the companies reversing positions in line with long-run target portfolio weights. In light of the greater flexibility of this group, it is somewhat surprising that it reacts the least to the spread widenings during duration jumps. However, due to the economic nature of the group, it may have a larger investment focus on other asset classes compared to bonds, see e.g. Autrup and Jensen (2021).[10,11]

No fixed income hedge group appears to react the least in terms of callable bonds Chart 9



Note: Same as chart 6.
Source: Danmarks Nationalbank.

Pension companies as a group act as net buyers of mortgage bond duration during periods of duration jumps

Evidence for the sector as a whole indicates that pension companies continue to buy callable mortgage bond duration during duration jumps, and evidence for the three groups of companies indicates that they do so regardless of the business model of the company. There may be several explanations for this, including that the interest rate hedge may be maintained using derivatives and that mortgages get cheaper and hence more attractive.

I&P companies' reaction to duration jumps might have spillovers to the government bond spread

Our results show that the flexible fixed income hedge group tends to sell Danish government bond duration during episodes of duration jumps for callable mortgage bonds. Furthermore, we find that companies with a balance sheet hedge appear to reduce their demand for Danish government bond duration although they continue to be net buyers during the duration jump episodes. Hence, the reaction of I&P companies could potentially be a contributing factor explaining the observed widenings of the Danish-German government bond spread during these episodes.

4. Investment funds and their response to duration jumps

The Danish investment fund sector consists of funds targeting retail investors (UCITS or retail funds) and funds targeting professional investors (alternative investment funds, AIF). Retail funds hold close to two thirds of the callable mortgage bonds held by investment funds, whereas the rest are held by the less tightly regulated alternative funds.

Retail funds with duration bands

The majority of retail funds follow, unlike alternative funds, a duration benchmark. The benchmark is constituted by a benchmark portfolio, which entails a

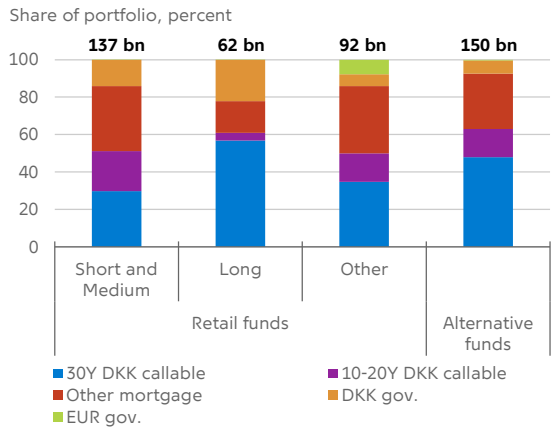
[10] Autrup, Søren Lejsgaard and Jakob Roager Jensen (2021), QE in a quasi-preferred habitat: The case of the Danish pension sector and the ECB asset purchase programme, *Danmarks Nationalbank Working Paper*, No. 167, January 2021.

[11] The main driving factor for the group of companies with no FI hedge is the balanced portfolio with broadly fixed weights and thus no pressure to rebalance over short periods, e.g. due to market volatility.

certain level of duration, and is typically rebalanced on a monthly basis. Moreover, these funds typically have to stay within a duration band. In order to be in line with the benchmark and the band, funds may counter duration jumps in callable mortgage bonds by rebalancing their portfolio, e.g. selling long-term bonds, and vice versa when duration is falling.[12]

Among the retail funds, callable mortgage bonds are primarily held by funds focusing on Danish bonds, short and medium as well as long funds, in which callable mortgage bonds constitute a large share of the portfolio, cf. chart 10.

Large share of callable mortgage bonds in Danish short and medium bond funds Chart 10



Note: Share of different bond categories with duration. Data is for July 2021. Callable mortgage bonds are divided in two categories: bonds with a maturity of 30 years and bonds with a maturity of 10 to 20 years. EUR gov. includes government bonds issued by a euro area government and denominated in euro. Other funds include mixed funds that invest in both bonds and shares.
Source: Danmarks Nationalbank.

Short and medium retail funds hold a large share of callable mortgage bonds with at maturity between 10 and 20 years compared to the total market for callable mortgage bonds and to alternative funds. These bonds are less sensitive to changes in interest rates compared to the 30-year bonds.

In the following, we focus on short and medium benchmark funds, since these often have both a lower and an upper limit for duration. Long funds in general only have a lower limit for duration.[13] Without an upper limit, long funds should therefore be less sensitive to market-induced upward duration jumps compared to short and medium funds. At the end of this section, we draw a comparison to all investment bond funds as well as to long and alternative funds.

Short and medium funds tend to counter large duration jumps

As a first step to examine whether short and medium funds react when duration on callable mortgage bonds jump, we plot the factual duration against the pre-transaction duration.[14] When the factual krone duration is below the pre-transactional krone duration, as was the case in March 2020 and March 2021, it indicates that short and medium funds react within that month by countering the duration increases and smoothing duration jumps through portfolio transactions, cf. chart 11. We find that this holds on the aggregates as well as for the vast majority of funds.

Funds closer to their benchmark tend to react stronger

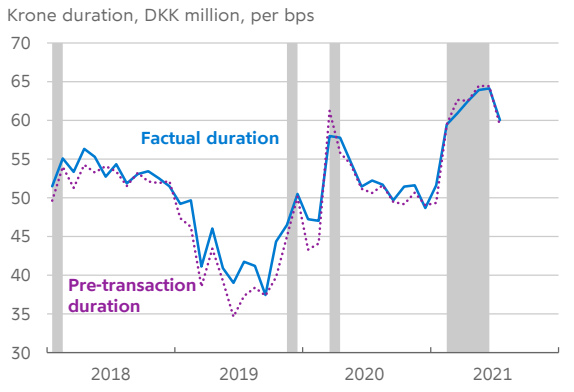
In order to bring the duration level back in line with the benchmark, funds may react stronger to an upward duration jump the further the duration is above the benchmark. Thus, the larger the difference between the duration of the factual portfolio and the benchmark, the stronger a reaction could be expected.

[12] Retail funds' portfolio duration is less likely adjusted through derivatives; most of the portfolio adjustment should therefore take place through changes in bond holdings.

[13] Finans Danmark has published these duration categories. The band is 0-3 years for short bond funds, 3-5 years for medium bond funds, and over 5 years for long bond funds. However, when examining the individual investment funds, we find that some individual funds deviate from these three categories.

[14] Methodology is described in section 2.

Danish short and medium bond funds smooth large duration changes Chart 11



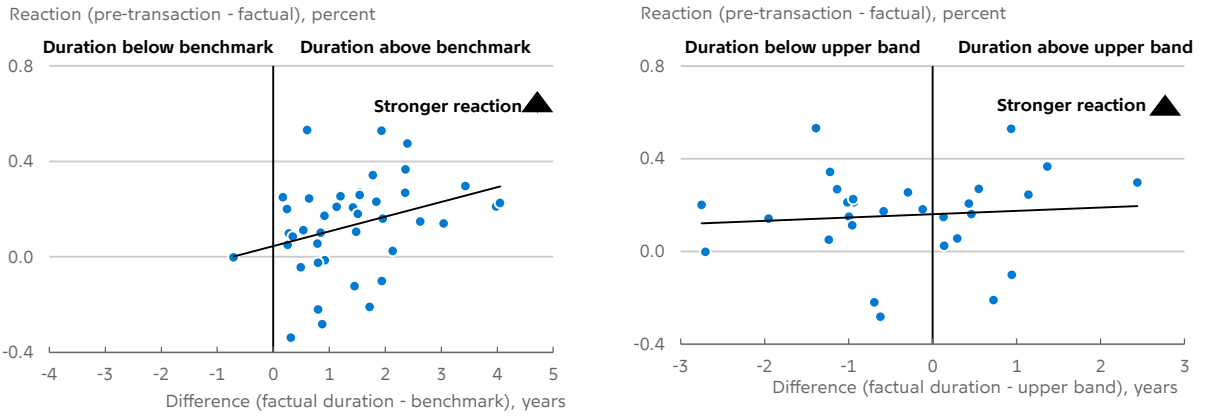
Note: Data is based on Danish short and medium UCITS bond funds with a benchmark for duration. The purple dashed line shows the pre-transaction duration at each month. The pre-transaction duration is the current duration of the funds' bond holdings before any transactions are made during the month. The calculation is solely based on duration induced by holdings in bonds, i.e. mortgage bonds and Danish and euro government bonds.
Source: Danmarks Nationalbank and own calculations.

In order to examine this conjecture, we calculate the reaction for each fund, i.e. the difference between the pre-transaction and the factual duration in percent of the total bond portfolio. The reaction is compared to the difference between the fund's duration and its benchmark. We apply this method to the single months with the highest increase in duration, since funds are expected to rebalance their portfolio as soon as they are out of line with the benchmark.[15]

We find evidence that during large upward jumps in a single month, e.g. in March 2021, funds tend to counter duration and rebalance their portfolio more, when the difference between the duration of the factual portfolio and the benchmark increases, cf. chart 12 (left). A similar, but not as strong, result holds for March 2020.[16]

Further, we examine if funds' reaction depends on the difference between the duration of the factual

Short and medium funds close to or above the benchmark tend to react stronger but react independently of the upper duration limit Chart 12



Note: Danish short and medium funds with a duration benchmark. Difference is measured as the difference between the factual duration of the fund and its benchmark (left) or its upper duration band (right). Reaction is the difference between the pre-transaction krone duration and the factual krone duration normalized with the market value of the bond portfolio. The calculation is solely based on duration induced by holdings in bonds, i.e. mortgage bonds and Danish and euro government bonds in March 2021.
Source: Danmarks Nationalbank and own calculations.

[15] The calculated duration of the portfolios is an approximation, and the funds with a calculated duration above the benchmark or upper band may be below in the funds' own calculations.

[16] Data is not shown in this memo. For the episodes in 2018 and 2019, the correlation between reaction and difference is not clear, but the jumps in duration in these episodes were also on a much smaller scale.

portfolio and the upper band. Funds that are close to or breaches the upper band may have a stronger reaction in order to reduce portfolio duration. However, evidence of this conjecture is less clear, cf. chart 12 (right). This could imply that fund's portfolio rebalancing is more driven by keeping track of the benchmark than by the upper band itself.

The IF sector as a whole buys duration, but short and medium bond funds sell duration

In the following we consider changes in krone duration from portfolio rebalancing through net transaction in callables and government bonds for the IF sector as a whole as well as for the different types of funds earlier identified. The method is identical to the one used for the I&P sector.

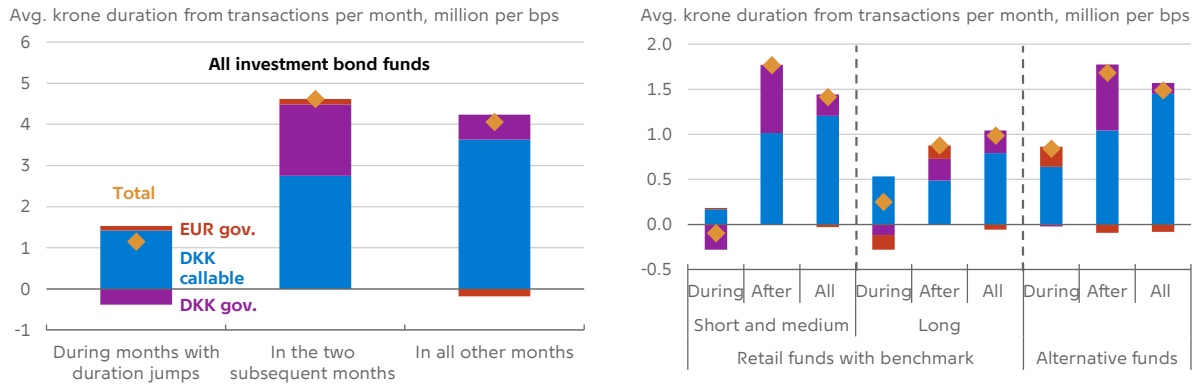
As a whole, investment funds do not reduce their exposure to callable mortgage bonds in times of large increases in duration, cf. chart 13 (left). However, they reduce their exposure to Danish government bonds during periods of duration jumps. This may help explain the spillover effects to the Danish-German government bond spread.

Danish short and medium retail funds have on average reduced their exposure to duration by selling government bonds while not buying more callable bonds in months where duration jumped. However, in the two subsequent months following the jump, they tend to add duration from callable bonds and Danish government bonds, cf. chart 13 (right). When narrowing the analysis to the two latest episodes, namely March 2020 and February-June 2021, we find that short and medium funds rebalanced their portfolio even more by also selling duration from callable bonds.

On average both Danish long retail funds and alternative funds purchase and add duration from callable mortgage bonds in months with duration jumps and continue to do so in the following two months. Similar to the IF sector as a whole, they do not add duration from Danish government bonds during jumps. This could reflect that the increase in duration provides an opportunity for these funds to shift and increase their portfolio exposure toward long mortgage bonds at a lower price and possible higher return.

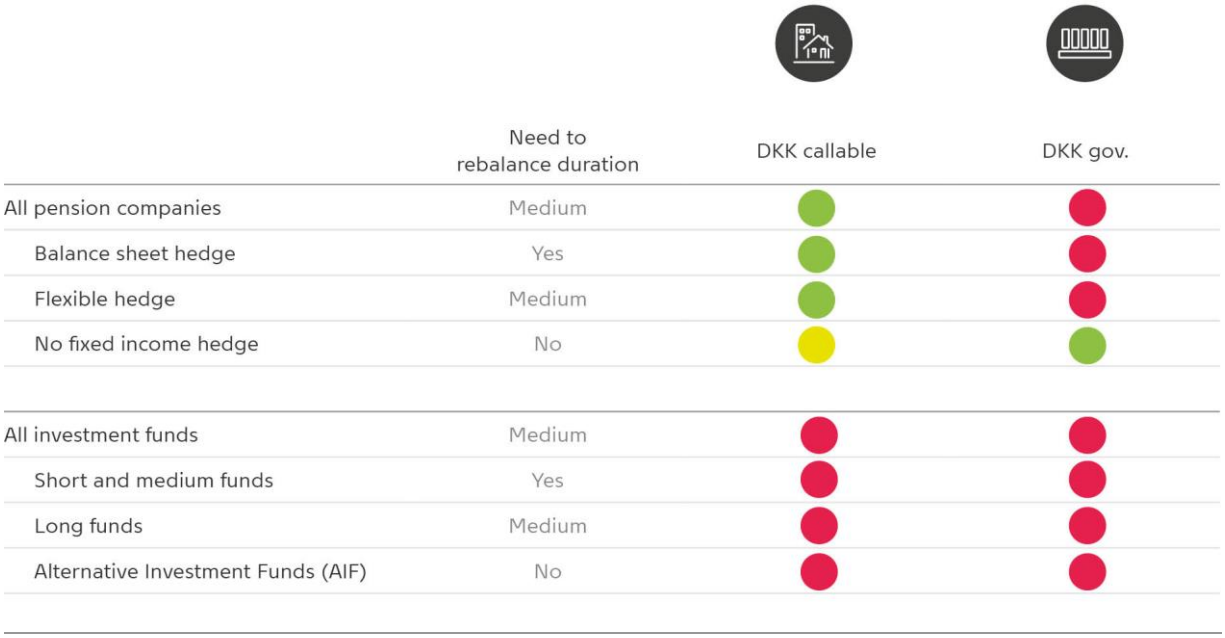
Short and medium funds sell duration during jumps while alternative and long funds purchase duration

Chart 13



Note: The stacked columns show the average change in duration from rebalancing the portfolio, i.e. the difference between the pre-transaction krone duration and the factual krone duration during events with duration jumps, the following two months after the event, and all other months. Left chart: All investment bond funds include all bond funds but not mixed funds. Right chart: Retail funds with benchmark as well as alternative funds (AIF).
Source: Danmarks Nationalbank and own calculations.

Changes in demand for bond duration during episodes of duration jumps for callable mortgage bonds compared to other periods Chart 14



Note: Green denotes higher demand for bond duration in periods of duration jumps for callable mortgage bonds relative to all other periods, red denotes lower demand for bond duration relative to all other periods whereas yellow denotes unchanged demand for bond duration relative to all other periods.
Source: Danmarks Nationalbank.

5. Overall findings, possible explanations, and macrofinancial implications

Domestic institutional investors remain active buyers of callable bond duration during duration jumps
Both the domestic I&P and IF sectors remain active buyers of callable mortgage bond duration when the duration increases. Hence, the investment behavior of these investors does not explain the observed widening in the mortgage bond yield spread per se. However, the behavior of the domestic investors may still entail a higher spread via a readjustment of the prices that they are willing to pay for buying bonds, i.e. through changes in reservation prices, cf. annex 4.

Increased demand for callable mortgage bond duration amid duration jumps
The pension sector increases its demand for callable bond duration amid the duration jumps relative to other periods without jumps in duration, cf. chart 14. Conversely, investment funds lower their demand, albeit remain buyers overall. The pension sector is larger than the IF sector, so the higher demand from the former dominates the lower demand from the latter.

Pension company type does not matter much for demand for callable bonds; IF type matters
The analysis of subgroups shows that all types of pension companies increase their purchases of callable mortgage bond duration. Even groups of companies with a need to manage duration increase their demand for callable bond duration. For investment funds, those with the largest need to rebalance duration lower their demand the most.

Lower demand for government bonds overall
We also find evidence that net buying of duration in Danish government bonds from domestic institutional investors as a whole is close to zero during duration jumps. Thereby, their demand is lower than in a normal period, where they typically

add duration by buying government bonds to counter the natural aging of their government bond portfolio. The lowered demand might contribute to the higher Danish-German government bond spread observed in these periods. The analysis of subgroups shows that the demand for government bonds is especially reduced for groups of pension companies with a need to manage duration and for investment funds with duration benchmarks.

Adding duration during jumps has increased returns
The institutional investors maximize the expected return of their portfolios given their risk and duration limits. Many of them are highly specialized in the callable mortgage bond market given the size and importance of this market in Denmark. Most of the duration jumps considered since 2015 and their market implications have been fairly short-lived, cf. chart 5. Therefore, investors have been able to realize a return, ex post, by buying mortgage bonds during duration jumps when they cheapen (higher spreads) and subsequently gradually reducing the duration exposure from the bonds again in other periods. However, ex ante there is no guarantee that such a strategy will lead to a sufficient return. In the 2021-episode, duration and spreads remained high.

Large degree of diversification of pension companies' assets may contribute to their duration tolerance
Pension companies' portfolios have over the last years as a total become less sensitive to callable bond duration jumps as the share of these bonds in their portfolios has decreased. The lower share of mortgage bonds and other bonds may reflect the development toward a higher share of market rate products among companies. As a group, this may provide them with more flexibility to tolerate the effect of duration jumps and, consequently, to take advantage of the cheapening of mortgage bonds.[17]

Contained effect on interest rates from recent duration jumps due to domestic investor support
All in all, the analysis of the most recent episodes of duration jumps suggests that the key domestic investors have remained active buyers of callable mortgage bonds. Had the investors decided to decrease their exposure to callable bonds, the spread increase would arguably have been higher during these episodes. That could also be the case if the investors had had stronger structural limitations to taking duration on their books. The analysis shows that most groups with limitations nonetheless buy bond duration and then manage duration by other means. Thus, the key domestic investors have reduced the self-enforcing mechanism in the callable mortgage bond market segment. They provide less back-stop support to the domestic government bond market. The switch in demand for bonds to the callable bond market from the government bond market may be due to a higher price reaction in callable bonds to duration jumps, making callable bonds more attractive relatively to government bonds.

The market effect of duration jumps depends on the demand from other investors, particularly foreign
The behavior of other investors is also important to monitor for market dynamics. As chart 1 shows, foreign investors constitute a large investor segment and have been rapidly increasing their share over the last couple of years. Therefore, the behavior of foreign investors is of particular interest. In 2021 amid the callable bond duration jump and spread widening, foreign investors have reduced their demand for Danish callable mortgage bonds. Their share of outstanding bonds has declined while the share of the I&P sector has increased reflecting that during 2021, the I&P sector has been the primary buyer of callable mortgage bonds, cf. chart 15.

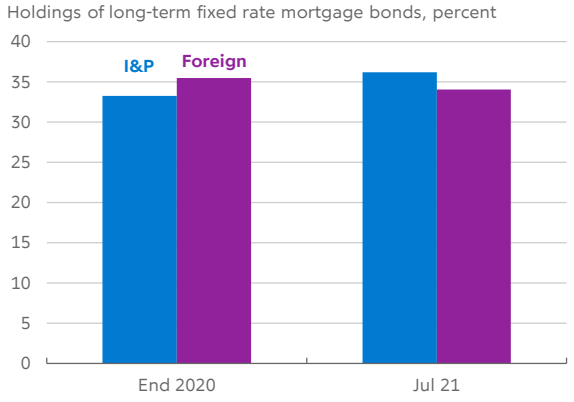
Foreign investors do not have a natural preferred habitat for Danish callable bonds. Thus, their interest is presumably driven by the possibility of obtaining a relatively high return on a low-credit risk bond. Their demand is therefore highly dependent, inter alia, on relative returns across international bond classes. The jumps in duration per se may not affect the risk of most foreign investors' portfolios too strongly

[17] As an example, the share of bonds in total assets dropped from 70 percent in January 2016 to 55 percent in April 2021, reflecting more than a doubling of equity holdings in the portfolio and a more modest increase of 15 percent in bond holdings.

because Danish mortgage bond holdings are likely to make up a small share of foreign investor portfolios. However, the associated volatility and adverse price reaction compared to e.g. government bonds may deter foreign demand at least for a while. An analysis of the drivers of their demand is outside the scope of this memo, see instead Danmarks Nationalbank (2021).[18]

Foreign investors' share of Danish long-term fixed-rate mortgage bonds has declined in 2021 whereas I&P's share has increased

Chart 15



Source: Danmarks Nationalbank.

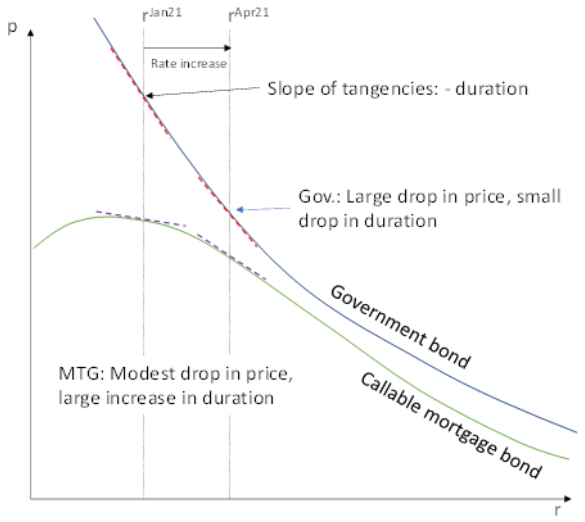
A different financial backdrop may lead to other dynamics in the future

Nevertheless, it is not obvious whether the moderate spread widenings associated with the past duration jumps will continue in future cases if, for example, interest rates increased by a lot more than during the analyzed episodes. There are other factors that can contribute to a stabilization of the callable bond markets, but the nature of these may be somewhat slow. For instance, homeowners may shift to other types of loans and thereby reduce the issuance of long-term callable bonds. Also, at some point homeowners may step in as buyers by repaying their loan at a price below par to reduce their debt. But the timing and magnitude of the prepayment is uncertain. Until the prepayment occurs, the willingness and capacity of domestic investors to absorb callable bonds is important to avoid or reduce the self-enforcing mechanism of duration increases described in the first section. Therefore, it is imperative to understand and closely follow the market dynamics and investor reactions.

[18] Danmarks Nationalbank (2021), Accommodative financial conditions strengthen the upswing, *Danmarks Nationalbank (Monetary and Financial Trends)*, Analysis No. 23, September 2021.

Annex 1: Illustration of offsetting duration effect of government and mortgage bonds

When interest rates increase and the duration of callable mortgage bonds increases, the krone duration of government bonds tends to decline and offset the increase in the krone duration of the callable bonds. The primary contribution is from the lower market value of the government bonds as the price of these declines. The table illustrates the effects for I&P's holdings of callable mortgage bonds maturing in 2050 and their holdings of the 4.5 percent government bonds maturing in 2039, and the changes are explained below. For simplicity, the example is shown for a constant nominal holding to avoid the noise from transactions.



Mortgage bonds

The combined holdings of mortgage bonds maturing in 2050 were DKK 167bn at the end of January 2021. With an average duration of 4.9 years, the krone duration of the holdings was 81m per bps. Through February-April, the average duration jumped by to 8.1 years, or by 66 percent. The duration of a plain vanilla bond declines as interest rates increase, but the embedded prepayment option makes the price-interest rate relationship concave when the option is in the money, see chart. In other words, the mortgage bonds exhibit negative convexity. For an unchanged holding of callable bonds, this led to an increase in krone duration of almost 49 million per bps. The increase of 60 percent is lower than the increase in duration as the total effect on krone duration is pulled slightly down by a modest 4 percent drop in the market value of the bonds.

Government bonds

Over the same period, the holdings of DKK 198bn of the long government bonds, 4.5 percent 2039, contributed with a negative 25 million per bps in krone duration to the portfolios of I&Ps; thus, in this example about half of the increase from the mortgage bonds above. For the government bonds, there was a negative contribution from a decline in duration (these bonds do not contain prepayment options), and a larger negative contribution from a decline in market value.

In total

Government bonds, including, for example, also the holdings of German government bonds, tend to offset increases in the duration of callable mortgage bonds in periods of rising rates for the pension sector as a whole, but with large variations across companies. The extent of the offset may differ from period to period because it depends on market-specific developments, as the duration and price of the different bonds depend on the development of different interest rates, e.g. German and Danish government bond yields and mortgage bond yields, that do not correlate perfectly.

	Nominal holdings, DKKbn	Price, DKK	Memo, market value, DKKbn	Duration, years	Krone duration, DKKm per bps
MTG 2050 – Jan 2021	165	101	*167*	4.9	**81**
MTG 2050 – Apr 2021	165	97	*160 (-7)*	8.1 (+3.2)	**130 (+49)**
DGB 4.5'39 – Jan 2021	105	188	*198*	14.6	**289**
DGB 4.5'39 – Apr 2021	105	176	185 (-13)	14.2 (-0.4)	**264 (-25)**

1. MTG 2050 includes 1.0, 1.5, and 2.0 percent coupons. Nominal holdings in end-January 2021 used for both periods to eliminate the effect of transactions for the example.

Annex 2: Data

Insurance and Pension (I&P)

Danish insurance and pension companies report holdings and transactions on securities on a monthly basis to Danmarks Nationalbank. Holdings through companies' majority-owned Danish investment funds (capital funds) are included. However, the companies' use of foreign entities to buy assets which could include buying Danish mortgage bonds is not included in the statistics. These activities are limited, and we assess that the major part of the mortgage bond activity is captured through Danish entities.

Investment funds (IF)

For Danish investment funds, we combine information from the security statistics and investment fund statistics. This allows for combining detailed information at security level with characteristics of the funds such as type of funds (UCITS or AIF), risk category, and benchmark. However, it provides us with a limited number of four duration events, since the quality of these characteristics only dates back to 2018. Moreover, to avoid duplicated values we disregard capital funds owned by the insurance and pension sector.

Danish investment funds report their benchmarks to Danmarks Nationalbank as a part of the general statistical reporting to the investment fund statistics. It is typically possible to infer the duration of the benchmark from the reporting. This duration of the benchmarks has been checked against information in the documents 'Central investor information' on the investment funds' webpages. From these documents it is in most cases possible to obtain information about the duration bands.[19]

Duration

For Danish long-term bonds, we rely on data from Scanrate RIO and use the option-adjusted durations as well as prices to calculate the krone duration. This is done in order minimize the effect of changes in duration from prepayment of the principal of callable bonds that are called by the issuer. The option element adjusts for prepayments, in which the duration of callable bonds decreases as the probability of prepayment increases. However, these calculations are model-based and thereby also sensitive to inputs and calibrations.

For euro government bonds (with no option element), the krone duration is calculated using an approximated Macaulay formula for duration.

Derivatives

Detailed information about the sectors' uses of interest rate swaps and derivatives, which are particularly relevant for I&P companies and some investment funds, is unavailable. This implies that we are unable to capture if the companies or funds counter duration increases using swaps and thereby fully explore how they react to duration jumps. Interest rate derivatives are necessary to have to obtain the full picture of duration management. With our data, we are still able to analyze the bond transaction reaction following duration jumps. These are what matters directly for the yield spread dynamics in the bond market.

[19] We are unable to find information on duration bands for all short and medium investment funds.

Annex 3: Identification of episodes with increases in duration for long-term fixed-rate mortgage bonds

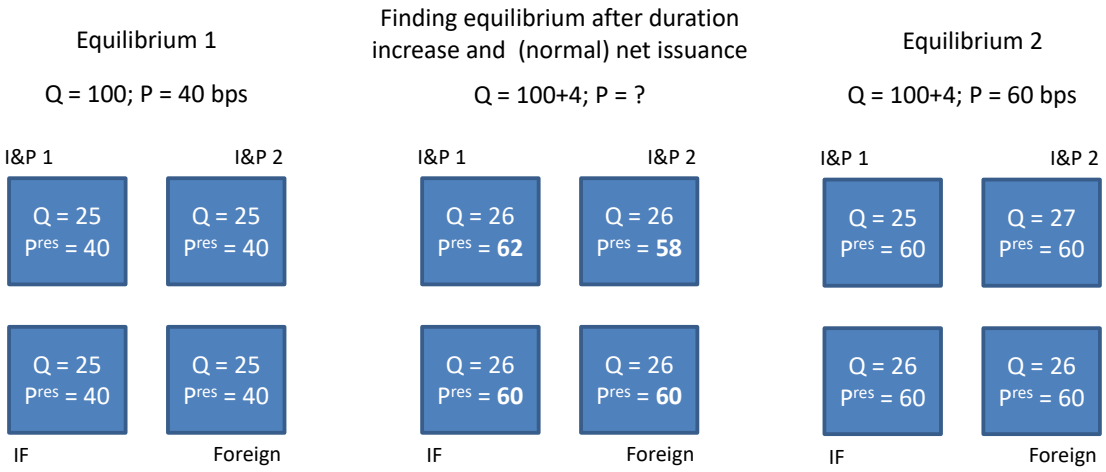
Periods	Duration development and coupons affected	Development in mortgage bond yields (basis points)	Macrofinancial backdrop	Development in DK-DE yield spreads (basis points)	Development in OAS to government bonds (basis points)
Mid-2015	2 and 2.5 per cent bonds increased from 9.3 and 7.7 to 10.5 and 9.5 years, respectively	+ 40.7 (2 per cent bond)	Global bond selloff led by improved economic growth projections	+ 5.5	+ 7.0
Late 2016	2 and 2.5 per cent bonds increased from 7.9 and 5.1 to 10.2 and 8.6 years, respectively	+ 34.7 (2 per cent bond)	US election, US yields increased	+ 1.7	+ 3.5
Early 2018	2 and 2.5 per cent bonds increased from 7.2 and 3.7 to 9.0 and 6.7 years, respectively	+ 19.8 (2 per cent bond)	Strong US key figures – high expected inflation	+ 6.7	+ 13.4
Late 2019	1 per cent bonds increased from 8.2 to 9.1 years. 1.5 per cent bonds increased from 2.9 to 4.2 years	+ 5.2 (1 per cent bond)	Brexit deadline October 31, US-China trade negotiations	+ 0.1	- 7.1
March 2020	1 and 1.5 per cent bonds increased from 4.9 and 1.4 years to 8.6 and 5.4 years, respectively	+ 32.7 (1 per cent bond)	Covid-19 financial turmoil	+ 22.0	+ 22.1
Early 2021	1 and 1.5 per cent bonds increased from 5.9 and 2.0 to 9.8 and 7.9 years, respectively	+ 35.2 (1 per cent bond)	Increasing interest rates globally led by the US	+ 12.3	+ 23.8

[1] Note: The periods covered are the following: May and June 2015, October and November 2016, January and February 2018, November and December 2019, March 2020, and February to June 2021.
[2] Source: Nordea Analytics and Scanrate RIO.

Annex 4: How market equilibrium prices adjust without flows

Market equilibirum prices, e.g. expressed in terms of relative pricing between two assets such as the yield spread, can change even without investors changing their portfolios. Consider the example in the chart showing four investors making up the entire market for callable mortgage bonds; two segments of insurance and pension (I&P) companies, domestic investment funds, and foreign investors.

- In the first equilibirum, they each hold 25 bonds, and their reservation price spread for buying/selling one more bond is 40 bps (in spread terms to government bonds); thus, the market is in equilibirum at a spread of 40 bps.
- Then the duration of the callable mortgage bonds rises. On top, but for unrelated reasons, four more bonds are issued, net.
- As a starting point, each sector buys one additional bond. As a result of the higher risk, the reservation price spread increases for all investors, but more so for I&P 1 than for the others and less so for I&P 2. To reach a new market equilibrium, the two I&Ps trade one bond between them, and subsequently all sectors' reservation price spread is 60 bps.
- Compared to the first equilibrium, I&P combined purchased two bonds, and IF and foreigners each purchased one bond. Thus, no sector sold bonds, and no subsector sold, but the spread went up.



Annex 5: Potential impacts of regulation on pension companies' behavior in reaction to duration jumps

During the jump periods in the data, market values fall, while OAS and duration increase.[20] Both the OAS and duration increases are captured in the Solvency II Volatility Adjustment (VA), which buffers the asset losses on the balance sheet via a parallel, albeit marginally smaller decrease in guaranteed liabilities. This is particularly relevant for pension companies with a balance sheet hedge, cf. box 1.

The following sections describe the VA, which types of companies use the VA, and the effects of callable mortgage bonds' OAS and duration on the VA and on company behavior.

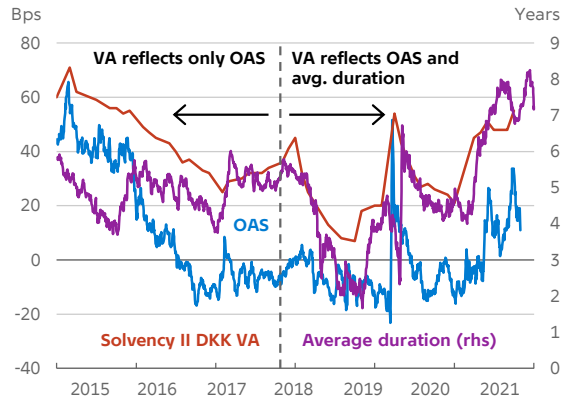
The Solvency II Volatility Adjustment

The Solvency II VA is an addition to the Solvency II risk-free term structure used to discount the future liabilities of insurance and pension companies. The VA allows long-term investors (insurers and pension companies) with predictable long-term nominal benefits to benefit from the credit-risk adjusted yields on local government bonds, mortgage bonds and corporate credit. The VA also buffers insurers, as long-term investors, from short-term market volatility. When credit spreads widen on companies' portfolios, the VA adjusts to include approximately 65 percent of the change in credit spreads in the discount curve.[21]

The spread on Danish mortgage bonds is incorporated into the Solvency II VA according to the OAS and the average duration of the underlying mortgage bonds held by the sector as a whole. Prior to September 2018, the average duration of Danish mortgage bonds was assumed constant in the calculation of the DKK VA. During this period, changes in the OAS affected the VA, but changes in the duration did not, cf. chart 1.

From September 2018 onward, both the OAS and the average duration affected the DKK VA. Since then, the VA has been more volatile and more market consistent, i.e. no arbitrage.

The Solvency II VA now incorporates both OAS and average duration Chart 1



Note: Solvency II VA for Danish kroner and OAS and average duration for Danish mortgage bonds.
Source: Rio ScanRate, Danmarks Nationalbank, and EIOPA.

The change in the DKK VA from changes in the OAS and duration of callable bonds is approximately:

$$\Delta(DKK\ VA) \sim 65\% \cdot \Delta(OAS) \cdot \Delta(Duration)$$

The change in the DKK VA is approximately linear in the change in OAS and linear in the change in average duration. When OAS and duration move in tandem, the change in the DKK VA is quadratic.

Chart 2 illustrates the mechanics of the Solvency II VA. The changes in yields and average duration of callable mortgage bonds come into the calculation of the DKK VA through changes in the market yields and the Risk Corrections.[22]

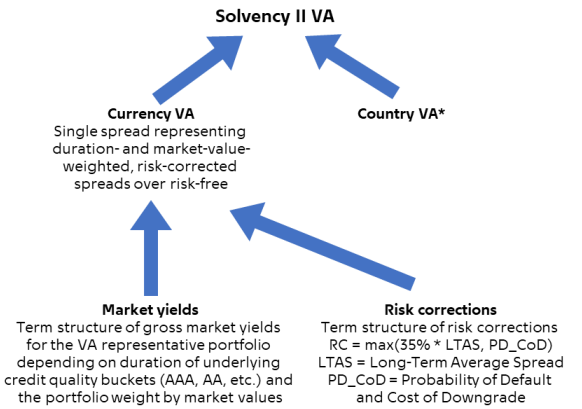
[20] In this annex, the discussion of duration focusses on the time aspect of duration, i.e. average duration for bonds and Macaulay duration for liabilities. However, movements in krone duration move in the same directions as described below for the time aspect.

[21] More precisely, the VA incorporates 65 percent of the credit-risk adjusted spreads after the prudent reduction of the gross spread of each bond by 35 percent of the 'long-term average spread'. On average, the VA allows for about half of gross credit spreads and captures about 65 percent of movements due to market volatility. See Volatility adjustment to the relevant risk-free interest rate term structure | EIOPA (europa.eu).

[22] EIOPA has provided a sample calculation in an Excel workbook. The interested reader is referred to the Background Material on the EIOPA risk-free rate website, Risk-free interest rate term structures | EIOPA (europa.eu).

Companies may choose whether to use the VA
For Solvency II discount rates, companies must use the EIOPA risk-free term structure, including the Ultimate Forward Rate. They may choose to use the VA, but this must be approved by the regulator.

Calculation of the Solvency II VA Chart 2



Note: The country VA is excluded from the diagram. Detailed calculations are provided by EIOPA. See footnote 22.
Source: Danmarks Nationalbank.

The VA is used most often for long-term fixed or guaranteed benefits where the backing assets are comprised mostly of government and corporate credit. The VA is generally not used for unit-linked, index-linked, or Danish market rate savings products. Companies with separate portfolios of average rate guaranteed products and market rate products generally use the VA for the average rate portfolio, but not the market rate portfolio.

Changes in the OAS do not affect market rate providers or companies with a flexible hedge
For pension companies with market rate products or conditional guarantees and a flexible hedge, Solvency II regulation does not have a direct impact on their solvency and day-to-day investment reactions in volatile markets. Both types of companies make investment decisions based on their risk models and return expectations.

Movements in the OAS and Solvency II VA do not affect market rate products, as these pension companies do not use the VA. Moreover, movements in the discount curve do not materially affect solvency as the customer bears the market risk.

For conditional guarantees, changes in the OAS and duration of mortgage bonds affect the discount curve with the VA. For these companies, the present value of conditionally guaranteed benefits is affected, but solvency is not materially impacted.

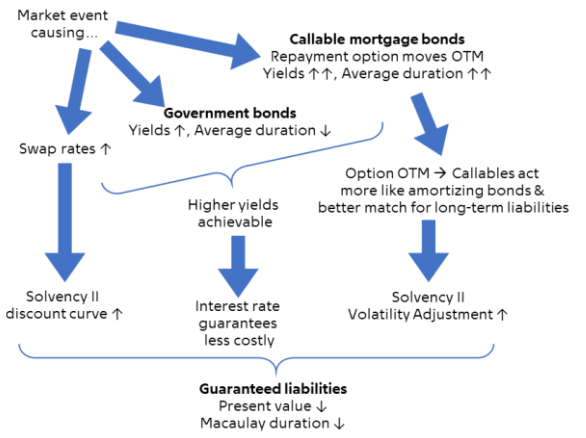
Credit spreads in the discount curve buffer pro-cyclical behavior
Compared to using a swap-based discount curve or the Solvency II discount curve without the VA, the inclusion of a portion of changes in credit spreads acts as a counter-cyclical buffer, reducing pressures to rebalance away from credit risk when spreads widen.

The net effect on the balance sheet is that approximately 65 percent of the market-value movements in mortgage bonds and other credit is absorbed by changes in the present value of liabilities. The remaining 35 percent is absorbed by equity capital. When spreads widen, a portion of equity capital is transferred to liability reserves, reducing the numerator of the solvency ratio.

As only about 65 percent of the spread widening is included in the discount curve, insurers or pension companies with low solvency ratios may still need to de-risk pro-cyclically. For example, such a company could decide to divest from mortgage bonds if volatility in mortgage bonds caused too much volatility in the balance sheet and solvency ratio.

Duration effects on guarantees are more complicated
During episodes of duration jumps, the average duration of a company's callable mortgage bonds increases markedly (see the chart in annex 1), while the average duration of government bonds decreases marginally. The duration of liabilities reacts similar to a long-maturity amortizing bond, i.e.

Duration effects on guaranteed liabilities Chart 3



Source: Danmarks Nationalbank.

marginally, because the future expected liability cash flows are not sensitive to small changes in rates.

Chart 3 illustrates how a market event of rising yields and duration jumps in callable mortgages can affect the present value and Macaulay duration of a pension company's guaranteed liabilities.

In this illustrative scenario, the decrease in duration of government bonds coincides with an increase in yields and an increase in swap rates, which are the starting point for the Solvency II discount curve. The repayment option for callable mortgage bonds moves out-of-the-money (OTM), and investors expect the callable mortgage bond to act more like an amortizing bond for the maturity of the mortgage and less like a repayment option bullet bond.

When the average duration of the callable mortgage bond increases, it is a better matching asset for long-term fixed liabilities and the increased market yield (OAS) is expected, under current market conditions, to be achievable. Hence, the contribution from the OAS in the Solvency II VA increases.

The increase in swap rates and in the VA shifts the discount curve up, which reduces the present value of guaranteed liabilities and their Macaulay duration.

During the jump periods in the data, we see the OAS and average duration increase for callable mortgage bonds. The increased average duration and OAS increase the VA doubly. This is a partial buffer against market volatility and a counter-cyclical measure to reduce companies' short-term need to de-risk.

Expected effects from the Solvency II VA in isolation

Companies with a balance sheet hedge the use of a combination of fixed income assets – German government bonds and Danish government bonds and mortgage bonds – and interest rate derivatives to hedge the interest rate risk of their guaranteed pension liabilities.

Hedging changes in the market value of mortgage bonds due to OAS movements is separate from hedging interest rates. When hedging net duration, the duration changes in mortgage bonds due to OAS movements needing to be balanced by buying or selling bonds or interest rate derivatives.

While approximately 65 percent of OAS movements is incorporated in the VA, 35 percent is not. The difficulty in hedging the risk of OAS spread-widening would be expected, in isolation, to push companies away from OAS risk.

Volatility of OAS and duration may cause solvency volatility, but investment decisions drive behavior

Historically, pension companies have invested mainly in German and Danish government bonds and mortgage bonds to back their guaranteed benefits.

For practical and economic reasons, pension companies have not divested from mortgage bonds due to the isolated regulatory issues of the OAS.

The size of the Danish mortgage market compared to the Danish government bond market means that the stock of mortgage bonds cannot be replaced by Danish government bonds to back Danish kroner denominated guaranteed benefits.

The investment behavior seen in the data – the combination of purchasing mortgage bonds during jumps and the active rebalancing of the fixed income portfolio—reflects the real-world combined constraints of regulation and investment targeted at prudent asset-liability management and risk-adjusted return.

LOW ↓FOR LONG

Low for long

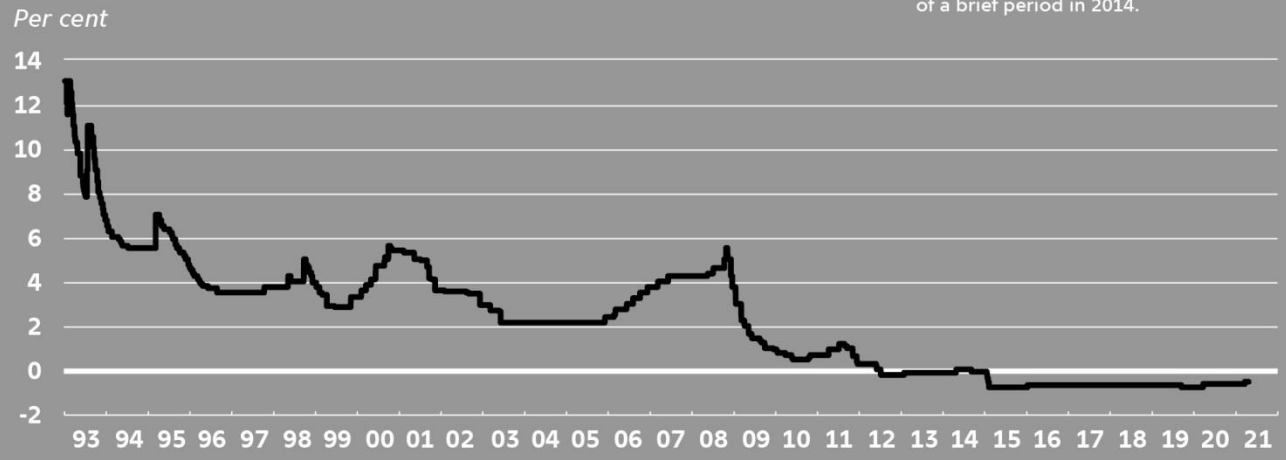
Denmark was the first country to introduce negative monetary policy rates in 2012. Since then, Switzerland, Sweden, Japan and the euro area have followed suit.

Very low and in some cases negative interest rates have characterised the past decade across the advanced economies. There are several reasons why interest rates have fallen to the current low levels. Low interest rates reflect the fact that inflation has been subdued in many countries, but structural changes in household and corporate savings and investment behaviour are also part of the explanation.

These developments have brought monetary policy and the economy into uncharted waters, which is why Danmarks Nationalbank will be issuing a series of publications on the topic of which this Economic Memo is one.

Danmarks Nationalbank's interest rate

Danmarks Nationalbank's key interest rate has been negative since the summer of 2012, with the exception of a brief period in 2014.



PUBLICATIONS

NEWS

News offers quick and accessible insight into an Analysis, an Economic Memo, a Working Paper or a Report from Danmarks Nationalbank. News is published continuously.

ANALYSIS

Analyses from Danmarks Nationalbank focus on economic and financial matters. Some Analyses are published at regular intervals, e.g. *Outlook for the Danish economy* and *Financial stability*. Other Analyses are published continuously.

REPORT

Reports comprise recurring reports and reviews of the functioning of Danmarks Nationalbank and include, for instance, the *Annual report* and the annual publication *Danish government borrowing and debt.*

ECONOMIC MEMO

An Economic Memo is a cross between an Analysis and a Working Paper and often shows the ongoing study of the authors. The publication series is primarily aimed at professionals. Economic Memos are published continuously.

WORKING PAPER

Working Papers present research projects by economists in Danmarks Nationalbank and their associates. The series is primarily targeted at professionals and people with an interest in academia. Working Papers are published continuously.

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