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# Danish Mortgage Bonds

## Key figure descriptions

In this file, you will find a short description of the Danske Bank mortgage pricing model as well as descriptions of the Danske Bank Mortgage Bond key figures published on our website.

### Danske Bank's DKK callable mortgage bond model description

Instead of using a traditional method/model based on historical data to estimate future levels of prepayments for callable bonds, Danske Bank has chosen to implement a new model approach (called **SuperFly**), where the future prepayments are estimated as *prepayments implied* by the market. This is a new and unique method to calculate the risk of callable bonds. There are several reasons why we have chosen this new method, but the most important are the following.

- The implied prepayment approach offers much greater flexibility in the model, which ensures more stable risk key figures. Hence, we do not expect to re-calibrate our model every quarter to align the model's expected prepayments to the actual prepayments, which was the case for our old, traditional model.
- We expect that the model will provide risk key figures that are more in line with markets' expectations of prepayments instead of our own model's expected prepayments.

So how do we estimate the implied prepayments? The price of the callable bond and the market interest rate are employed to:

- Determine whether the callable bond could experience prepayments (mostly determined by the difference in the bond's coupon and the yield of an alternative mortgage loan).
- Determine how many prepayments the callable bond could see in order to be fairly priced (mostly determined by the price of the bond).

Hence, if the callable bond is trading well above par, this could indicate that the implied prepayments are low, whereas a lower price would indicate that the implied prepayments have risen. All risk key figures are calculated on the back of implied prepayments.

Specifically, we introduce a new model parameter for each bond, **implied scale**, which is solved for alongside **OAS** in the pricing problem of matching the model price to the market price of each bond. Implied scale is, as the name suggests, trying to measure the amount of prepayments *implied* in the pricing of each bond, and thereby proposing an answer to the following question: 'Given the current market price, how large prepayments do investors expect?' Liquid bonds trading below par start out with an initial guess at implied scale of 20%, meaning that if prepayment gains (roughly defined as the difference between the coupon of the bond and the yield of the relevant refinancing alternative) of c.100bp arise the bond will prepay 20%.

Obviously, for bonds below par, implied scale, and changes to this parameter, do not affect the price of the bond very much as the bond will (in expectation) only rarely be in scope of large prepayment gains.

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Thus, the weight in the pricing problem will be skewed towards the OAS in this case, and this parameter will in general drive price changes in the lower coupons, and thus show higher volatility in that segment. On the other hand, in the case of high coupons the most important parameter is the expectation of future prepayments, since the expected cash-flow of the bond will likely be of a short duration, whereby the OAS will not be an important driver of price changes. Instead, for higher coupons the implied scale will show the largest volatility and be the driver of price changes.

This way of modelling callable mortgage bonds has important consequences for key figure dynamics. As an example, consider the pricing of a bond trading above par. If the price of such a bond decreases, ceteris paribus, the modelling framework will see the change as driven by a change in implied scale, and thereby result in an *increase* in expected prepayments. This again will give rise to a fall in BPV and a roughly unchanged OAS. This is in contrast to the dynamics of an empirically estimated mortgage model, in which a fall in price, ceteris paribus, can only be expressed through a widening of OAS. This will lead to a fall in future prepayments and an increase in BPV, and thus the exact opposite effect of what will be the result of the Danske Bank model.

Given the pricing problem involves two parameters, this implies the need for an additional equation in order to pin down both OAS and implied scale. The equation added to the problem takes the form of a loss function that takes on large values if either the OAS or implied scale needs to move by a lot in order to match the change in price, which then results in stable parameters over time.

### Model technicalities

The mortgage bond model in Danske Bank (SuperFly) is built on top of a 1-factor Cheyette model. Upon pricing and calculating risk for a mortgage bond the model is calibrated to a strip of swaptions that mimics the exercise schedule of the borrowers of the bond in question. Through this calibration procedure, the price and risk of a mortgage bond depends on an underlying European swaption model, which for a number of years has been a traditional shifted SABR model with -2% as the lower bound for rates.

However, due to negative interest rates and a general flattening of yield curves, the market has to a substantial degree moved to pricing and calculating risk on options in terms of a normal volatility model. The normal volatility model is basically a standard Gaussian model and has the advantage that it is free of a built-in lower bound for rates. Thus, starting in January 2021 we switched to the normal model.

# Key figures

- **Type** – This field is only available for covered bonds issued by Danish MCIs (mortgage credit institution) regulated under the Mortgage Credit Bonds and Mortgage Credit Loans Acts including Danish Ship Finance, that is regulated under a separate act. Types are one of the following: RO, SDO and SDRO. Only covered bonds issued by specialist mortgage banks (MCIs) are eligible to carry the SDRO label, whereas e.g. Danske Bank and Danish Ship Finance are not eligible to carry the label. RO bonds, including grandfathered covered bonds issued before 31 December 2007, are not subject to ongoing LTV requirements, but only at the time of the granting the loan, and as such carry larger risk weights under the standard method. RO bonds are issued out of separate capital centres. Nykredit, DLR and Jyske Realkredit issue covered bonds in the SDO format.
- **Current coupon** – This field is only available for floating rate bonds. Specifies the current coupon payable at the upcoming payment date. This contains both the underlying money market fixing index as well as any spread added.
- **Spread** – This field is only available for floating rate bonds. Specifies the current spread added to the underlying money market fixing index. The spread is often set at refinancing auctions where investors bid at the spread. Alternatively, the spread will be set by the issuer when a new floating rate bond is opened.
- **Next fixing** – This field is only available for floating rate bonds. Specifies the next fixing date of the underlying fixing index. Floating rate bonds typically fix 2-6 business days before the start of a new interest rate accrual period.
- **Floor** – This field is only available for floating rate notes. Specifies the minimum coupon receivable by investor – i.e. the investor buys a floor on the fixing index with strike equal to that of the floor minus the spread and with a maturity corresponding that of the relevant bond. Floors was introduced in 2015 as an ad hoc measure when coupons became negative, and floors are de factor only 0% floors. Most floaters issued today are without any floors.
- **Index ceiling** – This field is only available for capped floating rate bonds. Specifies the maximum current coupon – i.e. the investor sells a cap on the fixing index with strike equal to the index ceiling minus the spread and with a maturity corresponding to that of the relevant bond.
- **Price** – Specifies the mid price from our own pricing system and not from the exchange. Thus, the prices will rely on the market makers' of Danske Bank price setting and may differ from official exchange prices.
- **Acc int** – Specifies the accrued interest on the bond since the latest coupon payment date.
- **OAS** – This field is only available for callable mortgage bonds. Specifies the Option-Adjusted Spread to our mortgage discounting curve (DKMRTG), on which we discount all DKK mortgage cash-flows. That is, the fixed spread to be added to the DKMRTG in order to arrive at the market price, and is used along implied prepayments to match the model price to market. The DKMRTG curve is constructed such that the liquid 30Y callable bond has an OAS of zero. Hence, the OAS can be used as a cheap/rich measure *between* callables.

- **SWAPOAS** – This field is only available for callable mortgage bonds. Specifies the option-adjusted spread to the Danske Bank discounting curve (DKKDISC), which is fairly close to the DKKOIS. That is, the fixed spread to be added to the DKKDISC curve in order to arrive at the market price. A cheap/rich measure relative to DKKOIS.
- **GOVOAS** – This field is only available for callable mortgage bonds. Specifies the option-adjusted spread to the DKK government bond curve (DKGOVT). That is the fixed spread to be added to the DKGOVT curve in order to arrive at the market price. A cheap/rich measure relative to DGBs.
- **OAS6M** – This field is only available for callable mortgage bonds. Specifies the option-adjusted spread to the DKK6M zero coupon swap curve. That is, the fixed spread to be added to the DKK6M curve in order to arrive at the market price. A cheap/rich measure relative to DKK swaps.
- **ASW 5P** – This field is only available for callable mortgage bonds. Specifies the fixed spread an investor can receive above CIBOR 3M in a partial ASW package. The partial ASW package allows the investor to cancel *up to* 5% of notional in the ASW package each quarter, which is beneficial when facing prepayments and redemptions of varying size. The spread represents the cost of buying a series of Bermudan swaptions with exercise dates each quarter, a constant maturity equal to the maturity date of the bond and strike equal to the coupon of the bond. Opposite to the OAS measures above the ASW packages are fully tradable.
- **ASW 10P** – This field is only available for callable mortgage bonds. Same as above with up to 10% cancellation each quarter.
- **ASW 15P** – This field is only available for callable mortgage bonds. Same as above with up to 15% cancellation each quarter.
- **OAYield** – This field is only available for callable mortgage bonds. Specifies the option-adjusted yield, which is the continuously compounded discount rate that when applied to the option adjusted cash flow of the bond results in the market price of the bond. In Danske Bank's mortgage model we do not calculate OAYield by averaging expected cash-flows over the different future states for then to discount these at the OAyield, as this would result in OAyields exceeding the regular yield, when the market price is below 100, and as such not taking into account that prepayments is only experienced when the reinvestment yield is below the coupon of the bond. Instead, the problem boils down to inverting the formula below and solving for "OY".
    - $PV_0 = \sum D(t, OY) * \tilde{c}_t$, where $\tilde{c}_t = \frac{E_0[d_t c_t]}{\bar{D}(t)}$

OAYield specifies the hold to maturity return of the bond, and thus correlates fairly well with 12M holding period return (HPR). However, OAyield will typically be lower than the horizon return once the bond trades fairly close to, but below 100 (equal when the price is far below par), since the likelihood of prepayments in the short run is miniscule, but sizeable in the long run. For bonds trading far above par the OAYield will typically be larger than the HPR since in the short run the likelihood of sizeable prepayments is large, but lower in the longer run.

- **Yield –** The continuously compounded discount rate that when applied to the non-option-adjusted cash flow of a bond results in its market price. This is the yield seen from the borrower's perspective.
- **MMYield –** Same as above applying the money market yield convention.

- **YCS –** This field is only available for non-callable bonds. The fixed spread, that when added to the DISC curve in the relevant currency results in the market price of the bond.
- **GOVYCS –** This field is only available for non-callable bonds. The fixed spread, that when added to the GOVT curve in the respective currencies results in the market price of the bond.
- **MRTGYCS –** This field is only available for DKK non-callable bonds. The fixed spread, that when added to the DKMRTG curve results in the market price of the bond.
- **YY ASW OIS3M –** This field is only available for non-callable bonds. The yield-yield ASW spread, i.e. the difference between the yield of the bond and the matched maturity par swap rate in the relevant currency. In this case the par swap rate is derived from the OIS forward curve (fixed and received in arrears every 3M).
- **YY ASW 3M –** This field is only available for non-callable bonds. The yield-yield ASW spread, i.e. the spread between the yield of the bonds and the matched maturity par swap rate in the relevant currency. In this case the par swap rate is derived from the 3M forward curve.
- **YY ASW 6M –** This field is only available for non-callable bonds. The yield-yield ASW spread, i.e. the spread between the yield of the bonds and the matched maturity par swap rate in the relevant currency. In this case the par swap rate is derived from the 6M forward curve.
- **ASW OIS3M –** This field is only available for non-callable bonds. The true ASW spread in an ASW package where the investor buys the bond at par and receives a floating rate plus the ASW spread. In this case the floating rate is an OIS rate (fixed and received in arrears every 3M).
- **ASW 3M –** This field is only available for non-callable bonds. The true ASW spread in an ASW package where the investor buys the bond at par and receives a floating rate plus the ASW spread. In this case the floating rate is the 3M fixing in the relevant currency.
- **ASW 6M –** This field is only available for non-callable bonds. The true ASW spread in an ASW package where the investor buys the bond at par and receives a floating rate plus the ASW spread. In this case the floating rate is the 6M fixing in the relevant currency.
- **ASW EUR3M –** This field is only available for non-callable bonds. The true ASW spread in an ASW package where the investor buys the bond at par (EUR 100) and receives EURIBOR 3M plus the ASW spread. The spread in non-EUR bonds is approximately equal to the ASW 3M plus (or minus) the CCS spread in the relevant currencies for the relevant maturity.
- **ASW EUR6M –** This field is only available for non-callable bonds. The true ASW spread in an ASW package where the investor buys the bond at par (EUR 100) and receives EURIBOR 6M plus the ASW spread. The spread is approximately equal to the ASW EUR3M minus the EUR 3M/6M basis.
- **SpreadRisk** – Specifies the change in the price of the bond when changing the spread to the relevant discount curve by 100bp. Equal to BPV for non-callable fixed rate bonds. For floating rate bonds (also if including caps/floors), the spreadrisk is equal to the BPV/spreadrisk of a fixed rate bond of similar maturity. Specifically, for callable mortgage bonds it is the change in price per 100bp change in the spread to the DKMRTG curve (corresponding to widening the MRTGOAS 100bp). The sensitivity

is calculated as a central difference shifting the MRTGOAS +/-10bp. Note that SpreadRisk is always larger than BPV (numerically) for callables mortgage bonds. This is so since when we bump the OAS the refinancing alternative of the borrower is unaffected, which results in a larger price sensitivity as only a minor cash-flow redistribution takes place. This is in contrast to shifting the entire yield curve (done in the calculation of BPV), which affects the prices of all bonds and thereby also refinancing alternatives. Note that a cash-flow effect do take place, however, since the spread will determine the probability of the bond having a price above/below 100, and thus whether it is in scope of prepaying or not.

  - $SpreadRisk = \frac{PV(OAS+10bp)-PV(OAS-10bp)}{2*10bp} * \frac{1}{100}$

- **BPV** – The average change in price per 100bp change in the yield curve. The sensitivity is calculated as a central difference by shifting yields +/-10bp.
  - $BPV = \frac{dPV(r)}{dr} * 100bp = \frac{PV(r+10bp)-PV(r-10bp)}{2*10bp} * \frac{1}{100}$
- **CVX** – The average change in BPV per 100bp change in the yield curve. The sensitivity is calculated as a central difference by shifting yields +/-10bp.
  - $CVX = \frac{d^2PV(r)}{dr} * 100bp^2 = \frac{PV(r+10bp)+PV(r-10bp)-2*PV(r)}{(10bp)^2} * \left(\frac{1}{100}\right)^2$
- **ModDur** – The relative change in price per 100bp change in the yield curve.
  - $ModDur = \frac{dPV(r)}{dr} * \frac{1}{PV} = BPV * \frac{100}{PV}$
- **MacDur** – The Macaulay duration, i.e. the cash-flow weighted time to maturity of the bond. For callable bonds the non-options adjusted cash-flow is used.
- **WAL** – This key figure is only available for non-callable bonds. Weighted average life.
- **ImpliedScale** – Specifies the amount of prepayments resulting from a given prepayment gain. Usually around 20% for on-the-run bonds, which means that if a representative borrower in the bond series can obtain a c. 100bp gain (measured as the difference between the coupon and the relevant refinancing yield) by prepaying an existing mortgage, this will result in 20% worth of prepayments. The impliedscale is solved for in the model along with OAS.
- **ScaleRisk** – This key figure is only available for callable mortgage bonds. Specifies the change in price given a 1%-point change in ImpliedScale. ScaleRisk is thus largest for high coupon bonds as these bonds are almost surely above a price of 100 for the remaining maturity and thus in scope of prepayments.
- **OASweight** – This key figure is only available for callable mortgage bonds. It is a weight, as it is bounded between zero and one, and measures the relative weight given to OAS in the pricing procedure, when solving for OAS and implied scale. The remaining part of the weight (one minus the OASweight) is applied to implied scale, which results in the model's implied prepayments. What weight is largest is determined by looking at whether the price is mostly affected by changing the spread or implied prepayments. Intuitively the OASweight is high in low coupon bonds (trading below 100) since a change in credit spreads will have a large effect on price given the long duration of the estimated cash-flow. On the other hand the weight on implied scale should be low as a change in prepayment assumptions should not change the price by much given the low probability of future prepayments. This intuition is of course reversed in high coupon bonds trading above 100.

- **DV3M** – The 3M bucket of delta vector risk calculated in the same way as BPV, but by shifting the 3M point of the underlying curves only. The sum of the delta-vector sums approximately to the BPV of the bond. Note that for callable mortgage bonds not too much of the risk is concentrated in the 30Y delta vector. This is so since the refinancing alternative specified in the model is not a bullet notional but an annuity, the yield of which depends on the entire curve.
- **DV6M** – The 6M bucket of delta vector risk calculated in the same way as BPV, but by shifting the 6M point of the underlying curves only.
- **DV2Y** – The 2Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 2Y point of the underlying curves only.
- **DV5Y** – The 5Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 5Y point of the underlying curves only.
- **DV7Y** – The 7Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 7Y point of the underlying curves only.
- **DV10Y** – The 10Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 10Y point of the underlying curves only.
- **DV15Y** – The 15Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 15Y point of the underlying curves only.
- **DV20Y** – The 20Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 20Y point of the underlying curves only.
- **DV25Y** – The 25Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 25Y point of the underlying curves only.
- **DV30Y** – The 30Y bucket of delta vector risk calculated in the same way as BPV, but by shifting the 30Y point of the underlying curves only.
- **Vega** – This key figure is only available for callable bonds. Specifies the change in price per 1bp change in the underlying (normal) volatility surface. It is calculated as a central difference of +/- 10bp.
  - $Vega = \frac{PV(\sigma+10bp)-PV(\sigma-10bp)}{2*10bp} * \frac{1}{10000}$
- **1PP** – This key figure is only available for callable mortgage bonds. Specifies the first implied prepayment, i.e. the resulting prepayments from the mortgage model for the next upcoming payment date. The 1PP is special in that it depends in part on the actual preliminary prepayment data published each Monday, with increasing weight as one approaches the (almost) final prepayment figures. The first implied prepayment starts referencing the next payment date after the first Monday after the notification deadline, i.e. after the (almost) final preliminary prepayment amounts have become known (notification deadlines in callable DKK mortgages are two months before the payment date).
- **2PP** – This key figures in only available for callable mortgage bonds. Specifies the second implied prepayment, i.e. the resulting prepayments from the mortgage model for the second upcoming payment date.
- **3PP** – This key figures in only available for callable mortgage bonds. Specifies the third implied prepayment, i.e. the resulting prepayments from the mortgage model for the third upcoming payment date.

- **4PP** – This key figures in only available for callable mortgage bonds. Specifies the fourth implied prepayment, i.e. the resulting prepayments from the mortgage model for the fourth upcoming payment date.
- **OAS/ASW 3M (-1D)** – Specifies the change in OAS or ASW 3M over the last trading day.
- **OAS/ASW 3M (-1W)** – Specifies the change in OAS or ASW 3M over the last week.
- **OAS/ASW 3M (-1M)** – Specifies the change in OAS or ASW 3M over the last month.
- **ASW 15P (-1D)** – This key figure is only available for callable bonds. Specifies the change in ASW 15P over the last trading day.
- **ASW 15P (-1W)** – This key figure is only available for callable bonds. Specifies the change in ASW 15P over the last week.
- **ASW 15P (-1M)** – This key figure is only available for callable bonds. Specifies the change in ASW 15P over the last month.
- **Poolfactor** – This key figure is only available for callable bonds.
  - $Poolfactor = \frac{Current\ outstanding\ amount}{Max_{\{t=0,1,\dots\}}[Outstanding\ amount_t]}$
- **CK93** – This key figure is only available for callable mortgage bonds. Specifies the last published preliminary prepayment figure for the upcoming payment date in percent of the outstanding amount corrected for known upcoming prepayments and ordinary redemptions. The referenced payment date changes once the final prepayment amount has become known (see also 1PP).
- **CK93 -1W** – This key figure is only available for callable mortgage bonds. Same as above with a lag of one week.
- **CK95 - 1** – This key figure is only available for callable mortgage bonds. Specifies the published prepayment percentage for the last payment date. For an example on the 30th of September the figure specifies the published prepayment figures for the 1st of July payment date. Note this figure does not include ordinary redemptions.
- **CK95 - 2** – This key figure is only available for callable mortgage bonds. Specifies the published prepayment percentage for the second to last payment date. For an example on the 30th of September the figure specifies the published prepayment figures for the 1st of April payment date. Note this figure does not include ordinary redemptions.
- **CK95 - 3** – This key figure is only available for callable mortgage bonds. Specifies the published prepayment percentage for the third to last payment date. For an example on the 30th of September the figure specifies the published prepayment figures for the 1st of January payment date. Note this figure does not include ordinary redemptions.
- **CK95 - 4** – This key figure is only available for callable mortgage bonds. Specifies the published prepayment percentage for the fourth to last payment date. For an example on the 30th of September the figure specifies the published prepayment figures for the 1st of October payment date the year before. Note this figure does not include ordinary redemptions.
- **12M HPR -100bp** – Specifies the holding period return on a 12M horizon by applying a 100bp linear shift *down* in yields over the same period. The reinvestment assumption arising from coupons or redemptions is an investment in the same level of credit maturing in 12M. For an example the reinvestment assumption on a DKK flex bond

with an OAS of 5bp with a coupon arising in 3M, will be the 9M DKMRTG yield plus 5bp.

- **12M HPR -50bp** – Same as above but shifted 50bp.
- **12M HPR -25bp** – Same as above but shifted 25bp.
- **12M HPR** – Same as above but without applying a shift in yields.
- **12M HPR +25bp** – Same as above but applying a 25bp linear shift *up* in yields over a 12M period.
- **12M HPR +50bp** – Same as above but without applying a shift in yields.
- **12M HPR +100bp** – Same as above but without applying a shift in yields.

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This research report has been prepared by Danske Bank A/S ('Danske Bank'). The author of this research report is Daniel Brødsgaard, Analyst.

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