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Explaining the Danish-German sovereign yield spread

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Explaining the Danish-German sovereign yield spread

Abstract

In the years leading up to the pandemic, the yield spread between Danish and German sovereign bonds was roughly zero across maturities. In March 2020, the spreads widened and have stayed positive since.

This memo investigates the drivers of the 10-year yield spread, which has widened 25 basis points from January 2020 to March 2022. The widening is found to be driven mainly by a larger term premium spread. We propose two explanations behind this related to financial frictions. First, the ECB's significant bond purchases during the pandemic has increased collateral scarcity of German sovereign bonds. Second, duration on callable Danish mortgage bonds have increased substantially, possibly lowering demand for Danish sovereign bonds.

Empirically, collateral scarcity of German sovereign bonds and duration on Danish mortgage bonds are found to have widened the 10-year yield spread by 9 and 5 basis points, respectively, from January 2020 to March 2022. Differences in liquidity is found to be an important factor as well.

1. Motivation and main conclusions

Understanding the drivers of the 10-year yield spread between Danish and German sovereign bonds is important. First, it helps clarify why government bond yields in Denmark are currently higher relative to German bond yields. Second, it quantifies whether the widening of the spread has been caused by temporary or more long-lasting effects. This is especially important for government debt operations and investors' portfolio decisions.

Historically, the Danish 10-year government bond yield has followed its German counterpart closely, see chart 1. The Danish and German economies are both robust, their government bonds exhibit low credit risk, and there is limited exchange rate risk due to the Danish krone being pegged to the euro.

The 10-year yield spread between the Danish and German sovereign bonds was close to zero in the years leading up to the outbreak of the pandemic in March 2020, after which it widened to around 25 basis points and has stayed at that level since. This Economic Memo analyses the developments behind the widening in that period.[1][2]

Larger Danish term premium has widened the 10-year yield spread during the pandemic

Long-term bond yields reflect the expectations of future short-term bond yields and a 'term premium' capturing various risk premia for i.a. interest rate risk, credit risk, liquidity risk etc. In section 2, we decompose the 10-year yield spread between Denmark and Germany into differences in expectations of future short-term yields and differences in the term premium using the methodology in Joslin et al. (2011). The model

[1] This also implies that expectations of future policy rates evolve similarly in Denmark and the euro area. One exception is short-lived periods with pressure on the exchange rate between Danish kroner and euro.

[2] Short-term yield spreads have also widened after March 2020. For instance, the 2-year sovereign yield spread between Denmark and Germany has widened 15 basis points. The widening of the short-term yield spread is driven by some of the same factors as the long-term yield spreads, including the 10-year yield spread.

suggests that the increased 10-year yield spread mainly reflects a larger Danish term premium relative to the German, see chart 2. In addition, expectations of future short-term government bond yields have contributed around 7 basis points to the widening of the 10-year sovereign yield spread. For comparison, the monetary policy rate spread has increased 5 basis points in the period considered.[3]

The wider term premium spread could be driven by supply and demand effects

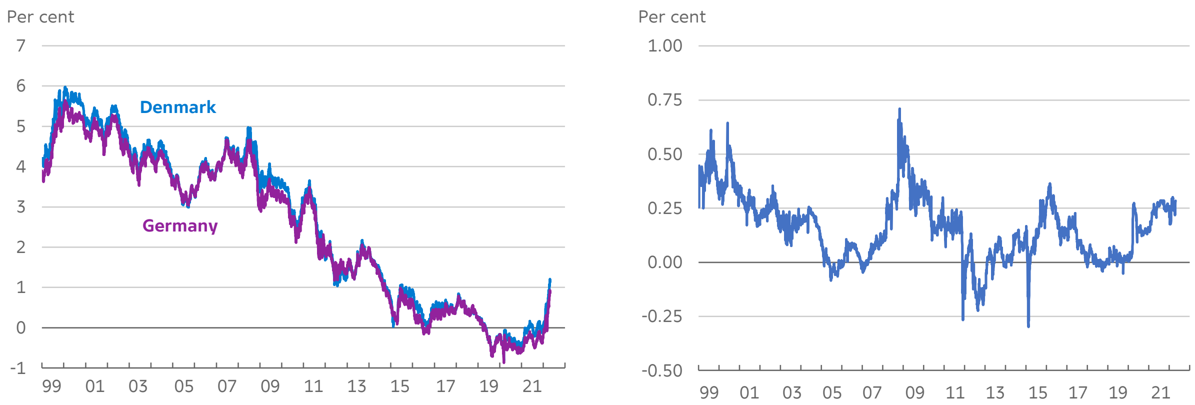
In section 3, we propose and explain two channels related to financial market frictions, which may explain the recent increase in the 10-year Danish term premium relative to the German. Both channels work by affecting the supply or demand for either Danish or German government bonds:

1. **Scarcity of German sovereign bonds following ECB quantitative easing (QE):** The Eurosystem's substantial purchases of German sovereign bonds since March 2020 have made them scarce for other investors. This could entail a scarcity premium, as German sovereign bonds are widely used as collateral in the repo-market.[4] Hence, investors might be willing to pay a premium for German government bonds compared to Danish.
2. **Increased duration on Danish mortgage bonds:** A larger supply of interest rate risk on Danish callable mortgage bonds, caused by the embedded prepayment option in the bonds, could have lowered the demand for Danish government bonds.

Empirically, multiple drivers contribute to the elevated term premia spread

In section 4, we set up an autoregressive distributed lag model to estimate the effect of the two channels for the widening of the 10-year term premium spread. We control for differences in traditional risk factors and differences in funding costs, measured by cross-currency basis. The risk factors included are liquidity, credit and volatility, measured by the bid-ask spread on 10-year sovereign bonds, 10-year credit default swaps and realised volatility, respectively.

Danish and German 10-year sovereign yields move in tandem, but the spread has widened during the pandemic Chart 1



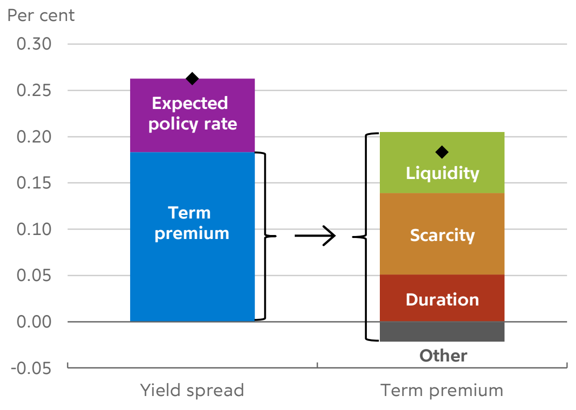
Note: The left-hand chart shows the 10-year par yields on Danish and German sovereign bonds. The right-hand chart shows the spread between Danish and German 10-year par yields. Daily observations until 21 April 2022.
Source: Nordea Analytics.

[3] In assessing the monetary policy rate spread, we consider the difference between Danmarks Nationalbank's current account rate (certificates of deposit rate prior to March 2021) and the ECB's deposit facility rate. We ignore the 10-basis point cut in the certificates of deposit rate in March 2021, since it was part of the technical adjustment of the monetary policy instruments, aiming at a neutral effect on benchmark money market rates and the exchange rate, see Danmarks Nationalbank (2021).

4 We measure the scarcity premium as the difference between repo rates with German sovereign bonds as general collateral and the deposit facility rate of the ECB.

Multiple drivers behind the wider 10-year sovereign yield spread since early 2020

Chart 2



Note: Change in the 10-year zero coupon government bond yield spread between Denmark and Germany from 31 January 2020 to 31 March 2022. Methodology is explained in section 4.
Source: Scanrate RIO, Refiniv Eikon and Datastream, Bundesbank, Bloomberg, BrokerTec, Danmarks Nationalbank, ECB and own calculations.

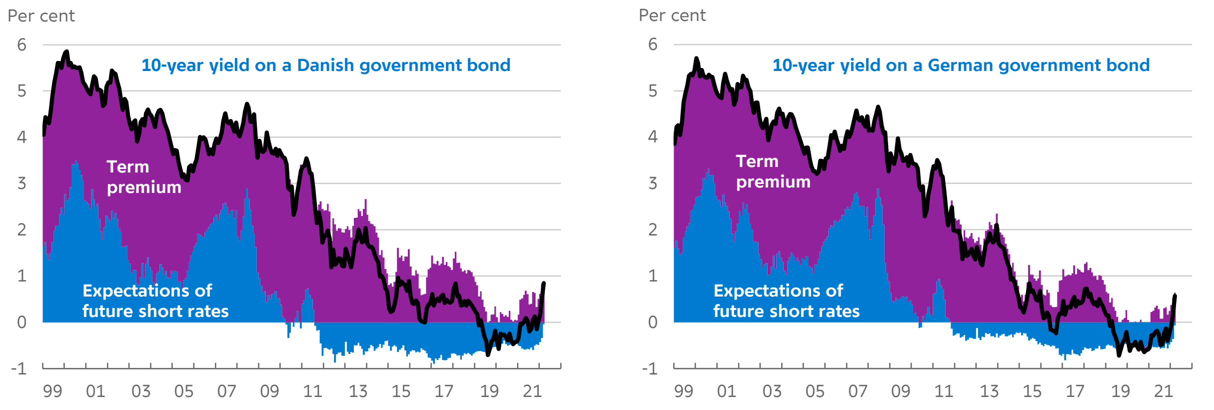
Of the suggested channels and risk factors, the scarcity of German sovereign bonds due to QE is the most significant contributor to the widening of the government bond spread from January 2020 to March 2022. The model suggests that collateral scarcity on German sovereign bonds has increased the 10-yield spread between Danish and German sovereign bonds by 9 basis points, cf. chart 2. Moreover, the jump in krone duration on Danish mortgage bonds is found to increase the yield spread by 5 basis points. Differences in liquidity, which is a well-known driver of the yield spread,[5] accounts for slightly below 8 basis points of the total widening of 25 basis points.

2. The spread between 10-year term premia on Danish and German sovereigns has widened

According to the linearised version of the risk-augmented expectations theory of the term structure, the yields on long-term bonds equal an

Term premiums at low levels

Chart 3



Note: Zero coupon yields on Danish and German sovereign bonds decomposed to risk neutral yields and term premia based on the approach in box 1. Last observation, 31 March 2022.
Source: Danmarks Nationalbank, Bundesbank and own calculations.

[5] See Abildgren et al. (2013).

average of expected future short rates (that can be interpreted as monetary policy rates) plus a time-varying and maturity-dependent term premium:

$$\underbrace{i_{t,n}}_{\substack{long-term\ yield \\ with\ maturity\ n}} = \underbrace{\frac{1}{n}\sum_{j=1}^{n} E_t[i_{t+j,1}]}_{\substack{Average\ expectation\ of\ future \\ short\ rates}} + \underbrace{TP_{t,n}}_{\substack{Term\ premium \\ for\ maturity\ n}}$$

The term premium captures the compensation that investors require to hold a long-maturity bond rather than rolling over short-maturity bonds, and reflects various risk premia, for instance interest rate risk, liquidity risk, credit risk etc. To estimate the term premium, expectations about the future path of interest rates are needed. As expectations of short-term interest rates are not directly observable, we need a model for describing the dynamics of yields with different maturities.

We decompose the yields on 10-year government bonds in Germany and Denmark into expectations of future short-term rates and a term premium using a dynamic no-arbitrage term structure model, see box 1. The estimated level of the term premium is subject to uncertainty and may differ across models and estimation techniques, see e.g. Cohen et al. (2018). The model used in this memo is robust to alternative specifications within the same model class, see box 2. The model used in this memo belongs to a broader class, which also includes the arbitrage-free Nelson-Siegel model, see Christensen, Diebold, and Rudebusch (2011).

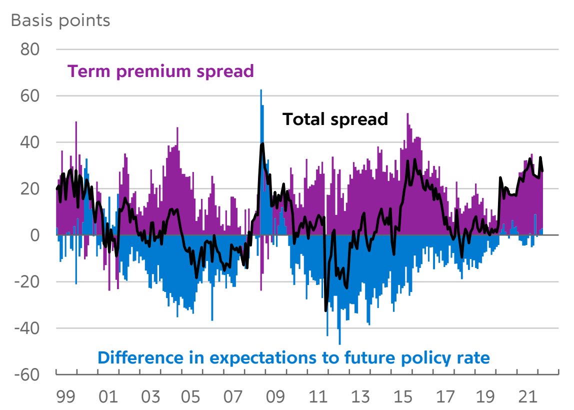
Expectations of future policy rates follow each other closely due to the peg

Overall, the development in expectations of future short rates and the term premium have evolved broadly similarly in Denmark and Germany, see chart 3. This reflects the credibility of the fixed exchange rate regime and that Danmarks Nationalbank will typically mirror the ECB's changes in policy rates. Since March 2020, expectations to future short-term rates have changed slightly, cf. chart 4. This reflects that the monetary policy rate spread between Denmark and the euro area has increased 5 basis points since the outbreak of the pandemic. Additionally, Danish overnight index swap (OIS) rates have moved closer to Danmarks Nationalbank's lending rate.[6]

Term premia tend to co-move, but have contributed to the recent widening of the spread

Both the Danish and German term premia were around 2 percentage points until early 2014, after which they dropped sharply, cf. chart 3. According to our estimates, the widening in the 10-year government bond spread during the pandemic is primarily caused by a larger increase in the Danish term premium relative to the one in Germany.

The recent widening in the 10-year yield spread is driven by term premia Chart 4



Note: Zero coupon yields on Danish and German sovereign bonds decomposed to risk neutral yields and term premia based on the approach in box 1. Last observation, 31 March 2022.
Source: Danmarks Nationalbank, Bundesbank and own calculations.

[6] See Danmarks Nationalbank (2022) for further explanations.

A no-arbitrage model for the term structure of interest rates

Box 1

Expectations of future short-term interest rates are not observable, and to obtain an estimate of the term premium, we need a model of the term structure of interest rates.

So-called 'affine' term structure models are a popular class of models for estimating the term structure.[1] These models are based on the empirical observation that interest rates are highly correlated across different maturities and across time. Principal component analysis shows that 99.9 per cent of variation in Danish and German interest rates can be explained by three orthogonal factors, the level, slope and curvature of the yield curve. By describing the dynamic evolution of these latent factors, and by imposing no-arbitrage conditions, we can develop forecasts for short-term interest rates, as e.g. needed for estimating the term premium.

We use the model from Joslin et al. (2011). The model is a no-arbitrage model estimated in two steps based on principal components. The model and estimation method are among the most widely used by practitioners and in academia, see e.g. Eser et al. (2019). The model assumes that the three latent factors follow a VAR(1) process,

$$X_t = \mu + \Phi X_{t-1} + \Sigma_u u_t, \quad u_t \sim N(0, I_k).$$

Based on a stochastic version of the expectation hypothesis, along with an assumption that the price of risk is linear in the factors, X_t, $\lambda_t = \lambda_0 + \lambda_1' X_t$, it is possible to derive model-based zero-coupon interest rates, $i_{t,n}$, for a government bond with maturity in n months as,

$$i_{t,n} = -\frac{1}{n}(A_n + B_n' X_t),$$

where A_n and B_n contain recursive no-arbitrage conditions,

$$A_n = A_{n-1} + B_{n-1}'(\mu - \lambda_0) + 0.5 B_{n-1}' \Sigma_u \Sigma_u' B_{n-1} - \delta_0,$$

$$B_n' = B_{n-1}'(\Phi - \lambda_1) + \delta_1',$$

which are initialised in $A_1 = -\delta_0$, $B_1' = -\delta_1'$. The model-implied one-month (policy) interest rate is therefore $i_{t,1} = d_0 + d_1' X_t$.

The model is estimated in two steps.[2] In the first step X_t is derived as the first three principal components from the term structure of interest rates,[3] after which μ, Φ and Σ_u can be estimated using OLS. In the second step, $\delta_0, \delta_1, \lambda_0$ and λ_1 are estimated using maximum likelihood, conditional on the estimates from the first step.

Because the model explicitly imposes no-arbitrage and provides a value for the price of risk (the parameters in the matrices λ_0 and λ_1), it is possible to compute the expected interest rates in a world with no risk, i.e. one in which the expectation hypothesis holds. Practically, this is done by computing A_n and B_n' with $\lambda_0 = \lambda_1 = 0$. Doing so yields a term structure defined solely by expectations about future short interest rates. This risk-neutral term structure is denoted $\frac{1}{n}\sum_{j=1}^{n} E_t(i_{t+j,1})$. The term premium at time t for a bond with maturity n is defined as the difference between the observed zero-coupon interest rates, and the expectation about future short interest rates under the physical probability measure,

$$TP_{t,n} = i_{t,n} - \frac{1}{n}\sum_{j=1}^{n} E_t(i_{t+j,1}).$$

Phrased differently, observable zero-coupon interest rates can be decomposed into two parts, one which relates to the expectations about future short-term interest rates, $E_t(i_{t+j,1})$, and the term premium,

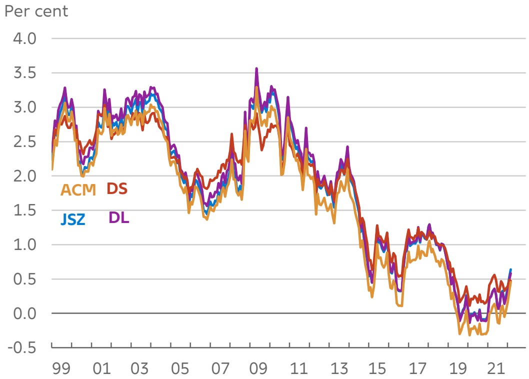
$$y_{t,n} = \frac{1}{n}\sum_{j=1}^{n} E_t(i_{t+j,1}) + TP_{t,n}.$$

1. The class of models was introduced by Duffie and Kan (1996), and Dai and Singleton (2000) as an extension of the Vasicek (1977) and Cox, Ingersoll and Ross (1985) models. Alternatives to the affine term structure models include dynamic Nelson-Siegel models, which were introduced in Diebold and Li (2006).
2. The model is estimated using the stepwise procedure introduced by Joslin, Singleton and Zhu (2011).
3. In this analysis bonds of maturities $n = [6M, 1Y, 2Y, 5Y, 7Y, 10Y]$ are used. We use monthly Danish and German government zero-coupon yields, which are calibrated using a static Nelson-Siegel-Svensson model. The sample spans 1999/01-2022/03.

Term premium estimates are robust across different estimation methods Box 2

As a sanity check, we estimate three alternative models in addition to the one outlined in box 1. All four models imply mean-reversion of the short rate to an unconditional mean, and can be considered to be of the same family of models. We note that the models are favoured work-horse models in the literature. Overall, the estimated term premia are broadly similar: While the level of the estimated term premia varies slightly, the variation is unaffected across the methods, as is commonly found in the literature, see e.g. McCoy (2019). Dai and Singleton (2000) is identical to Joslin et al. (2011). However, the model is estimated via a Kalman filter. Theoretically, it delivers a more efficient estimation method, but can in practice give rise to some estimation issues. Adrian et al. (2013) is identical to the Dai and Singleton (2000) and Joslin et al. (2011) model, but is estimated using Fama-MacBeth regressions. It is developed and used by the New York Fed. Diebold and Li (2006) is a dynamic Nelson Siegel model. The model does not enforce no-arbitrage conditions, and the risk-neutral measure is unknown. In practice, the model is easier to estimate and interpret than no-arbitrage models. It is also commonly used by central banks. We use the Nyholm (2015) version of the model.

The 10-year term premium on German sovereign yields



Note.: Term premia on 10-year German sovereign yields. JSZ refer to the Joslin et al. (2011) model, DS to the Dai Singleton (2000) model, ACM to the Adrian et al. (2013) model, and DL to the Diebold Li (2006) model. Last observation, 31 March 2022.
Source: Danmarks Nationalbank, Bloomberg and own calculations.

3. Supply and demand channels driving the widening in the term premia spread

In efficient financial markets, yield spreads reflect differences in risk. If not, they should be traded to zero by arbitrageurs. Hence, the wider yield spread between Danish and German government bonds could be due to changes in investors' perceived risk of the bonds. However, it could also be related to financial frictions, driven by supply and demand factors. Greenwood, Hanson, and Liao (2018) argue that market segmentation imply that investors are specialised in specific bond classes and might have inflexible investment mandates. Hence, a supply shock originating in one bond market segment (like German sovereign bonds) might not entail perfect spillovers to other segments (for instance Danish sovereign bonds). Furthermore, Vayanos and Vila (2009) argue that if investors are risk averse and have preferred investment habitats, supply shocks to a specific group of bonds (e.g. due to changes in duration) affect relative prices. As a consequence, capital allocation might be slow-moving between markets, meaning that supply and demand shocks could have persistent price impact.

3.1 Collateral scarcity on German sovereign bonds due to ECB QE

The Eurosystem's asset purchases have lowered the free float of German government bonds
Since the introduction of the pandemic emergency purchasing program (PEPP) in March 2020, the Eurosystem's monthly net purchases have been substantial, see chart 5. Recently, the net purchases have been in line with or higher than the net issuance of government bonds in the euro area. This has affected the 'free float' of German sovereign bonds, measuring the share of the bonds not held by the Eurosystem, cf. chart 6. During the pandemic ECB's asset purchase programmes has lowered the 'free float' of German sovereign bonds substantially. The Eurosystem currently owns around half of German sovereign bonds. The purchases have lowered the

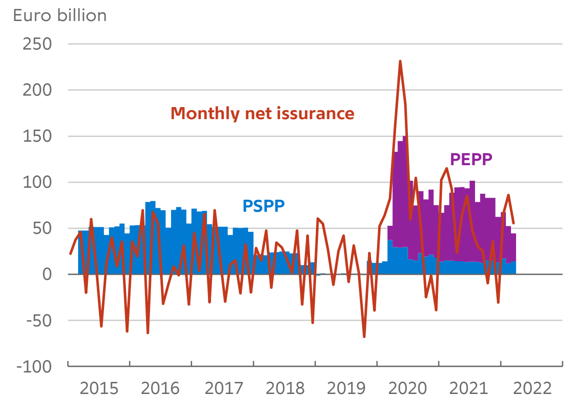
supply of duration left for private investors, contributing to keeping the German term premium at a low level, cf. Eser et al. (2019). In an arbitrage-free term structure model they show that a lower share of free float duration in the euro area has compressed the term premium. Li and Wei (2012) find similar effects of the Federal Reserve's large-scale asset purchase programmes on the 10-year term premium on US Treasuries.

Assets purchases of the Eurosystem spill over to Danish bonds, but not perfectly

Several papers have identified sizable spillovers from asset purchase programmes to other bond market segments.[7] According to Jensen et al. (2017) there were large spillovers from the ECB's Public Sector Purchase Programme (PSPP) starting in March 2015 to the Danish sovereign bond market. Intuitively, Danish and German government bonds have similar risk profiles, and investors might rebalance their portfolios towards Danish government bonds, when the Eurosystem's purchases lower the supply of German government bonds.

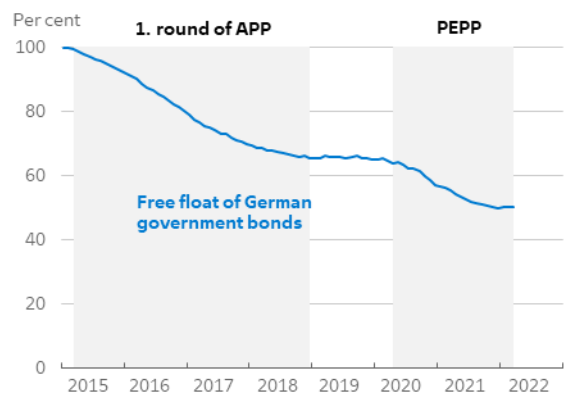
However, the spillovers to the Danish government bond market might not be perfect. For instance, German sovereign bonds are the benchmark safe assets in the euro zone, and are widely used as collateral in the European repo market.[8] Hence, investors might have some special preferences for German sovereign bonds compared to Danish ones.

The ECB has conducted substantial net purchases since March 2020 Chart 5



Note: Monthly net issuances cover all government bonds in the euro area. Latest observation is March 2022. Purchases under PEPP are mainly public sector bonds.
Source: ECB and own calculation.

PEPP has reduced the free float of German sovereigns significantly Chart 6



Note: Free float is defined as the share of bonds not held by the ECB under the asset purchases.
Source: ECB and own calculations.

[7] See Krishnamurthy and Vissing-Jørgensen (2011) for bond market spillovers in the US, Jensen et al. (2017) for spillovers to Denmark from ECB monetary policy shocks, and Autrup and Jensen (2021) for spillovers from the ECB's APP to the demand for Danish bonds via Danish pension funds.

[8] A sovereign repo is a financial security where the buyer of the security provides the seller with short-term liquidity. In return, the buyer receives a sovereign bond from the seller as collateral. The buyer receives the repo rate as remuneration for the provision of short-term liquidity. The repo is thus for the buyer comparable to securities lending, and the repo rate can be interpreted as a securities lending fee.

Collateral scarcity of German sovereign bonds has increased

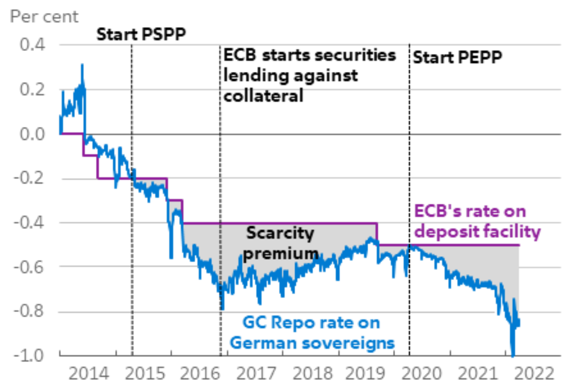
The combination of a low free-float and collateral scarcity implies that investors might be willing to pay a premium for German government bonds. Additionally, the ECB's asset purchase programmes have increased excess liquidity in the euro area banking system significantly, and also created a rebalancing need among private investors selling bonds to the Eurosystem. Both put downward pressure on repo rates, since the latter might imply that investors deposit more funds through the repo market. The expansion in central bank reserves associated with QE can thus have implication for the prices (and yields) on other assets than the ones eligible for purchase (Christensen and Krogstrup (2018) refer to this as "reserve-induced portfolio effects").

These effects are illustrated by the repo rates of German sovereign bonds having moved below the interest rate of the ECB's deposit facility, cf. chart 7.[9] This was also the case during PSPP in 2015. The purchaser or borrower of the repo therefore has to pay a comparatively high premium for borrowing German bonds in the repo market, increasing the "collateral scarcity" of the bonds. This suggests that investors generally have been willing to pay a premium for borrowing German sovereign bonds. Besides QE this could reflect a special preference for German sovereign bonds over Danish ones, for instance due to regulatory reasons, safe-haven dynamics etc.

We define the 'collateral scarcity' premium as the difference between the deposit facility rate of the ECB and the general collateral repo rate of German sovereign bonds, cf. box 3. The collateral scarcity premium has been positive since the introduction of PSPP in 2015. The findings are in line with Jank and Mönsch (2018) and Arrata et al. (2020), who document that PSPP have lowered repo rates on German sovereign bonds due to a higher collateral scarcity premium.

The collateral scarcity premium depends on the actual purchases by the ECB, and not the announcement of the purchases. This reflects that collateral scarcity occurs as bonds flow from the private market to the balance sheet of the ECB.

German sovereign bonds have been in high demand Chart 7



Note: The repo rate on German sovereign bonds is based on RFR Euro Benchmark indices. The repos are overnight. The repo rates measure the effective cost of overnight funding of German sovereign collateral. The rates are calculated from repo trades that use German government bonds denominated in EUR as the underlying collateral. End-of-year effects have been removed due to large fluctuations in the repo rates in the beginning and the end of a year. This is often due to efforts by financial intermediaries to retain German sovereign bonds, which are considered safe and liquid, and avoid offering them on the repo market on regulatory reporting dates, see Danmarks Nationalbank (2022). Last observation, 31 March 2022.
Source: BrokerTec, ECB and own calculations.

The scarcity premium gradually vanished towards the end of the first round of the PSPP, cf. chart 7. However, the premium has widened after the introduction of PEPP. Under the first round of the PSPP, the collateral scarcity premium peaked in December 2016 just before the ECB introduced its security lending against cash collateral. Specifically,

[9] However, various regulatory measures implemented in the same time frame may have an impact on the repo market. For example, the leverage ratio and liquidity coverage ratio introduced as part of Basel III come into question as potential influencing factors.

Specialness and scarcity premium on German sovereign bonds

Box 3

Collateral scarcity premium

Short-maturity repo rates will typically trade close to the monetary policy rates, as this constitutes an alternative to deposit funds for monetary counterparties. We compute the scarcity premium, defined as the average rate in a given general collateral (GC) segment minus the policy rate:

$$Scarcity\ premium = Policy\ rate - \ GC\ repo\ rate$$

A positive scarcity premium indicates that funds can be placed in the repo market at rates *below* the ECB deposit facility rate. This partly reflects that not all participants in the repo market are monetary counterparts, and hence cannot deposit their funds at the ECB. This effect has been amplified by the increased euro area excess liquidity. It may also reflect that government bonds may be scarce and in demand in repo transactions for other uses. GC repos do not specify the specific security the cash lender will receive, but only a broad basket of bonds, for instance German government bonds. The introduction of the PSPP pushed the scarcity premium into positive territory for all GC collateral segments, cf. Schaffner (2019). The impact of the PSPP has been strongest in the German collateral segment as highlighted in chart 8.

Collateral specialness premium

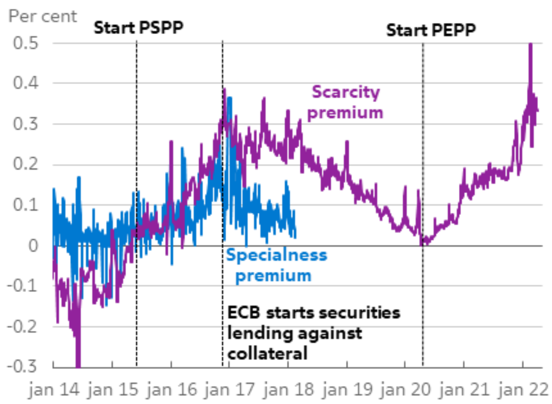
In some cases agents demand specific bonds for collateral. For instance, if a bank wants to short a specific bond, the bank is willing to pay a premium to borrow that specific collateral (SC) in a repo rather than general collateral. According to Duffie (1996), the repo specialness premium is defined as the spread between the GC and SC repo rates of the same collateral segment:

$$Specialness\ premium = GC\ repo\ rate - \ SC\ repo\ rate$$

This premium is normally positive with the size reflecting the importance of the demand for specific collateral.

The scarcity and specialness premia on German sovereign bonds are shown in the chart below. The specialness premium has been positive during most of the available period, reflecting that investors generally have been willing to pay a premium for borrowing a specific German sovereign bond. This indicates that they are in high demand, potentially because the Eurosystem's asset purchases have left a low outstanding amount available for investors.

Developments in scarcity and specialness premium on German sovereigns



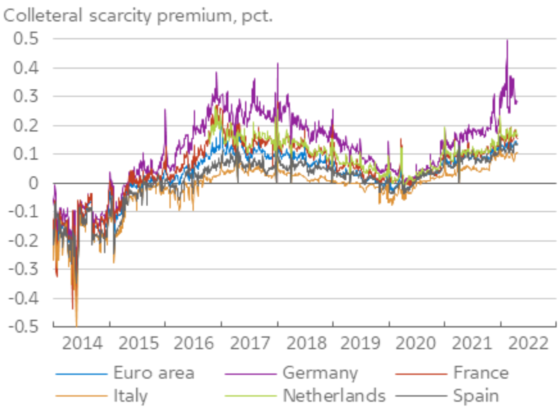
Note: The GC repo rate on German sovereign bonds is based on RFR Euro Benchmark indices and are based on overnight contracts. The specialness premium is calculated from the data on the SC repo rate on German sovereigns offered by Jank and Mönsch (2018). The data is only available up to February 2018. Last observation for the collateral scarcity premium is 31 March 2022.

Source: BrokerTec, ECB and own calculations and Jank and Mönsch (2018)

ECB assets were made available for securities lending against cash up to a certain limit.

Seen in isolation, the ECB's securities lending against cash collateral led to unchanged repo rates on specific collateral (SC) repos due to their 'specialness', while repo rates on general collateral (GC) increased because the GC repos do not specify which security the cash lender will receive. For details see box 3. The collateral scarcity premium on German sovereign bonds has widened relatively to the ones on similar GC repos in other euro area countries, see chart 8. This suggests that investors have a preference for German sovereign bonds due to their collateral value. Consequently, private investors might not be willing to pay the same premium for Danish government bonds. We do not include the scarcity premium on Danish government bonds due to insufficient data, and since Danmarks Nationalbank has not launched asset purchase programmes.

Larger collateral scarcity premium on German government bonds during QE Chart 8



Note: The repo rate on bonds is based on RFR Euro Benchmark indices. The repos are overnight. The repo rates measure the effective cost of overnight funding of sovereign collateral. The rates are calculated from repo trades that use government bonds denominated in EUR as the underlying collateral. End-of-year effects have been removed. Last observation, 31 March 2022.
Source: BrokerTec, ECB and own calculations.

3.2 Duration on Danish mortgage bonds

In Denmark, mortgages are typically financed directly through the issuance of mortgage bonds by a credit mortgage institution (match-funding principle). Fixed-rate mortgages are typically financed by 30-year callable bonds. Hence, the borrower has an option to redeem the underlying bond at par, making the maturity of the bonds highly uncertain, affecting their duration (a measure of interest rate risk). When interest rates rise and the price of the underlying bond therefore falls, it becomes less likely that the option is exercised, and the duration of the bond increases, see Achord et al. (2021).

Substantial spike in duration on Danish callable mortgage bonds Chart 9

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. Last observation, 31 March 2022.
Source: Own calculations.

Rising yields have led to a jump in duration on Danish callable mortgage bonds
The yield to maturity on 30-year callable mortgage bonds has increased substantially since the outbreak of the pandemic, and in particular since the beginning of 2021, driven by rising risk-free rates and

a widening of the option-adjusted spread (OAS).[10] Consequently, the krone duration on the outstanding callable mortgage bonds have approximately doubled since the start of 2021, cf. chart 9.[11]

Spike in krone duration may have dampened the demand for Danish sovereign bonds
The higher duration on Danish callable mortgage bonds increases the krone duration of the investors' assets as well, possibly creating a mismatch between the desired and actual duration of their portfolios. If investors have duration mandates, this could, in theory, lead to a lower demand for high duration bonds (including long term government bonds).

Achord et al. (2021) document that some domestic investors sell, or hold back on purchases of, Danish government bonds during duration jumps. Specifically, pension funds with flexible liability hedges typically sell Danish government bonds to buy more callable mortgage bonds during duration jumps. This might indicate that some investors have reduced their demand for high krone duration assets (like Danish sovereign bonds) for given market prices. The relative market pricing of these bonds could therefore be affected, possibly translating into a widening of the yield spread to Germany or other euro area countries.

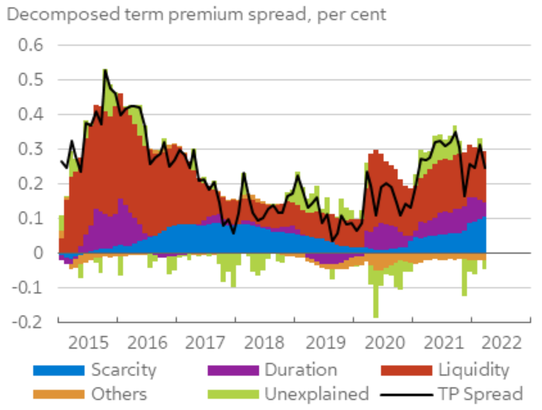
4. Explaining the 10-year sovereign term premia spread

We now use an autoregressive distributed lag model to explain how the 10-year sovereign term premium spread relates to the collateral scarcity premium on German bonds and year-to-year changes in krone duration on Danish callable bonds, cf. box 4.

Besides the key explanatory variables, the model includes a range of control variables. These controls reflect risk factors, which investors want compensation for. Most importantly, we control for differences in liquidity risk, measured by the bid-ask spread on 10-year Danish and German government bonds. Liquidity reflects uncertainty of how quickly the bonds can be sold without affecting the price. German sovereign bonds are more liquid than e.g. Danish bonds due to i.a. a deeper market, a larger number of market participants, the size of the bond series, and since there is also a futures market for German government bonds.

We also control for differences in realised volatility[12] and credit risk, measured by differences in 10-year credit default swaps on the Danish and German government. The impact of the latter is expected to be negligible for the period considered due to AAA-ratings on both Danish and German sovereigns.

Several factors affect the 10-year government bond term premium spread Chart 10



Note: The methodology is explained in box 4. 'Other' include realized volatility, credit default swap and the cross-currency basis. Unexplained includes residuals from the regression. Last observation, March 2022.
Source: Scanrate RIO, Refiniv Eikon and Datastream, Bundesbank, Bloomberg, BrokerTec, Danmarks Nationalbank, ECB and own calculations.

To control for relative funding costs between euro and Danish kroner, we include the cross-currency basis.[13] The cross-currency basis affects the cost of

[10] See Danmarks Nationalbank (2022).
[11] The OAS widening may reflect a lower demand for callables due to the already observed increase in duration. OAS widening thus works as self-reinforcing effect that implies higher duration which hence increases rates and thus led to additional rise in duration.
[12] We measure yield volatility as the annualised standard deviation of monthly changes in 10-year yields, calculated over a 25-day window.
[13] We define cross-currency basis as the deviation from the covered interest rate parity between Danish kroner and euro. Specifically, we

funding an investment in Danish kroner for a euro area investor, and could affect demand for Danish government bonds.[14]

Several factors have contributed to the wider government bond spread
According to the model, the widening of the 10-year term premium spread in March 2020 was driven by a lower liquidity in Danish government bonds relative to German ones and higher duration on Danish mortgage bonds, which spiked due to rising yields, cf. chart 10. Since the spring of 2020, the effect from liquidity has reversed somewhat, but differences in liquidity is still keeping the term premium spread above its pre-pandemic level. The contribution from liquidity reflects that the bid-ask spread on the Danish 10-year government have increased since the start of the pandemic.

The term premium spread widened further during 2021. The Eurosystem's substantial purchases of German government bonds through PEPP and PSPP and a low net issuance of new bonds in 2021 increased the collateral scarcity premium on German government bonds, adding to the term premium spread. A similar effect was seen in 2016-18 during the first round of ECB's APP. The surge in duration during the start of 2021 also added to the larger term premium spread.

The effect of collateral scarcity on German sovereign bonds indicates, that although there are substantial spillovers from the ECB asset purchase programmes to Denmark, the spillovers are less than one-to-one, when the intensity of asset purchases is large.

At first glance, this might seem to contrast the findings of Jensen et al. (2017). They show a close to one-to-one movement in 9-year Danish and German sovereign zero coupon yields in the two days following announcements regarding the ECB's APP based on event study approach. Although the correlation is striking, the events cover a small part of the entire sample and do not take the collateral value of German sovereign bonds into account. Hence, our results indicate that differences in collateral value means that the pass-through from ECB's asset purchase programmes to the Danish bond market is less than one-to-one.

The widening in 2015-16 mainly driven by liquidity
In 2015, the term premium spread to Germany peaked at around 50 basis points and stayed elevated during 2016.[15] The widening of the term premium spread was then partly driven by duration increases on Danish mortgage bonds due to rising government bond yields. However, the main driver of the widening in 2015-16 was differences in bond liquidity, triggered by the unconventional measures taken to prevent the Danish krone from appreciating against the euro during the reverse krone crisis in the start of 2015.[16] The lack of issuance of Danish government bonds from the Ministry of Finance, after recommendation from Danmarks Nationalbank, lowered liquidity markedly.[17] This led to an increase in the compensation required by investors, resulting in a wider yield spread to Germany across maturities. Naturally, this could also be a driver behind the increase in duration on callable mortgage bonds.

5. Implications

We have found that, since 2015, the 10-year Danish-German sovereign yield spread has depended on three main factors: The collateral scarcity premium on German government bonds, the yearly growth in the krone duration on Danish mortgage bonds, and differences in sovereign bond liquidity, measured by the bid-ask spreads. Accordingly, future movements in the 10-year government bonds yield spread

use the 3-month FX forward spread minus the 3-month OIS spread between Denmark and the euro area. A larger cross-currency basis makes it more attractive for euro area investors to buy Danish bonds.

[14] However, it should be noted that the causal link is unclear. An increase in the cross-currency basis could also reflect a lower demand for Danish kroner.

[15] Note that the 10-year yield spread in total "only" increased around 30 basis points, reflecting that Danmarks Nationalbank conducted an independent policy rate cut to counter a appreciation pressure on the Danish krone in January and February 2015.

[16] See Danmarks Nationalbank (2015).

[17] The issuance stop initially worked similar to Quantitative Easings, since the supply of government bonds available for private investors declined. As a result, Danish government bonds yields dropped across maturities following the announcement.

between Denmark and Germany may depend on developments in these three factors.

The collateral scarcity premium on German government bonds could be somewhat eased as the ECB concludes its net purchases under the APP. This was also the case when the ECB ended its first net purchase phase through PSPP between 2015 and 2018.

The development in duration on Danish callable mortgage bonds depends on the interest rate path and behaviour by borrowers. Recently, many borrowers have conducted buybacks of the bonds behind their mortgages at prices significantly below par on the back of rising interest rates. Refinancing to new mortgages implies that duration declines. Adjustable-rate mortgages are financed by shorter maturity bonds having less duration than 30-year mortgages. New callable mortgage bonds are issued close to par, making it more likely that borrowers exercise the option on the new loan compared to the one, they might have bought back in the market. Hence, the duration on the bond behind the new mortgage is lower. Although buybacks could have implications for the development in duration, the financial incentives for refinancing to higher coupon rate mortgages are less obvious than refinancing to a lower one (see Hensch (2021)).

A simple model for the 10-year Danish-German sovereign term premium spread

Box 4

To examine the driving forces of the Danish-German term premium spread, we set up an autoregressive distributed lag (ADL) model. Let y_t^{DK-GE} denote the 10-year term premium spread at time t, and let X_t denote the vector of explanatory variables. The model is then

$$y_t^{DK-GE} = \phi y_{t-1}^{DK-GE} + \gamma' X_t + u_t,$$

for $t = 1, \dots, T$ and $u_t\ iid\ (0, \sigma^2)$. Here, X_t contains the explanatory variables covered in the main text. The lagged value of the term premium spread is included to account for the autocorrelation inherent in the term premium spread, ensuring that the model is well-specified. As the krone duration is non-stationary, we include the year-on-year growth rate in duration to ensure valid inference. Besides the key explanatory variables, the year-on-year relative change in the krone duration and collateral scarcity of German government bonds, the model includes control variables for differences in volatility, credit risk, liquidity and the cross-currency basis.

In order to assess how the explanatory variables affect the term premium spread, we rewrite the ADL-model in its moving-average (MA) form by recursive substitution:

$$y_t^{DK-GE} = \sum_{i=0}^{t-1} \phi^i (\gamma' X_{t-i} + u_{t-i}) + \phi^t y_0^{DK-GE},$$

such that the term premium spread at time t is a function of all lagged explanatory variables in X_{t-i}, past shocks u_{t-i}, and a contribution from the initial value, $\phi^t y_0^{DK-GE}$.[1]

By rewriting the model in the MA-form, we can study which variables drive the yield spread at a given point in time, without the influence of the lagged yield spread.

The parameters ϕ and γ are estimated using OLS and are reported in table 1 along with residual misspecification tests. The model is estimated on monthly data from January 2015, the month the ECB announced its first round of QE (implemented from March 2015), to March 2022. The residual misspecification tests indicate that the model is well-specified.

We find that the estimated coefficients of the (year-on-year relative change in) krone duration and collateral scarcity of German government bonds have the expected sign and are economically and statistically significant. Furthermore, the term controlling for differences in liquidity is also economically and statistically significant. The remainder of the control variables are insignificant. The decomposition from 2015 to 2022 is shown in chart 10.

As a robustness check, we also estimate the model on a larger sample, from July 2008 to March 2022, which yields the same overall conclusions.[2] The robustness check can be found in chart A in the appendix.

Estimation results

Table 1

	Estimate	t-statistic
ΔDuration/Duration	0.0003	3.09
Collateral Scarcity	0.1093	3.14
Liquidity	1.7854	3.33
Volatility	0.0007	0.24
FX Basis	0.0465	1.21
Credit risk	0.0008	0.60
Lagged TP spread	0.6580	9.21
Adj. r^2	80.0 %	

Misspecification tests

	p-value
Autocorrelation	0.09
Heteroscedasticity	0.82
Normality	0.19

Note: The misspecification tests conducted are for the absence of autocorrelation, the absence of heteroscedasticity, and whether the error terms follow a normal distribution with a zero mean.

Source: Authors calculations.

1. Because the estimated process is geometrically ergodic and strictly stationary, |φ|<1, the contribution from the initial value vanishes exponentially fast.
2. In the extended sample, the estimated parameters are broadly similar, but collateral scarcity is insignificant. Additional diagnostics indicate that there is a structural break in the parameters following the period of 2008-2012, i.e. the financial crisis and the sovereign debt crisis.

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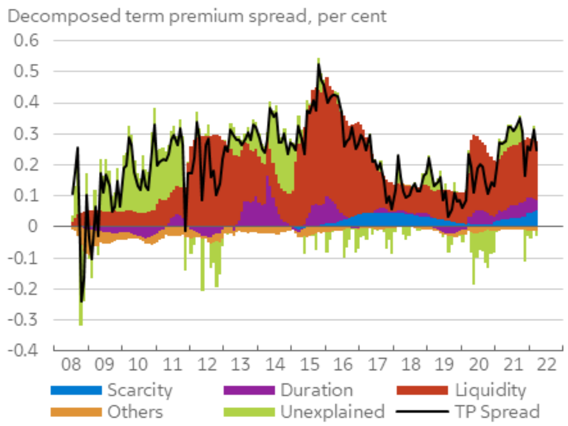
A. Appendix

Chart A depicts the historical decomposition of the term premium spread for a longer sample, going back to 2008. We again find that collateral scarcity of German sovereign bonds, duration on Danish mortgage bonds and differences in liquidity are the primary drivers of the Danish-German 10-year term premium spread.

Historical decomposition of the term premium spread, long sample Chart A



Note: The methodology is explained in box 4. 'Other' include realized volatility, credit default swap and the cross-currency basis. Unexplained includes residuals from the regression. Last observation, March 2022.
Source: Scanrate RIO, Refiniv Eikon and Datastream, Bundesbank, Bloomberg, BrokerTec, Danmarks Nationalbank, ECB and own calculations.

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