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MARKET RISK MANAGEMENT IN A LOW INTEREST RATE ENVIRONMENT

Over the last decade, the financial crisis, the European sovereign debt crisis and most recently the pressure on the Danish krone in early 2015 have had a visible effect on the risk profile of Denmark's central government debt. After this turbulent period, the status at the beginning of 2016 is that the debt structure is very robust. The central government has a considerable liquidity reserve, and the rate of interest on a substantial part of the debt has been locked for a long period. Rising interest rates will therefore pass through only slowly to the central government's interest costs. Together with low debt, this implies a very limited impact on the government budget.

Under normal circumstances, high duration can be expected to involve additional costs compared with lower duration, but in the current low interest rate environment, the expected additional costs are considered to be low. Moreover, there is a lower bound to how much further interest rates may fall, whereas interest rate increases are not subject to such a limit. Against this background, the central government maintains a high duration in 2016. The target band for the average duration has been set at 11.5 years ± 1 year, calculated without discounting.

RISK MANAGEMENT DURING AND AFTER THE FINANCIAL CRISIS

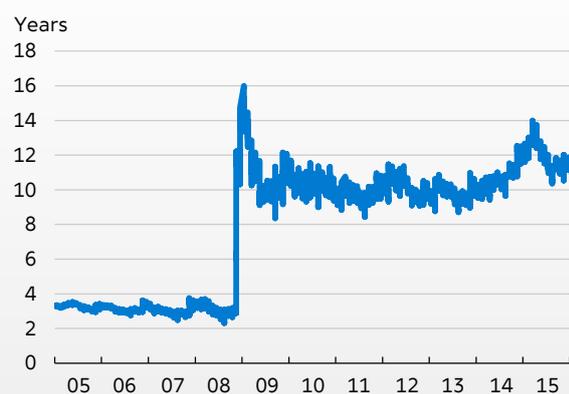**THE CENTRAL GOVERNMENT'S INTEREST RATE RISK AND DEBT DURATION**
Risk management of the central government debt supports the overall objective of the government debt management policy: to cover the central government financing requirement at the lowest possible long-term costs, while taking the degree

of risk into account. Special focus is on risks related to interest rate developments, since the central government's exchange rate risk and credit risk are very limited.

The exchange rate risk is negligible, since the foreign debt is solely exposed to fluctuations in the exchange rate of the euro, which is the anchor

Duration of central government debt

Chart 3.1

Years

Note: Macaulay duration.

The duration of the central government debt is influenced by the balance on the central government's account

Box 3.1

The balance on the central government's account at Danmarks Nationalbank constitutes a short-term asset. This means that the account has an impact on the cash flows related to the central government debt – and hence on the duration of the central-government debt.
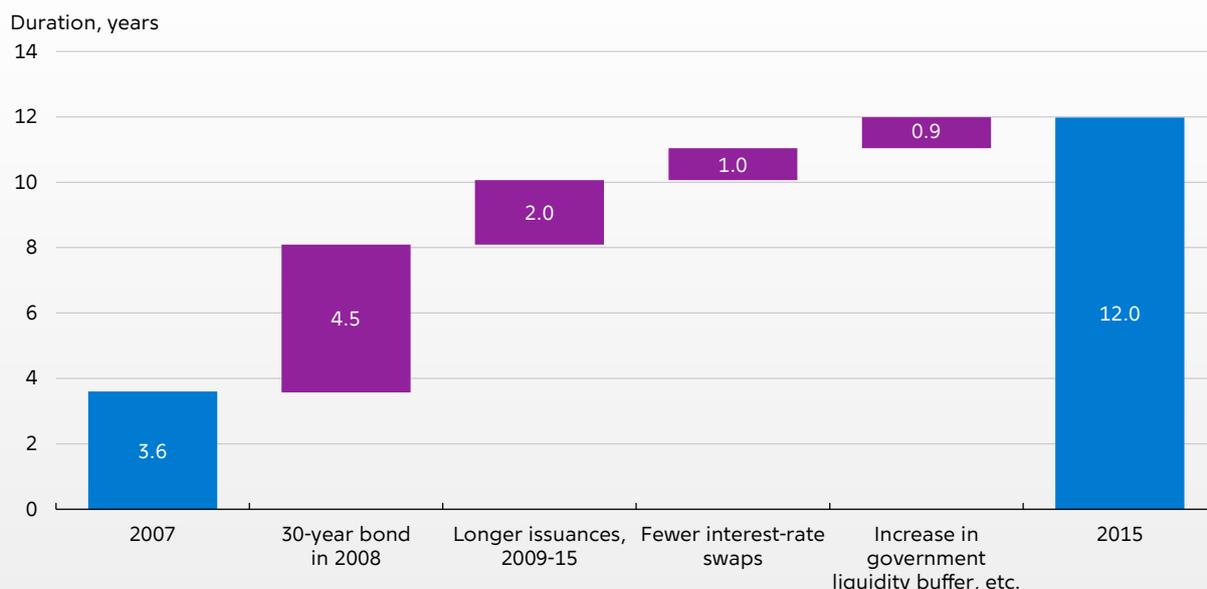
Duration is calculated on the basis of the time profile for interest and redemption payments on the liabilities less interest and redemption on the central government's assets. In practice, a large balance neutralises the impact of corresponding short-term liabilities. This means that longer-term loans have a relatively larger weight, increasing the duration compared with having a lower account.

The balance on the central government's account rose strongly in connection with the financial crisis and has subsequently been kept at a high level. It was deemed appropriate to have a sizeable liquidity buffer in a period of heightened uncertainty about the economic outlook and central government finances. At the same time, the focus on refinancing risk was intensifying – not least in connection with the sovereign debt crisis in several euro area member states.

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of Denmark's fixed exchange rate policy. The credit risk on the central government's swaps is also very low due to collateral agreements, cf. Chapter 4, Credit risk management: transition to two-way collateral agreements.

The central government's interest rate risk is the risk of higher interest costs as a result of financing at higher interest rates in the future. The risk depends on the combination of short-term and long-term bonds in the debt portfolio, among other factors. In risk management, the average fixed interest period – the duration – is used as a key measure of the interest rate risk on the debt portfolio. High duration means that the interest rate is locked for a long period of time for a large part of the debt. As a result, the risk of sudden hikes in the central government's interest costs is low.

THE FINANCIAL CRISIS LED TO CONSIDERABLY HIGHER DURATION

The duration was stable at around 3 years for a long period prior to the financial crisis, cf. Chart 3.1. Issuance was concentrated in the 2-, 5- and 10-year maturity segments, resulting in a duration of around 5 years for the bond portfolio. The duration of the central government debt was then reduced to 3 years by concluding interest rate swaps.

The duration soared at the end of 2008, cf. Chart 3.1. The main driver of the surge was the extraordinary issuance in a new 30-year government bond of almost kr. 90 billion in connection with the financial turmoil at the end of 2008.[1] A markedly higher balance on the central government's account also contributed to the rise in duration, cf. Box 3.1. In the following period with high budget risk, the high duration contributed to a lower refinancing amount and more stable interest costs on the government's budget. Conversely, the high duration implied a slower pass-through to the central government's interest costs from the following decrease in interest rates.

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1   The financial turmoil led to increased demand for a long-term Danish government bond – especially from Danish insurance and pension companies, which had a natural interest in hedging their long-term commitments in kroner. The long-term government bond thus contributed to supporting the central government's access to the capital markets, and in the short term it contributed to bolstering demand for kroner to the extent that the pension companies sold other European bonds in order to buy the Danish government bond, cf. *Danish government borrowing and debt, 2008*.

Decomposition of the change in government debt duration from 2007 to 2015

Chart 3.2

Duration, years

2007	30-year bond in 2008	Longer issuances, 2009-15	Fewer interest-rate swaps	Increase in government liquidity buffer, etc.	2015
3.6	4.5	2.0	1.0	0.9	12.0

Note: Duration has been calculated without discounting. Calculated at year-end.

HIGH DURATION MAINTAINED

At end-2015 the duration was 12 years. Apart from the extraordinary issuance of 30-year bonds in 2008, the increase in duration since 2007 was also caused by increased long-term issuances and a reduced swap portfolio, cf. Chart 3.2.

The period 2008-12 was characterised by rising debt and increased budget risks resulting from central-government lending and guarantees to the financial sector, among other factors. In this light it was found to be expedient to maintain a low refinancing risk and interest rate risk by over-weighting the issuance of long-term bonds and to maintain a high balance on the account. Since 2012, the maintenance of a high duration tends more to reflect the assessment that the expected saving from reducing the duration was low. No new interest rate swaps were concluded to reduce the duration in that period, resulting in a marked reduction of the central government portfolio of interest rate swaps. At end-2015, less than 5 per cent of the central government debt had been swapped to a variable rate, while half of the debt had been swapped to a variable rate in 2007.

In recent years, other EU member states have also focused on increasing the duration of their debt portfolios. This reflects that some countries have sought more robustness in the light of rising debt, as well as the shared perception among many countries that the additional costs linked to high duration are low.

LOW DEBT IMPLIES SUBSTANTIAL RISK CAPACITY

After a turbulent period since the financial crisis, several factors indicate that the central government now has the capacity to assume greater interest rate risk: Debt is relatively low, the central government has a considerable liquidity reserve, and the debt portfolio is very robust with high duration. In addition, interest rate increases will typically coincide with an economic recovery, higher inflation, and an improved budget balance. Such circumstances make higher interest costs easier to manage.

An assessment of duration is not the only way to ascertain the robustness of the debt portfolio. Duration is an average concept, which does not take into account that the substantial outstanding amount in the 30-year bond distorts the redemption profile. Consequently, the interest rate risk is also assessed on the basis of a more faceted

**Share of government debt[1]
subject to interest rate fixing**

Chart 3.3

Per cent

- Share of central-government debt adj. for on-lending
- Share of GDP
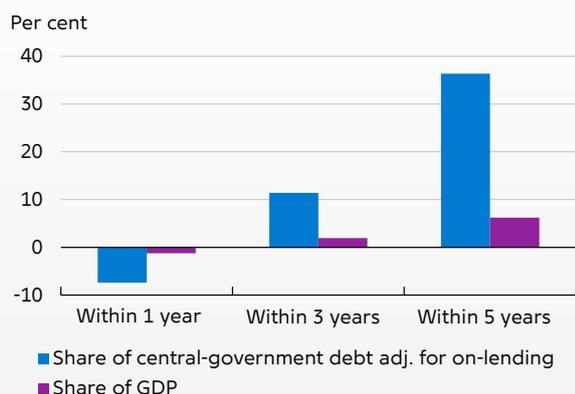
Note: The amount of debt and swaps subject to interest rate fixing within 1, 3, and 5 years, respectively, less the central government assets (balance on the central government's account, funds and on-lending). The negative interest rate fixing within the first year primarily reflects that the liquidity buffer exceeds the amount of debt subject to interest rate fixing within the first year. Calculated at end-2015.

1. Government debt adjusted for on-lending

**Simulated development in
central government interest costs**

Chart 3.4

Per cent of GDP

—— Mean   ····· 95 per cent confidence interval

Note: Distribution of future net interest costs based on a technical debt projection and 50,000 simulated interest rate scenarios from a shadow rate model, which is based on Danish government bond yields since 1999, cf. Box 3.2.
Source: Ministry of Finance and own calculations.

picture of the distribution over time of the interest rate exposure relating to the government debt portfolio.

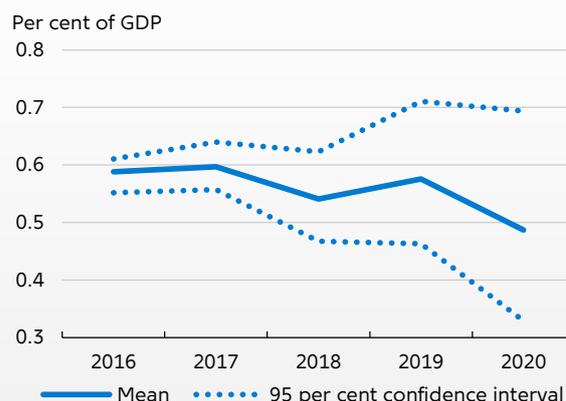**SLOW INTEREST RATE PASS-THROUGH**
Interest rate fixing is a supplementary risk measure indicating the share of central government debt for which new interest rates must be fixed within a given time horizon. This measure also indicates that Denmark's central government debt is robust with very limited exposure to interest rate increases.

Over one year, an equal rise in all interest rates will actually *reduce* the central government's net interest costs, because higher interest income on the central government's assets will more than offset the higher interest costs on the liabilities, cf. Chart 3.3. The reason is the immediate pass-through to the interest rate on the substantial balance on the central government's account.

Over time, a larger share of the debt is subject to refinancing, but even over a five-year horizon, only around a third of the government debt will be subject to interest rate fixing. This is a lower

share than in comparable countries, where higher interest rates will typically have an impact on around half of the debt within five years.

Besides its robust composition, the government debt is also relatively low as a percentage of GDP. As a result, the debt that is subject to interest rate fixing within the next five years only amounts to around 7 per cent of GDP. Consequently, a permanent interest rate hike of e.g. 3 percentage points across the board in early 2016 would increase the central government's interest costs in 2020 by a mere 0.2 per cent or so of GDP. This is around four times less than in many comparable countries.

SIMULATED INTEREST COSTS REMAIN LOW
The central government's future interest costs are determined by developments in both Danish government yields and the other items on the government budget. A Cost-at-Risk model is used to illustrate the risk associated with the uncertainty about interest rate developments. This model is based on simulated interest rate scenarios from an interest rate model and a technical projection of the central government financing requirement. In the mean scenario, interest costs[2] decline from 0.6 per cent of GDP in 2016 to 0.5 per cent of GDP in

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2   Interest costs on central government debt adjusted for on-lending.

Danish government yields

Chart 3.5

| 10-year Danish government yield | Slope of the Danish yield curve |
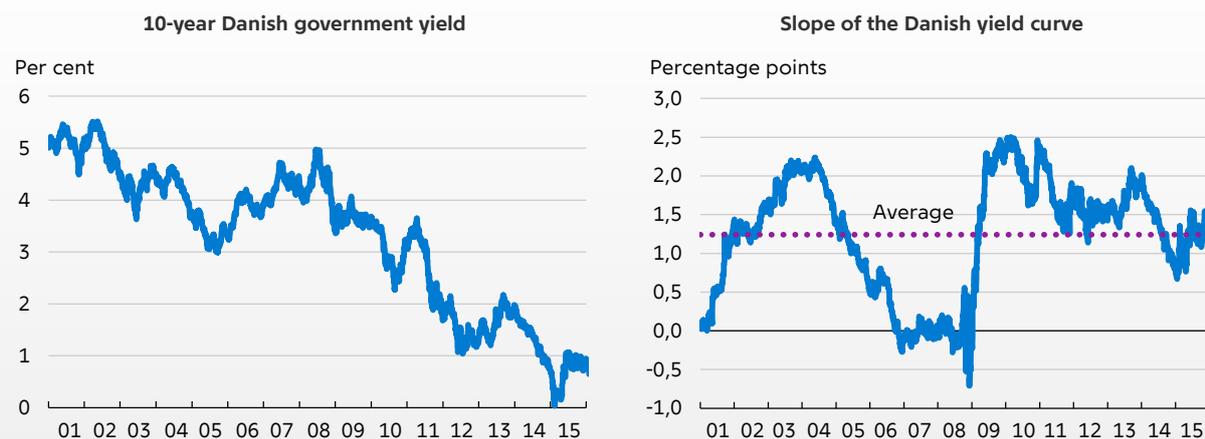
Note: Left-hand chart: 10-year par yield. Right-hand chart: The slope is defined as the difference between a 10-year and a 1-year par yield.
Source: Nordea Analytics.

2020, cf. Chart 3.4, despite the deficit outlook for government finances. The effect from the expected deficits for the coming years are offset by a gradual impact of the low level of interest rates on a larger share of the government debt. Since a positive rate of economic growth is expected, interest costs as a ratio of GDP are declining slightly. Even if future interest rates are at the upper end of the simulated distribution, the central government's interest costs will remain low until 2020 under the given assumptions of developments in the other government budget items.

STRATEGY FOR MARKET RISK MANAGEMENT IN 2016

THE TARGET FOR DURATION OF CENTRAL-GOVERNMENT DEBT IN 2016 IS 11.5 YEARS

In the current situation, the expected saving from reducing duration is found to be limited. Against this backdrop, it is not found to be expedient to reduce duration in 2016 by concluding interest rate swaps.[3] This means that the central government maintains a high duration in 2016. The target band

for average duration has been set at 11.5 years ± 1 year, calculated without discounting.

ISSUANCE IN A LOW INTEREST RATE ENVIRONMENT

Long-term interest rates are currently at a very low level, cf. Chart 3.5 (left). Despite the low long-term interest rates, the immediate saving from reducing duration, expressed as the slope of the yield curve, is close to the average for the last 15 years, cf. Chart 3.5 (right). However, the objective is to ensure the lowest possible *long-term* costs. This assessment requires estimation of term premia. Term premia express the additional cost of locking the rate of interest over many years rather than refinancing on a continuous basis via short-term loans.

TERM PREMIA ESTIMATED USING AN INTEREST RATE MODEL

Term premia cannot be observed directly, but can be estimated using an interest rate model. The special circumstances of the current situation are the unusually low interest rates and the asymmetrical distribution of future interest rate developments. This is taken into account in the model

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3   Given the very robust government debt, it would not be expedient either to *increase* duration by concluding interest rate swaps in which the central government pays a fixed rate of interest, as there is not deemed to be any need for further robustness in relation to the debt portfolio.

Shadow rate model for projection of interest rates in the current environment

Term premia for Danish government bond yields are estimated using model-based interest rate projections, which are based on the development in Danish government bond yields since 1999. So far, the projections have been made using a 3-factor arbitrage-free Nelson-Siegel (AFNS) term structure model. But the low interest rate environment presents certain issues when it comes to projecting interest rates using an AFNS model.

Firstly, the AFNS model ignores the lower bound for short-term interest rates. For example, in some scenarios short-term interest rates are projected as low as -7 per cent. Such interest rate paths do not seem plausible, given investors' option to hold cash rather than investing in assets with very negative returns.[1]

Secondly, the AFNS model is unable to capture the low volatility at the short end of the term structure for long periods in recent years. Technically, the reason is that the variance of interest rate projections in the AFNS model is constant over time, meaning that it does not reflect the current low interest rate environment. The AFNS model thus generates a very broad distribution of future interest rates,

compared with e.g. the low implied volatility for swaptions and the low realised volatility for short-term government yields which have characterised the low interest rate period.
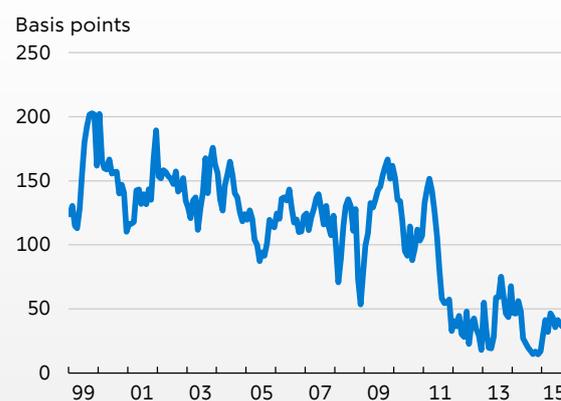
In academia the two issues are addressed by introducing a lower bound for the short-term model interest rate, resulting in a shadow rate model.[2] An implementation of the shadow rate model on Danish government bond yields is described in Christensen, Nysteen, and Pedersen (2016). [3] The choice of the lower bound level is, however, uncertain, as emphasised e.g. by developments throughout 2015, when interest rates fell to negative levels not previously seen. In the current implementation of the model, the lower bound has been set at -1 per cent, corresponding to the lowest observed 3-month interest rate at month-end. The shadow rate model with a fixed lower bound is challenged by the decreasing Danish yields, and the resulting interest rate projections are not improved in the same way as observed in other markets. In spite of the challenges the shadow rate model is preferred over classical AFNS models as the former accounts for the asymmetric distribution of future interest rates which characterises the low interest rate environment.

1. Conversion to cash is not without costs, as storage, transport and insurance must be paid for. Besides, transactions over large geographical distances are cumbersome. The attractiveness of going from bank deposits or securities to cash depends on the size of these costs and on the expected period of negative interest rates.
2. See e.g. L. Krippner, A tractable framework for zero lower bound Gaussian term structure models, *Discussion Paper Series*, Reserve Bank of New Zealand, 2013.
3. Christensen, Nysteen, and Pedersen, Modelling Danish government bond yields in a low-rate environment, *Danmarks Nationalbank Working Papers*, 2016.

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used to estimate interest rate developments, cf. Box 3.2. On the basis of a large number of simulated scenarios, the model estimates a mean path for short-term interest rates over the coming years. The model projections show a small expected annual saving at the end of 2015 from rolling over very short-term bonds over the next 10 years relative to issuance of a 10-year bond today. Term premia are assessed continuously over the year, and according to the model they have been low in the low interest rate environment seen in recent years, cf. Chart 3.6. The perception of currently low term premia is not a particular Danish phenomenon. It is supported by studies based on euro swap rates and US government yields.[4]

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4. According to the estimation of Adrian, Crump and Moench from the Federal Reserve Bank of New York, the term premium on a 10-year US government bond is zero at end-2015. Lemke and Vladu, A Shadow-Rate Term Structure Model for the Euro Area, conference paper, ECB, 2014, estimate the term premium on a 10-year EONIA swap rate to have been negative throughout most of 2012 and onwards.

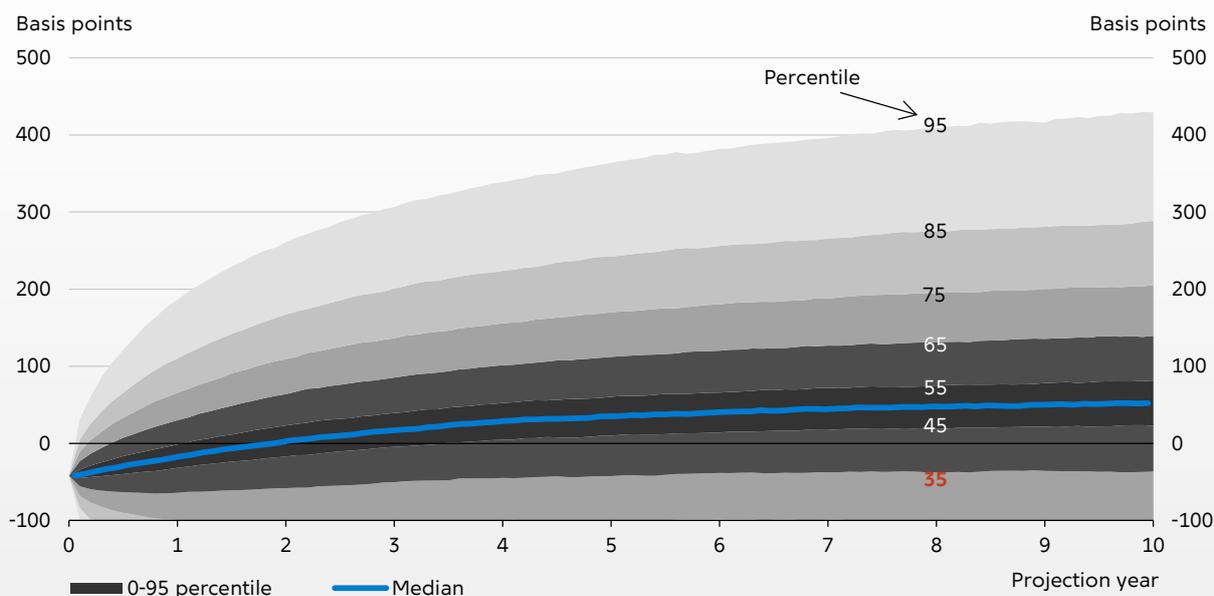**Estimated 10-year term premium**

Basis points

Note: The term premium is defined as the difference between a 10-year zero coupon yield and the geometric average of short-term yield projections over the next 10 years.
Source: RIO and own calculations.

Asymmetrical distribution of very short-term model future interest rates

Chart 3.7

Note: The empirical counterpart of the very short-term model interest rate is an overnight interest rate. The distribution is based on 50,000 simulated interest rate paths with a lower bound for the short-term interest rate of -1 per cent, cf. Box 3.2.

ASYMMETRICAL DISTRIBUTION OF FUTURE INTEREST RATES

As a consequence of the low term premia, the central government pays a limited premium for maintaining a robust portfolio composition with high duration. In addition, there is a limit to how much further short-term interest rates can fall. However, since no similar limit applies to potential interest rate increases, the distribution of future interest rates is asymmetrical, cf. Chart 3.7. As regards the strategic trade-off between cost and risk, the asymmetrical distribution of future interest rates implies that the potential saving to the central government is limited, while there is a risk of considerably higher costs if interest rates rise sharply.

CENTRAL BANK PURCHASES PUSH LONG-TERM INTEREST RATES DOWNWARDS

The low term premia should also be viewed in the light of the perception among investors that the probability of interest rate increases in the euro area is limited in the current interest rate environment. This is due to expectations of modest economic growth and relatively low inflation for a prolonged period, cf. Box 3.3.

To this should be added the ECB's purchases of government bonds. The increased demand for bonds is pushing up prices and reducing longer-term interest rates. This will prompt some investors to shift towards shorter maturities, but certain investors have a natural preference for selected maturity segments. This applies to e.g. insurance and pension companies, which need to hedge their long-term liabilities by means of long-term assets. That is why they – to a certain degree – refrain from investing in shorter-term bonds instead. The result is a flatter term structure and lower term premia.[5]

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5   The fall in interest rates at the long end reflects expectations of low monetary policy interest rates for a prolonged period (the signalling effect) and lower term premia (the portfolio balance effect). According to studies, the portfolio balance effect can explain the main part of the fall in long-term interest rates in the market for US and UK government bonds, see e.g. Gagnon et al., Large-scale asset purchases by the Federal Reserve: Did they work, *FRBNY Economic Policy Review*, May 2011, and Joyce et al., The Financial Market Impact of Quantitative Easing, *International Journal of Central Banking*, September 2011.

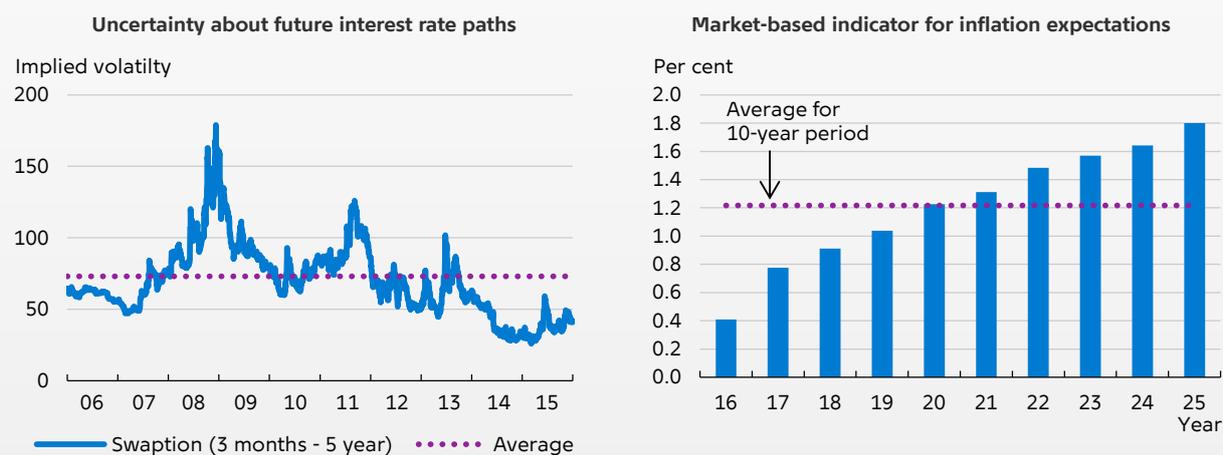**Low expected inflation means low interest rate risk**

Box 3.3

The primary risk associated with investing in long-term Danish government bonds is capital losses in the event of interest rate increases. This risk is reflected in the term premium. If there is a high degree of uncertainty among market participants about the future path of interest rates, they will typically demand a considerable premium on investment in long-term assets, resulting in high term premia.

At present, the interest rate risk is assessed to be low among market participants. This is reflected e.g. in the low costs of buying the right to conclude a 5-year interest rate swap in three months at a price known in advance, cf. the chart (left). One explanation of the low level of perceived interest rate risk is that inflation expectations in the coming years are very low, cf. the chart (right).[1] A low level of inflation reduces the risk of monetary policy tightening and hence higher interest rates.

Market-based perception of interest rate risk and inflation expectations

Uncertainty about future interest rate paths

Implied volatilty

Market-based indicator for inflation expectations

Per cent

Note: Left-hand chart: Implied volatility on swaptions where the buyer has an option to conclude a 5-year euro interest rate swap in three months at a rate of interest known beforehand (typically the current market rate). High implied volatility thus entails expensive options and vice versa. The broken line is the average for the period.
          Right-hand chart: Implied inflation expectations for the next 10 years based on inflation-linked swaps linked to HICP excluding tobacco for the euro area.
Source: Bloomberg and own calculations.
[1] Inflation expectations have not been adjusted for the inflation risk premium, which may be either positive or negative.