Danmarks Nationalbank

Financial Management at Danmarks Nationalbank

D A N M A R K S

N A T I O N A L

B A N K 2 0 0 4

Danmarks Nationalbank
Havnegade 5
DK-1093 Copenhagen K
Telephone: +45 33 63 63 63
Telefax: +45 33 63 71 15
Web site: www.nationalbanken.dk

Please direct any questions concerning financial management at Danmarks Nationalbank to Financial Markets, by e-mail: kma@nationalbanken.dk. More copies may also be ordered at this address.

Explanation of symbols:

-	Magnitude nil
0	Less than one half of unit employed
•	Category not available
…	Numbers not available

Details may not add due to rounding.

This publication is based on information available up to 15 December 2003.

Print: Scanprint as, Viby J
ISSN: 1603-547X

Contents

APPENDICES

Charts

Boxes

Tables

Foreword

Financial management has gained importance in recent years in step with the integration of the financial markets and the increasing complexity of the financial instruments.

Financial management at Danmarks Nationalbank has likewise undergone major changes, and the principles and methodologies are subject to ongoing development.

This book provides a full description of Danmarks Nationalbank's portfolio management and financial management. The cornerstone of financial management is the fixed-exchange-rate policy, although good returns are also an objective.

Danmarks Nationalbank considers it important to provide a comprehensive description of the principles for financial management and to ensure that the principles are known by the general public.

Danmarks Nationalbank would like to thank colleagues in Denmark and abroad for their many useful observations and suggestions during the making of this book.

Questions and comments regarding this book may be addressed to Financial Markets at kma@nationalbanken.dk.

1. Introduction

As the Danish central bank, Danmarks Nationalbank is responsible for monetary policy in Denmark. Denmark maintains a fixed-exchange-rate policy vis-à-vis the euro. This means that the objective of monetary and foreign-exchange-rate policy is to keep the Danish krone stable against the euro.

In addition, Danmarks Nationalbank issues banknotes and coins and acts as banker to the banks and the central government.

In pursuit of these responsibilities Danmarks Nationalbank holds substantial assets comprising the foreign-exchange reserve and a domestic securities portfolio. On the liability side, the assets are partly offset by banknotes and coins, by the government's and the banks' deposits at Danmarks Nationalbank and by Danmarks Nationalbank's net capital.

The size and structure of the balance sheet are for the most part a consequence of Danmarks Nationalbank's role as monetary authority. As an example, the size of the foreign-exchange reserve changes as a consequence of interventions in the foreign-exchange market. Other changes result from Danmarks Nationalbank seeking to achieve a good return in relation to the risks it assumes. This is a consequence of its role as financial institution. Considerations relating to monetary and foreign-exchange policy and other tasks in respect of the role as monetary authority always rank higher than considerations relating to return.

Danmarks Nationalbank's financial result depends on a number of uncertainties, primarily the development in interest and exchange rates (market risk), but also counterparties' ability and willingness to meet their payment obligations (credit risk).

A part of Danmarks Nationalbank's financial risks reflects the risks related to its role as monetary authority, and another part reflects the risks related to its role as financial institution.

Risks arising from the role as monetary authority are inevitable. For instance, it is necessary to have a foreign-exchange reserve in order to maintain the fixed-exchange-rate policy. The foreign-exchange reserve thus entails inevitable currency risk and credit risk since the assets must be invested. Likewise, the role as monetary authority means that Danmarks Nationalbank is exposed to risk in connection with monetary-policy instruments and payment systems.

Other risks reflect that in its capacity of financial institution Danmarks Nationalbank seeks to achieve a good return. The investment of the foreign-exchange reserve in bonds that are subject to a degree of interest-rate exposure rather than as bank deposits thus reflects a trade-off between expected return and risk. On the one hand a higher return is expected on bonds, but on the other hand bonds entail capital losses if interest rates are rising.

All financial risks in relation to the roles as monetary authority and as financial institution are subject to assessment and management.

The purpose of this publication is to describe the risk management of Danmarks Nationalbank's portfolios. The risks related to monetary policy and payment systems are not considered here, but are described further in Danmarks Nationalbank, *Monetary Policy in Denmark*, 2003.

Danmarks Nationalbank also manages the central-government debt, as described in its annual publication *Danish Government Borrowing and Debt*.

BACKGROUND TO DANMARKS NATIONALBANK'S RISK PROFILE

Danmarks Nationalbank's choice of risk level is characterised by prudence. The reason is that substantial losses in connection with risk beyond the role as monetary authority are not compatible with high credibility. Moreover, a low risk level makes it possible to maintain a high degree of solvency, even under extreme market conditions.

The financial risks assumed by Danmarks Nationalbank as a financial institution are the result of a deliberate and explicit trade-off of the various considerations. This fundamental assessment is made by the Board of Governors.

The risk level reflects an assessment of the expected return in relation to a number of different risk indicators. Danmarks Nationalbank thus does not apply a specific model when deciding the risk level.

The risk level can be assessed by considering the probability that Danmarks Nationalbank will sustain a deficit, and in a broader sense Danmarks Nationalbank's ability to resist losses. One method for assessing currency and interest-rate risks is to calculate the Value-at-Risk. This calculation shows that with very great probability Danmarks Nationalbank's capital losses will not exceed DKK 3-4 billion in 2003. Compared with Danmarks Nationalbank's financial result of approximately DKK 5 billion in recent years, the size of the capital loss means that the probability of a deficit is acceptable. Stress tests are also applied to assess the loss in the event of a collapse of the normal market

conditions. In the most extreme stress scenario the loss amounts to one third of the net capital.

MANAGING FINANCIAL RISKS

The management of the different types of risks reflects Danmarks Nationalbank's aim to avoid major losses as a consequence of fluctuations in interest and exchange rates, and to completely avoid losses as a result of counterparty failure.

The risk management includes the total balance sheet, so that risks on both the asset and liability side are seen on an aggregated basis. Furthermore, it is taken into account that the purpose of the central-government foreign debt is to finance the foreign-exchange reserve. The euro exposure of the foreign-exchange reserve thus reflects the fixed-exchange-rate policy, but also that the central government's foreign debt is in euro.

Interest-rate risk is managed by imposing limits on interest-rate exposure, i.e. limits to the price fluctuations that are acceptable on a given change in interest rates.

The level of the total interest-rate exposure is independent of the size of the portfolios, and thus implies that the duration of the net capital is unchanged when the foreign-exchange reserve fluctuates.

In a longer perspective Danmarks Nationalbank has achieved a higher return from assuming interest-rate risk. Interest-rate risk also contributes to reducing credit risk since the alternative to investment in bonds issued by central governments with a high credit standing is deposits with banks with a lower credit standing.

The *currency risk* is kept very low by almost exclusively holding exposures in euro. Investments in other currencies than euro contribute to spreading the interest-rate risk across several markets, but the currency risk on these investments is transformed into euro via forward foreign-exchange contracts. Experience shows that exchange-rate fluctuations can lead to substantial losses, and the risk can be high in relation to the potential return.

Danmarks Nationalbank has a minor exposure in US dollars, however, reflecting the wish to be able to intervene in dollars.

When the foreign-exchange reserve is invested, it is sought to keep the *liquidity risk* at a low level. This entails that the positions easily and fast can be sold, pledged as collateral or settled without excessive costs. The foreign-exchange reserve must to a large extent be immediately liquid if it becomes necessary to intervene in support of the krone.

Credit risk is inevitable, but can, however, be kept very low by setting high requirements of the counterparties' credit standing, by spreading the investments on many counterparties, and by requiring collateral for investments. The objective is to avoid any credit losses due to counterparty failure. By spreading the risk on several counterparties a potential loss will be limited.

Compared with commercial banks, Danmarks Nationalbank has a low credit risk. Commercial banks achieve earnings from assuming credit risk and must therefore accept credit losses from time to time.

The credit losses previously suffered by Danmarks Nationalbank, e.g. in connection with the failure of a bank, did not reflect investment decisions, but rather broader financial-stability considerations.

In addition to market and credit risks comes *operational risk.* It is difficult to quantify this type of risk, but qualitative standards are applied. Operational risk is managed via risk assessments, written procedures, physical security measures, IT security guidelines, and contingency plans. Operational risk is also reduced since Danmarks Nationalbank does not undertake transactions of an unnecessarily complex nature.

2. Danmarks Nationalbank's Financial Result and Balance Sheet

Danmarks Nationalbank's financial result comprises core earnings, reflecting Danmarks Nationalbank's role as monetary authority, and the return from assuming further risk, reflecting the role as financial institution. Core earnings are seignorage and the return on the counterpart of net capital, less the costs of holding the foreign-exchange reserve. In addition, the result from currency risk is included in core earnings since the currency risk is a consequence of the role as monetary authority. Interest-rate risk is the primary source of the return achieved from assuming further risk, which in recent years due to the falling interest-rate level has made a significant contribution to Danmarks Nationalbank's overall financial result.

In 2002 core earnings amounted to DKK 3.1 billion, while the return from assuming further risk was DKK 4.0 billion. Danmarks Nationalbank's financial result thus totalled DKK 7.1 billion.

DANMARKS NATIONALBANK'S FINANCIAL RESULT

Danmarks Nationalbank's financial result can be presented in various ways. The annual accounts published in Danmarks Nationalbank's *Report and Accounts* present the total earnings. Below, however, the financial result is presented on the basis of "business areas". This breaks down the result into core earnings, reflecting the role as monetary authority, and the return from assuming further risk in order to obtain good returns, reflecting the role as financial institution.

The breakdown by business area is incomplete since it focuses on the major factors that generate the result.

Table 2.1 presents Danmarks Nationalbank's financial result broken down into core earnings and the return from assuming further risk.

Core earnings

Core earnings are Danmarks Nationalbank's financial earnings were it solely to undertake transactions that are essential for the role as monetary authority. The role as monetary authority includes a number of inevitable risks, reflecting the banks strictly necessary business areas, and an extra currency risk vis-à-vis the US dollar and gold.

DANMARKS NATIONALBANK'S FINANCIAL RESULT 2002 Table 2.1

	Interest, per cent per annum*		Amount, DKK billion*		Result, DKK billion
Core earnings					
Seignorage	3.50	x	42	=	1.5
Counterpart of net capital	3.50	x	48	=	1.7
Foreign-exchange reserve and its financing	-0.25	x	184	=	-0.5
Currency risk, EUR					-0.3
Currency risk, USD and gold					0.7
Total					3.1
Return from assuming further risk					
Interest-rate risk, direct return (carry), etc.					0.9
Interest-rate risk, interest-rate-driven capital gains					3.1
Total					4.0
Total financial result					7.1

Note: * The figures are monthly averages for 2002. Therefore the items do not correspond to the balance sheet in Table 2.2. Seignorage is calculated by using notes and coins in circulation exclusive cash centres.
Source: Danmarks Nationalbank, *Report and Accounts*, 2002.

Core earnings can be divided into four areas:

- Seignorage.
- Counterpart of net capital.
- Foreign-exchange reserve and its financing.
- Currency risk.

Seignorage is Danmarks Nationalbank's return from investing the counterpart of banknotes and coins. Banks that receive cash from Danmarks Nationalbank accrue a debt to Danmarks Nationalbank. This debt is remunerated at the monetary-policy interest rates. Banknotes and coins, on the other hand, can be regarded as an interest-free loan to Danmarks Nationalbank, which thus earns the margin between the monetary-policy interest rates and zero. The higher the circulation of banknotes and the higher the monetary-policy interest rates, the larger the seignorage. Seignorage accounted for earnings of approximately DKK 1.5 billion in 2002.

The *net capital* reflects that Danmarks Nationalbank's assets exceed its debt. Danmarks Nationalbank achieves earnings by investing the counterpart of its net capital. If the counterpart of net capital is remunerated at the monetary-policy interest rates the risk of capital losses is non-existent. In 2002 the counterpart of net capital contributed approximately DKK 1.7 billion to core earnings.

The *foreign-exchange reserve* is financed by loans denominated in Danish kroner from either banks or the central government, whereas it

is remunerated at the euro interest rate, which is lower than the Danish interest rate. Therefore in the first instance the foreign-exchange reserve represents expenditure.

Assuming that the foreign-exchange reserve is invested exclusively in euro on the money market, so as to keep the interest-rate risk and the currency risk at a very low level, the costs of holding the foreign-exchange reserve will correspond to the spread between the money-market interest rate in the euro area and the monetary-policy interest rate in Denmark.

In 2002 the short-term interest rate in the euro area was approximately 25 basis points lower than the official lending rate in Denmark, so that investment at the euro interest rate entailed expenditure of around DKK 0.5 billion. The interest-rate differential has been considerably narrower in 2003.

The *currency risk vis-à-vis the euro* is inevitable for Danmarks Nationalbank as a result of the fixed-exchange-rate policy. Even though the krone is very stable against the euro, even minor fluctuations in the exchange rate affect the result. In 2002 the Danish krone overall strengthened a little vis-à-vis the euro, entailing a loss of approximately DKK 0.3 billion. On the other hand, if the krone weakens this will entail a gain for Danmarks Nationalbank.

Finally the *currency risk vis-à-vis the US dollar and gold* is included in core earnings. These risks are a consequence of the monetary-authority role and amounted to around DKK 0.7 billion in 2002. The currency risk vis-à-vis the US dollar and gold is described in Chapter 6 and the gold holding is described in Chapter 4.

Core earnings including the currency risk totalled approximately DKK 3.1 billion in 2002, cf. Table 2.1.

The result of assuming risk

Danmarks Nationalbank assumes a moderate interest-rate risk as a consequence of the role as financial institution, reflecting the trade-off between risk and return. High returns are not a primary objective of Danmarks Nationalbank, although it does seek to achieve a good return at an acceptable degree of risk.

The result of *interest-rate risk* relates to the holdings of bonds. When Danmarks Nationalbank invests in a bond, the return can be perceived as the yield on a money-market investment, and the return spread between the bond and the money-market investment. The money-market interest rate is part of Danmarks Nationalbank's core earnings, whereas the spread between the bond return and the money-market interest rate is the result of assuming interest-rate risk. The result of interest-rate

risk can again be divided into two elements: the direct return ("carry"), and the result of interest-rate-driven capital gains[1].

The direct return (carry) is the return on the investment if the interest rates remains unchanged. The direct return reflects that the short-term interest rate is typically lower than the long-term interest rate, but the direct return may be negative in certain periods. Direct return also includes all other minor "business areas".

Interest-rate-driven capital gains reflect that in periods of falling interest rates Danmarks Nationalbank achieves a capital gain due to price increases in the bond portfolios, whereas Danmarks Nationalbank will have a capital loss when interest rates are rising.

In 2002 the total gain from assuming interest-rate risk amounted to approximately DKK 4.0 billion, cf. Table 2.1, reflecting the significant drop in interest rates during the year.

Distribution of profit

In 2002 the financial result totalled DKK 7.1 billion. The profit for the year after Other items amounted to DKK 6.7 billion (Other items mainly comprises operating costs). Since 1995 the principles governing the transfer of a part of Danmarks Nationalbank's profit has ensured a degree of consolidation while smoothing the transfer to the central government.

The transfers are smoothed via the Value Adjustment Reserve. Positive value adjustments are allocated to the Value Adjustment Reserve, while negative value adjustments are covered from the Value Adjustment Reserve as far as possible.

After transfer to/from the Value Adjustment Reserve for 2002, 80 per cent of the profit was transferred to the central government. The remaining 20 per cent was allocated to the General Reserves for consolidation purposes.

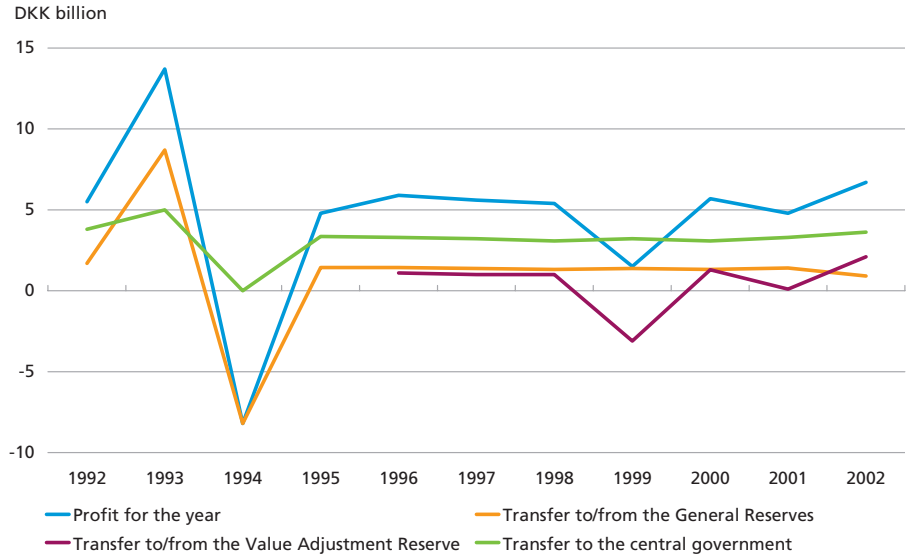
The distribution of profit in recent years is shown in Chart 2.1.

It is important that there is indisputable confidence in a central bank's solvency, and that the central bank's own economic position does not affect monetary and foreign-exchange policy. The central bank's net capital should therefore be substantial. Since 1982 Danmarks Nationalbank's net capital has increased at a rate more or less equivalent to the rate for Denmark's Gross Domestic Product, GDP, cf. Chart 2.2.

---

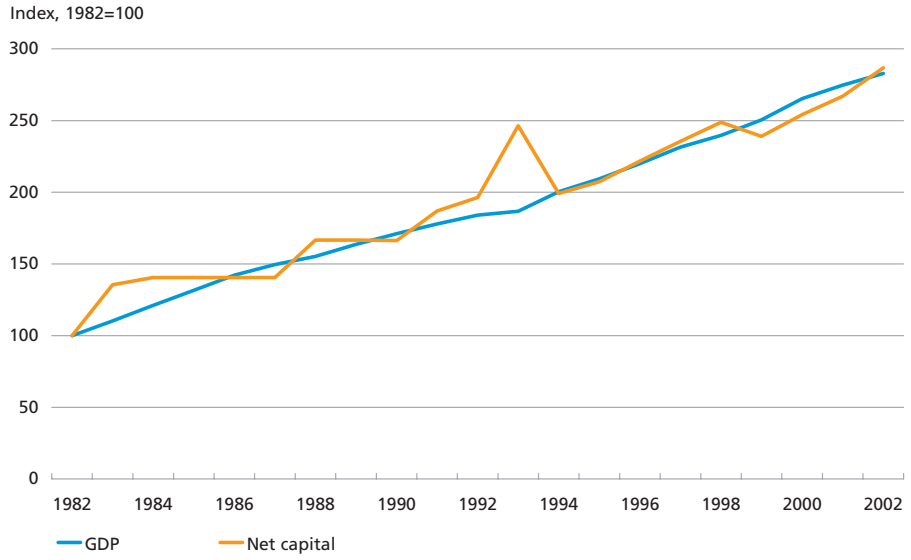
[1] Decomposition of the return is described in further detail in Chapter 13 on performance measurement.

DISTRIBUTION OF PROFIT Chart 2.1



Source: Danmarks Nationalbank, *Report and Accounts*, 1992-2002.

DEVELOPMENT IN DANMARKS NATIONALBANK'S NET CAPITAL AND GDP Chart 2.2



Sources: Danmarks Nationalbank and Statistics Denmark.

DANMARKS NATIONALBANK'S BALANCE SHEET

Danmarks Nationalbank's balance sheet reflects its activities and provides an overview of the financial risks to which Danmarks Nationalbank is exposed. The key items are shown in Table 2.2.

Assets are dominated by the foreign-exchange reserve and the domestic securities portfolio.

The *foreign-exchange reserve* is held in order to support the fixed exchange rate vis-à-vis the euro. If the krone is weak, foreign exchange from the reserve is used to purchase kroner. The foreign-exchange reserve contributes to Danmarks Nationalbank's interest-rate, currency and credit risks.

The *domestic securities portfolio* comprises Danish government and mortgage-credit bonds and contributes to Danmarks Nationalbank's earnings via the interest-rate and credit risks.

The historical development and structure of the portfolios are described in further detail in Chapter 4.

Liabilities are dominated by Danmarks Nationalbank's obligation to issue banknotes and coins and its function as banker to the commercial banks and the central government.

The *volume of banknotes and coins in circulation* is mainly determined by demand from the public. The *banks' net position* comprises all monetary-policy outstandings between Danmarks Nationalbank and the monetary-policy counterparties, i.e. banks and mortgage-credit institutes. The monetary-policy counterparties may make deposits to their current accounts at Danmarks Nationalbank, or invest in certificates of deposit. The counterparties may also borrow with Danish bonds as collateral via the monetary-policy loans. The net position is defined as current-account deposits and certificates of deposit less monetary-policy loans. The net position is remunerated at the monetary-policy interest

KEY ITEMS OF THE BALANCE SHEET, END-2002, DKK BILLION — Table 2.2

Assets		Liabilities	
Foreign-exchange reserve, net	193	Banknotes and coins in circulation	48
of which gold	5	The banks' net position	90
of which claim on the IMF	8	Central-government deposits	50
Portfolio of domestic securities	41	Net capital	50
Other	4		

Note: The item "Other" under Assets comprises other assets less other liabilities. The banks' net position comprises the asset item "Lending, etc." and the liabilities items "Deposits, etc." and "Certificates of deposit". The balance-sheet total therefore differs from the balance-sheet total in *Report and Accounts*, 2002.

Source: Danmarks Nationalbank, *Report and Accounts*, 2002.

rates. In contrast to e.g. the European Central Bank, ECB, Danmarks Nationalbank does not apply reserve requirements, which means that the banks are obliged to hold a certain deposit at the central bank.

Danmarks Nationalbank is also banker to the central government. The *central-government account* is used for settlement of the central government's large-value receipts and disbursements. In accordance with Article 101 of the EU Treaty, this account may never be overdrawn. This rule ensures that the EU member states do not finance government deficits via central-bank credit, i.e. monetary financing. This account is remunerated at the discount rate.

The Foreign-exchange reserve and the portfolio of domestic securities are not net assets for Danmarks Nationalbank

It is important to bear in mind that the foreign-exchange reserve and the domestic securities portfolio do *not represent net assets for Danmarks Nationalbank.* These assets naturally counterbalance Danmarks Nationalbank's liabilities. For example, purchases of foreign exchange for the foreign-exchange reserve are offset by increased debt to the banks or higher central-government deposits with Danmarks Nationalbank. Likewise, purchase and sale of bonds for the domestic securities portfolio change the banks' net position. An increase in the portfolio's value as a result of purchases therefore does not increase Danmarks Nationalbank's net capital since the expansion of the portfolios is offset by higher debt. Correspondingly, a decrease as a result of sale does not entail a reduction of Danmarks Nationalbank's net capital.

Examples of changes in Danmarks Nationalbank's portfolios

The examples in Table 2.3 show the balance-sheet effect of expanding either the foreign-exchange reserve or the domestic securities portfolio by DKK 100 billion.

EXAMPLES OF CHANGES IN BALANCE-SHEET ITEMS — Table 2.3

DKK million	Assets	Liabilities
Example 1. Intervention, purchase of foreign exchange for DKK 100 million		
Foreign-exchange reserve	+100	
The banks' net position		+100
Example 2. Danmarks Nationalbank buys Danish bonds for DKK 100 million		
Domestic securities portfolio	+100	
The banks' net position		+100

In *example 1* the foreign-exchange reserve increases because Danmarks Nationalbank wishes to counter a strengthening of the krone by purchasing foreign exchange against Danish kroner. Danmarks Nationalbank concludes transactions with the monetary-policy counterparties whereby the counterparties' net position in Danish kroner increases.

As the Table shows, Danmarks Nationalbank's debt to the banks increases simultaneously with the foreign-exchange reserve. The debt to the banks is remunerated at the Danish monetary-policy interest rates. These interest rates correlate closely with the short-term euro interest rates. If the foreign exchange purchased via intervention is invested as short-term euro investments, the interest-rate risk on the asset and liabilities sides is very similar. The *interest-rate risk* thus remains almost unchanged.

In view of the very stable krone rate vis-à-vis the euro, Danmarks Nationalbank's *currency risk* is not significantly affected. The effect on the currency risk would be far more pronounced if the foreign exchange were to be invested in US dollars.

There is an increase in the *credit risk* since more assets have to be invested. The increase in the credit risk is very limited, however, because the credit standing of the counterparties is subject to very stringent requirements.

Example 2 shows the balance-sheet impacts if Danmarks Nationalbank's purchases Danish bonds. As a result, the bond portfolio and the banks' net position are both expanded.

The risk impact for Danmarks Nationalbank of an expansion of the domestic securities portfolio is an increase in the *interest-rate risk* and a moderately greater *credit risk*. The interest-rate risk increases because the bonds in the portfolio have a longer maturity than the instruments included in the net position. The higher credit risk is due to more assets invested.

Central-government borrowing and the balance sheet

Central-government borrowing impacts directly on Danmarks Nationalbank's balance sheet, although the effects of domestic and foreign borrowing differ. *Domestic borrowing* (issue of krone-denominated government bonds) increases the balance of the central-government account and equivalently reduces the banks' net position. The opposite applies in the case of central-government expenditure, since the balance of the account diminishes and the banks' net position increases. The balance-sheet total, as well as Danmarks Nationalbank's financial result and risk, remain unchanged.

CENTRAL-GOVERNMENT BORROWING — Table 2.4

Euro loan of DKK 100 million	Central government		Danmarks Nationalbank	
	Assets Kroner	Liabilities Euro (in DKK)	Assets Euro (in DKK)	Liabilities Kroner
Central-government debt		+100		
Foreign-exchange reserve			+100	
Central-government account ...	+100			+100

Foreign borrowing has a slightly more complex impact on the balance sheet since the foreign-exchange reserve is affected. If the central government e.g. raises a euro-denominated foreign loan of DKK 100 million, the central government receives euro to be exchanged for Danish kroner at Danmarks Nationalbank. Consequently, the central-government account increases by the krone amount, and the foreign exchange expands equivalently, cf. the example in Table 2.4. The total balance sheet increases by DKK 100 million.

3. Decision-Making Process and Division of Responsibility

In relation to financial risk management Danmarks Nationalbank applies a formalised decision-making process to ensure a clear division of responsibility.

Within Danmarks Nationalbank's organisation the portfolio management is clearly divided into trading functions, back-office functions and strategy management.

Danmarks Nationalbank considers it important that risk management and portfolio management are in accordance with current international guidelines.

ORGANISATION

In the areas of portfolio and risk management Danmarks Nationalbank's organisation comprises front-, middle- and back-office functions, i.e. Market Operations, Financial Markets and Accounting.

Market Operations is responsible for day-to-day portfolio management, including the specific composition of the portfolio and positioning within the specified framework.

Financial Markets is responsible for the overall management of Danmarks Nationalbank's foreign-exchange and interest-rate positions. The department also prepares outline strategies for the Board of Governors and draws up specific frameworks and policies that implement the decisions of the Board of Governors. Furthermore Financial Markets is responsible for Danmarks Nationalbank's risk analysis.

Accounting is responsible for settlement, bookkeeping and control and provides data input to risk management.

The current organisation was implemented in 1996 on the basis of, among other things, recommendations in international guidelines emphasising the importance of an up-to-date separation of functions. The organisational changes are described in Danmarks Nationalbank's *Report and Accounts 1996*.

The responsibility for executing transactions is segregated from Danmarks Nationalbank's strategic portfolio considerations. Bookkeeping and settlement responsibilities are likewise segregated from the trading function.

The three departments each have their own head of department and are furthermore physically separated. Accounting reports to a different member of the Board of Governors than Market Operations and Financial Markets.

DECISION-MAKING PROCESS

The Board of Governors holds the ultimate responsibility for portfolio management and for decisions relating to Danmarks Nationalbank's financial risks.

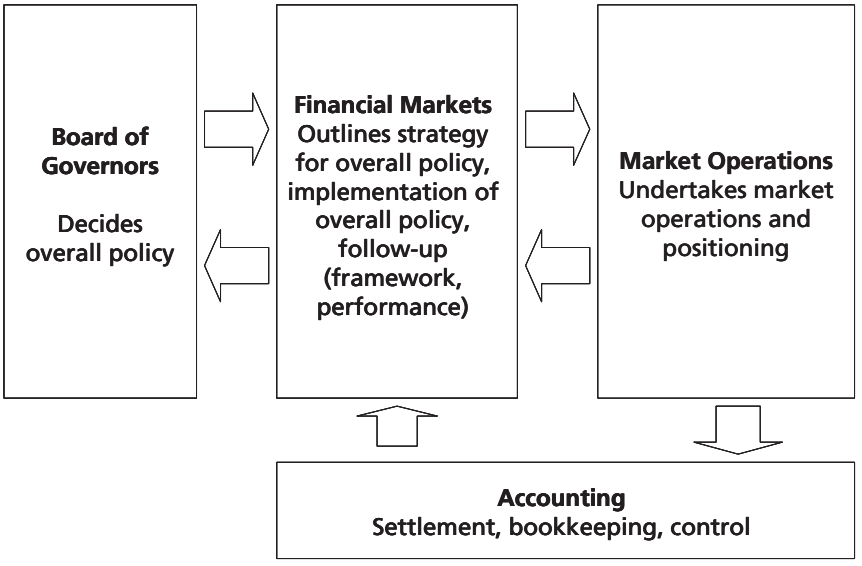
The Committee of Directors considers the risk level in connection with the annual review of Danmarks Nationalbank's large single exposures.

The Board of Governors makes the overall decisions regarding Danmarks Nationalbank's financial risks on the basis of recommendations from Financial Markets. The decision-making process is outlined in Chart 3.1.

The objective of the decision-making process is to ensure that financial transactions concluded by Danmarks Nationalbank reflect a specific delegation of competence by the Board of Governors.

The overall decision concerning the level of financial risk is normally taken once a year. It relates to Danmarks Nationalbank's exposure to various currencies, the overall level of interest-rate risk and appurtenant fluctuation margins, as well as the rules that are to apply to credit risk

DESICION ON DANMARKS NATIONALBANK'S FINANCIAL RISK — Chart 3.1



and the guidelines for liquidity risk. The decision is reviewed quarterly, but may also be adjusted on an ongoing basis, e.g. in the event of extreme market conditions.

On a quarterly basis, Financial Markets reports to the relevant governor whether the limits have been complied with, whether the lines seem appropriate in the given market conditions, and on the return achieved from the actual positions.

Danmarks Nationalbank considers it important that the decision-making process and portfolio management in general are in compliance with international guidelines in the area. In *Guidelines for Foreign Exchange Reserve Management* the International Monetary Fund, IMF, has stipulated a number of optional guidelines for central banks' management of the foreign-exchange reserve. According to the IMF's guidelines the management of the foreign-exchange reserve must:

- be controlled by the monetary authorities and consistent with and supportive of the specific policy environment;
- be transparent (disclosure of the official reserves according to a pre-announced schedule, and publication of the broad objectives of reserve management) and accountable (clear specification of roles and responsibilities);
- be based on a sound legislative framework and internal governance;
- be subject to risk management, to calculate the financial risks and apply stress tests to e.g. assess the ability to counter losses;
- be conducted in markets that have sufficient depth and liquidity.

COMPLIANCE

Compliance with the frameworks and guidelines is controlled at several levels of the organisation. Before a transaction is executed, Market Operations is responsible for ensuring pre-trade compliance. Market Operations is also responsible for registering the transaction in Danmarks Nationalbank's systems ("deal capture").

Accounting is responsible for settlement and bookkeeping of the transaction. Accounting's systems then submit the information on the transaction to the portfolio management system used by Financial Markets. The system is updated on a daily basis and any cases of non-compliance with the stipulated framework for the market risk are reported to Financial Markets. Accounting is responsible for monitoring the framework for the credit risk on the foreign-exchange reserve and the domestic securities portfolio. The distribution of responsibility is set out in written rules of procedure.

In the event of non-compliance the nature of the non-compliance is first determined, followed by a report on why it occurred and how it can be eliminated. Normally Financial Markets approves the non-compliance. Though, larger events of non-compliance are reported to the Board of Governors.

Danmarks Nationalbank's Audit office undertakes ongoing control of portfolio management. Audit is an independent office that reports to the Board of Governors and to Danmarks Nationalbank's Committee of Directors and Board of Directors. The annual accounts are subject to external audit as well.

All employees in Danmarks Nationalbank are subject to a prohibition of speculation, cf. a statutory order from the Danish Financial Supervisory Authority, FSA.

4. Danmarks Nationalbank's Portfolios

The foreign-exchange reserve and the portfolio of domestic securities are Danmarks Nationalbank's key portfolios and constitute most of Danmarks Nationalbank's total assets. The following is an outline of the historical development in and the composition of the two portfolios.[1]

THE FOREIGN-EXCHANGE RESERVE

The foreign-exchange reserve is used by Danmarks Nationalbank to intervene in the foreign-exchange market, i.e. to purchase or sell foreign exchange against kroner in order to influence the krone rate. The foreign-exchange reserve is thus a key element of Denmark's fixed-exchange-rate policy.[2]

Chart 4.1 shows the development in the foreign-exchange reserve and in the central government's foreign debt since 1960.

Changes in the size of the foreign-exchange reserve can be for two main reasons:

- Danmarks Nationalbank's purchase and sale of foreign exchange.
- The central government's raising or repayment of foreign loans.

In addition, the foreign-exchange reserve reflects ongoing interest accrual and value adjustments. Foreign-exchange transactions between the commercial banks and the rest of the private sector do not affect the foreign-exchange reserve.

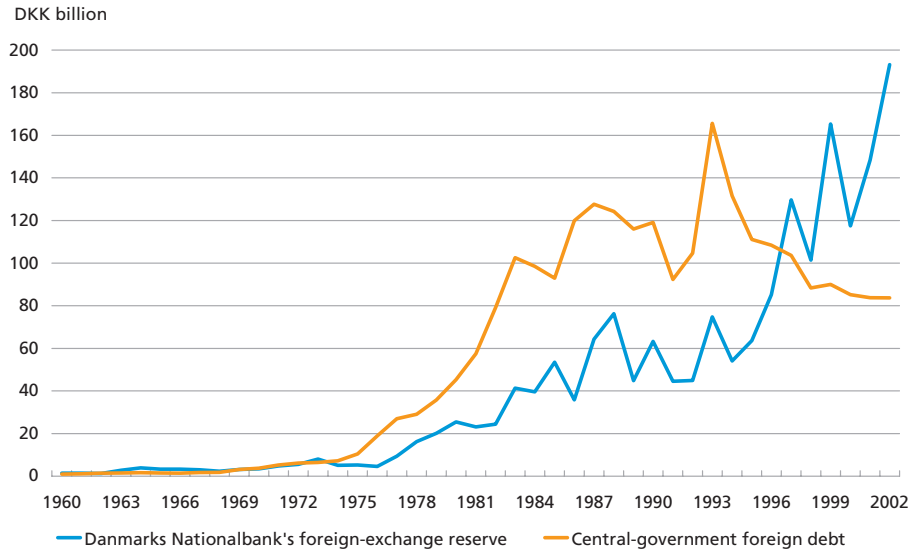
The central government may raise loans in foreign exchange to increase the foreign-exchange reserve. As an element of Denmark's government-debt policy, for the last 15 years the central government has adhered to the principle that foreign-exchange loans raised by the central government may not be used to finance the central government's current deficit denominated in kroner.

The central government's foreign loans thus constitute a buffer against fluctuations in the foreign-exchange reserve. In periods when the foreign-exchange reserve diminished as a result of intervention to support the krone, the central government raised loans denominated in foreign exchange in order to ensure an adequate foreign-exchange re-

1 For more detailed descriptions of the two portfolios, see Jensen (1999) and Jayaswal (2003).
2 The foreign-exchange reserve is only one of Danmarks Nationalbank's methods of obtaining foreign exchange. The others are described in Chapter 9, Liquidity Risk.

THE FOREIGN-EXCHANGE RESERVE AND THE CENTRAL-GOVERNMENT FOREIGN DEBT, YEAR-END

Chart 4.1



Sources: Mikkelsen (1993) and Danmarks Nationalbank.

serve. In more stable periods, Danmarks Nationalbank has been able to purchase foreign exchange.

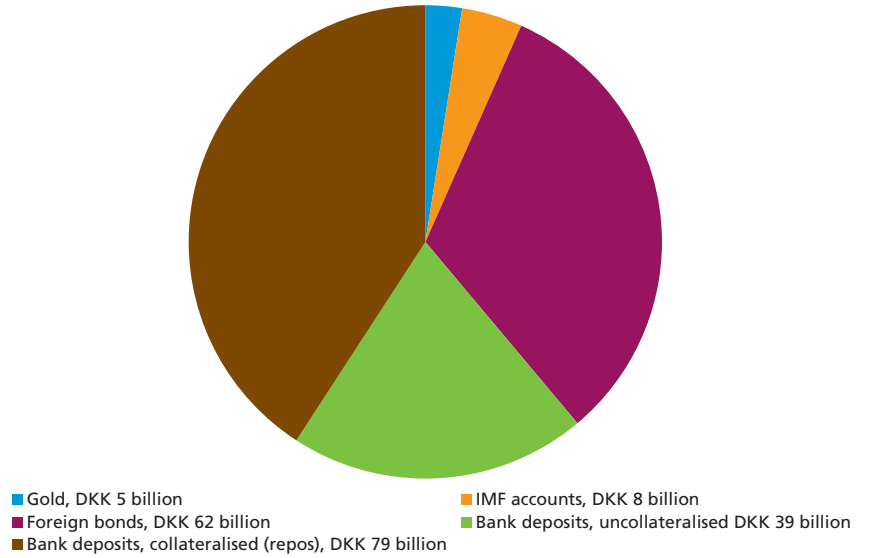
The foreign-exchange reserve cannot be used to reduce the central government's foreign debt unless the size of the foreign-exchange reserve is found adequate and the central government's balance on its account at Danmarks Nationalbank can finance the reduction of the debt. If there are not enough funds on the central government's account, the domestic-government debt must be increased in order to fund a reduction of the foreign-government debt.

The foreign-exchange reserve has increased significantly during the past 10 years, cf. Chart 4.1. This increase reflects the foreign-exchange purchases by Danmarks Nationalbank in order to maintain a stable krone rate. At the same time the balance on the central government's account at Danmarks Nationalbank has limited the opportunity to repay the central government's debt denominated in foreign exchange.

Composition of the foreign-exchange reserve

The foreign-exchange reserve is invested as deposits in foreign banks and in foreign bonds. The bank deposits comprise collateralised and uncollateralised deposits. In addition, the gold holding and claims on

THE FOREIGN-EXCHANGE RESERVE, END-2002 Chart 4.2



Note: Danmarks Nationalbank's liabilities vis-à-vis non-residents are deducted from Foreign bonds.
Source: Danmarks Nationalbank.

the International Monetary Fund, IMF, are also included.[1] On the other hand, Danmarks Nationalbank's obligations vis-à-vis abroad are deducted.[2]

The foreign-exchange reserve comprises secure and liquid assets that can rapidly be sold or pledged as collateral. The foreign-exchange reserve is invested in the euro area, the USA, the UK and Sweden.

At end-2002 the market value of the foreign-exchange reserve was DKK 193 billion net. Chart 4.2 shows the individual items of the foreign-exchange reserve.

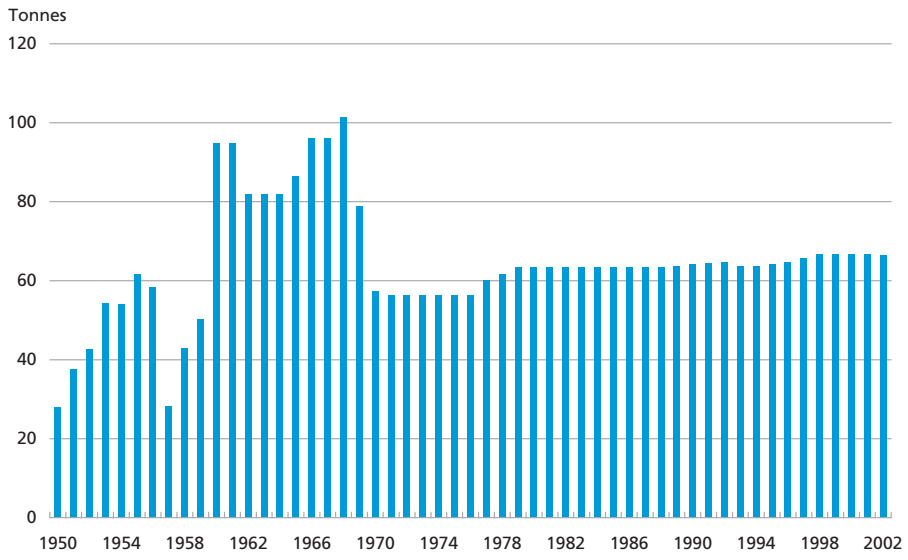
A number of special circumstances affect Danmarks Nationalbank's gold holding. These are outlined below.

The gold holding in the foreign-exchange reserve

The *gold holding* amounts to approximately 67 tonnes corresponding to around DKK 5 billion.[3] Under the Danmarks Nationalbank Act, Danmarks Nationalbank must hold a gold fund. During some time Danmarks Nationalbank has had an unchanged gold holding, cf. Chart 4.3. The risk related to the gold holding comprises currency risk (in kroner vis-à-vis dollars) and price risk (in dollars vis-à-vis gold). The currency risk on the

1 Danmarks Nationalbank's claims on the IMF are described in Mogensen (2003).
2 Primarily any unutilised credits from the European Central Bank and the balance on the European Commission's account.
3 For further information on Danmarks Nationalbank's gold holding and the international role of gold, see Bie and Pedersen (1999).

DANMARKS NATIONALBANK'S GOLD HOLDING Chart 4.3



Source: Danmarks Nationalbank.

gold holding is included in the overall management of Danmarks Nationalbank's currency risk, cf. Chapter 6. The gold-price risk is not hedged, in view of Danmarks Nationalbank's relatively small holding of gold.

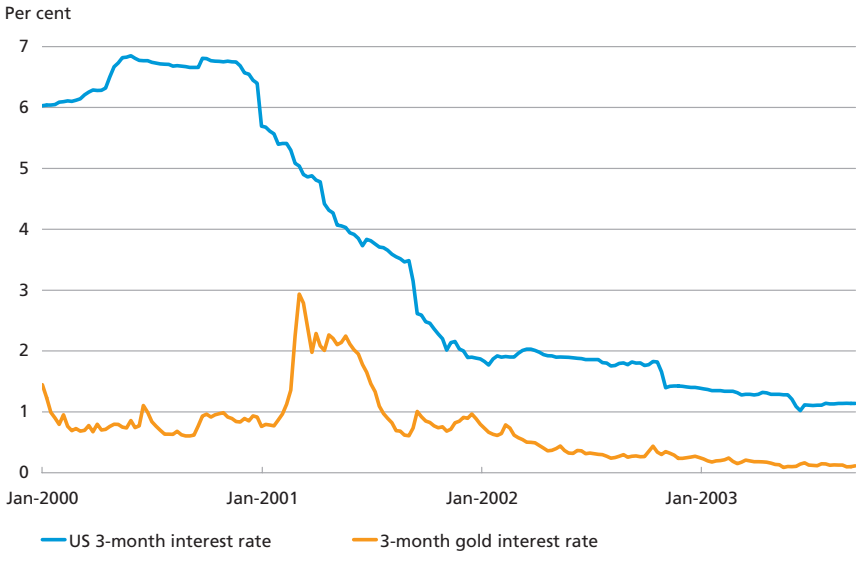
The return on the gold holding comprises any appreciation over time, as well as interest from lending the gold.

Lending of gold is interest bearing since gold producers and others wish to protect against future price decreases. This is done by borrowing gold and selling it immediately. As gold is produced, the gold loan can be repaid. Danmarks Nationalbank does not lend directly to gold producers, but to commercial banks. In this way Danmarks Nationalbank does not incur any direct credit risk in relation to the gold producers.

Danmarks Nationalbank began to lend gold in 1987. Gold is lent to banks with high ratings and primarily deposited at the Bank of England. The gold interest rate is currently very low, cf. Chart 4.4.

If Danmarks Nationalbank's interest and currency risks are to remain almost unchanged, the alternative investment option instead of gold is the US money market. The US money-market interest rate has fallen significantly more than the gold interest rate in recent years, so that the ongoing cost of investing in gold is currently relatively low compared to the US money market.

GOLD INTEREST RATE AND SHORT-TERM US INTEREST RATE Chart 4.4



Source: Danmarks Nationalbank.

The gold holding also contributes to diversification of Danmarks Nationalbank's market risk. This is described in more detail in Chapter 8, Measuring Market Risk.

THE PORTFOLIO OF DOMESTIC SECURITIES

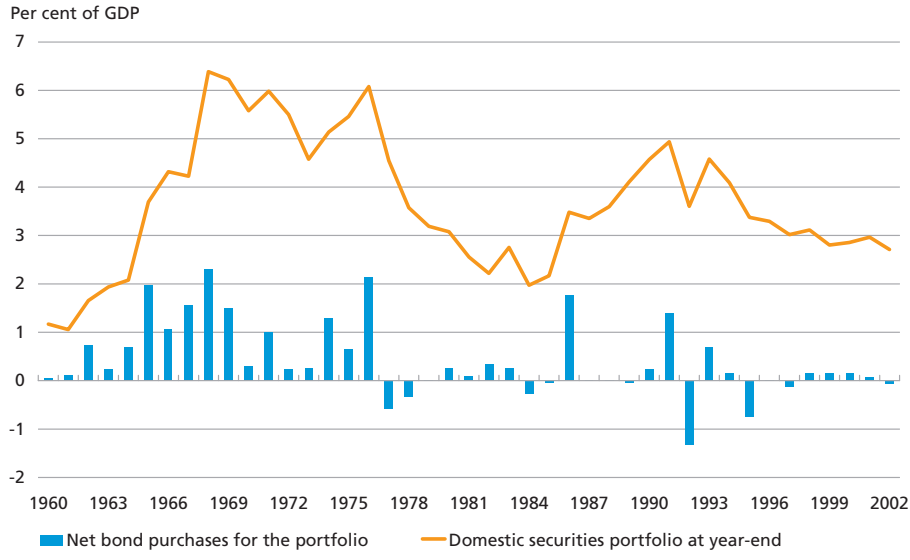
Danmarks Nationalbank holds a portfolio of Danish bonds that has served various purposes over time. Formerly, the purchase and sale of bonds were used as monetary-policy instruments to influence bond yields. In view of today's free movement of capital such operations are no longer considered an effective means of influencing long-term yields.

In the management of the domestic securities portfolio it is the aim not to influence the Danish bond market. The historical development in the domestic securities portfolio since 1960 is shown in Chart 4.5.

In the 1960s Danmarks Nationalbank from time to time sought to counteract rising interest rates by purchasing bonds. These purchases also helped to supply liquidity that was absorbed via the government budget surpluses in those years.

During the 1970s Danmarks Nationalbank adjusted its presence in the bond market and no longer sought systematically to stabilise interest rates, although strong price fluctuations were still dampened, foreign-exchange-reserve conditions permitting.

THE PORTFOLIO OF DOMESTIC SECURITIES Chart 4.5



Sources: Danmarks Nationalbank and Statistics Denmark.

In 1986 Danmarks Nationalbank once again became very active in the bond market. For a short period during the summer Danmarks Nationalbank thus sought to dampen falling bond prices by purchasing bonds.

Apart from very short-term market operations to manage liquidity in the early 1990s, monetary-policy operations in the bond market have not been applied.

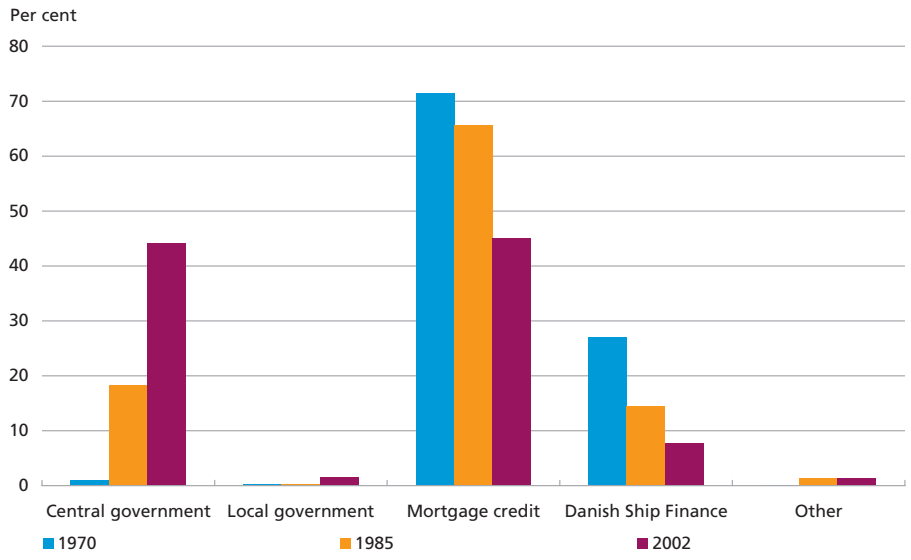
The composition of the domestic securities portfolio

By the end of 2002 the market value of the domestic securities portfolio was around DKK 41 billion. The portfolio of domestic securities contributes significantly to Danmarks Nationalbank's financial result, since investments in bonds typically have a higher return than money-market investments. Chart 4.6 shows the development in the composition of the portfolio.

Historically, most of the portfolio has been invested in mortgage-credit bonds. The high proportion of Danish Ship Finance bonds is partly related to the fact that Danmarks Nationalbank was previously an active party to a number of subsidy schemes to finance shipbuilding, cf. Appendix B on Ship Finance Schemes.

By the end of 2002 the portfolio of mortgage-credit bonds comprised 2/3 un-callable and 1/3 callable bonds. The latter are the traditional long-term mortgage-credit bonds with maturities of up to 30 years. When a bond is callable, the borrower is entitled to repay the loan at

THE PORTFOLIO OF DOMESTIC SECURITIES BY ISSUER Chart 4.6



Note: For 2002 is shown the market value of the portfolio of domestic securities and the portfolio for hedging debentures in ship finance schemes, cf. Appendix B.
Source: Danmarks Nationalbank.

par value throughout its maturity. This is taken into account in risk management, cf. Chapter 7 and Appendix A.

Since 1970 the domestic securities portfolio has been restructured from mortgage-credit and Danish Ship Finance bonds to government bonds. The portfolio of mortgage-credit bonds has been reduced in step with the increase in central-government borrowing, which has expanded the issuance of Danish government bonds.

Purchase and sale of government bonds

Under the EU Treaty, EU member states are committed to sound and sustainable public finances. The central banks of the member states may thus not finance public expenditure either directly by lending to the central government, or indirectly by purchasing a disproportionally large volume of bonds issued by public authorities[1]. Rules have therefore been established to monitor the central banks' transactions.

Danmarks Nationalbank may not buy government bonds directly from the central government, but buys and sells government bonds in the secondary market.

[1] Bonds issued by public authorities primarily comprise government bonds and municipal bonds. Bonds issued subject to a government guarantee or bonds subject to other significant public influence are also covered by the rules.

LITERATURE

Bie, Ulrik and Astrid Henneberg Pedersen (1999), The Role of Gold in the Monetary System, Danmarks Nationalbank, *Monetary Review,* 3rd Quarter.

Jayaswal, Peter (2003), Danmarks Nationalbank's Portfolio of Domestic Securities, Danmarks Nationalbank, *Monetary Review*, 2nd Quarter.

Jensen, Peter Kjær (1999), The Foreign-Exchange Reserve, Danmarks Nationalbank, *Monetary Review*, 1st Quarter.

Mikkelsen, Richard (1993), Dansk pengehistorie 4 (Danish Monetary History 4, in Danish), Danmarks Nationalbank.

Mogensen, Louise (2003), The IMF and Danmarks Nationalbank's Balance Sheet, Danmarks Nationalbank, *Monetary Review*, 4th Quarter.

Olsen, Erling and Erik Hoffmeyer (1968), Dansk pengehistorie 2 (Danish Monetary History 2, in Danish), Danmarks Nationalbank.

5. Market Risk, Introduction

Danmarks Nationalbank's market risk is the risk of loss as a consequence of price fluctuations on the financial markets. The *risk factors* comprise interest rates, exchange rates and the price of gold.

Danmarks Nationalbank cannot avoid market risk, and to some extent also assumes market risk voluntarily. The reasons are to achieve earnings or to meet other objectives. However, it is of great importance to keep the market risk at a low level. Thereby, Danmarks Nationalbank can resist extreme market conditions, e.g. significant interest-rate increases, while maintaining a high degree of solvency. A low market risk also helps to ensure stable development in the return that falls to the central government.

MANAGING MARKET RISK

Danmarks Nationalbank's interest-rate and exchange-rate risks are managed via the limits set for the exposure or sensitivity of financial positions to changes in interest and exchange rates. The limits are fixed as krone amounts, and the actual exposures are also calculated in kroner. *Interest-rate exposure* is expressed as the krone duration, e.g. the loss in kroner on a general increase in the level of interest rates by 1 percentage point, while *exchange-rate exposure* can be expressed as the change in the market value in kroner on a 1-per-cent change in the exchange rate. For a position in foreign exchange the fact that exposure is compiled in kroner means that the exposure is affected by the exchange rate of the krone vis-à-vis the relevant currency. Both interest-rate and exchange-rate exposure will increase (decrease) when the krone weakens (strengthens) vis-à-vis the currency.

The interest-rate exposure of a foreign-exchange position is therefore calculated on the basis of a fixed exchange rate (base rate), which is only adjusted in connection with major changes in the actual exchange rate. The need to conduct many minor transactions in order to maintain a given krone duration is thus eliminated, since minor fluctuations in the exchange rate do not affect the calculated interest-rate exposure.

The exchange-rate exposure of a given foreign-exchange position is calculated on the basis of the actual exchange rate. The limits applied to the exchange-rate exposure allow the actual exchange-rate exposure to

vary with both the exchange rate and the level of interest rates in the relevant currency.

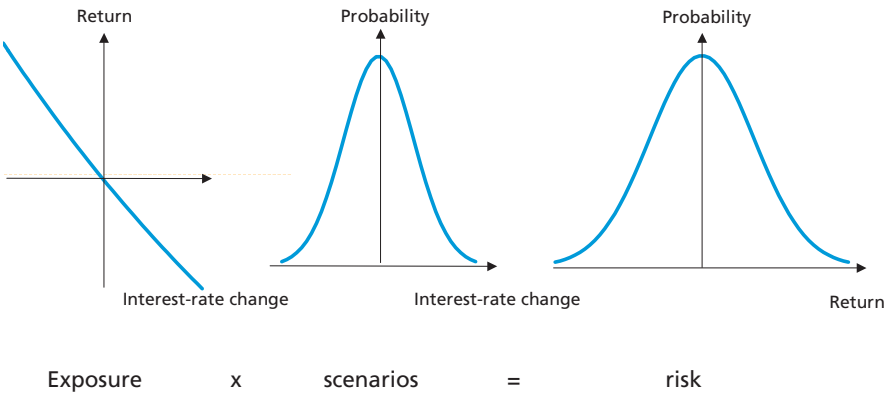
Danmarks Nationalbank's currency and interest-rate risks are described in further detail in Chapters 6 and 7.

RISK VERSUS EXPOSURE

The market risk is determined not only by the exposures but also by the actual fluctuations in the risk factors.

Generally it is important to distinguish between exposure and risk. The difference between the two concepts is illustrated in Chart 5.1. The left-hand diagram shows the exposure, in this case the interest-rate exposure, of a bond portfolio. An increase in the level of interest rates leads to a capital loss, while a drop in the level of interest rates leads to a capital gain. The middle diagram shows interest-rate scenarios, illustrated as a distribution of probabilities. Minor interest-rate changes have a high probability, while major interest-rate changes have a low probability. Combining the interest-rate exposure with the scenarios for interest-rate changes leads to the right-hand diagram that depicts the interest-rate risk as a probability distribution for the return on the portfolio.

INTEREST-RATE EXPOSURE VERSUS INTEREST-RATE RISK ON A BOND PORTFOLIO — Chart 5.1



Note: Return means a capital gain or loss as a consequence of market development.
Source: Danmarks Nationalbank.

In practise several risk factors are affected at the same time. For instance, a position in foreign bonds may result in a large krone-denominated loss on a simultaneous weakening of the currency and increase in bond yields. In other cases the loss resulting from the currency's weakening may be fully or partly offset by falling bond yields. In a third scenario, the loss resulting from an increase in bond yields may be fully or partly offset by a strengthening of the currency. Finally, a substantial gain may be achieved if the currency strengthens concurrently with a decrease in bond yields.

Risk is inherently forward-oriented. Quantification of the risk thus implies that future fluctuations in the risk factors must be taken into account. Quantified risks will therefore always include some uncertainty.

Danmarks Nationalbank's market risk is measured by Value-at-Risk, which can be interpreted as the maximum loss under normal market conditions, as well as stress scenarios focusing on losses under extreme market conditions. No explicit limits are set for these risk measures, but the risk measures are part of the determination of the overall limits for interest-rate and exchange-rate exposure.

Chapter 8 expands on the measurement of Danmarks Nationalbank's market risk.

A particular type of market risk is liquidity risk, i.e. the risk that an asset cannot be sold, pledged as collateral, or settled without excessive costs. Liquidity risk cannot be quantified in the same way as exchange-rate and interest-rate risks. This is, however, a very significant risk, since Danmarks Nationalbank may require substantial funds at very short notice in connection with its market intervention. Ultimately liquidity risk is the risk that Danmarks Nationalbank cannot intervene in the foreign-exchange market. To avoid this situation a liquidity reserve is maintained. Liquidity risk and the liquidity reserve are described in more detail in Chapter 9.

6. Currency Risk

Danmarks Nationalbank's objective is to keep the krone stable vis-à-vis the euro. The fixed-exchange-rate policy requires that Danmarks Nationalbank must be able to intervene in the foreign-exchange market to ensure a stable krone vis-à-vis the euro. This is achieved by maintaining a foreign-exchange reserve in euro.

Danmarks Nationalbank thus cannot avoid currency risk, and the exposure in euro is an inevitable risk as a result of the monetary authority role.

Part of the foreign-exchange reserve is invested in interest-bearing instruments denominated in US dollars, pounds sterling and Swedish kronor, cf. Chapter 7. These investments entail a considerable currency risk, since the value of the krone has been seen to fluctuate significantly vis-à-vis these currencies. Most of Danmarks Nationalbank's exposure vis-à-vis these currencies, however, has been transformed into euro. Together with the krone's stability vis-à-vis the euro, this ensures that Danmarks Nationalbank's currency risk is small in relation to the size of the foreign-exchange reserve. In addition, Danmarks Nationalbank finds that the potential gains from exposure vis-à-vis non-euro currencies do not match the risk of losses.

The remaining non-transformed currency risk, which is therefore minor and reflects the role of Danmarks Nationalbank's as the monetary authority role, concerns the risk vis-à-vis the US dollar and the gold price.

In connection with the financial result the risk is a strengthening of the krone. If the krone strengthens vis-à-vis the euro, the value of the reserve in euro will diminish, and Danmarks Nationalbank will sustain a loss. However, the fixed-exchange-rate policy also entails that this risk can be regarded as minor.

TRADE-OFF BETWEEN RISK AND RETURN

Most of the foreign-exchange reserve is invested in interest-bearing instruments denominated in euro, but there are also substantial investments in the interest-rate markets in US dollars, pounds sterling and Swedish kronor. The investments in the non-euro currencies entail a considerable currency risk. Substantial fluctuations in the value of the krone vis-à-vis these currencies may occur, cf. Table 6.1. However, most

VOLATILITY OF THE KRONE VIS-À-VIS OTHER CURRENCIES AND GOLD Table 6.1

Euro	US dollar	Yen	Pound sterling	Swedish krona	Gold price
0.3	9.4	10.8	8.0	6.0	14.2

Note: The volatilities are calculated as the spread in the monthly percentage changes in the period January 1998-December 2002, projected to annual level.
Source: Danmarks Nationalbank.

of the exposure to non-euro currencies is converted into euro. Furthermore, the krone has been very stable for many years vis-à-vis first the D-mark and since 1999 the euro. Therefore, the currency risk on the part of the foreign-exchange reserve that is invested in euro is therefore relatively small.

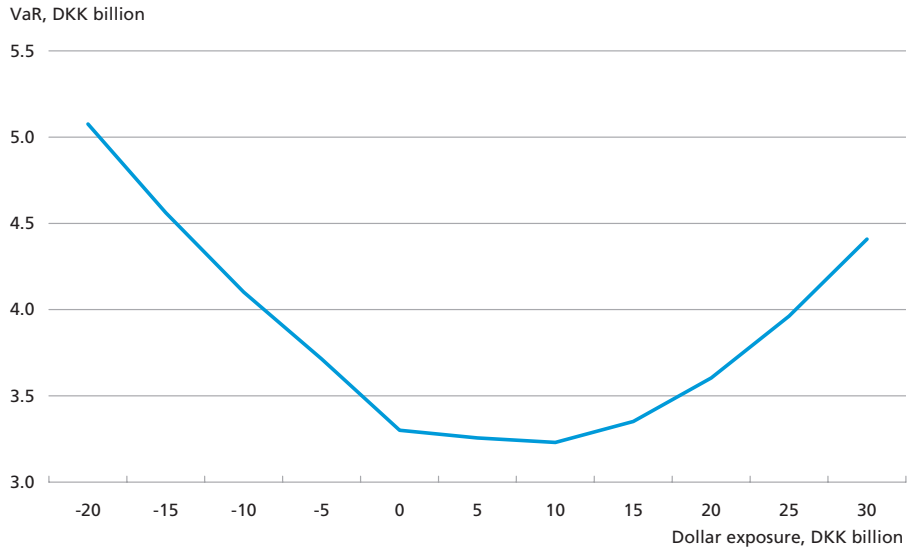
The risk of a loss is the risk of a strengthening of the krone vis-à-vis the euro. Within the framework of the fixed-exchange-rate policy, the krone can strengthen by 4.5 per cent vis-à-vis the euro, if it moves from the weakest to the strongest value in the allowed fluctuation band. At end-2002 Danmarks Nationalbank's exposure to euro was close to DKK 200 billion. A strengthening of the kroner by 4.5 per cent would at that time have implied a loss of about DKK 9 billion for Danmarks Nationalbank. In recent years, however, in practice the volatility in the value of the krone vis-à-vis the euro has been very small compared to the allowed fluctuation band, cf. table 6.1. Furthermore the krone-rate has been very close to the central rate. A large strengthening of the krone should therefore only be expected due to a preliminary weakening, which would entail a gain for Danmarks Nationalbank.

The currency risk resulting from positions in non-euro currencies is not to the same extent inevitable for Danmarks Nationalbank. Consequently, this risk should be avoided, unless there are good reasons for assuming it.

An additional currency risk could possibly be justified on the basis of potential return. Since non-euro currencies are highly volatile, it is necessary for the expected gains on such exposures to be significant. Experience shows that even over very long periods exchange rates can fluctuate quite considerably. This makes it more difficult to predict movements in exchange rates. Thus, the transformation to euro of exposure to non-euro currencies should also be seen in the light of the large risk associated with exposure in non-euro currencies.

By virtue of the role as monetary authority Danmarks Nationalbank is exposed to dollar and gold, cf. the following.

DANMARKS NATIONALBANK'S VALUE-AT-RISK AT DIFFERENT LEVELS OF EXPOSURE IN US DOLLARS — Chart 6.1



Note: Calculations on holdings as of 30 December 2002 based on VaR with a probability of 95 per cent and a time horizon of 1 year.
Source: Danmarks Nationalbank.

RISK VIS-À-VIS THE US DOLLAR

Danmarks Nationalbank has a (small) exposure to US dollars. At end-2002 this exposure was about DKK 4 billion.

The positive dollar exposure allows the use of dollars to strengthen the krone by intervention, without being obliged to borrow dollars. However, the primary intervention currency is euro.

Viewed in isolation, the dollar exposure contributes to increasing the currency risk. However, Danmarks Nationalbank's total market risk does not necessarily increase with the exposure to dollars, provided that it is relatively low. This is illustrated in Chart 6.1, which shows the risk expressed as Value-at-Risk for different levels of dollar exposure.[1] In the calculations, the purchase and sale of dollars are offset by the equivalent purchase and sale of euro, so that the total market value of the portfolios remains unchanged.

As Chart 6.1 illustrates, Danmarks Nationalbank's risk decreases when the dollar exposure is increased from zero to around DKK 10 billion. The reason is that the increase in the dollar exposure contributes to diversifying the portfolios. When the exposure is small, the increased dollar risk is dominated by the diversification gain. The reason for the diversifica-

[1] The calculation of Danmarks Nationalbank's Value-at-Risk is elaborated on in Chapter 8.

tion gain is that losses and gains on dollars do not always coincide with losses and gains resulting from fluctuations in the other risk factors.

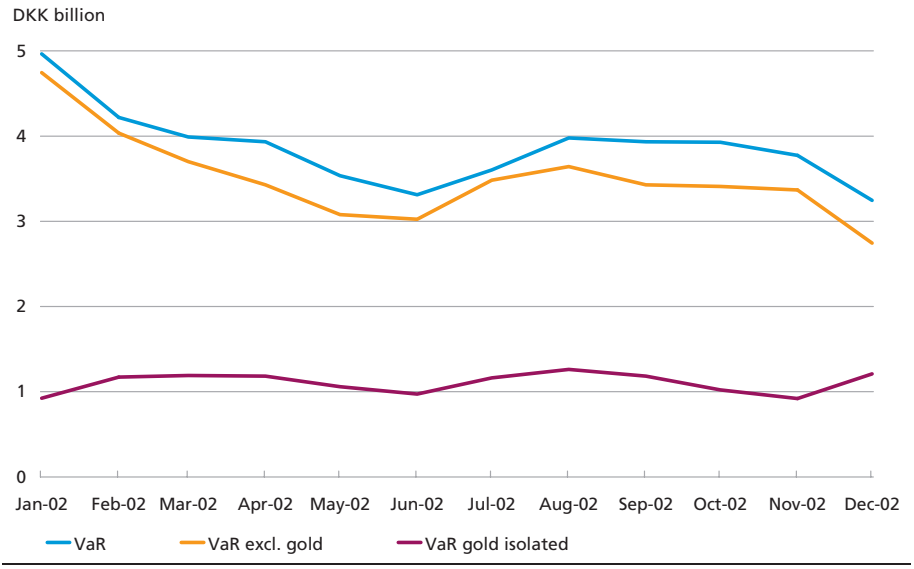
It should be noted that the risk-minimising dollar exposure is not constant, but may vary in step with the correlation in data or in Danmarks Nationalbank's other positions. The result is relatively robust, however.

RISK VIS-À-VIS GOLD

Danmarks Nationalbank has a (small) gold holding. It is a buy-and-hold portfolio, since Danmarks Nationalbank does not buy and sell gold on an ongoing basis, but maintains a constant physical holding of gold. The value of Danmarks Nationalbank's gold holding was approximately DKK 5.2 billion at end-2002. The gold holding is described in more detail in Chapter 4.

The gold holding contributes to the dollar exposure, since gold is priced and traded in US dollars. Viewed in isolation the gold holding thereby contributes to both the exchange-rate and the gold-price risk. This is equivalent to a US bond contributing to both the exchange-rate and the interest-rate risk. The dollar risk of gold is included in the total exposure vis-à-vis the dollar of which the major part is hedged by transformation to risk vis-à-vis the euro.

THE IMPACT OF THE GOLD HOLDING ON DANMARKS NATIONALBANK'S TOTAL VALUE-AT-RISK — Chart 6.2



Note: Calculations on holdings as of 30 December 2002 based on VaR with a probability of 95 per cent and a time horizon of 1 year.
Source: Danmarks Nationalbank.

The risk vis-à-vis the gold price in dollars is kept. In some periods the gold price can be highly volatile, so that viewed in isolation gold is a high-risk asset. However, the gold holding is relatively small. In addition, the holding contributes to a certain degree of diversification.

The diversification gain from holding gold can be illustrated by calculating Danmarks Nationalbank's market risk expressed as Value-at-Risk with gold, without gold and for gold in isolation. The result is shown in Chart 6.2. As the Chart shows, viewed in isolation, the gold holding had a Value-at-Risk of more than DKK 1 billion in 2002, but selling the gold would only reduce the overall Value-at-Risk to Danmarks Nationalbank by DKK ¼-½ billion.

USE OF CURRENCY OVERLAY TO TRANSFER OTHER CURRENCY RISKS TO EURO CURRENCY RISK

The exposure vis-à-vis non-euro currencies is transformed into exposure vis-à-vis the euro via foreign-exchange swaps whereby euro is purchased on forward terms.

The overlay of the exchange-rate exposure into euro means that it is not necessary to consider the related currency risk on selecting its interest-rate markets. In other words, interest-rate risk can be assumed without incurring currency risk. The transformation of the exchange-rate exposure in US dollars, pounds sterling and Swedish kronor into euro ensures a large reduction of the currency risk. Expressed as Value-at-Risk, the market risk would thus more than double from DKK 3.2 billion to DKK 6.7 billion if the exchange-rate exposure were not transformed into euro.[1] The reason for this increase is that the krone's volatility vis-à-vis the non-euro currencies is far greater than its volatility vis-à-vis the euro, cf. Table 6.1.

At end-2002 Danmarks Nationalbank had concluded foreign-exchange swaps for an amount equivalent to DKK 51 billion, cf. Table 6.2 showing the foreign-exchange outstandings. As the Table illustrates, an amount equivalent to DKK 144 billion had been invested in euro-denominated assets. The purchase of euro on forward terms increased the euro exposure to DKK 197 billion. Coincidently the exposure in the other currencies was eliminated, except for a minor US dollar exposure.

The Annex to this Chapter describes the currency overlay by both forward foreign-exchange contracts and by foreign-exchange swaps. The

[1] Calculations as of 30 December 2002. The effect of the transformation of the exposure vis-à-vis the non-euro currencies to euro depends on the date of calculation.

DANMARKS NATIONALBANK'S FOREIGN-EXCHANGE ASSETS Table 6.2

Market value, DKK billion	End-2001 net	End-2002			
		Investments	Gold	Forward purchases	Net
Euro	157	144	-	53	197
Pounds sterling	0	11	-	-11	0
Dollars	3	30	5	-32	4
Yen	0	1	-	-1	0
Swedish kronor	-	7	-	-7	0
Total	161	193	5	2	201

Note: Negative amounts indicate that Danmarks Nationalbank suffers a loss when the value of the foreign currency strengthens. The value of SDR is distributed on the respective currencies. The investment in Japanese yen solely relates to SDR.

bid-offer spread when concluding foreign-exchange swaps is very low, due to the high liquidity of the swap market, cf. Chapter 12.

SDR

Danmarks Nationalbank's account with the International Monetary Fund (IMF) is stated in SDR. SDR is a basket of currencies comprising the US dollar, the euro, the Japanese yen and the pound sterling. The krone value of SDR therefore depends on the krone's rate vis-à-vis the underlying currencies. Assets in SDR thus entail a risk vis-à-vis these currencies. In the compilation of Danmarks Nationalbank's exposures SDR are distributed on the underlying currencies. At end-2002 Danmarks Nationalbank's net claim on the IMF was 0.9 billion SDR, equivalent to DKK 8.3 billion. The breakdown on the underlying currencies is illustrated in Table 6.3.

COORDINATION WITH THE CENTRAL GOVERNMENT'S FOREIGN BORROWING

Since most of Danmarks Nationalbank's return is transferred to the central government, and the central government's foreign debt is primarily raised to provide Danmarks Nationalbank with an adequate foreign-exchange reserve, the currency distribution of the foreign-exchange reserve and the central-government debt is considered as one. This ensures that the overall risk to the central government and Danmarks Nationalbank is not unnecessarily high and that the proceeds of loans in one currency are not invested in another currency. In the period 1992-2000 the currency distribution of the foreign-exchange reserve and the central-government debt were subject to formalised coordination. To-

SDR-DENOMINATED PORTFOLIO BY CURRENCY, END-2002 Table 6.3

Billion currency units	USD	EUR	JPY	GBP	Total
Value in currency	0.5	0.4	17.8	0.1	
Value in Danish kroner	3.6	2.7	1.1	1.0	8.3

Note: Breakdown on the underlying currencies as follows: 1 SDR = 0.577 USD + 0.426 EUR + 21 JPY + 0.0984 GBP. The key is determined by the IMF and applies to the period January 2001-December 2005.
Sources: MF and own calculations.

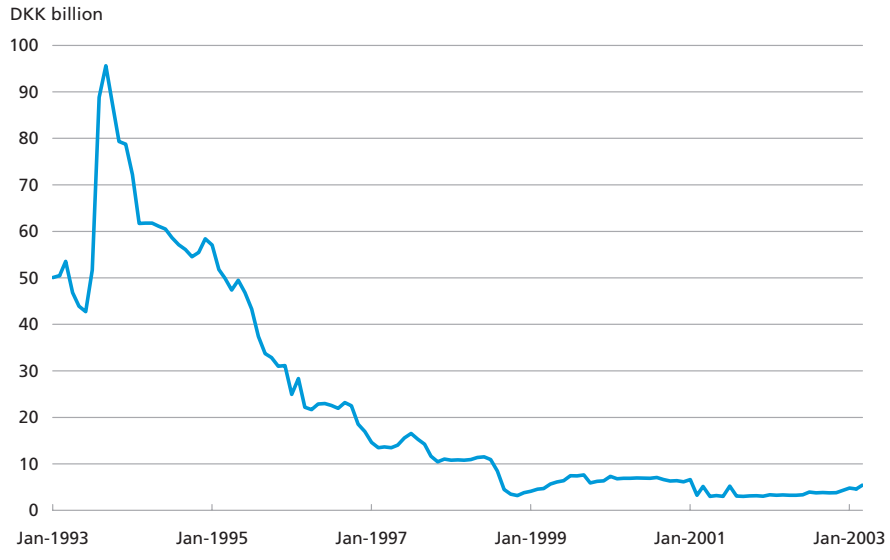
day the central government's foreign debt is only sensitive to fluctuations in the euro rate. At the same time, Danmarks Nationalbank's exchange-rate exposure is predominantly in euro, cf. Chart 6.3. This coordination ensures that the total currency risk is minor.

CURRENCY RISK UNDER THE COMMERCIAL PAPER PROGRAMME

Danmarks Nationalbank may enhance liquidity in foreign exchange via the central government's Commercial Paper (CP) programme, cf. Chapter 9 on Danmarks Nationalbank's liquidity risk. Under the programme, the central government raises a loan in euro or dollars and transfers the proceeds to Danmarks Nationalbank.

The central government's gain or loss in connection with a CP programme is offset by an equivalent loss or gain for Danmarks Nationalbank. Consequently, taking the central government and Danmarks Nationalbank as one, there is no currency risk attached to the CP pro-

DANMARKS NATIONALBANK'S EXPOSURE IN NON-EURO CURRENCIES Chart 6.3



Source: Danmarks Nationalbank.

CURRENCY-EXPOSURE LIMITS, END-2002 Table 6.4

DKK billion	EUR	GBP	SEK	USD	JPY	Other
Gross exposure	-	5 - 15	5 - 15	20 - 30	-	0 - 5
Net exposure	-	-0.2 - 0.2	-0.2 - 0.2	3,6 - 4,4	-0,2- 0,2	-0.2 - 0.2

Note: Other currencies comprise CAD and CHF.
Source: Danmarks Nationalbank.

gramme. However, in connection with CP issues in dollars the currency risk of both Danmarks Nationalbank and the central government is transformed to euro. This reduces the risk of large gross losses. In connection with the overlay the central government purchases dollars against euro on forward terms from Danmarks Nationalbank.

MANAGEMENT AND CONTROL OF THE CURRENCY RISK

Danmarks Nationalbank's currency risk is managed via limits fixed for the market value in kroner of the individual currencies. Limits are fixed for both the gross exposure and the net exposure, i.e. the foreign-exchange exposure before and after conclusion of foreign-exchange swaps. The level of the gross exposure is determined so that the desired interest-rate risk can be assumed, while also ensuring a certain diversification across capital markets.

The limits at end-2002 are shown in Table 6.4. As the Table shows, there are no limits to the euro exposure. The reasons are that the size of the foreign-exchange reserve is determined by the need for interventions, and that in principle the changes in the reserve are in euro.

The foreign-exchange exposure is calculated and reported on a daily basis in the PSS system, cf. Chapter 14.

ANNEX: CURRENCY OVERLAY VIA FORWARD FOREIGN-EXCHANGE CONTRACTS AND FOREIGN-EXCHANGE SWAPS

Forward foreign-exchange contracts

A forward foreign-exchange contract is an agreement with counterparty to exchange amounts in different currencies at a future time and at an agreed exchange rate.

Typically Danmarks Nationalbank's forward foreign-exchange contracts have a maturity of 1-2 months. The agreed exchange rate, the forward rate, will depend on the spot rate and the difference between the short-term interest rates in the currencies included in the forward contract.

Forward foreign-exchange contracts can be used to e.g. eliminate the currency risk or to transform the risk from one currency to another.

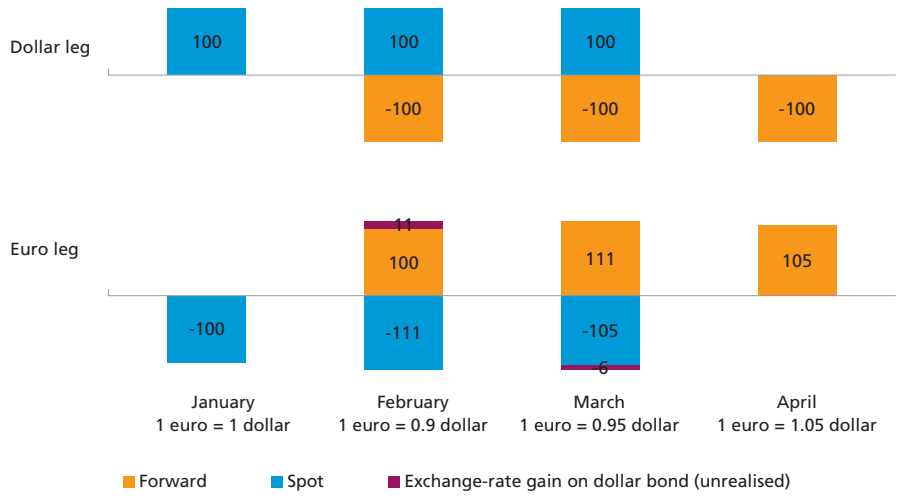
If the risk is to be eliminated over a longer period, new forward contracts must be rolled over on an ongoing basis.

Example of a forward foreign-exchange contract

It is assumed that Danmarks Nationalbank wishes to expand its interest-rate exposure in the US market. It therefore purchases dollar-denominated bonds for a market value of USD 100 million. The dollar amount is procured by selling euro for dollars.

This investment has augmented Danmarks Nationalbank's risk vis-à-vis the dollar. The risk is transformed to euro via forward foreign-exchange

CASH FLOWS IN FORWARD FOREIGN-EXCHANGE CONTRACT — Chart 6.4



Source: Danmarks Nationalbank.

contracts whereby, on a future date, euro will be received and dollars delivered. The payment flows are illustrated in Chart 6.4 and explained below. To simplify the example, it is assumed that the forward rate is equivalent to the spot rate, and that the market value of the dollar bonds remains USD 100 million.

In *January* USD 100 million is purchased spot against sale of euro at a rate of 1 dollar per euro (the USD 100 million is subsequently used to purchase US bonds). The exposure in dollars is transformed into an exposure in euro via a forward contract whereby USD 100 million is payable and EUR 100 million is receivable when the forward contract expires in February.

In *February* the USD 100 million is procured by selling euro for dollars spot. If the dollar has strengthened to 0.9 dollar per euro, Danmarks Nationalbank will have to pay EUR 111 million to buy USD 100 million spot. Since only EUR 100 million is received under the forward contract, it has cost EUR 11 million in isolated terms. However, this is offset by the increase in the euro value of the underlying dollar position by EUR 11 million to EUR 111 million as a consequence of fluctuations in the exchange rate. A new forward contract is now entered into, under which USD 100 million is payable and EUR 111 million is receivable when the contract expires in March.

In *March* the February procedure is repeated. The USD 100 million payable under the forward contract is procured by selling euro for dollars spot. If the dollar has weakened to 0.95 dollar per euro, Danmarks Nationalbank will have to pay EUR 105 million to buy USD 100 million spot. Since EUR 111 million is received under the forward contract, it has achieved a gain of EUR 6 million in isolated terms. However, this is offset by the euro value of the underlying dollar position having fallen by EUR 6 million as a result of the exchange-rate fluctuation. A new forward contract is now entered into, whereby USD 100 million is payable and EUR 105 million is receivable when the forward contract expires in April.

In *April* the dollar bonds are sold and the proceeds are used for the dollar payment under the forward contract.

By continuously combining forward contracts with spot transactions the dollar exposure can be transformed into euro for as long as is required. There will be ongoing losses and gains on the forward contracts as a result of exchange-rate fluctuations, but these will be offset by gains and losses on the dollar bond.

Foreign-exchange swaps

Actual purchase and sale of foreign exchange on forward terms takes place via foreign-exchange swaps. A foreign-exchange swap is a forward

contract and spot transaction in the same instrument. In a foreign-exchange swap – as in a forward contract – amounts in different currencies are thus exchanged with counterparty at a future time, at a rate agreed in advance. This is combined with an agreement for a reverse spot transaction. This way the simultaneous spot and forward transactions illustrated in figure 6.4 are transacted as a swap and not as separate transactions.

The payment flows in the foreign-exchange swap are identical to the payments flows for hedging via forward contracts (combined with spot transactions), but the foreign-exchange swap has the advantage over the forward contract that the counterparty's currency risk is not affected by the conclusion of a swap. Foreign-exchange swaps therefore have high liquidity, which supports sound price formation.

7. Interest-Rate Risk

Danmarks Nationalbank has invested part of the foreign-exchange reserve and the portfolio of domestic securities in bonds. In the long run these investments lead to a higher return than very short-term investments, since the long-term interest rates are usually higher than the short-term interest rates. However, the higher expected earnings also entail additional *interest-rate risk*.

Bond investments are part of Danmarks Nationalbank's strategy to achieve a good return and cannot be regarded as part of its role as monetary authority. Even though a high return is not in itself a vital objective, Danmarks Nationalbank does seek a higher return on the foreign-exchange reserve and the domestic securities portfolio than can be obtained from money-market investments. However, this must be achieved within the framework of the role as monetary authority, cf. Chapter 1.

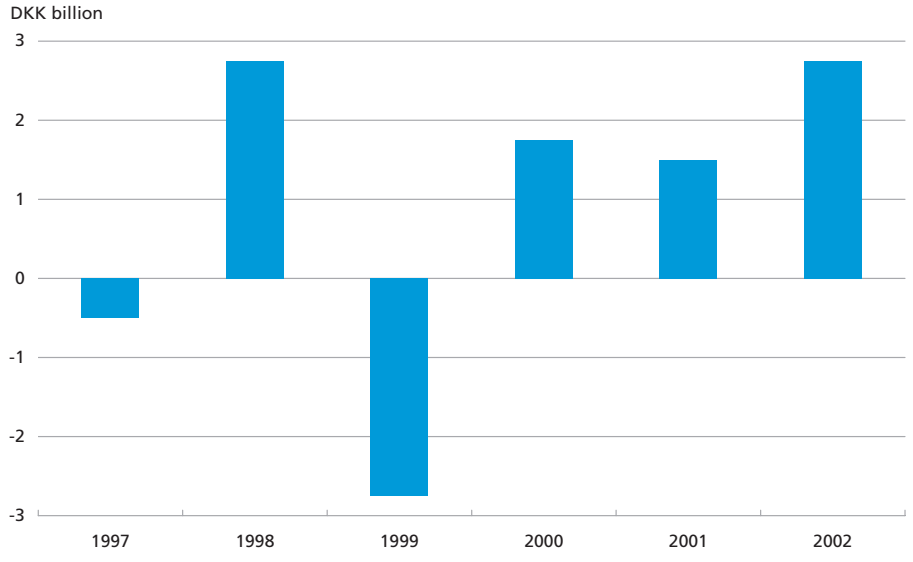
Danmarks Nationalbank's interest-rate risk is considered on an aggregated basis. At least once a year the Board of Governors sets out an overall value for the krone duration, i.e. how much the portfolios' market value in *kroner* changes on a shift in the yield curve by 1 percentage point. In 2003 this value is DKK 2.4 billion. By using an absolute measure, krone duration, the level of interest-rate risk is independent of the size of the portfolios, and in principle corresponds to maintaining a fairly constant duration for the more stable net capital.

HOW DOES DANMARKS NATIONALBANK ASSUME INTEREST-RATE RISK?

By placing part of the foreign-exchange reserve and the portfolio of domestic securities in bonds, Danmarks Nationalbank assumes interest-rate risk in the expectation of excess return compared to short-term money-market investments. Interest-rate risk is the area where Danmarks Nationalbank, as a result of its role as financial institution, has opted to assume the greatest risk, in order to achieve a higher return. The interest-rate-driven capital gains or losses are therefore considerable, cf. Chart 7.1, and Danmarks Nationalbank's earnings are sensitive to interest-rate developments.

In addition to the interest-rate-driven capital gains or losses, an upward sloping yield curve will also make it possible to achieve a higher

ESTIMATE OF INTEREST-RATE-DRIVEN CAPITAL GAINS OR LOSSES Chart 7.1

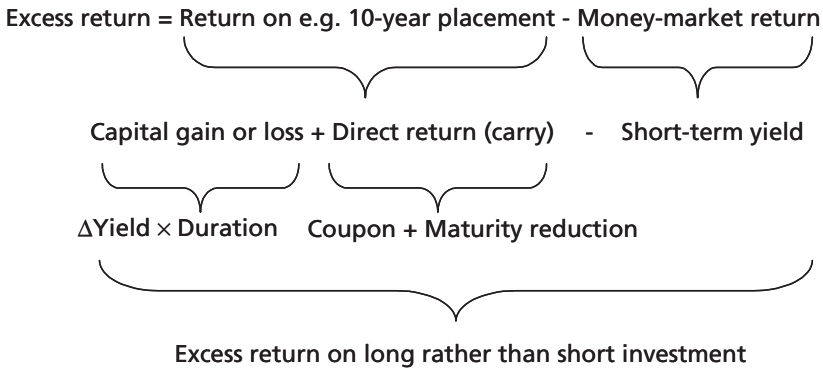


Note: Calculated as changes in prices less estimates of mathematical price adjustments (the effect of maturity reduction).
Source: Danmarks Nationalbank.

direct return on long-term rather than short-term investments. The excess return is illustrated in Chart 7.2.[1]

The return on 10-year bonds is partly a current *direct return,* reflecting the return with unchanged market conditions, i.e. coupon interest and

EXCESS RETURN ON LONG RATHER THAN SHORT INVESTMENT Chart 7.2



Note: The effect of maturity reduction is also known as the "pull to par" effect and here it comprises the effect from the yield curve not being flat (roll down). See Appendix C on effects of maturity reduction and Appendix D for a detailed description of decomposition of return.

[1] Only interest-rate risk is considered, which is reasonable for bullet central-government loans in highly rated countries. For other types of instruments credit, liquidity and prepayment risks, etc. may be relevant.

capital gains or losses as a result of the reduction of remaining maturity, and partly *capital gains or losses* as a consequence of interest-rate developments. Price changes depend on the bond's exposure to interest-rate changes and the actual development in interest rates.

When money-market investments are replaced by bond investments, Danmarks Nationalbank loses the return in the money market, but gains a return on the bond comprising the direct return as well as any capital gains or losses resulting from the development in interest rates.

DOES INTEREST-RATE RISK ENTAIL AN EXCESS RETURN?

Normally short-term interest rates are lower than long-term interest rates. The yield structure is said to be upward sloping. This entails a higher direct return, reflecting among others the premium on tying up money for a longer period. Whether an overall *excess return* is achieved in the long run when investing in a more long-term bond rather than in a short-term bank deposit, cannot be determined beforehand. If the interest rate has increased, the higher direct return on the bond may have been cancelled by a falling bond price. The steeper the yield curve, the more the interest rate must increase over the period for the gain to be cancelled by capital losses. If the bond yield is decreasing, both a current gain and a capital gain will be achieved.

The strategy of investing long rather than short can be seen as expectations that interest rates will not increase so much that a higher direct return is offset by capital losses. An expected excess return is an expectation that actual interest rates will not increase as much as the implied forward interest rates would indicate.

The implied forward interest rates are the interest rates that equal the return on investments for a given period across instruments with different maturity. The implied forward interest rates can thus be regarded as break-even interest rates between various strategies, cf. Box 7.1. Forward interest rates reflect many circumstances, e.g. the expectations of the future interest-rate development and the risk premium on tying up funds for long periods.

Empirics of excess return on investing long rather than short

Historically, the long-term interest rates have on average been higher than the short-term interest rates. In other words, over a certain period a higher direct return could be achieved from investing in long-term bonds than from investments at variable interest rates, e.g. short-term bank deposits. In addition, for a long period interest rates have been falling, cf. Chart 7.3, which has lead to interest-rate-driven capital gains.

ZERO-COUPON YIELDS AND FORWARD INTEREST RATES Box 7.1

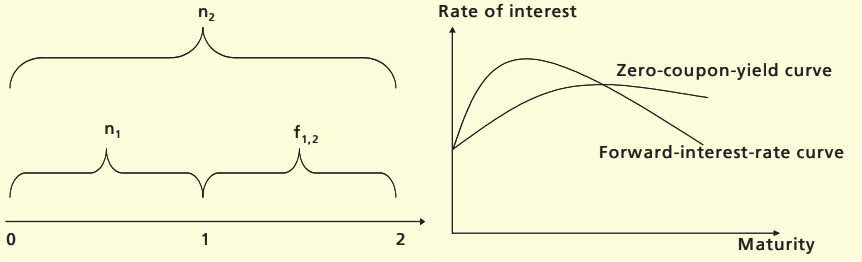
The zero-coupon yield is the yield to maturity on a zero-coupon bond that has only one payment, the principal, which falls due on maturity. On the basis of the zero-coupon yields it is possible to determine the implied forward interest rates, i.e. the interest rates applying between various dates, if the return is to be the same regardless of the investment strategy.

The implied forward interest rates are determined on the basis of a break-even argument. If, for instance, an investment in a 2-year zero-coupon bond must yield the same return as an investment in two successive 1-year zero-coupon bonds, then this should hold:

(1) $(1+n_2)^2 = (1+n_1)*(1+f_{1,2})$

The relationship is illustrated in the left-hand side of the Chart. n_1 and n_2 are respectively the 1-year and 2-year zero-coupon yields today. $f_{1,2}$ is the 1-year forward interest rate in period 2, i.e. the 1-year interest rate to apply in one year's time if an investment in a 2-year bond today is to correspond to an investment in a 1-year bond today with reinvestment in a 1-year bond in one year's time.

RELATIONSHIP BETWEEN ZERO-COUPON YIELDS AND FORWARD INTEREST RATES



If the 1-year interest rate in one year's time is expected to be lower than the 1-year forward interest rate indicates, and these expectations are fulfilled, there will be a higher yield from investing in the 2-year bond today than from investing in the 1-year bond today with reinvestment of the funds in a 1-year bond in one year's time.

This can be illustrated via an example. Assume that the 1-year zero-coupon yield is 4 per cent, and the 2-year zero-coupon yield is 5 per cent. The 1-year forward interest rate for period 2 ($f_{1,2}$) is equal to $((1.05^2/1.04)-1)= 6.01$ per cent.

An investment in the 2-year zero-coupon bond yields a return of $((1.05)^2-1)= 10.25$ per cent. The yield from investing in two successive 1-year zero-coupon bonds is not known *ex ante*, since the 1-year interest rate in one year's time is not known. If the implied forward interest rate is realised, the total yield will be 10.25 per cent ((1.04*1.0601)-1), cf. the definition of the forward interest rate. If the 1-year interest rate in one year's time is 5 per cent, however, the yield will be 9.2 per cent ((1.04*1.05)-1). In other words, the yield will be lower than on the investment in the 2-year bond, which is also reflected in the fact that the rate of interest has risen less than the forward interest rate indicated.

CONTINUED Box 7.1

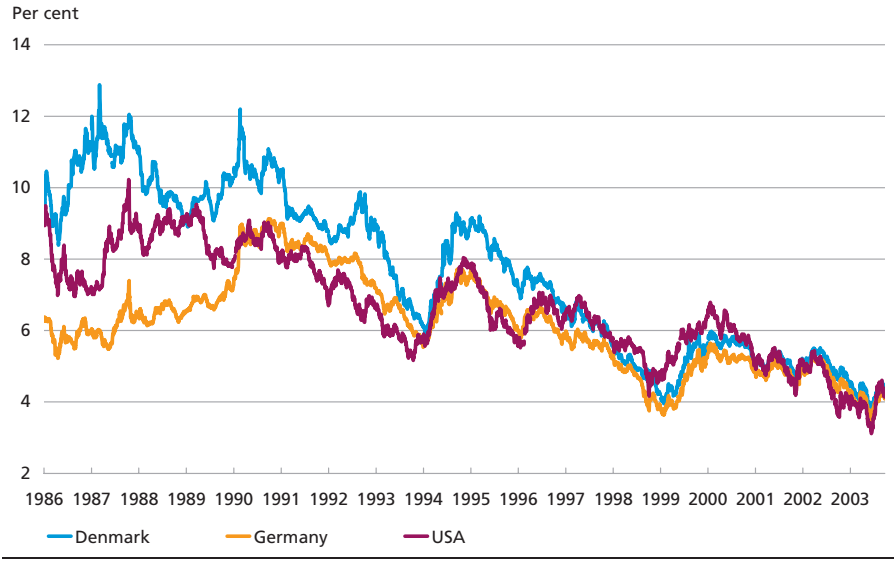
Even though the 1-year interest rate has increased from 4 per cent to 5 per cent, it was most worthwhile to invest in the long-term (2-year) bond rather than the short-term bond (two successive 1-year bonds). This is the case for as long as the interest rate increases less than the forward interest rate indicates.

The forward-interest-rate structure can be derived for all maturities. For instance, the 6-year forward interest rate in one year's time is the equilibrium interest rate that equals the yield on a 7-year zero-coupon bond with the yield on two successive investments in a 1-year and a 6-year zero-coupon bond. In this case the forward interest rate should be viewed against the expectations of the 6-year interest rate in one year's time.

The relation between the zero-coupon-yield and forward-interest-rate structures is illustrated on the right-hand side of the Chart. If the zero-coupon yield curve is upward sloping, the forward interest rate will be higher than the zero-coupon yield, and vice versa. This entails that the forward-interest-rate curve intersects the zero-coupon rate at its maximum.

Empirical studies show that there is often an excess return related to interest-rate risk. The relative excess return appears to be highest at the short end, and the return is volatile.[1] Box 7.2 describes an analysis that supports this.

10-YEAR GOVERNMENT-BOND YIELDS IN DENMARK, GERMANY AND THE USA Chart 7.3



Source: EcoWin.

[1] See e.g. Fama (1984) and Ilmanen (1996A).

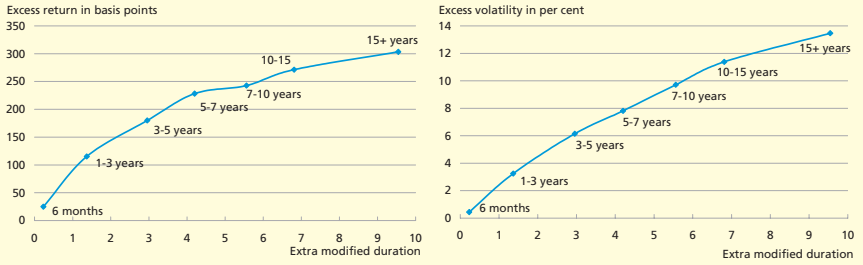
ANALYSIS OF THE GAIN ON ASSUMING INTEREST-RATE RISK Box 7.2

An analysis of US government bonds for the period 1978-September 2001 shows the reward of a higher return from increasing the duration of the investment and thereby the interest-rate risk.[1]

The left-hand side of the Chart shows the excess return on an investment in securities with different maturities compared to the return on a current 3-month investment. The excess return is set against the higher duration in relation to a 3-month investment. By return is meant the total return, i.e. both the direct return and capital gains/losses.

The longer duration entails a higher interest-rate risk, and the fluctuations in the excess return increase. This is illustrated on the right-hand side of the Chart, where the volatility in the excess return is seen in relation to the duration.

EXCESS RETURN IN RELATION TO 3 MONTH INVESTMENT



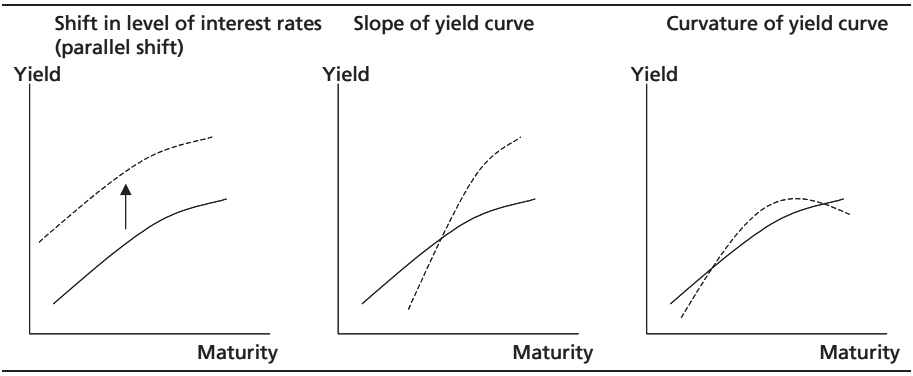
Note: Estimated for the period 1978-September 2001.
Source: Berndsen (2003).

The return increases with the duration, but not linearly, and the relative reward appears to be highest at the short end where the yield structure is typically steep. However, the result is greatly influenced by e.g. the period and structural conditions, etc. In the period under review interest rates were generally falling, which led to interest-rate-driven capital gains.

[1] See Berndsen (2003). Ilmanen (1996B) reaches a similar conclusion based on US data for the period 1970-94.

It would be incorrect to say that an excess return is systematically always achieved on long rather than short positions. This depends on several factors, e.g. the development in interest rates in the period considered, and the selection of securities, correlations, structural circumstances, etc. When the yield curve is upward sloping, a higher direct return is still achievable on long-term positions rather than short-term positions, but changes in the interest-rate level will influence the level of capital gains or losses. In view of the current low level of interest rates, capital gains cannot be expected to the same degree as in the recent long period of falling interest rates. On the contrary, the higher direct return may be offset by capital losses as a result of rising interest rates.

FACTORS DRIVING THE YIELD CURVE Chart 7.4



MEASURING INTEREST-RATE EXPOSURE

As stated above, the return on a bond investment depends on the development in interest rates. Several factors drive the yield curve, cf. Chart 7.4. The general level of interest rates, or the slope of the yield curve, may change. A third factor is the curvature, which can also vary. The contribution to earnings from the development in interest rates may thus be broken down into several factors, cf. also Chapter 13.

By applying a statistical analysis known as a principal-component analysis, 97 per cent of the variation in the Danish yield curve can be explained by the three circumstances in Chart 7.4.[1] The most important factor affects the general level. This factor, which shifts the entire yield curve up and down, explains approximately 70 per cent of the change. The second most important factor affects the steepness of the curve. This factor, which changes the slope of the yield curve, explains approximately 23 per cent of the change. Finally, almost 4 per cent of the change in the yield curve can be explained by a factor affecting its curvature. The analysis of principal component is elaborated on in the Annex to this Chapter.

The duration concept

A measure of a bond's exposure to parallel shifts in the yield structure is the *duration*, which is an expression of the bond's percentage price change on a parallel shift in the yield curve. The duration is calculated using the slope (tangent) at a point on the price/yield curve. The percentage price change on a change in interest rates thus only applies to marginal changes around the point, unless the price/yield curve is linear.

[1] The principal components are estimated on the basis of data for the monthly change in Danish zero-coupon yields in the period February 1987-July 2001, cf. the Annex to this chapter.

DURATION Box 7.3

The Macauley duration is defined as the percentage change in a bond's price, P, on a change in the yield to maturity (1+y) by 1 per cent. The Macauley duration is thus an elasticity, calculated as follows:

$$\text{Macauley duration} = -\frac{dP}{d(1+y)} \times \frac{(1+y)}{P}$$

When calculating the duration a change in the zero-coupon-yield structure is often applied rather than a change in the yield to maturity. An alternative to the Macauley duration is the modified duration, which states the percentage change in a bond's price on a change in either the yield to maturity or the zero-coupon-yield structure by 1 percentage point. Modified duration thus states the relative price change in connection with an *absolute* change in yield, whereas the Macauley states the relative price change on a *relative* change in yield. Modified duration is calculated as follows:

$$\text{Modified duration} = -\frac{dP}{d(1+y) \times P} \times \frac{1}{100} = \frac{\text{Macauley duration}}{1+y} \times \frac{1}{100}$$

Duration and modified duration express price exposure in relation to the funds invested. In the management of Danmarks Nationalbank's portfolios it is of less interest to relate exposure to the funds invested. Consequently, krone duration, i.e. the invested *kroner* multiplied by the *modified duration,* is applied. This states the absolute price change on a change in the yield to maturity or zero-coupon-yield structure by 1 percentage point. When calculating Danmarks Nationalbank's krone-duration target a change in the zero-coupon-yield structure, is applied.

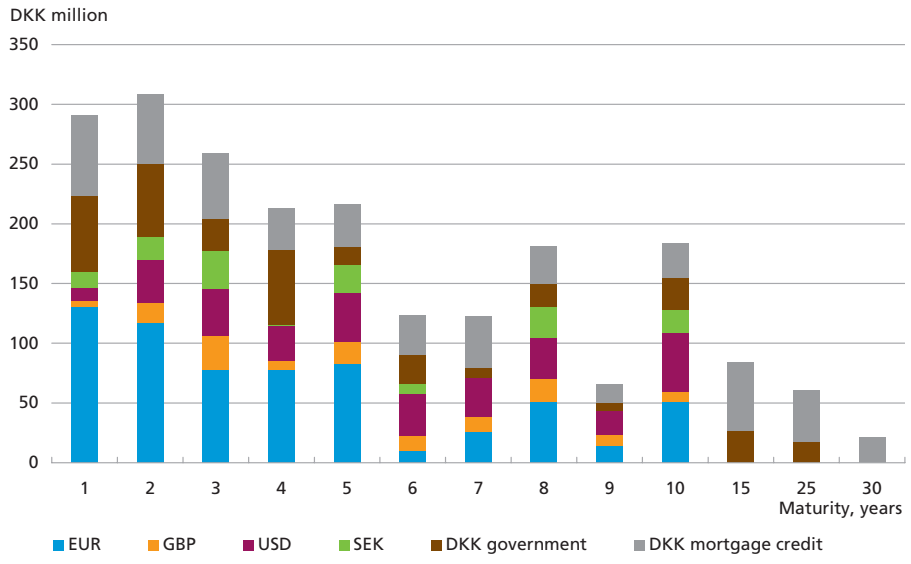
The krone duration/100 is also frequently used. This is known as basis point value (BPV) and is the absolute price change on a change in yield by 1 basis point. It should be noted that for both the krone duration and BPV, as for modified duration, absolute yield changes are considered. The krone duration is expressed as:

$$\text{Krone duration} = -\frac{dP}{d(1+y)} \times \frac{1}{100} = -\frac{dP}{d(1+y) \times P} \times \frac{P}{100} = \text{Modified duration} \times P$$

The more the curve bends, the less precise the scaling of the price exposure to major interest-rate changes will be, cf. also Appendix A to this book. The duration concept is described in more detail in Box 7.3.

As explained above, most of the variation in the yield curve can be attributed to parallel shifts, and this supports the use of the duration concept. However, the latter does not capture all of the risk factors behind the yield curve. To take care of this, the interest-rate exposure vis-à-vis each maturity can be calculated (key-interest-rate duration).

INTEREST-RATE EXPOSURE BY CURRENCY AND MATURITY, END-2002 Chart 7.5



Note: The Chart shows capital losses on an increase in interest rates by 1 percentage point in the yield for a given maturity.
Source: Danmarks Nationalbank.

Key-interest-rate duration

Instead of considering the exposure to changes in the entire yield structure it may be relevant to consider a portfolio's exposure to interest rates with different maturities. Applying a shock to the interest rate for a given maturity, and then calculating the price change resulting from the shock, calculates such key-interest-rate durations. In connection with identical interest-rate shocks to all key interest rates, a summary of the duration of the individual key interest rates will correspond to the aggregate duration in connection with a parallel shift.

The individual key interest rates are correlated to a high degree since a very large share of their changes can, as stated, be explained by parallel shifts in the yield curve.

Key-interest-rate duration is applied to e.g. Value-at-Risk (VaR) calculations and stress tests, and in analyses of interest-rate exposure to "twists" in the yield curve. Chart 7.5 shows Danmarks Nationalbank's interest-rate exposure broken down by currency and maturity.

DANMARKS NATIONALBANK'S INTEREST-RATE-EXPOSURE TARGETS

Danmarks Nationalbank's interest-rate exposure is considered on an aggregated basis, and the size of the individual portfolios must not in

itself affect the level of the interest-rate risk. Consequently the interest-rate exposure of the foreign-exchange reserve and the portfolio of domestic securities is managed according to a target for the *krone duration*, i.e. how much the market value in *kroner* of the portfolio changes on a change in the yield curve of 1 percentage point, cf. also Box 7.3.

The *duration* of the portfolio must thus be adjusted to changes in the value of the portfolio. For instance, if the value of the foreign-exchange reserve increases, the average duration must be lowered in order to keep the krone duration unchanged. The level of the interest-rate exposure is therefore independent of the size of the foreign-exchange reserve. In principle this corresponds to maintaining a fairly constant duration for the more stable net capital.

The size of the foreign-exchange reserve depends on the market conditions. The reserve varies as a consequence of the fixed-exchange-rate objective. In recent years the value of the foreign-exchange reserve has increased, and the average duration has fallen accordingly in order to maintain the interest-rate risk. The level of the krone duration to a high degree reflects a choice of risk level based on the market conditions and expectations of the future interest-rate development, cf. below.

MANAGEMENT OF INTEREST-RATE EXPOSURE

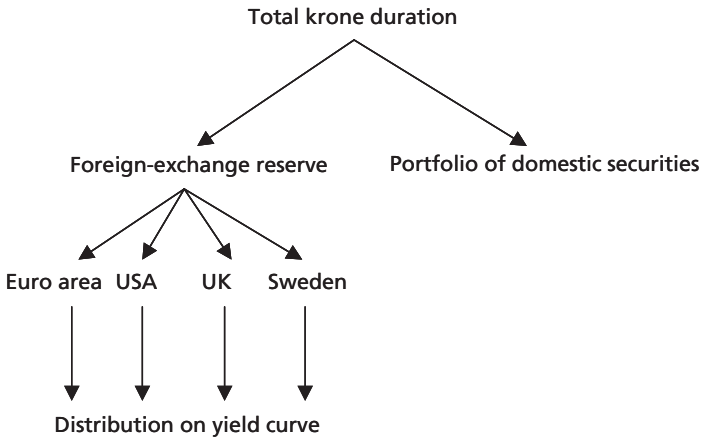
The actual interest-rate exposure is a result of decision making on several levels. At least once a year an aggregate value is determined for Danmarks Nationalbank's krone duration on a change in interest rates of 1 percentage point. In 2003 the value is DKK 2.4 billion. The value is distributed on respectively the foreign-exchange reserve and the portfolio of domestic securities. These overall values for the krone duration are known as *neutral values* and are a strategic choice for Danmarks Nationalbank.

Fluctuation bands are likewise determined for the neutral values, i.e. the maximum deviation of the krone duration from the neutral value. The krone duration may typically deviate by up to 20 per cent from the neutral value. If interest-rate expectations change significantly, the neutral value must be changed.

The neutral values and fluctuation bands are determined on the basis of an assessment of Danmarks Nationalbank's total financial risks and reflect a long-term trade-off between risk and return. VaR calculations and stress tests are part of the assessment, but there are no explicit targets for these.

The decision is evaluated every quarter, and it is possible to change the strategic framework during the year. This flexibility is important,

DISTRIBUTION OF KRONE DURATION Chart 7.6



since interest-rate expectations are not stationary, and the timing of a strategic shift is important.

The total neutral krone duration of the foreign-exchange reserve is distributed on the financial markets in the euro area, the USA, the UK and Sweden. The choice of country is based for example on an assessment of the markets' liquidity, the accessibility of market information, and the macroeconomic conditions. The distribution on several countries is primarily designed to spread the risk of capital losses if interest rates increases. The various financial markets do tend to show a degree of co-variation, but this co-variation is not perfect, so that the risk of capital losses is reduced when the interest-rate exposure and positions are spread on several markets.[1] Finally, the krone duration for the individual countries is distributed on the yield curve. The distribution of the krone duration is illustrated in Chart 7.6.

Most of Danmarks Nationalbank's interest-rate exposure relates to the bond holdings in the foreign-exchange reserve and the portfolio of domestic securities. In addition, the interest-rate exposure is influenced to a minor degree by a number of business areas, including outstandings with Danish Ship Finance, cf. Appendix B. Table 7.1 shows Danmarks Nationalbank's aggregate interest-rate exposure by currency.

[1] Using forward contracts makes it possible to assume interest-rate risk for the various markets without assuming the concurrent currency risk, cf. Chapter 6.

DANMARKS NATIONALBANK'S AGGREGATE INTEREST-RATE EXPOSURE Table 7.1

Capital loss in DKK billion on a general increase in interest rates by 1 percentage point	End-2002
Kroner	0.7
Euro	0.6
Pounds sterling	0.1
USD	0.6
Swedish kronor	0.2
Total	2.2

Note: The Table shows the actual krone duration for Danmarks Nationalbank's aggregate interest-rate exposure, i.e. for the foreign-exchange reserve, the portfolio of domestic securities, Danish Ship Finance schemes, the banks' net position, etc.
Source: Danmarks Nationalbank, *Report and Accounts,* 2002.

MANAGEMENT OF INTEREST-RATE EXPOSURE ON THE FOREIGN-EXCHANGE RESERVE

Appropriate diversification of the risk is achieved by spreading the foreign-exchange reserve on various financial markets (countries), and by spreading the investment in individual financial markets on different maturities on the yield curve. This is reflected in the benchmark structure for the foreign-exchange reserve.

Choice of benchmark

A benchmark portfolio is a fictive portfolio created to be a reference portfolio with which the actual portfolio can be compared. The choice of benchmark reflects Danmarks Nationalbank's risk profile.

Danmarks Nationalbank has constructed its own benchmark portfolio for the foreign-exchange reserve. An alternative option would be to apply an index from one of the large investment banks, e.g. a market-weighted index. This would be time-saving, but also entail a number of drawbacks. There would not be the same possibility of tailoring the benchmark to Danmarks Nationalbank's chosen investment strategy and there would be a lack of transparency regarding the structure of the index. Finally, it would limit the opportunities to analyse and decompose return and performance, cf. Chapter 13. Another alternative consists of combining a number of indices from the investment banks so that the combined index reflects Danmarks Nationalbank's required risk exposure. However, this requires considerably more work than using a market-weighted index, and there would still be problems with transparency and the possibilities of decomposition of the combined benchmark. Therefore Danmarks Nationalbank has opted for its own benchmark that allows for a more active choice of where to invest the foreign-exchange reserve. In addition, a self-developed benchmark provides

greater flexibility since its components can be changed, e.g. the distribution over the yield curve, the selection of individual securities in the benchmark, and current rebalancing to ensure a fixed krone duration.

Distribution of the foreign-exchange reserve on the yield curve

For the chosen level of krone duration an appropriate risk diversification is sought. This is primarily achieved by spreading the foreign-exchange reserve on different financial markets. Moreover, the investments in the individual financial markets are distributed on various maturities over the yield curve.[1] The distribution by maturity constitutes the overall structure of the benchmark for investments in the individual financial markets. The distribution of the interest-rate risk by maturity serves several purposes, including diversifying the interest-rate risk, return and investment options, and simplifying day-to-day administration. It is difficult to determine "optimum" distributions of krone duration over the yield curve that ensure the optimal return/risk combination. Therefore a pragmatic approach has been taken, whereby in principle the krone duration is distributed evenly across the yield curve. Danmarks Nationalbank thus has equal exposure across the entire yield curve from 0 to 10 years.

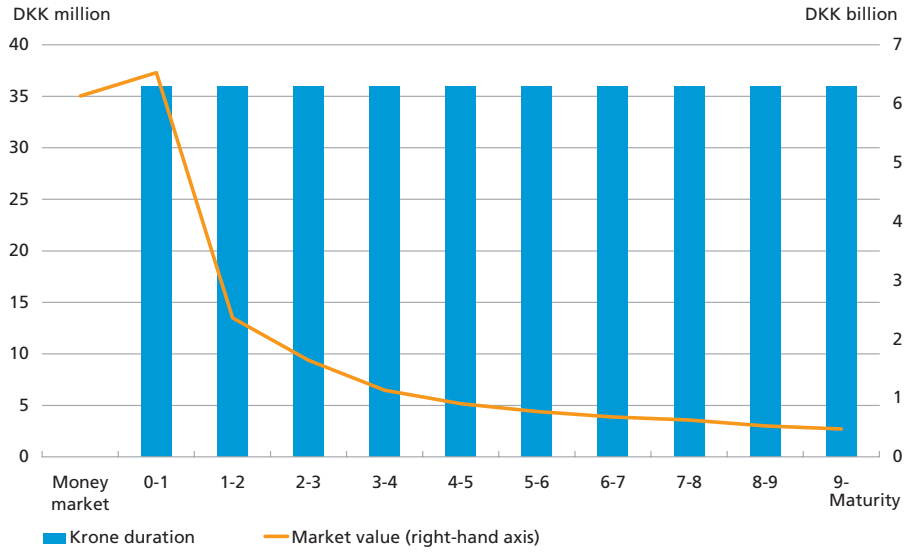
The specific benchmark is hereafter found by attributing market values to specific bonds and money-market investments in the selected maturities, so that the total market value of these securities corresponds to the size of the foreign-exchange reserve. The choice of securities reflects intervention and liquidity considerations. These are met in the bond market by selecting liquid government bonds as benchmark instruments. In the money market, short-term bank deposits can be released immediately for intervention, and are therefore included in the benchmark. The securities structure of the benchmark takes into account that the money-market investments may not exceed credit lines. This can be achieved by using many different bank deposits as money-market instruments. For practical reasons, however, only bank deposits at the Bank for International Settlements (BIS) are applied as a money-market instrument in the benchmark for all portfolios, since BIS has been allocated a sufficiently high credit line.[2] The yield on deposits at BIS is lower than in the money market, which should be taken into account when assessing performance.

---

[1] A smaller part of the foreign-exchange reserve is invested in gold and SDR. Gold can be lent for a maximum period of 6 months. SDR are remunerated by the IMF with a 3-month interest rate. Because of the short duration and the modest size of these holdings the contribution to the overall interest-rate risk from these holdings is limited.

[2] Deposits with BIS entail smaller credit risks than deposits with commercial banks, therefore the BIS deposits have a relatively high credit line, see Box 10.3 in Chapter 10 on credit risk.

EXAMPLE OF HOW THE DISTRIBUTION OF KRONE DURATION AFFECTS THE DISTRIBUTION OF MARKET VALUE BY MATURITY Chart 7.7



Note: The size of money-market investments varies from day-to-day. On the day shown in the example money-market investments amount to DKK 35 billion.
Source: Danmarks Nationalbank.

For each of the four main currencies (euro, US dollar, pound sterling and Swedish kronor) the krone duration is distributed on maturities ranging from 0 to 10 years. The maturities are divided into 1-year buckets, and each bucket is assigned a proportion of the total krone duration. The market value in a given bucket is calculated as the krone duration divided by the modified duration. Remaining funds are invested as bank deposits at variable interest rates.

Chart 7.7 illustrates the relation between market value and krone duration. The krone duration is identical for each of the 10 maturity buckets, i.e. equal distribution. For longer maturities the duration of a bond will be higher, all other things being equal, and the market value that achieves a given krone duration will therefore be lower. In view of the equal distribution of the krone duration the market value declines with maturity. The market value of the money-market investments comprises the difference between the total investments and the bond investments.

The total investment in each currency is determined so as to achieve a suitable level for the money-market investments. For the pound sterling and the Swedish kronor this means that there are sufficient funds to take positions along the yield curve, while the money-market investments are held at a very low level. For the US dollar, a slightly higher level for the money-market investments has been chosen, since the US dollar is readily available as an intervention currency.

The liquidity reserve requires a certain level of money-market investments in euro. Typically, interventions will only result in movements in these investments. If the money-market investments in euro decrease below a desirable level, they may be augmented by e.g. changing the maturity distribution of the krone duration, cf. Chapter 9 on liquidity management. Likewise it is possible to reduce the money-market investments if these are assessed to be too high. A high level of money-market investments is not always deemed appropriate, since it entails an increase in the credit risk, cf. Chapter 10.

Taking positions

On the basis of the neutral values and the fluctuation bands, *tactical* margins for the krone duration of the foreign-exchange reserve are determined on a monthly basis. These margins narrow the fluctuation bands around the neutral values.

The tactical margins reflect the expected development in interest rates in the various financial markets in the near future. If interest rates are expected to fall, the tactical margins are set at the upper end of the neutral fluctuation band, i.e. the krone duration of the portfolio is increased to achieve a higher capital gain in the event of falling interest rates.

Within these tactical margins, *actual* positions are taken on the basis of the expected development in interest rates in the short term. The actual krone duration in the various financial markets thus deviates from the neutral values within the margins that are set.

The decision-making process and the margins for Danmarks Nationalbank's interest-rate exposure via the foreign-exchange reserve are summarised in Chart 7.8. The blue curve indicates the neutral value for the krone duration, while the yellow curves indicate the upper and lower fluctuation bands. The Board of Governors decides these strategic margins. The maroon curve indicates the tactical position with equivalent fluctuation bands (green curves). Finally, is shown the actual position (brown curve), which can entail both greater and smaller krone duration than the neutral level and the tactical position, as the Chart shows.[1]

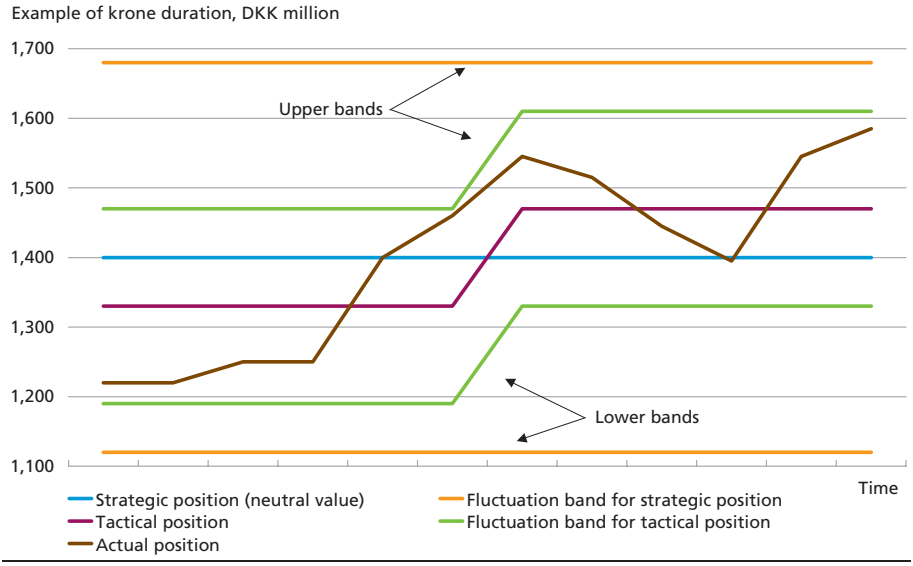
MANAGEMENT OF INTEREST-RATE EXPOSURE ON THE PORTFOLIO OF DOMESTIC SECURITIES

No tactical limits are determined for the domestic securities portfolio, so that actual positions are taken within the strategic framework. A

[1] Management of interest-rate risk on the foreign-exchange reserve is also described in Jensen (2001).

EXAMPLE OF DECISION CONCERNING INTEREST-RATE POSITION IN THE FOREIGN-EXCHANGE RESERVE

Chart 7.8



Source: Danmarks Nationalbank.

benchmark and performance measurement are currently being prepared.

Callable bonds in the domestic securities portfolio

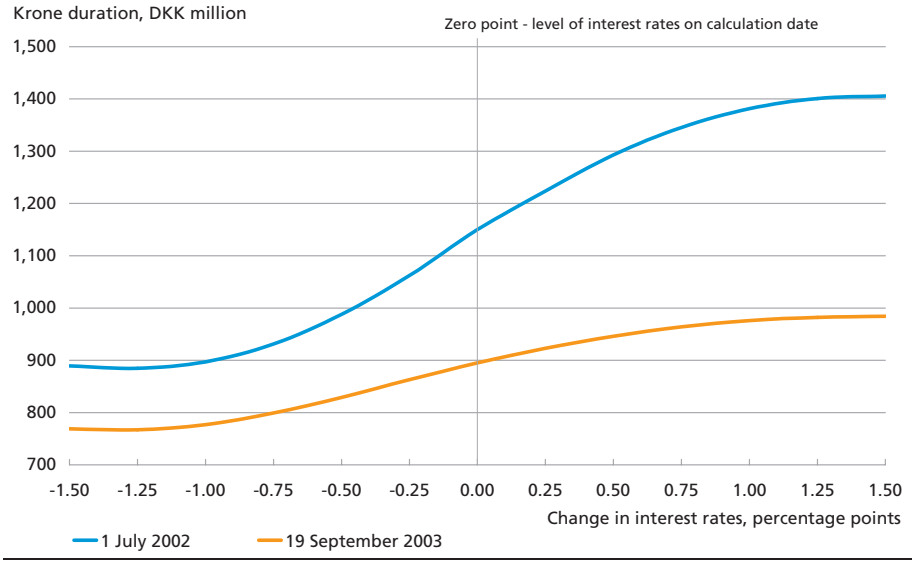
Most of the domestic securities portfolio is invested in government bonds and mortgage-credit bonds, the latter distributed as 2/3 uncallable and 1/3 callable bonds.

A callable bond can be considered to be a purchased uncallable bond and a sold option entitling the borrower to redeem the loan at par value. This makes it difficult for the price of a callable bond to increase very much above par, resulting in negative convexity between price and yield. The interest-rate exposure of the bond is thus closely linked to the level of interest rates compared to the coupon yield on the bond. Callable mortgage-credit bonds are described in further detail in Appendix A.

The bond thus not only entails interest-rate, credit and liquidity risk, but also a *prepayment risk*, i.e. a risk that the borrower redeems a bond at a yield that is high compared to the market level, so that the funds must be reinvested at a lower yield. This risk must be compensated for. The trade-off between expected return and risk is based on option-adjusted key figures, where the price of the call option is estimated and incorporated in the key figures.

KRONE DURATION OF THE PORTFOLIO OF DOMESTIC SECURITIES ON CHANGES IN INTEREST RATES

Chart 7.9



Source: Danmarks Nationalbank.

Convexity margin

When interest rates are falling, high-coupon callable bonds will be subject to a "prepayment risk", and their duration will decrease due to the negative convexity. This means that on a drop in interest rates it may be necessary to purchase duration, i.e. purchase at higher bond prices. In order to limit the prepayment risk, the exposure to changes in interest rates of the *krone duration* on the domestic securities portfolio is subject to a ceiling. This is known as a *convexity limit* and indicates that the krone duration may not change by more than DKK 100 million on a change in the yield curve by 50 basis points.

Chart 7.9 shows changes in the krone duration of the portfolio of securities for interest-rate changes on two given days. The krone duration at the zero point was DKK 895 million on 19 September 2003. On 1 July 2002 the krone duration was higher, and an increase in interest rates on 1 July 2002 would thus have entailed a higher capital loss than on 19 September 2003. In other words, the interest-rate exposure has been reduced.

It is also seen that the interest-rate exposure has become less sensitive to changes in interest rates. On an increase in interest rates by 1 percentage point, the krone duration on 19 September 2003 would have increased from DKK 895 million to DKK 976 million, while the krone

duration on 1 July 2002 would have increased from DKK 1,150 million to DKK 1,381 million.

One reason that the krone duration has become less sensitive to changes in interest rates is that there were fewer callable mortgage-credit bonds in the portfolio of domestic securities in September 2003 than in the summer of 2002.[1]

Option to use euro futures

It is the aim of Danmarks Nationalbank that the management of the portfolio of domestic securities does not influence the Danish bond market. This means that in situations where the development in interest rates has led to a significant increase in the demand for/supply of duration in the bond market, it is possible to purchase/sell duration temporarily via euro futures, a liquid market that is not affected by Danmarks Nationalbank's transactions.

In this way the overall duration is kept unchanged. The purchased/sold duration of the euro portfolio is only temporary up to the expiry of the futures contract. Since this is a contingency arrangement, euro futures are only used in this way under very exceptional circumstances.

[1] The portfolio of domestic securities and its management are described in further detail in Jayaswal (2003).

LITERATURE

Berndsen, Jan (2003), Does duration extension enhance excess returns?, Danmarks Nationalbank, *Working Papers*, 2003:10.

Fama, Eugene F. (1984), Term Premiums in Bond Returns, *Journal of Financial Economics*, pages 529-546.

Ilmanen, Antti (1996A), When Do Bond Markets Reward Investors for Interest Rate Risk?, *The Journal of Portfolio Management,* Volume 22, number 2, pages 52-65.

Ilmanen, Antti (1996B), Does duration extension enhance long-term expected returns?, *Journal of Fixed Income,* Volume 6, number 2, pages 23-36.

Jayaswal, Peter (2003), Danmarks Nationalbank's Portfolio of Domestic Securities, Danmarks Nationalbank, *Monetary Review*, 2nd Quarter.

Jensen, Peter Kjær (2001), Management of the Interest-Rate Risk on the Foreign-Exchange Reserve, Danmarks Nationalbank, *Monetary Review*, 1st Quarter.

ANNEX: ANALYSIS OF PRINCIPAL COMPONENT

The idea behind an analysis of principal component is to determine the direction of a data set. A data set with observations for e.g. two variables may be presented as dots in a two-dimensional coordinate system. An example is given in Chart 7.10 where the dots show the relation between the monthly change in a 1-year yield and a 5-year yield during the period from February 1987 to July 2001. It is seen that the dots form an oblong cloud stretching from south-west to north-east. This indicates that small (large) changes in the 1-year yield are often accompanied by small (large) changes in the 5-year yield.

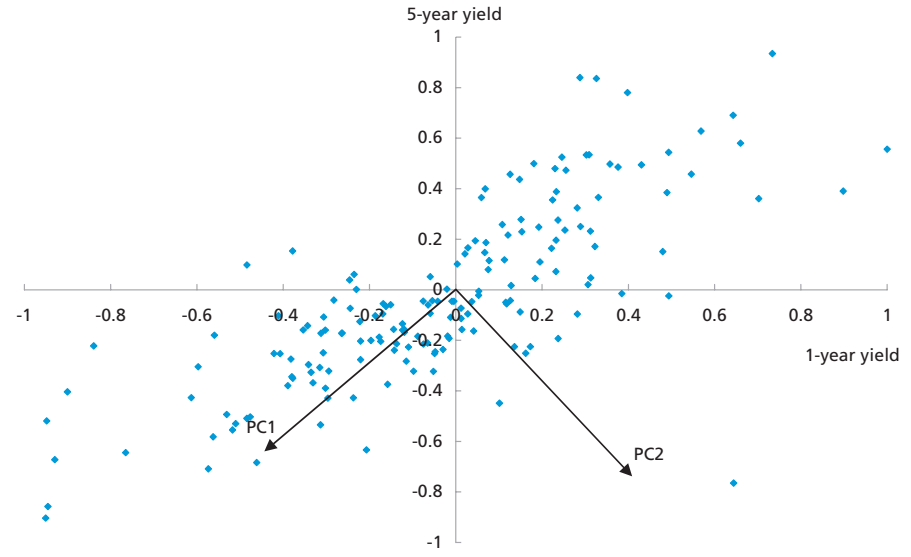
A principal-component analysis of the aforementioned data set is a formalised means of determining the direction of the cloud or the prevailing direction of the data set. This direction is also known as the data set's *first principal component*. The result is often presented as a vector with a length of 1. In Chart 7.10, the vector is called PC1. The vector points in the direction (-0.765;-0.644), indicating that the 5-year yield falls by 0.644/0.765 = 0.84 percentage point whenever the 1-year yield decreases by 1 percentage point. The direction of the vector is of no consequence and might just as well have been north-east as south-west. What is important is the slope of the vector. The fact that the 1-year and 5-year yields change by almost as much is equivalent to PC1 representing a movement that relates to the general level of interest rates.

In Chart 7.10 a vector called PC2 has also been drawn. PC2 points in the direction (0.644;-0.765) and is thus perpendicular to PC1, i.e. it does not explain the same as can be explained by PC1. In the direction of PC2 the 5-year yield will move by -0.765/0.644 = -1.19 percentage point whenever the 1-year yield increases by 1 percentage point. A decrease in the 5-year yield on an increase in the 1-year yield corresponds to a change in the slope of the yield curve, i.e. PC2 represents a movement that relates first and foremost to the steepness of the yield curve.

In data sets with more than two variables the direction of PC2 is given as the prevailing direction in the data set subject to the restriction that the direction is perpendicular to PC1. PC2 can therefore be said to be the second most important direction of the data set, and PC2 is therefore also called the *second principal component*.

As a general rule, there are just as many principal components as there are variables, but with diminishing explanatory power. The *i*'th principal component expresses the prevailing movement in the data set subject to the restriction that the movement is perpendicular to the principal components 1,...,*i*-1, i.e. those that are "better".

RELATION BETWEEN 1-YEAR AND 5-YEAR YIELDS (MONTHLY CHANGES IN PERCENTAGE POINTS) Chart 7.10



Source: Danmarks Nationalbank.

If a third yield is included in the analysis, e.g. the 2-year yield, a third principal component is obtained, typically a curvature effect. In this analysis PC1 explains 70 per cent, PC2 23 per cent and PC3 4 per cent of the variation in the yield curve.

The interesting aspect of the analysis is that the first three principal components explain most of the variation in the yields (97 per cent), even though many yields are included. Another robust result is that PC1 is mainly a level factor, while PC2 is mainly a steepness factor, and PC3 a curvature factor, cf. the three factors in Chart 7.4.

8. Measuring Market Risk

The last 10-15 years have seen considerable development of the methodology for measuring the risks to which financial corporations are subject. This applies especially to measuring market risk, due to the typical availability of substantial data, such as the historical volatility in market prices that can be used to estimate their future volatility.

Danmarks Nationalbank quantifies the market risk as Value-at-Risk (VaR), which can be interpreted as the maximum loss under normal market conditions, and as the loss in stress scenarios, i.e. the loss under extreme market conditions. Both risk measures combine Danmarks Nationalbank's financial positions with scenarios for the volatility in the risk factors within a certain time horizon. On the basis of VaR calculations Danmarks Nationalbank's capital loss is estimated with a probability of 95 per cent not to exceed DKK 3-4 billion for a horizon of one year. The losses may be far greater under extreme market conditions, but do not in any way jeopardise Danmarks Nationalbank's net capital.

The VaR measure combines the financial positions at a given time with an estimate of the typical volatility in the risk factors. This estimate takes into account the correlation in the risk factors, thereby capturing the diversification gain. The diversification gain is due to the fact that losses on all risk factors hardly ever appear at the same time.

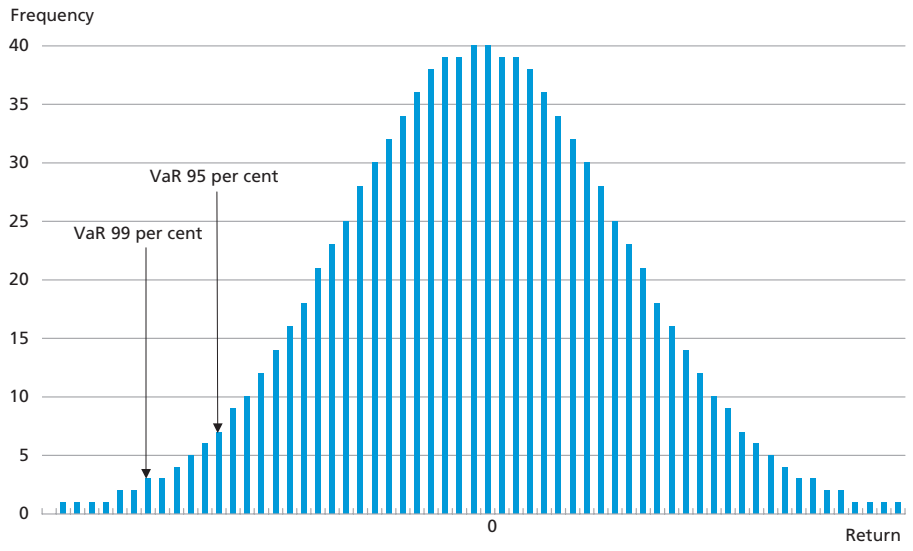
The stress tests combine the financial positions with volatility in the risk factors, but in this case the focus is solely on very poor scenarios for the risk factors. Furthermore, the correlation in the risk factors is not necessarily included. The stress tests are to determine the loss on the collapse of the normal market conditions.

VALUE-AT-RISK

The prevalent measure of market risk is Value-at-Risk (VaR). It estimates the financial loss that with a high probability will not be exceeded over a given time horizon. In other words, VaR measures the financial loss that will be exceeded in rare cases. Loosely interpreted, VaR measures the maximum loss under normal market conditions. VaR thus does not capture the loss when the volatility in market prices is unusually high.

The VaR concept is illustrated in Chart 8.1 that shows the expected distribution of the return on a portfolio. On the basis of this distribution the loss in kroner (or another currency) that can only be expected to be exceeded in

DISTRIBUTION OF RETURN ON A PORTFOLIO Chart 8.1



Note: Distribution of 1,000 observations extracted from a normal distribution.
Source: Danmarks Nationalbank.

e.g. 1 per cent of the cases can be found. This corresponds to determining the 1st percentile in the distribution. The result is called VaR calculated with a probability of 99 per cent, since there is a 99 per cent probability of the return not falling below the calculated figure. A lower probability level could also be selected, e.g. 95 per cent. VaR will then measure the loss expected to be exceeded in 5 per cent of the cases. This figure will be numerically lower than VaR calculated with a probability of 99 per cent.

Elements of the calculation of Value-at-Risk

A number of factors should be taken into account when calculating VaR, especially the horizon and the desired probability for the VaR figure.

The applied horizon should depend on the purpose of the calculation. A horizon of 1 day may be relevant for an institution that is able and willing to settle its positions on an intra-day basis. A longer horizon is relevant for other institutions that require a longer period to settle their positions. VaR may also be applied to portfolio decisions of a more strategic nature. A longer horizon, e.g. one year, may also be relevant in such cases.

VaR is often calculated first for a short horizon and then scaled to a longer horizon. Scaling is achieved by the square-root formula.[1] The

[1] For a time sequence consisting of independent and identically distributed variables the standard deviation over h periods will be $h^{1/2}$ times the standard deviation in one period. The square-root formula can be inaccurate if the observations are not independent and identically distributed. See e.g. Christoffersen, Diebold and Schuermann, 1998.

formula is exact for time series consisting of independent, identically distributed variables. This assumption rarely applies in practice, since the market prices now and then show extreme values, often in "clusters". Scaling the calculated VaR using the square-root formula will therefore add an extra element of inaccuracy to the calculations.

There is no "correct" level for the probability applied, but VaR is usually reported with a probability of 95 or 99 per cent. The argument in favour of 95 per cent is that larger losses must be expected from time to time. This makes it possible to assess whether the calculated VaR is reasonable in relation to the actual losses. The argument in favour of 99 per cent is that larger losses can only be expected in very rare cases. The calculated VaR can thus be regarded as an upper limit for losses (with a probability of 99 per cent).

In general, the calculation of VaR for a portfolio will be based on identification of the financial risk factors affecting the portfolio. In principle, these risk factors may comprise all financial risks, including credit risk, but VaR will normally comprise only market risk. The risk factors are therefore typically stock prices, exchange rates, interest rates and commodity prices. Once the risk factors have been identified, it is possible to determine the portfolio's exposure to changes in the risk factors. The next step is to create scenarios for the risk factors as their expected distribution, including their correlation, for the selected horizon. Combining these distributions with the exposures of the portfolio allows for the determination of an expected distribution of the return on the portfolio. VaR can then be determined at e.g. the 5th percentile. Box 8.1 shows an example of estimation of VaR in Danish kroner on a portfolio of US government bonds.

The expected distribution of the risk factors plays a crucial role in the calculation of VaR. The distribution can be determined in several ways. A basic distinction is made between simulation and analytical methods. In the simulation methods the distribution of the risk factors is created on the basis of a number of observations for the risk factors. This can be the actual historical observations (historical simulation) or observations generated by Monte Carlo simulation. In an analytical method, the risk factors are assumed to follow a distribution function based on parameters. In most cases, a multidimensional normal distribution is applied with parameters in the form of spreads and correlations estimated on historical data.

EXAMPLE OF VALUE-AT-RISK (VaR) ESTIMATION Box 8.1

As an example of a VaR estimation a Danish investor's portfolio of 10-year US government zero-coupon securities with a nominal value totalling USD 1 million is considered. With a horizon of one day and a probability of 95 per cent the task is to calculate the loss in Danish kroner that is only exceeded in 5 per cent of the cases, or in one out of 20 days.

For the Danish investor the portfolio implies two sets of risk factors, i.e. the USD exchange rate and the US interest rates for a maturity of up to 10 years. The portfolio's exposure to the risk factors follows from the theoretical market value at time t written as DKK $MV_t = e_t \times (1+y_t)^{-10}$ million. In this calculation e_t is the USD exchange rate measured as DKK per USD, and y_t is the 10-year US zero-coupon yield. At end-2002, the market value of the portfolio was DKK 7.07 x $(1.040)^{-10}$ = DKK 4.8 million.

Historical VaR is calculated by first calculating the daily returns $MV_t - MV_{t-1} = e_t \times (1+y_t)^{-10} - e_{t-1} \times (1+y_{t-1})^{-10}$ over a historical period. The 5 per cent poorest observations are then excluded, and VaR is the worst observation among the remainder. The daily returns during 2002 can be taken as example. The bars in the Chart below show the distribution of the 260 observations in total. The Chart shows that on certain days the market value fell by more than DKK 100,000. However, the VaR calculation should disregard the 0.05 x 260 = 13 worst observations. On the basis of the Chart, the historical VaR of the portfolio can thus be estimated at approximately DKK 75,000.

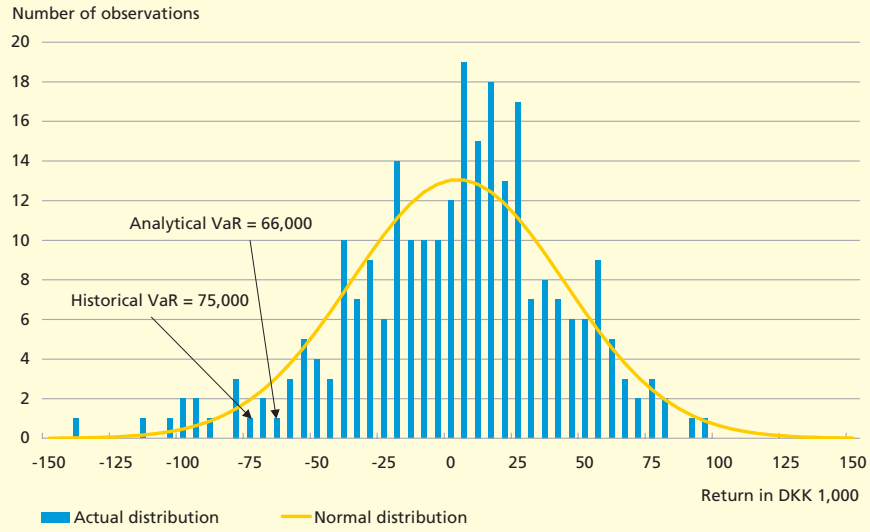
Continued

There are advantages and drawbacks to the various methods of determining the distribution of the risk factors. A general drawback of assumption of normal distribution is that in practice the distribution of the volatility in stock prices, exchange rates, commodity prices and interest rates shows "fatter tails", i.e. more extreme observations, than normally distributed elements. The normal distribution assumption thus often leads to a smaller VaR than that calculated by deploying distribution assumptions that can more accurately capture large fluctuations in the risk factors.

A common feature of the various methods to determine the distribution of the risk factors is that they all to one extent include historical information. Irrespective of method, the validity of the calculated VaR will therefore be conditional on the distribution of risk factors having relatively constant characteristics over time. In practice, this rarely applies over long horizons. Estimation of VaR for a longer horizon should take into account that the distribution of the risk factors changes over time. This could be taken into account using statistical or structural methods that include expectations of macroeconomic factors, including fiscal-policy and monetary-policy conditions.

CONTINUED Box 8.1

EXAMPLE OF VALUE AT RISK ESTIMATION



The calculation of analytical VaR utilises the fact that the return on the portfolio can be written as approximately $(MV_t\text{-}MV_{t-1})/MV_{t-1} = (e_t\text{-}e_{t-1})/e_{t-1} - 10 \times (y_t\text{-}y_{t-1})$. This gives a linear correlation between the relative return and the risk factors. Assuming that the relative change in the USD rate and the absolute change in the interest-rate level are subject to normal distribution, the normal distribution also applies to the relative return on the portfolio subject to a variance of VaR $((MV_t\text{-}MV_{t-1})/MV_{t-1}) = \text{Var}((e_t\text{-}e_{t-1})/e_{t-1}) + 10^2 \times \text{Var}(y_t\text{-}y_{t-1}) - 2 \times 10 \times \text{Cov}((e_t\text{-}e_{t-1})/e_{t-1}, y_t\text{-}y_{t-1})$. A normally distributed element furthermore leads to the result that the 5th percentile is given by 1.65 times the spread. The estimated co-variation matrix for the risk factors derived from the day-to-day volatility during 2002 allows the spread on the relative daily return to be estimated at 0.85 per cent. A portfolio of DKK 4.7 million entails a VaR of DKK 0.85/100 x 4.7 x 1.65 = DKK 0.066 million = DKK 66,000.

The analytical VaR is smaller than the historical VaR. The reason is that the left-hand tail is thicker for the risk factors and thereby the return on the portfolio than for the normal distribution. The Chart illustrates this as a somewhat larger actual loss on individual days in 2002 than would have been the case with the normal distribution.

ESTIMATION OF DANMARKS NATIONALBANK'S VALUE-AT-RISK

Danmarks Nationalbank estimates Value-at-Risk by both an analytical method on the basis of market data for a short period, and by using historical simulation on the basis of market data over a large number of years. In both cases, a probability of 95 per cent and a horizon of one

year are applied. A VaR with a one-year horizon is used in the annual determination of the overall risk level for Danmarks Nationalbank's positions.

Analytical Value-at-Risk

The estimation of analytical VaR is based on daily observations. The volatility in the positions' underlying risk factors is assumed to follow a multidimensional normal distribution of which the parameters are estimated on the basis of observations for the preceding 160 days.

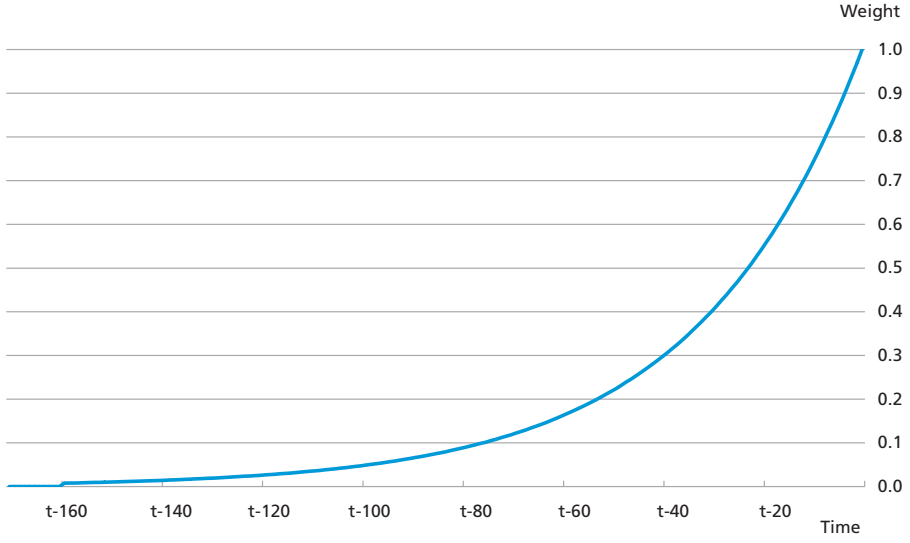
The length of the historical period should be viewed in the light of the application of decaying weights to the historical observations. The latest observation is thus weighted at 100 per cent, while observations one month back in time are weighted at only 50 per cent. Observations more than 2½ months back are weighted at very small ratios. With this weighting profile, a longer historical period will only marginally affect the VaR estimate. The weighting profile is shown in Chart 8.2.

The rationale for applying decaying weights to the historical market observations is that volatility changes over time, and that the volatility in the near future often resembles the volatility in the immediate past.

The weighting of the historical observations, as well as the length of the estimation period can have a major impact on the estimated VaR. A combination of very rapidly decaying weights and a very short estima-

WEIGHTING OF HISTORICAL OBSERVATIONS IN THE CALCULATION OF VALUE-AT-RISK

Chart 8.2



Note: Weighting of historical observations in the calculation of VaR on day t with a decay factor of 0.97.
Source: Danmarks Nationalbank.

DANMARKS NATIONALBANK'S VALUE-AT-RISK, END-DECEMBER 2002 Table 8.1

DKK billion	VaR	VaR excl. DKK/EUR risk
Interest-rate risk	2.9	2.9
Currency risk	0.9	0.9
Risk vis-à-vis gold price	1.2	1.2
Diversification gain	-1.8	-1.8
Total	3.2	3.2

Note: Analytical VaR with a horizon of one year and a probability of 95 per cent. The distribution of the risk factors is estimated on the basis of 160 previous daily observations included with a decaying weight.
Sources: RiskMetrics Group and own calculations.

tion period may entail large variations in the estimated VaR over time. Correspondingly, the combination of unchanged weighting and a long estimation period will support stable development in the estimated VaR. In this case changes in market conditions will, however, only slowly be reflected in the estimated VaR, which could be undesirable.

Calculating VaR by the above method yields a total VaR of DKK 3.2 billion at end-December 2002, cf. Table 8.1. With a probability of 95 per cent Danmarks Nationalbank's financial losses will thus not exceed DKK 3.2 billion in one year. This loss is equivalent to 7 per cent of the net capital at end-2002.

Danmarks Nationalbank is first and foremost exposed to interest-rate volatility. In isolated terms, the interest-rate volatility accounts for a VaR of DKK 2.9 billion, which is close to the total VaR.

Exchange-rate volatility seen in isolation accounts for a VaR of more than DKK 0.9 billion. This is a modest amount in terms of the overall foreign-exchange reserve. The small currency risk is related to the krone's stability vis-à-vis the euro and to the fact that most of the exchange-rate exposure is in euro.

In isolated terms Danmarks Nationalbank's gold holding accounts for a VaR of DKK 1.2 billion. This is a rather large amount compared to the size of the gold holding. The reason is the high volatility in the gold price. However, the gold also helps to reduce Danmarks Nationalbank's risk by diversifying the positions. An example is that the total VaR is only reduced by DKK 0.3 billion when the gold holding is excluded from the VaR calculation.

As Table 8.1 shows, the sum of the contributions from the individual groups of risk factors – interest rates, exchange rates and the gold price – exceeds the total VaR by DKK 1.8 billion. In other words, VaR is reduced by DKK 1.8 billion when all of the risk factors are taken into account at once. This reduction, also known as the diversification gain, is attributable to the fact that losses are seldom incurred on all risk factors simultaneously.

In view of the fixed-exchange-rate policy the DKK/EUR risk is not a traditional market risk. The fixed-exchange-rate policy implies that the risk, despite small day-to-day volatility, is actually very small, also over a longer horizon. Furthermore, Danmarks Nationalbank has not only the opportunity, but also the obligation, to influence the development in the krone's rate vis-à-vis the euro. Against this background, it is also relevant to calculate VaR excluding the risk of volatility in the DKK/EUR exchange rate. The result is shown in Table 8.1. It appears that excluding this risk has only an insignificant effect on VaR at end-2002. This is attributable to the krone's stability vis-à-vis the euro.

One problem in relation to the calculation of Danmarks Nationalbank's VaR by the analytical method concerns the horizon of the VaR estimate. Although Danmarks Nationalbank wishes to assess the risk of losses one year ahead, the risk is assessed against the background of the immediate past. In other words, the risk is assessed on the basis of historical data for a significantly shorter period than the horizon for the VaR estimate. Another issue is that in principle VaR is calculated for a horizon of one day, and then scaled to one year. This aggregation is only exact when subject to assumptions that do not apply in practice.

Historical Value-at-Risk

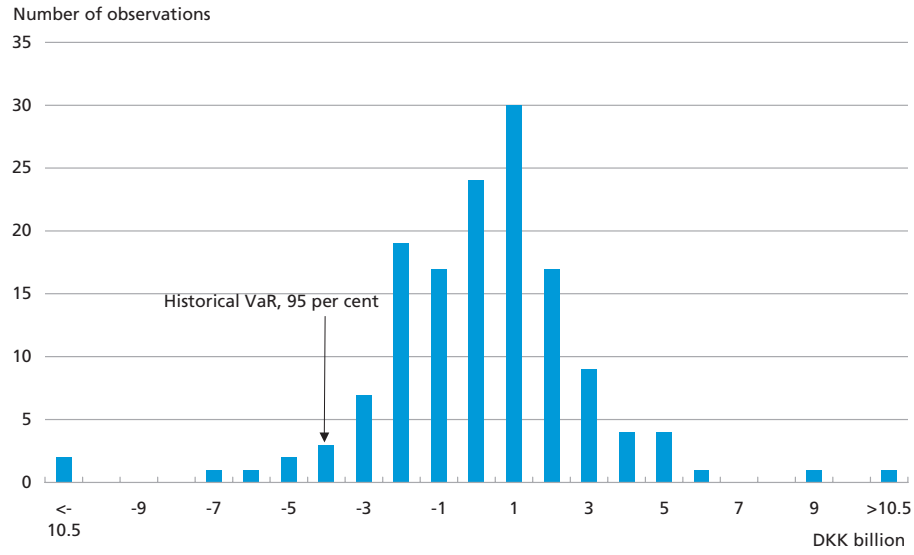
In order to examine the significance of and resolve some of the issues associated with the calculation of analytical VaR, VaR is also calculated by historical simulation on the basis of monthly observations for an extended period. The calculation combines the historical monthly volatility in interest rates, exchange rates and the gold price with the exposure of the positions vis-à-vis the various risk factors on a given date. Chart 8.3 shows the result of a calculation as of end-December 2002.

Interest-rate and exchange-rate observations for the period 1991-2002 lead to 143 monthly returns that are sorted by size and scaled to annual level. The square-root formula is again used to scale to annual level. However, the scaling is less massive than for the calculation of VaR on a daily basis. The 5th percentile in the resulting distribution (equivalent to the 7th largest loss) constitutes the historical VaR at a probability level of 95 per cent for a horizon of one year. This loss is around DKK 4 billion, cf. Chart 8.3.

In this case the historical VaR is greater than the analytical VaR. One explanation is that the return on Danmarks Nationalbank's portfolio becomes very negative in certain months when actual volatility in market prices is applied over a long period. In Chart 8.3 this is illustrated by the "fat" left-hand tail of the return distribution.

DISTRIBUTION OF HISTORICAL RETURNS ON DANMARKS NATIONALBANK'S PORTFOLIO

Chart 8.3



Note: 143 monthly returns for the period February 1991-December 2002 on positions at end-December 2002. The returns are scaled to annual levels.
Source: Danmarks Nationalbank.

One weakness of historical VaR calculated for a long period is that it does not fully capture structural volatility shifts or correlations over time. Trends in interest and exchange rates 5-10 years back, including observations from the crises at the beginning of the 1990s, are regarded as a just as representative indication of the future developments as the development over the past year.

STRESS TESTS

Value-at-Risk does not provide information on the extent of the losses to Danmarks Nationalbank in extremely negative conditions. Experience shows that the actual loss may far exceed the loss calculated using VaR. The VaR analysis should therefore always be supplemented with other risk measures, including stress tests.

Stress scenarios are calculation examples whereby the consequence of an extreme market development is investigated. Naturally, the results of stress scenarios depend on the degree of stress applied. The scenarios must be extreme, while still appearing realistic.

The approach taken here is to consider the historical development in interest and exchange rates in the period 1991-2002, and to identify particularly unfavourable periods. On the basis of the portfolio composition at end-2002 the estimated loss to Danmarks Nationalbank is calcu-

DANMARKS NATIONALBANK'S LOSSES IN STRESS SCENARIOS, END-2002 Table 8.2

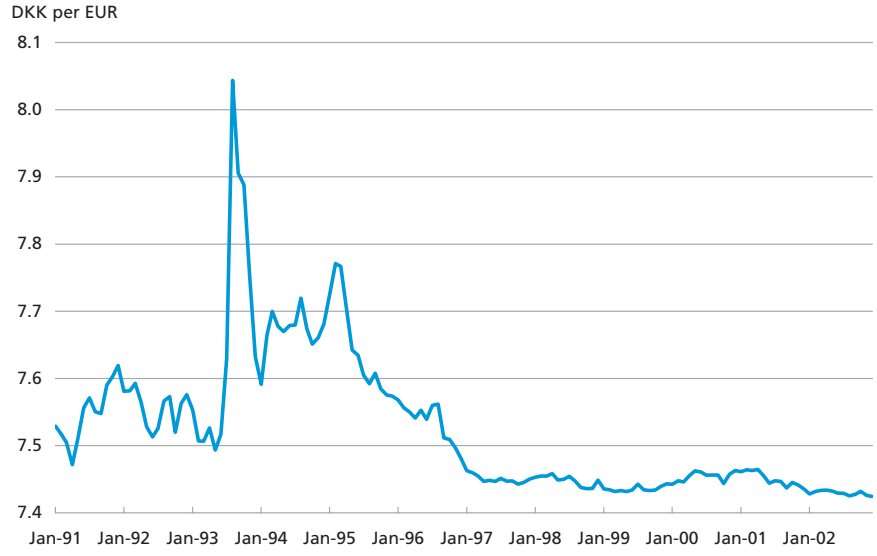
DKK billion	Interest-rate loss	Currency loss	Gold loss	Total
Greatest total interest and exchange-rate losses	2.9	8.3	-0.2	11.0
Greatest total interest-rate loss combined with the greatest total exchange-rate loss	5.3	8.3	1.2	14.7
Greatest interest-rate loss in 1-year segments in each currency combined with the greatest exchange-rate loss in each currency	6.3	8.7	1.2	16.2

Note: The greatest total interest and exchange-rate losses occurred in the 12-month period from September 1993 to August 1994. In this period, the gold holding yielded a capital gain of DKK 200 million.
Source: Danmarks Nationalbank.

lated in the event of an identical development. Three scenarios have been specified:

- The annual period which would give the greatest total interest-rate and exchange-rate losses.
- The annual period, which would give the greatest total interest-rate loss, combined with the annual period, which would give the greatest total exchange-rate loss. The losses do not have to be concurrent.
- The annual period which for each one-year maturity segment in each currency would give the greatest interest-rate loss, combined with the annual period, which for each currency would give the greatest exchange-rate loss. The losses do not have to be concurrent.

EXCHANGE RATE OF THE KRONE VIS-À-VIS THE EURO Chart 8.4



Note: Before 1 January 1999 the exchange rate via-à-vis the D-mark is applied.
Source: Danmarks Nationalbank.

The three scenarios result in total capital losses of DKK 11-16 billion, cf. Table 8.2. The greatest loss is a result of a general increase in interest rates by 2-3 percentage points, combined with a strengthening of the krone by approximately 4 per cent.

Like the VaR calculations, the stress scenarios are affected by the DKK/EUR risk, and especially by the gradual strengthening of the krone after its weakening in August 1993, cf. Chart 8.4. If this factor is disregarded, the loss is considerably lower.

APPLICATION OF DANMARKS NATIONALBANK'S RISK MEASURES

Danmarks Nationalbank's net capital was approximately DKK 50 billion at end-2002, and its core earnings are approximately DKK 3 billion per year, cf. Chapter 2. Danmarks Nationalbank's credit risk is considered to be very modest. Against this background, a probable maximum loss of DKK 3-4 billion in the course of one year appears acceptable to Danmarks Nationalbank.

The stress scenarios result in major losses, but do not pose a serious threat to Danmarks Nationalbank's net capital. In the most extreme of the scenarios described, approximately one third of Danmarks Nationalbank's net capital is lost. For comparison, in 1994, when Danmarks Nationalbank's exposure to the US dollar was considerably greater than today, the capital loss amounted to 30 per cent of the net capital.

Danmarks Nationalbank's market risk is managed within the framework for the interest-rate and exchange-rate exposure, cf. Chapters 5, 6 and 7. No explicit targets apply to VaR or to the losses in stress scenarios, but these elements are taken into account in the Board of Governors' decision on the overall framework for the interest-rate and exchange-rate exposure.

The market risk is reported to the Board of Governors on an ongoing basis. Analytical VaR is reported on a monthly basis together with a statement of Danmarks Nationalbank's overall interest-rate and exchange-rate exposure. Table 8.3 presents an example of a table from the monthly report. Historical VaR for an extended period and stress tests are compiled on an annual basis.

Danmarks Nationalbank's market risk is published in its annual *Report and Accounts*.

DANMARKS NATIONALBANK'S MARKET EXPOSURE, END-2002 Table 8.3

DKK billion	Foreign-exchange reserve			Portfolio of domestic securities	Central-government deposits	Banks' net position	Danish Ship Finance	Banknotes and coins	Total
	Portfolio of foreign securities	SDR	Gold						
Market value	183.8	6.5	5.2	36.9	-46.7	-89.6	0.9	-47.7	49.4
Krone duration	1.3	-	0.0	0.9	-	0.0	0.0	0	2.2
Foreign-exchange exposure	1.8	0.1	0.1	0	-	0	0.1	0	2.0
Value-at-Risk	2.5	0.5	1.3	0.9	0	0.0	0.9	0	3.2

Note: All forward transactions are assigned to the portfolio of foreign securities. The compilation of the foreign-exchange exposure and the calculation of Value-at-Risk for the portfolios of SDR, gold and Danish Ship Finance

LITERATURE

Christoffersen, Peter F., Francis X. Diebold and Til Schuermann (1998) *Horizon Problems and Extreme Events in Financial Risk Management*, Federal Reserve Bank of New York Economic Policy Review.

Jakobsen, Svend "Value-at-Risk for danske realkreditobligationer" (1996) *finans/invest,* nr. 1.

Mina, Jorge and Jerry Yi Xiao (2001) "Return to RiskMetrics – the Evolution of a Standard", RiskMetrics Group.

9. Liquidity Risk

The liquidity risk comprises several factors. For Danmarks Nationalbank, the liquidity risk is first and foremost the risk that it is not possible to release funds to support the krone, even though the funds are part of the reserve. Another type of liquidity risk occurs when even small transactions affect the price. In such cases, portfolio adjustments may entail considerable transaction costs.

The principal purpose of the foreign-exchange reserve is for Danmarks Nationalbank to be able to intervene in the foreign-exchange market. In the management of the foreign-exchange reserve it is therefore very important to ensure that the greater part of the reserve can quickly be transferred into liquid funds. Furthermore, the foreign-exchange reserve is invested in securities for which transactions do not affect the price excessively.

The liquidity aspect is less relevant with regard to the management of the portfolio of domestic securities.

THE NEED FOR LIQUIDITY

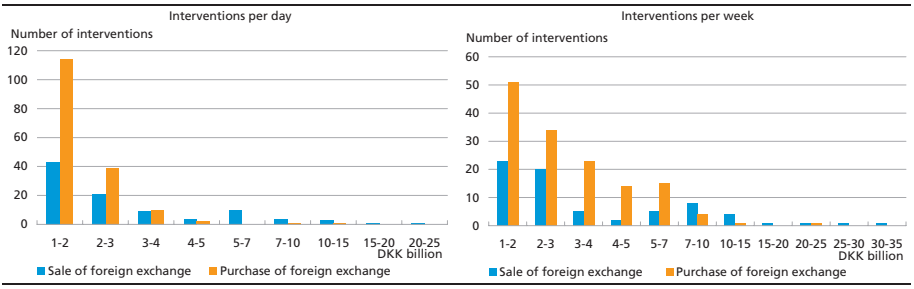
It is difficult to estimate the degree of intervention that can be required should the krone come under pressure. However, Danmarks Nationalbank's experience may give an indication of the potential volumes involved. Chart 9.1 shows the intervention volumes (purchase and sale of foreign exchange) since 1986. One panel of the Chart shows interventions on a daily basis. Since large-scale intervention can take place over several days the second panel shows interventions on a weekly basis. It appears that the maximum purchases in support of the krone were DKK 25 billion on a daily basis and DKK 35 billion on a weekly basis.

The need for liquidity is ensured by investing a part of the foreign-exchange reserve as very short-term deposits that can be released for liquidity purposes immediately (settlement in less than two days).

Another element of the management of liquidity risk is that the investments are spread across various liquid markets. Should problems arise in individual markets, it is thus possible to sell bonds on the other markets.

Furthermore, investments are solely made in bonds with a high credit quality that can be pledged as collateral for loans (repos). In this way the bonds can be used to obtain liquid funds, even though they are not sold.

INTERVENTIONS DURING RESPECTIVELY ONE DAY AND ONE WEEK BY VOLUME SINCE 1986 Chart 9.1



Source: Danmarks Nationalbank.

This also ensures that the interest-rate risk on the foreign-exchange reserve is not necessarily affected should bank deposits prove insufficient. Danmarks Nationalbank has entered into agreements with several international banks so that bonds can quickly be pledged as collateral for loans.

A greater liquidity risk is assumed on the portfolio of domestic securities, which is not subject to special liquidity requirements derived from Danmarks Nationalbank's primary responsibilities. A part of the portfolio of domestic securities is thus invested in bonds that are not very liquid in order to achieve additional returns.

FRAMEWORK FOR LIQUIDITY RISK

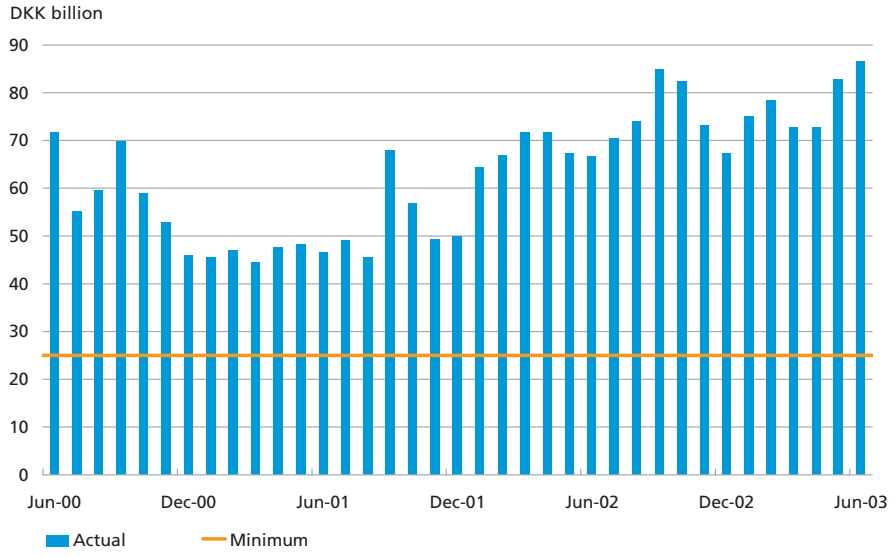
The management of the liquidity requirement is based on the general rule that it must be possible to release a given amount within two days[1]. In periods when foreign-exchange markets are stable, the minimum requirement is DKK 25 billion. In periods of unrest on the foreign-exchange markets, the degree of liquidity required of the foreign-exchange reserve may be augmented. In recent years the degree of liquidity has considerably exceeded the minimum requirement, cf. Chart 9.2.

The principal intervention currencies, euro and US dollar, are subject to special minimum requirements for money-market investments. Compliance with the liquidity requirement is ensured by adjusting the benchmark for investments in these two currencies. Should the money-market investments in euro or US dollar fall below the required level, these investments can be increased by adjusting the maturity distribution of the krone duration. Increasing the krone duration for longer maturities

[1] A settlement period of two days applies to the foreign-exchange market. This means that the trade is settled two days after the trade date. Liquidity for intervention purposes must therefore be available in no later than two days.

DEGREE OF LIQUIDITY OF THE FOREIGN-EXCHANGE RESERVE AT MONTH-END

Chart 9.2

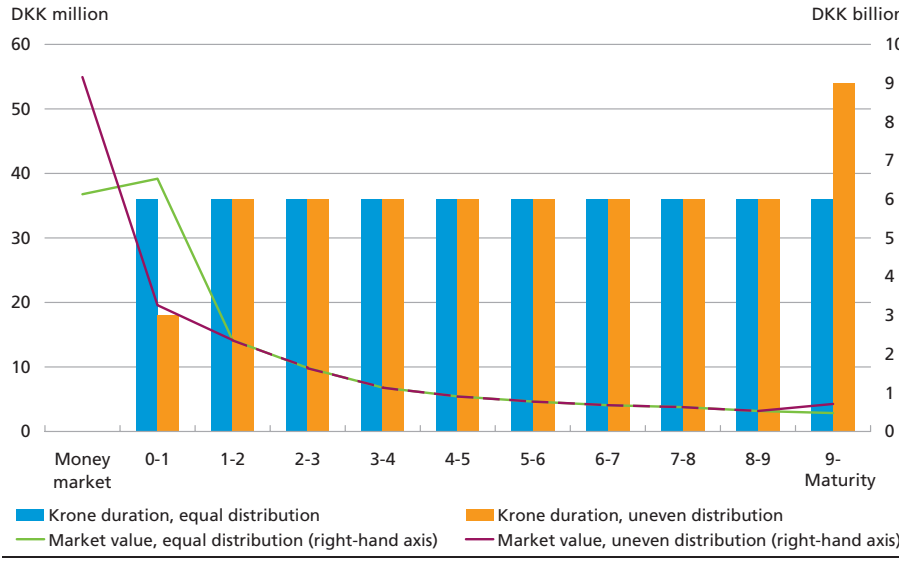


Source: Danmarks Nationalbank.

maturities reducing it for shorter maturities releases funds from the bond market, since a given krone duration can be achieved at a lower market value for longer than for shorter maturities, cf. Chart 9.3.[1]

EXAMPLE OF THE IMPACT ON THE DISTRIBUTION OF MARKET VALUE BY MATURITY OF A CHANGE IN THE DISTRIBUTION OF KRONE DURATION

Chart 9.3



Source: Danmarks Nationalbank.

[1] See also Chapter 7 on the distribution of the foreign-exchange reserve across the yield curve.

It has been necessary from time to time to adjust the benchmark in this way when the money-market investments have fallen below the required level.

THE FOREIGN-EXCHANGE RESERVE IS NOT THE UPPER INTERVENTION LIMIT

Danmarks Nationalbank may support the krone with far larger amounts than the size of the foreign-exchange reserve.

As stated in Chapter 6, the purpose of the central government's foreign borrowing is to maintain an appropriate foreign-exchange reserve. If there is a need to increase the foreign-exchange reserve, the central government has access to raise loans in foreign exchange at very short notice via the Commercial Paper programmes, cf. Box 9.1. This will augment the foreign-exchange reserve and enhance Danmarks Nationalbank's abilities to undertake further intervention. The programmes have been used from time to time, especially in connection with the foreign-exchange unrest at the beginning of the 1990s. Borrowing via the Commercial Paper programmes may be replaced by more long-term debt if required.

Denmark is a member of the European Exchange Rate Mechanism II (ERM II). Denmark participates at a central rate of DKK 746.038 per 100 euro and with a fluctuation band of +/- 2.25 per cent. As a consequence Danmarks Nationalbank and the European Central Bank (ECB) have agreed on a mutual intervention obligation should the krone/euro-rate reach its agreed fluctuation limits. In accordance with the ERM II agreement, Danmarks Nationalbank furthermore holds an automatic borrowing right at the ECB should the krone reach the fluctuation limit vis-à-vis the central rate. This facility has not been used during the lifetime of ERM II but serves as a safety net for the fixed exchange-rate policy.

THE COMMERCIAL PAPER PROGRAMMES — Box 9.1

Commercial Paper (CP) consists of short-term debt securities (zero-coupon papers) with maturities of up to one year. The central government has two CP programmes with a maximum outstanding amount of USD 12 billion (almost DKK 80 billion). One programme is on the US market with a maximum outstanding amount of USD 6 billion. In this programme CPs are issued in USD with a maturity of between 1 and 270 days. The other CP programme is on the European market with a maximum outstanding amount equivalent to USD 6 billion. Under this programme the debt securities can be issued in various currencies with maturity that varies between 7 and 365 days. The facilities are tested on an ongoing basis to ensure the availability of the required liquidity.

Danmarks Nationalbank also has access to the forward foreign-exchange market, where interventions can be made directly on the forward market.

Finally, Danmarks Nationalbank can enter into foreign-exchange swaps where Danmarks Nationalbank receives currency and delivers kroner spot against delivering currency and receiving kroner forward. Danmarks Nationalbank can thereby raise foreign exchange against collateral in kroner, which can then be used to support the krone. However, Danmarks Nationalbank has not utilised the options in the forward and the swap market for many years.

In view of Denmark's high credit standing it therefore has several opportunities to augment the foreign-exchange reserve by raising loans in foreign exchange.

10. Credit Risk

Credit risk is the risk of losses due to counterparty payment default. This chapter describes the credit risk associated with the investment of the foreign-exchange reserve and the portfolio of domestic securities.

The market risk is quantified by Value-at-Risk and stress tests, but no such quantification applies to Danmarks Nationalbank's credit risk. The reasons are that credit-risk models are less developed than market-risk models and that the high credit standing of Danmarks Nationalbank's counterparties makes it difficult to calculate worthwhile probabilities of credit losses.

The credit exposure is compiled as the market value of the assets. The credit exposure, i.e. the loss if the counterparties default on their payment obligations, on the foreign-exchange reserve and the portfolio of domestic securities amounted to DKK 243 billion at end-2002, cf. Table 10.1. Banks accounted for a little more than half of the exposure, while central governments, government-guaranteed entities or mortgage-credit institutes accounted for the remainder. Forward foreign-exchange transactions are subject to an add-on for potential credit exposure. The add-on reflects that the market value of the actual transactions may increase up to the expiry of the contracts from the value at the time of compilation.

TOTAL CREDIT EXPOSURE ON THE FOREIGN-EXCHANGE RESERVE AND THE PORTFOLIO OF DOMESTIC SECURITIES, ETC., END-2002 Table 10.1

DKK billion	2001 Total	Bonds		Bank claims		Supranational institutions	Total
		Central government	Others	Collateralised	Uncollateralised		
Aaa	90.8	56.9	19.4	3.5	5.7	3.6	89.1
Aa1	19.1	1.8	0.7	30.3	5.8	-	38.6
Aa2	18.6	10.9	7.9	8.7	11.2	-	38.7
Aa3	47.2	-	3.1	33.1	19.3	-	55.6
A1	5.5	-	-	-	4.0	-	4.0
A2	3.8	-	-	-	1.1	-	1.1
A3	-	-	-	-	-	-	-
No rating	13.6	-	3.3[1]	3.7	0	8.4[2]	15.5
Total	198.6	69.6	34.4	79.4	47.1	12.1	242.6

Note: Moody's credit rating is used.

[1] Individual Danish mortgage-credit institutes and similar.

[2] Exclusively covers BIS and IMF. The IMF exposure is calculated at the current amount. The maximum drawing is DKK 23.7 billion.

DANMARKS NATIONALBANK'S CREDIT RISK

The main credit risk for Danmarks Nationalbank's investments is *counterparty risk* vis-à-vis securities issuers and banks receiving deposits. Other types of credit risk play a minor role, as described below.

Danmarks Nationalbank's credit risk can be broken down as follows:

- *Counterparty risk*. The risk that counterparty defaults on its payment obligations. Counterparty risk also includes if the market participants assess that the credit standing of the counterparty has diminished.
- *Trading and settlement risk*. The counterparty's failure to deliver a purchased asset in a trade may result in a loss. The loss may arise because payment has already been made for the non-delivered asset (Herstatt risk). In addition, the market price of the non-delivered asset may have risen so that replacing the asset is subject to a higher price (replacement risk). Correspondent banks are used to settle payments in foreign currency. The overnight deposits to these accounts are limited, although intra-day deposits can be significant.
- *Risk vis-à-vis custodian banks.* The securities are deposited with central banks, central securities depositories and private custodian banks. In addition, the custodian banks hold securities received as collateral for collateralised bank deposits. The credit risk on custodian banks is limited, since they are not counterparties.

CREDIT POLICY

On investing the foreign-exchange reserve and the portfolio of domestic securities, credit risk can be kept at a low level, but not avoided completely. It is not a natural consequence of Danmarks Nationalbank's role as monetary authority to assume credit risk against an expected excess return, cf. Chapter 1. Danmarks Nationalbank therefore seeks to completely avoid credit losses due to failures.

A credit loss on a bond may also occur, however, in cases where the issuer's credit standing is perceived by the market to have diminished. The market will therefore require an interest premium (a higher credit spread) to cover the higher credit risk, forcing the bond price to drop. A wider credit spread may also reflect the market's perception that the return on a bond with a given credit quality must be higher, e.g. in connection with a cyclical downturn. This type of credit risk is often called the (credit) spread risk.

Investments are made solely in assets with a low credit risk that are not expected to lead to losses due to counterparty failure. The current investments comprise:

- government bonds with a high rating
- government-guaranteed bonds with a high rating
- bonds with underlying assets, e.g. mortgage-credit bonds
- short-term deposits with banks with a high rating
- bond futures
- forward foreign-exchange contracts
- gold.

On establishing the credit rules, the counterparties' credit standing and the maturity requirements of the exposures are balanced against each other. The reason is that the credit risk depends not only on the counterparty's credit standing but also on the maturity of the exposure. The longer the maturity, the greater the risk of the counterparty encountering financial difficulties before expiry of the exposure.

Assuming higher credit risk might increase the expected return on the investments, e.g. by relaxing the rating requirements or via purchase of corporate bonds or stocks with a high rating. However, the applied credit policy to avoid credit losses implies that the credit risk is kept at a low level.

BOND INVESTMENTS

Different rules apply to investments in bonds and bank deposits. On investing in foreign bonds it is a requirement that the purchased assets are government-guaranteed, or that government support can be assumed.

Counterparties' credit standing is based on the *long-term ratings* of the three large credit-rating agencies: Fitch, Moody's and Standard & Poor's[1]. The rating scale ranges from AAA as the best rating to C or D as the poorest rating. Investments are solely in securities rated AA or better.

The rating scale is described in further detail in Box 10.1.

The long-term ratings express the rating agency's assessment of the outlook for compliance with the payment obligations. As might be expected, the probability of entities with a high rating encountering payment problems has proved lower than for entities with a low rating. Table 10.2 shows one-year transition probabilities from one rating to

[1] The ratings defined by rating agencies are described in Andersen and Matzen (1998).

OVERVIEW OF THE RATINGS OF RATING AGENCIES Box 10.1

The purpose of the ratings of the three large credit-rating agencies, Fitch, Moody's and Standard & Poor's, is to classify borrowers by credit standing. All three rating agencies apply a range of letters from A to D to their long-term ratings, where A is the highest rating. Within each letter category, the credit quality can be specified by doubling or tripling the number of letters. Furthermore, Moody's provides an additional classification of credit quality by adding 1, 2 or 3, e.g. Aa3, while Fitch and Standard & Poor's add a plus or minus, e.g. AA-.

Investment grade ratings

AAA/Aaa is the highest rating given only to borrowers with an extremely strong ability to repay debt.

AA/Aa is awarded to borrowers with a very strong ability to repay debt and is only marginally different from AAA/Aaa.

A is awarded to borrowers with a strong ability to repay debt, but where the exposure to a change in the economic situation is greater.

BBB/Baa is awarded to borrowers with an adequate ability to repay debt, but where a change in the economic situation can be expected to weaken the ability to repay debt.

Speculative grade ratings

BB/Ba is awarded to borrowers less vulnerable in the short term than other lower-rated borrowers. However, there are major uncertainties and exposure to business, economic or financial circumstances that may lead to default.

B is awarded to borrowers that are more vulnerable than BB/Ba-rated borrowers. An unfortunate business, economic or financial development can be expected to lead to default.

CCC/Caa, CC/Ca and C/C: C-rated borrowers are currently vulnerable and dependent on favourable business, economic or financial conditions to maintain their ability to repay debt.

D: There has been a payment suspension.

another for all entities rated by Standard & Poor's. The probability of an entity suspending its payments (D rating) one year ahead is virtually zero for entities complying with Danmarks Nationalbank's requirement of a AA rating.

Credit lines are used to diversify investments. A credit line is the maximum permitted exposure vis-à-vis a given *issuer*. Credit lines are determined in kroner.

Securities lines regulate the absolute scale of securities investments in *individual countries.* In the same way, an absolute line applies to securities investments in supranational institutions such as the World Bank. Both are approved at least once a year by the Board of Governors. Table 10.3 gives an overview of securities lines.

ONE-YEAR TRANSITION PROBABILITIES BETWEEN RATING CATEGORIES, PER CENT

Table 10.2

From/To	AAA	AA	A	BBB	BB	B	CCC	D
AAA	93.06	6.29	0.45	0.14	0.06	0.00	0.00	0.00
AA	0.59	90.99	7.59	0.61	0.06	0.11	0.02	0.01
A	0.05	2.11	91.43	5.63	0.47	0.19	0.04	0.05
BBB	0.03	0.23	4.44	88.98	4.70	0.95	0.28	0.39
BB	0.04	0.09	0.44	6.07	82.73	7.89	1.22	1.53
B	0.00	0.08	0.29	0.41	5.32	82.06	4.90	6.95
CCC	0.10	0.00	0.31	0.63	1.57	9.97	55.82	31.58

Note: D rating means that the rated entity is subject to suspension of payments.
Source: Standard & Poor's, *Ratings performance 2002*, February 2003, p. 13.

Slightly different credit rules apply to the *portfolio of domestic securities.* A number of Danish issuers are not rated by the three large rating agencies, or they are rated by only one agency. No weight is therefore given to rating in the selection of issuers for the domestic investments. Instead, the requirement applied is investment solely in bonds weighted at zero or 10 per cent in the credit institutions' solvency statements. These are securities of high credit quality such as government securities, mortgage-credit bonds or securities issued by e.g. Kommunekredit.

It is considered important to avoid the role of dominant creditor. Ownership of an issuer's bonds is therefore kept below 10 per cent of the issuer's total amount of outstanding bonds.

SECURITIES LINES

Table 10.3

	Moody's rating	Securities line, DKK billion	Utilisation, per cent
Germany	Aaa	30	62
USA	Aaa	25	40
UK	Aaa	15	32
France	Aaa	15	44
Italy	Aa2	15	71
Sweden	Aaa	15	47
Netherlands	Aaa	10	7
Spain	Aaa	10	3
Belgium	Aa1	10	18
Finland	Aaa	5	15
Austria	Aaa	5	13
Ireland	Aaa	2	14
Portugal	Aa2	2	0
Canada	Aaa	2	0
Australia	Aaa	2	0
Switzerland	Aaa	-	-
Norway	Aaa	-	-
Supranational units	Aaa	10	36

Note: Data as at end-2002.
Source: Danmarks Nationalbank.

The aim is to spread the investments on a range of counterparties. Each issuer is subject to a line of 15 per cent of the value of the total domestic securities portfolio. The central government is, however, the exception to this rule.

To support the liquidity of the Danish bond market Danmarks Nationalbank lends bonds from the domestic securities portfolio against a fee. Loans are granted solely against collateral that complies with the general securities requirements applying to the domestic securities portfolio. The collateral value must exceed the loan by 5 per cent in order to guard against price fluctuations. The loans normally have a maximum maturity of three days.

UNCOLLATERALISED BANK DEPOSITS

Danmarks Nationalbank places short-term uncollateralised deposits with foreign banks. The uncollateralised deposits are the foreign-exchange-reserve investments subject to the highest risk, and the maturity is limited to a maximum of three months. It is considered important to have only banks with a high credit standing as counterparties. The special *Fitch bank ratings* are applied, since Fitch is considered to have special expertise in the credit rating of banks.

The Fitch bank ratings take into account that banks close to liquidation may expect varying degrees of support from the central government or from shareholders. Fitch therefore awards a rating for the probability that the bank will encounter problems (from A down to E), and a rating for the probability of external support (from 1 down to 5) in the event of problems.

Investments are only made with banks holding a Fitch bank rating better than C2. Applying the two bank ratings rather than long-term ratings makes it possible to ensure that exposures are undertaken solely with counterparties whose credit standing is not based exclusively on the expectation of support.

The Fitch bank ratings are described in further detail in Box 10.2.

The total volume of uncollateralised bank investments is limited by a *total line* that is determined monthly on the basis of the size of the foreign-exchange reserve. This line amounted to DKK 56 billion at the close of 2002.

In order to avoid a concentration of investments with banks in certain countries, *country lines* are used. A country's line is set as a fixed percentage of the total line.

FITCH BANK RATINGS Box 10.2

Individual rating

The individual Fitch rating is Fitch's assessment of the probability of a bank encountering difficulties without consideration of possible external support. This rating is based on factors such as the bank's profitability, balance sheet integrity, franchise, management, operating environment and prospects.

***A*:** A very strong bank. Characteristics may include outstanding profitability and balance sheet integrity, franchise, management, operating environment or prospects.

***B*:** A strong bank. No major concerns. Characteristics may include strong profitability and balance sheet integrity, franchise, management, operating environment or prospects.

***C*:** An adequate bank, which, however, possesses one or more troublesome aspects. There may be some concerns regarding its profitability and balance sheet integrity, management, operating environment or prospects.

***D*:** A bank which has weaknesses of internal and/or external origin. There are concerns regarding its profitability and balance sheet integrity, franchise, management, operating environment or prospects.

***E*:** A bank with very serious problems, which either requires or is likely to require external support.

Support rating

Support ratings are Fitch's opinion on the likelihood and source of external support, should a bank experience financial difficulties. The support may be granted from the central government and the owner of the bank. The assessment is based on the support providers' propensity and ability to give support. The propensities could be guarantees, ownership of the bank or the bank's importance to the financial system. The ability to give support is assessed on the basis of the support providers' long-term ratings.

1: A bank for which there is an *extremely high* probability of external support. The potential provider of support is very highly rated in its own right and has a very high propensity to support the bank in question.

2: A bank for which there is a *high* probability of external support. The potential provider of support is highly rated in its own right and has a high propensity to provide support to the bank in question.

3: A bank for which there is a *moderate* probability of support because of uncertainties about the ability or propensity of the potential provider of support to do so.

4: A bank for which there is *limited* probability of support because of significant uncertainties about the ability or propensity of any possible provider of support to do so.

5: A bank for which external support, although possible, cannot be relied upon. This may be due to a lack of propensity to provide support or to a very weak financial ability to do so.

Source: www.fitchratings.com.

COUNTRY LINES FOR UNCOLLATERALISED BANK EXPOSURE — Table 10.4

	Country line, DKK billion	Utilisation, per cent
Germany	14.0	37
USA	8.4	12
UK	8.4	52
France	11.2	17
Italy	5.6	38
Sweden	5.6	64
Netherlands	5.6	26
Spain	5.6	32
Belgium	5.6	42
Finland	5.6	35
Austria	5.6	0
Ireland	5.6	0
Portugal	5.6	0
Canada	5.6	45
Australia	5.6	11
Switzerland	14.0	9
Norway	5.6	24

Note: Data as at end-2002. The different country lines cannot each at the same time be utilised 100 per cent.
Source: Danmarks Nationalbank.

An absolute line is determined for each counterparty bank (deposit line). The size of the deposit line depends on the counterparty's rating, so that counterparties with a high credit standing are awarded a higher line. The deposit line also depends on the counterparty's equity capital, so that small counterparties are awarded smaller lines.

Table 10.4 shows the country lines at end-2002.

Danmarks Nationalbank may make short-term deposits with the Bank for International Settlements (BIS), cf. Box 10.3. BIS is not rated, but is considered to have a very high credit standing. BIS' line is set quarterly at half of the foreign-exchange reserve.

Gold investments with counterparty banks are subject to special lines. The rating requirements are more stringent than for normal bank deposits and the line is determined as only half of counterparty's ordinary deposit line. However, investments for up to 6 months are accepted for counterparties with especially high ratings.

REPURCHASE AGREEMENTS (REPOS)

Repurchase agreements (repos) are used on a significant scale for deposits with foreign banks. In repos only highly rated government bonds, which meets the criteria for inclusion in the foreign-exchange reserve, are received as collateral. Should counterparty default on the agreed payments, Danmarks Nationalbank's deposits are covered by the collat-

BANK FOR INTERNATIONAL SETTLEMENTS, BIS — Box 10.3

The Bank for International Settlements, BIS, is an international organisation, which fosters international monetary and financial cooperation and serves as a bank for central banks.

Danmarks Nationalbank may enter into the following transactions with BIS:

- Short-term deposits. There are no requirements of receiving collateral.
- Liquidity raising by using repos.
- Lending of securities. There are no requirements of receiving collateral.
- Foreign-exchange spot- and forward foreign-exchange contract trading.

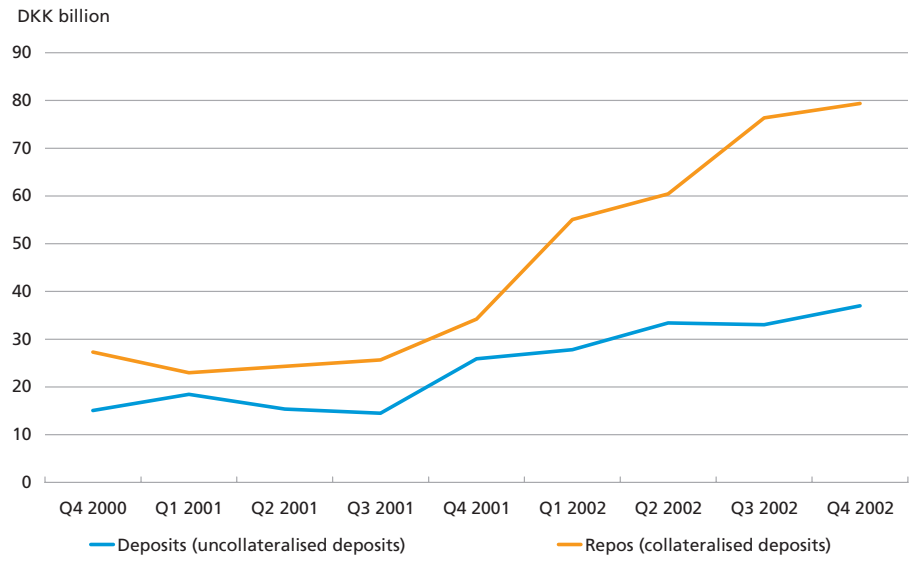
BIS has no rating but is considered to have a very high credit standing. On that basis the line is set at half of the foreign-exchange reserve.

Sources: www.bis.org and Danmarks Nationalbank.

eral provided. The credit risk on a repo deposit is thus considerably smaller than for uncollateralised deposits. However, repos entail a small legal risk. The mechanisms of repos are described in Box 10.4.

The use of repo deposits has expanded in recent years, cf. Chart 10.1. The principal reason is the increase in the foreign-exchange reserve that has led to an equivalently greater investment requirement. This greater investment requirement has been accommodated without an equivalent increase in the credit risk via investment as collateralised bank deposits, i.e. repos, rather than uncollateralised deposits.

BANK DEPOSITS SINCE END-2000 — Chart 10.1



REPO AGREEMENTS Box 10.4

Danmarks Nationalbank uses Master Repurchase Agreements to make deposits against securities as collateral, to raise liquidity by borrowing against securities, and for lending securities from the portfolios.

To achieve protection against counterparty creditors the agreement is legally designed as an agreement on purchase/sale of securities whereby the seller undertakes to repurchase the securities on an agreed date at a pre-specified price. Absolute title to the purchased securities is transferred to the buyer – with the exception that the seller shall receive any interest after the sale – and the buyer may sell the securities on or after the repurchase date, should the seller be unable to repurchase them. Any difference between the original purchase price and the value of the securities at the time of realisation is netted. The seller of the securities enters into a repo, while the buyer of the securities enters into a reverse repo.

Danmarks Nationalbank contracts reverse repos as bilateral or 3-party repos. When transacting a bilateral repo the securities are deposited with one of Danmarks Nationalbank's central securities depositories. With respect to 3-party repos the securities are deposited with a third party, which moreover undertakes to monitor on an ongoing basis whether the market value of the collateral is correct and sufficient and, if necessary, requires additional collateral.

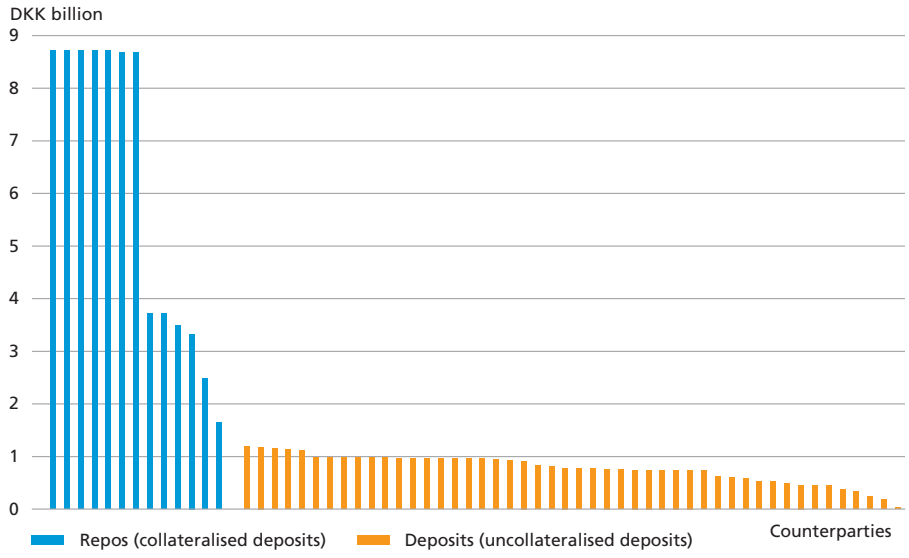
Most of Danmarks Nationalbank's repos are 3-party repos, whereby Danmarks Nationalbank avoids administration of the collateral. 3-party repos require entering into a Global Master Repurchase Agreement, which is an internationally applied standard agreement, with the counterparty and a service agreement with the third party. These agreements set out the general terms for the repo contracts, including the type of collateral that is accepted, and the amount of excess cover. Only government bonds with a rating of at least Aa3/AA- are accepted, in line with the requirements for securities investments. In order to cover for fluctuation in the collateral value during the contract period Danmarks Nationalbank requires excess cover of 2 per cent, i.e. collateral must be provided for EUR 102 million for a deposit of EUR 100 million (if two different currencies are used, the excess cover is 5 per cent). Additional collateral is required in the event of insufficient cover due to subsequent fluctuation in market prices.

Repo lines are determined as an absolute level per counterparty, depending on the counterparty's rating and equity capital. No limit applies to the total repo volume. Moreover, lines are determined for the custodian banks that manage the collateral.

When the foreign-exchange reserve increases, the requirement for short-term bank investments also increases. In view of the objective of a constant interest-rate risk, the excess foreign exchange is not invested in long-term bonds. The repo lines are currently adjusted in order to accommodate fluctuations in the requirement for short-term investments.

Danmarks Nationalbank has far more deposit counterparties than repo counterparties, cf. Chart 10.2, which shows the bank deposits for each counterparty. Each bar in the Chart represents a deposit with counter-

BANK DEPOSITS BY COUNTERPARTY Chart 10.2



Source: Source: Danmarks Nationalbank.

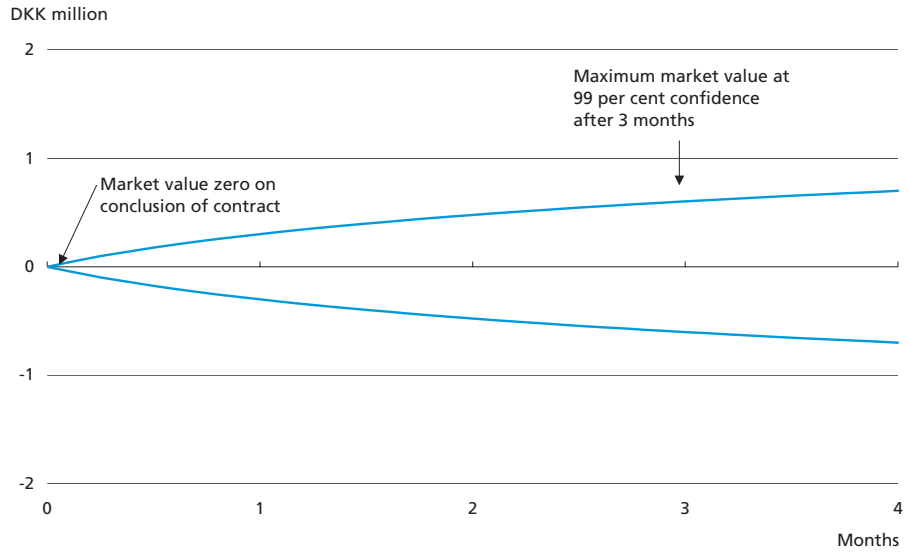
party bank. The explanation of the relatively small number of repo counterparties is that it can be difficult to find counterparties with a high credit standing that are interested in concluding repos on a sufficiently large scale. In addition, negotiating and finalising the legal contracts governing repos with a repo counterparty is a time-consuming process. In view of the smaller risk on repo positions, a deposit with a repo counterparty may be considerably greater than a deposit with counterparty for uncollateralised deposits. To ensure the required diversification on counterparties, a certain percentage of the bank deposits is still held with counterparties that do not provide collateral. As more and more repo contracts are concluded, this percentage will be reduced.

Repo contracts are also used to raise liquidity against securities as collateral and for lending of securities from the portfolios. The purpose of lending securities from the foreign-exchange reserve is to achieve a higher return on the portfolios.

FORWARD FOREIGN-EXCHANGE CONTRACTS

Forward foreign-exchange contracts are used to restructure the foreign-exchange exposure of the foreign-exchange reserve, cf. Chapter 6 on currency risk. When it is concluded, a forward foreign-exchange contract has no market value. Up to the expiry of the contract exchange-rate fluctuations will cause the value of the contract to fluctuate. If the mar-

EXAMPLE OF THE DEVELOPMENT IN THE MARKET VALUE OF A FORWARD FOREIGN-EXCHANGE CONTRACT Chart 10.3



Source: Danmarks Nationalbank.

ket fluctuation is in favour of Danmarks Nationalbank a credit exposure arises since Danmarks Nationalbank will lose this gain if the counterparty defaults.

Most forward foreign-exchange contracts are concluded in order to restructure from US dollar to euro exposure. The development in credit exposure on the forward foreign-exchange contracts is thus driven primarily by the development in the US dollar exchange rate.

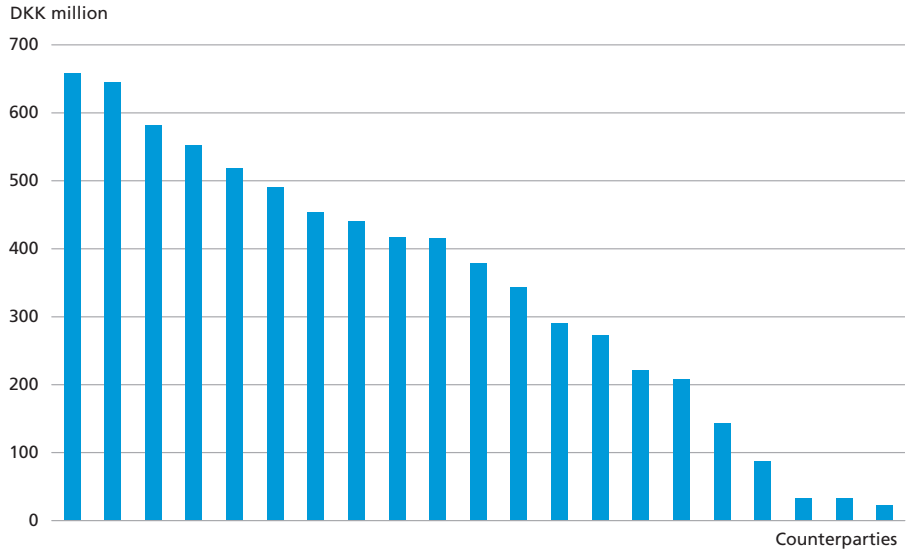
Chart 10.3 illustrates the development in the market value of a hypothetical forward foreign-exchange contract. The area within the blue lines illustrates the interval for the contract's market value with a probability of 99 per cent. The longer the maturity, the greater the probability of a higher positive market value and thereby credit exposure.

Danmarks Nationalbank only concludes contracts with a maturity of less than 100 days.

The credit standing of the counterparties to forward foreign-exchange contracts must be as high as for foreign bank deposits. The same rating requirement is applied, i.e. a Fitch bank rating better than C2. Based on the counterparty's rating and equity capital a limit is set for the credit exposure on the counterparty.

The credit exposure on the forward foreign-exchange contracts is calculated as market values plus a premium for a potentially higher future credit exposure. This means that a line is put to use when a contract is concluded.

CREDIT EXPOSURE ON FOREIGN-EXCHANGE COUNTERPARTIES Chart 10.4



Source: Danmarks Nationalbank.

Chart 10.4 shows the credit exposures calculated for each foreign-exchange counterparty. The credit exposure at end-2002 totaled almost DKK 9 billion, of which DKK 6 billion was a potential credit-exposure premium for the remaining maturity.

LITERATURE

Andersen, Kristian Sparre and Anders Matzen (1998), The Use of Ratings in the European Capital Markets, Danmarks Nationalbank, *Monetary Review,* 3rd Quarter.

Fitch, *Ratings*, April 2001.

Moody's, *Global Ratings Guide*, March 2003.

Standard & Poor's, *Ratings performance 2002*, February 2003.

Standard & Poor's, *Global Ratings Handbook*, April 2003.

11. Operational Risk

Over the past years, there has been a major evolution within operational risk management. However, Danmarks Nationalbank is still in an introductory phase in setting up models and methods for managing operational risk.

The Bank for International Settlements (BIS) has defined operational risk as "the risk of loss resulting from inadequate or failed internal processes, people and systems, or from external events"[1]. For a central bank it is important that assessments of operational risk also take loss of reputation into account.

Since operational risk thus covers a wide range of different risk factors, Danmarks Nationalbank's operational risk management cannot be defined in isolation as financial risk management, but reflects a wider management framework for all of its business areas.

Operational risk management is not a new area for Danmarks Nationalbank, but has long been a central element of its business. However, as more and more work processes – operations – are supported by IT, with the possibility of highly disruptive system failures, and as financial instruments have become increasingly more sophisticated, with the risk of mismanagement and fraud, the focus on operational risk has increased. There are ongoing efforts to implement and further develop a framework for operational risk management in all of Danmarks Nationalbank's business areas. Operational risk in relation to portfolio management is managed via qualitative objectives. Operational risk is reduced since Danmarks Nationalbank does not undertake transactions of an unnecessarily complex nature.

INTERNATIONAL STANDARDS

BIS recommends a number of principles for sound practices in management of operational risk. These can be summarised as follows:

- The management[2] of the bank should *be aware of, approve and review* the bank's framework for managing operational risk.

[1] *Sound Practices for the Management and Supervision of Operational Risk*, February 2003, Basel Committee on Banking Supervision, www.bis.org.

[2] By management is meant the Committee of Directors and Board of Governors.

- The management of the bank should be responsible for *implementing* the framework and ensuring that it is *reviewed* by independent auditors.
- For all activities, products, processes and systems, *risk assessments* should be conducted.
- The bank should have policies, processes and procedures to *identify, control and monitor* operational risk.
- The bank should have in place a *business continuity plan*[1] in the event of severe business disruption.
- The bank should publicly *disclose* its strategy for operational risk management.

Danmarks Nationalbank's operational risk management strategy is based on these principles.

Danmarks Nationalbank's framework for operational risk management is based solely on a *qualitative standard*. Among other things, this standard entails that monitoring of operational risk management comprises:

- Ensuring that measures against operational risk are intact,
- Analysing various risk scenarios,
- Ongoing management reporting on operational risks and their significance to Danmarks Nationalbank,
- Assessing whether the model's requirements are observed within the organisation.

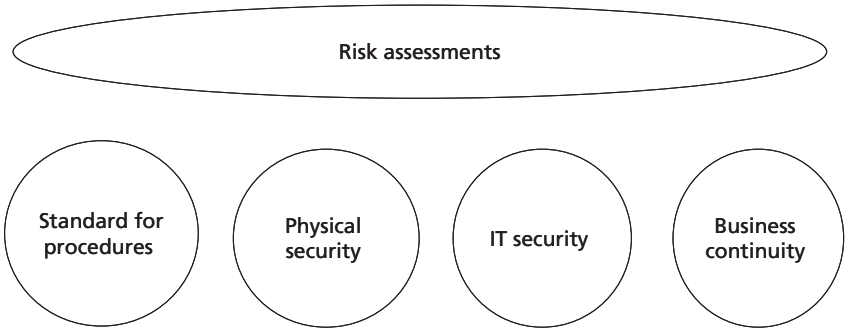
This standard ensures that Danmarks Nationalbank at all times has an overview of its operational risk and the measures taken to reduce the impact to an acceptable level.

DANMARKS NATIONALBANK'S FRAMEWORK FOR OPERATIONAL RISK MANAGEMENT

As Chart 11.1 shows, Danmarks Nationalbank's framework for operational risk management comprises a risk assessment model, a standard for procedures, physical security, IT security management and business continuity plans. These areas relate directly to the various elements of the definition of operational risk. This entails that the probability of faults are reduced by:

[1] Business continuity management objective: to counteract interruptions to business activities and to protect critical business processes from the effects of major failures or disasters (ISO/IEC 17799 *Information technology – Code of practice for information security management*, Business Continuity Management chapter).

DANMARKS NATIONALBANK'S FRAMEWORK FOR OPERATIONAL RISK MANAGEMENT Chart 11.1



Source: Danmarks Nationalbank.

- processes closely related to the procedure concept,
- systems linked to IT security management,
- external events being covered by business continuity plans.

The risk of human error is addressed within all areas, and there is also some overlap between the areas.

Danmarks Nationalbank has included physical security, since due to its responsibility for banknotes and coins a central bank has a number of processes, such as the production, storage and transport of assets, that impose the requirement for special measures to physical security.

The individual areas of the framework are not new to the bank, but they are now managed from one organisational unit and are related to operational risk management.

Each area within the framework comprises overall requirements in accordance with policies and in-depth guidelines, as well as related general procedures. Furthermore, IT systems have been introduced to support the implementation.

Risk assessment model

The purpose of the risk assessment model is to support the identification and assessment of operational risk for given activities, products, processes or systems. A risk assessment comprises an estimate of the probability that loss events will occur, as well as the possible impact of such events. The need to take measures is particularly high in cases where the probability is high, and the consequences are also significant.

EXAMPLES OF RISK ASSESSMENTS AND MEASURES — Table 11.1

Risk / threat	P	I	R	Measures	Residual risk	P	I	R	Conclusion
External power outage	3	4	12	1. Guidelines for power supply 2. Calculation of coverage requirement 3. Establishment of internal generator 4. Regular testing of internal generator	Internal generator fails	3	1	3	Measures deemed to be sufficient
Unauthorised trading	3	4	12	1. Clean criminal record required 2. Physical and logical division of front and back office into two separate departments 3. Line management of counterparty exposures	Separation of front and back office is compromised	1	3	3	Measures deemed to be sufficient
No physical access to dealers' workstations	2	4	8	1. Establishment of alternative workstations for dealers 2. Procedure for use of alternative workstations 3. Regular testing of alternative workstations	Simultaneous failure of normal and alternative workstations	2	1	2	Measures deemed to be sufficient

Note: "P" indicates probability (1= very low, 2= low, 3 = medium, 4= high), "I" indicates impact, and "R" (probability multiplied by impact) indicates risk factor. All factors are assessed before and after measures are taken.

The risks[1] that may affect activities, products, processes and systems must be identified in the individual risk assessments and their impact assessed, after which a risk factor is calculated as the product of probability and impact. Hereafter the measures taken are described. Such measures may be of an organisational, technical or procedural nature. If there is a residual risk, it must be described and a decision taken on whether it is acceptable or should perhaps be reduced.

Table 11.1 gives examples of measures to reduce the risk or impact of various events. The examples given are not exhaustive.

The risk assessments are prepared by the individual departments, but to ensure uniformity and cross-organisational measures the risk assessments must be submitted to a central function for comment.

[1] *Working Paper on the Regulatory Treatment of Operational Risk*, Annex 2: "Detailed loss event type classification", September 2001, Basel Committee on Banking Supervision, www.bis.org.

IMPLEMENTATION

Implementation of the model for operational risk management is a protracted process. Danmarks Nationalbank is still in an introductory phase in a number of areas. In this phase the model's areas are introduced and implemented gradually as an important tool for each department.

Subsequent implementation phases will e.g. include development of routines for closer monitoring of operational risks, including centralised compilation and reporting of residual risks and their potential significance to Danmarks Nationalbank.

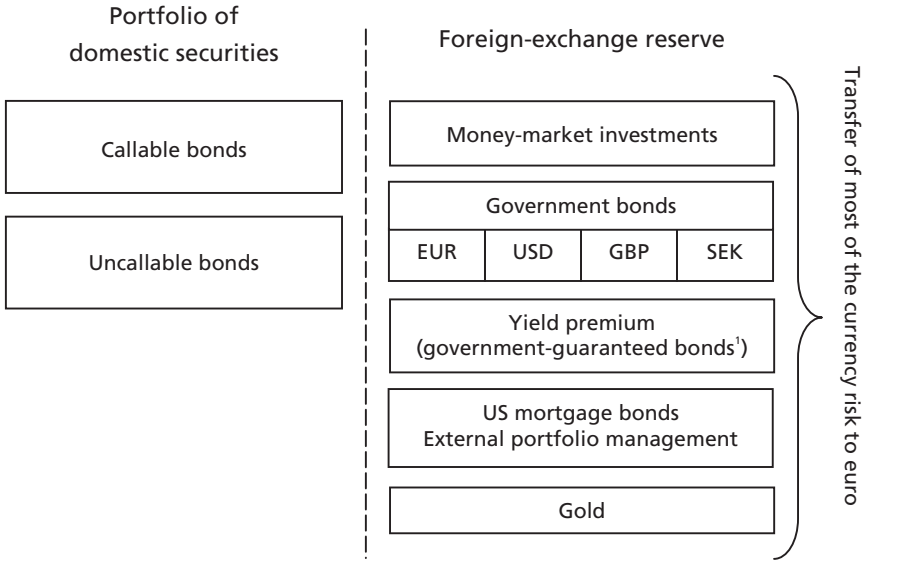
12. Front Office Portfolio Management

The responsibilities of Danmarks Nationalbank's front office include the day-to-day management of the portfolios, i.e. purchase and sale of domestic and foreign bonds, investment of liquidity in money-market instruments, and lending of gold. Furthermore, foreign-exchange swaps are concluded in order to manage the foreign-exchange exposure that is predominantly denominated in euro.

The aim for portfolio management is to result in higher returns relative to the benchmark through an active ongoing review and adjustment of the positions. Another objective is to ensure close contact with the financial markets in order to maintain trading expertise, market knowledge and good counterparty relations. This is vital in a situation where parts of the foreign-exchange reserve are to be liquidated or collateralised for intervention purposes. Finally, the portfolio managers monitor the market as a whole, and important information is communicated to the rest of Danmarks Nationalbank.

Front office manages ten subportfolios. The domestic securities portfolio is divided into a callable and an uncallable subportfolio. The foreign-exchange reserve consists of eight sub-portfolios, cf. Chart 12.1. The

ORGANISATION OF PORTFOLIOS IN FRONT OFFICE — Chart 12.1



[1] The guarantee might be implicit.

foreign-exchange reserve and the domestic securities portfolio are generally managed according to the same principles.

RISK AND RETURN OF PORTFOLIO MANAGEMENT

By deviations from the tactical benchmark portfolio management in front office will impact directly on the overall risk level.

With regard to *interest-rate risk,* positioning may change Danmarks Nationalbank's total krone duration (interest-rate exposure) by ±20 per cent for the securities portfolio and by ±10 per cent relative to the tactical benchmark for the foreign-exchange reserve, cf. Chapter 7.

The portfolio management furthermore affects Danmarks Nationalbank's *liquidity* and *credit risk* – but to a limited extent. On investing in other instruments than BIS[1] deposits and government bonds, the actual positions deviate from the tactical benchmark.

Investing in callable mortgage-credit bonds contains a *prepayment risk* that is adjusted by the portfolio manager within the convexity framework, cf. Appendix A on callable mortgage-credit bonds.

The *currency risk* is not subject to active portfolio management. Deviations from the strategic position – i.e. primarily euro – are very limited and can generally be attributed to the impact of transactions vis-à-vis the central government, the IMF, etc. Investment in the interest-rate markets does not contribute to changing the currency risk, since the same currency is bought and sold.

The portfolio management also contributes to *operational risk,* cf. Chapter 11.

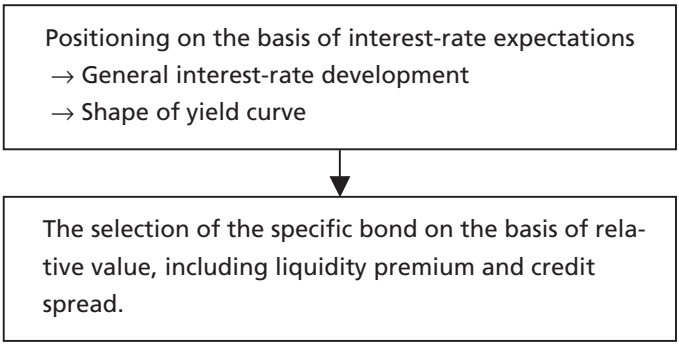
Portfolio management seeks to maximise returns within the risk limits. The level of return reflects this framework. Security and liquidity are key aspects of the management of the foreign-exchange reserve, which must at all times support the exchange-rate policy. This reduces the opportunities to achieve high returns.

THE INVESTMENT DECISION

The Investment decisions in relation to the portfolios include several elements, cf. Chart 12.2. The first is to establish the expectations of the future level of interest rates, and where on the yield curve this impact is expected. The portfolio manager then selects the individual bond to be bought or sold on the basis of its relative value. This includes an assess-

[1] See also Chapter 10, Box 10.3.

THE INVESTMENT DECISION Chart 12.2



Note: The yield-premium portfolio of the foreign-exchange reserve differs from this investment strategy since it focuses exclusively on relative value as the criteria for selection of instruments.

ment of the credit and liquidity premiums. Decisions in relation to positioning and choice of instrument are described below.

Positioning in relation to interest-rate expectations

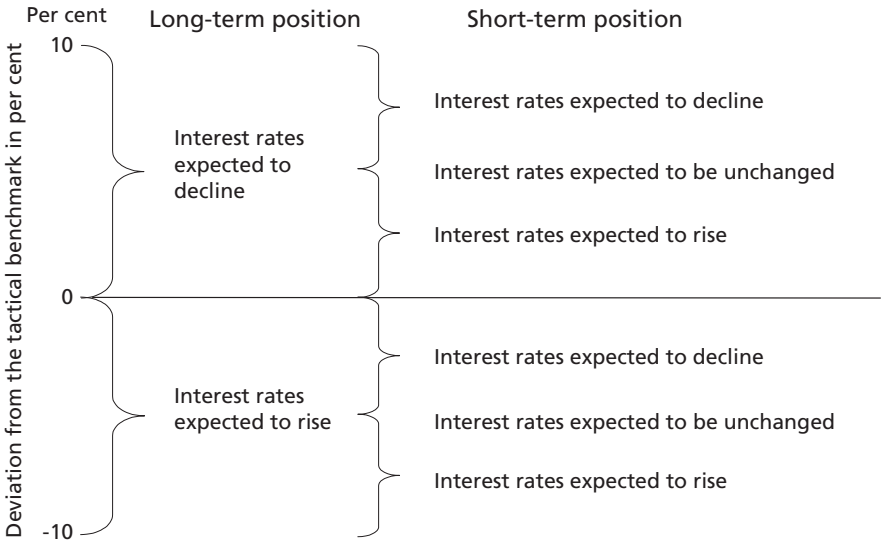
Expectations of the general level of interest rates are affected by a number of factors. In principle, the development in interest rates is driven primarily by the economic fundamentals in the long term and market conditions in the short term. Assessment of the future level of interest rates includes forward rates, the development in macroeconomic data, issuing policy, technical analysis, positions and flows among major market participants, market sentiment, volatility and correlations among e.g. the equity, currency and bond markets.

The above mentioned data is supplied to the portfolio manager by several information systems (e.g. Bloomberg and Reuters) as well as trading counterparties, who also contribute with input to the investment decision.

With regard to the foreign-exchange reserve the investment decision is normally divided into a long-term position with a horizon of e.g. one month and a more short-term position with a horizon e.g. of one day or one week. The portfolio manager chooses the time horizon for the short-term and long-term investment, which corresponds to the horizon for the interest-rate expectations. The long-term horizon extends for no longer than a few months.

On the commencement of the period the interest-rate level at the end of the period is assessed, and this assessment typically determines the general positioning throughout the period. If interest rates are found to be declining in the *long term,* a long position relative to the benchmark

SHORT-TERM AND LONG-TERM POSITIONING RELATIVE TO THE TACTICAL BENCHMARK Chart 12.3



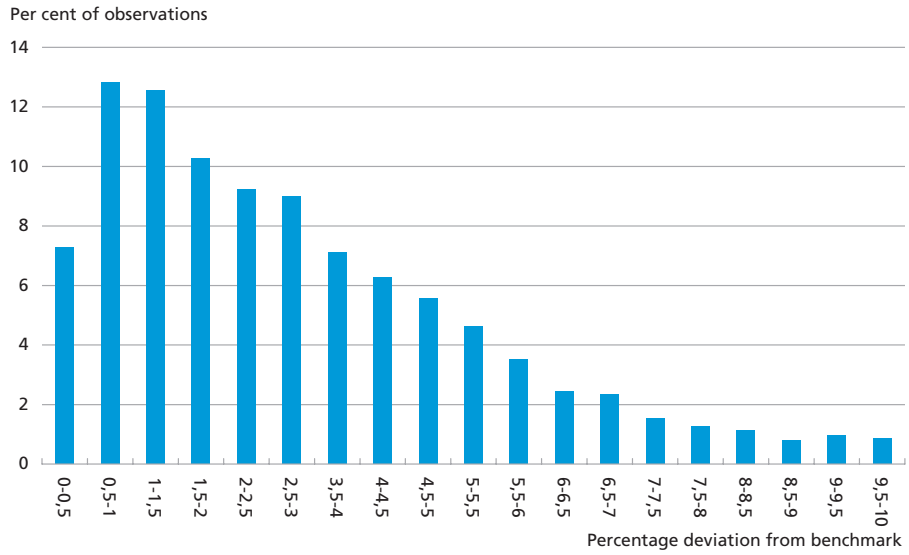
is taken. However, if the portfolio manager believes that interest rates are rising in the *short term*, the overall position will be (far) closer to the benchmark. This positioning approach establishes a "corridor" for active short-term trading, cf. Chart 12.3.

The portfolio manager can thus react to new information on interest-rate developments at any time, ensuring that the position in relation to long-term expectations can be maintained. A further objective is to ensure a certain degree of discipline when taking positions. This method makes it possible to revisit the scenario on which the position is based and to assess whether there are any significant changes in the analysis that should be reflected in the position.

Each portfolio manager determines the size of the position within the framework stipulated for e.g. interest and credit risk. The portfolio manager may as mentioned earlier deviate by ±10 per cent relative to the tactical benchmark for the foreign-exchange reserve. Chart 12.4 shows the distribution of the actual percentage deviations from the tactical benchmark.

Once the portfolio manager has determined expectations of the general development in interest rates, the next step in the investment decision is normally the allocation of the exposure on the yield curve. For the domestic securities portfolio no framework has been stipulated for yield-curve positions. With regard to the foreign-exchange reserve the krone duration of the benchmark is in principle distributed equally on maturities of up to 10 years. The portfolio manager may deviate by

DEVIATIONS IN THE KRONE DURATION FROM THE TACTICAL BENCHMARK ON THE FOREIGN-EXCHANGE RESERVE Chart 12.4



Note: Daily observations for the period January 1999-September 2003. Positions measured at end-of-day.

15 per cent in each 2-year maturity segment for as long as the position remains within the overall framework for krone duration (+/-10 per cent).

The investment decision in the individual segments includes the forward interest rates. For a given investment horizon the portfolio manager thus compares his or her own interest-rate expectations with the forward interest rates and takes positions in cases of substantial deviation. If the forward rate exceeds the expectations the exposure in that part of the yield curve is increased.

Choice of instrument

Once the total krone duration and its distribution on the yield curve have been selected, the portfolio manager selects the individual bonds in each maturity segment. Each bond is assessed for its relative high or low cost in relation to e.g. the zero-coupon yield structure. The portfolio manager will seek to sell the high-cost bonds and/or purchase the low-cost bonds, unless it is expected that the spread of the relative price offering will be further amplified. This would offset the current yield premium associated with the low-cost bond in relation to the higher-priced bonds.

High or low pricing of a bond in the market can be assessed by several methods. Naturally, these methods are not unequivocal, but together

Z SCORE ON THE RELATIVE BOND VALUE Box 12.1

The Z score takes into account that too high or too low pricing, e.g. in relation to the zero-coupon yield curve, may be of a more permanent nature. The Z score relates the yield spread of the bond to the spread's historical fluctuation. The Z score is calculated as follows:

$$\text{Z score} = \frac{\text{Current spread} - \text{average spread}}{\text{The spread's standard deviation}},$$

where the spread is the difference between e.g. the yield to maturity and the theoretically compounded yield. The Z score is thus an expression of the number of standard deviations of the current yield spread from its historical average. The Chart below shows Z scores for selected German bonds on 15 September 2003.

Z SCORES FOR GERMAN GOVERNMENT BONDS

Source: HSBC.

they provide a basis for assessment of the relative value of the bonds. These methods include:

- The interest-rate spread to the swap curve.
- The net present value, i.e. the difference between the theoretical price calculated via the zero-coupon yield structure and the market price.
- Z scores and similar models that take mean reversion into consideration, cf. Box 12.1.

Generally, it is considered an advantage to invest in a bond with a high positive spread to the swap curve, a high net present value and a high Z

score – preferably a standard deviation exceeding 1.5. This approach to assessing the relative value of bonds is extremely useful and provides a systematic evaluation of trading ideas.

In the selection of the specific bond liquidity is also considered. The liquidity of bonds has an impact on their relative prices. Low liquidity tends to increase transaction costs (a wider spread between bid and offer prices). This reduces the price of the bond.

The tactical benchmark of the foreign-exchange reserve consists of highly liquid government bonds. The portfolio manager may choose to invest in bonds with the same interest-rate and yield-curve risk as the benchmark, but with lower liquidity. This will typically generate a liquidity premium and thereby a higher expected return, although in active trading the higher trading costs must be taken into account.

Also considerations of the bonds credit quality are included in the selection of the specific bond. The credit quality of bonds has an impact on the relative prices. Bonds with a lower credit quality than government bonds normally generate higher yields to maturity. The higher yield is the payment for the additional risk assumed via such an investment, e.g. the risk of issuer-specific losses and of a widening of the general credit spread. Furthermore, credit products are normally less liquid than government securities.

A constant krone duration in the benchmark is central to the risk management of the foreign-exchange reserve. Consequently, the larger the foreign-exchange reserve, the higher the money-market investments. The benchmark of these investments is the remuneration offered for very short-term investments with BIS, see Box 10.3. BIS deposits are a very liquid instrument with a high credit rating, but a relatively low return. Placing this market value in repos or as time deposits with banks can generate a higher return relative to the benchmark.

Two bond portfolios of the foreign-exchange reserve are allocated to investment in other bonds than government bonds – such as US mortgage bonds – in order to generate a higher return. Also, the benchmark for the portfolio of European government bonds comprises government bonds issued by the central governments of Germany, France and Italy. An overweight of e.g. Italian government bonds compared to German government bonds generates an expected higher return, since Italian government bonds are traded at a higher yield to maturity.

Part of the domestic securities portfolio is invested in other instruments than Danish government bonds, primarily mortgage-credit bonds with a high credit rating. The choice of coupon and maturity is an important investment decision in relation to the inherent option in callable bonds, cf. Appendix A on callable mortgage-credit bonds.

SECURITIES LENDING

The management of the foreign-exchange reserve involves ongoing lending of securities from the portfolio in order to generate a higher return. Bonds are also lent from the domestic securities portfolio, although for the sole purpose of supporting the market, and not to achieve higher returns.

Some bonds are in particularly high demand and can be lent at an extra return. These bonds are traded as "specials". The pricing is often special when the trade involves:

- A benchmark bond.
- A bond that must be delivered on expiry of a futures contract. Investors that are obliged to deliver the bond on expiry of the future may wish to borrow the bond rather than purchase it.
- An investor or offerer having sold the bond without owning it. The delivery obligation can be fulfilled by borrowing the bond.

The bonds traded as specials in the repo market are often relatively highly-priced. Revenue from lending must therefore be set against the relatively lower current return.

Bonds from the foreign-exchange reserve are lent mainly via 3-party repos for periods of up to 14 days, cf. Chapter 10. Danmarks Nationalbank also operates an automatic securities lending scheme via the Euroclear clearing house, which is the custodian of a major share of Danmarks Nationalbank's securities. Under this scheme the loan is commenced and concluded overnight within one settlement period.

THE TRADE

The investment decision is followed by the actual trade. The first step is to ensure *pre-trade compliance,* i.e. that the trade can be transacted without exceeding lines. The trade is assessed in relation to residual lines for credit exposure and to the interest-rate exposure framework.

The next step is typically to find indicative prices for the bond. An overview of the counterparties' prices can be found on information pages such as Bloomberg, Reuters, Tradeweb and the Copenhagen Stock Exchange (CSE).

At the end of 2003 electronic market-making in the MTS-system[1] for Danish bonds was introduced. Danmarks Nationalbank has access to the

[1] MTS (Mercato dei titoli di stado) is an electronic trading platform for professional market participants on the European market for government bonds.

market as a pricetaker, so that it may only trade at prices offered by market makers in the system. In future, most government bonds traded for the domestic portfolios will be executed via this system. Other bonds will continue to be traded via CSE. Telephone-based trading of Danish bonds is primarily with the largest market participants and typically on the basis of own or counterparties' prices entered to CSE's electronic systems.

When bonds are traded in relation to the foreign-exchange reserve counterparties are in competition to offer the best price for a specified amount. The market convention is not to split trades among counterparties.

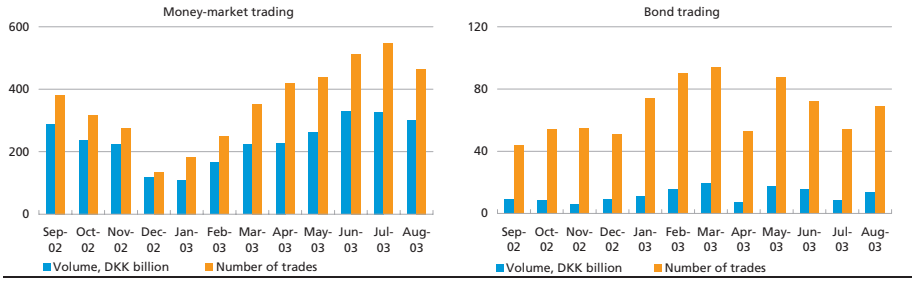
TradeWeb, an electronic multi-dealer trading platform, is often used for trading in the European and US government bond markets. Trading is screen-based and several market makers offer simultaneous, tradeable prices directly to the portfolio manager. These trading platforms present many advantages. It is easy to locate the best price, and the system contains all information relevant to registration and settlement. This makes the procedure considerably more efficient, and reduces the likelihood of errors. Furthermore, the trading situation can be re-established if an audit calls for evaluation of whether the best price was obtained.

There are several other multi-dealer platforms besides TradeWeb. Danmarks Nationalbank furthermore uses the electronic trading platform FXall for trading in foreign exchange and for forward foreign-exchange transactions.

The maximum value of a single trade is the equivalent of USD 100 million. Large-value trades are therefore split up into several smaller trades with the same counterpart in order to reduce the settlement risk.

As Chart 12.5 shows, trading is considerably greater for the money-market portfolio than for the bond portfolios in terms of both volume and number of trades. This is attributable to ongoing re-investment of money-market investments and the distribution of trades on a wide range of counterparties. In addition, the restriction of the size of trades

NUMBER OF TRADES AND VOLUME IN THE FOREIGN-EXCHANGE RESERVE Chart 12.5



plays a greater role for money-market investments than for bond trading, since the amounts invested are considerably higher. Finally, a full pre-trade analysis is a key parameter in portfolio management. The individual bond portfolio manager thus undertakes a limited number of trades per day.

Once the trade is concluded, it is entered into the trading system, which transmits the data to the back-office function in charge of settlement. The trading system also transmits lists of holdings that are updated in real time and constitute the basis for counterparty statistics.

TRADING COUNTERPARTIES

It is important to limit the number of counterparties in relation to the individual portfolios, since an adequate trading volume is a prerequisite for sound relations with the counterparty. Nevertheless, the number of counterparties must ensure competitive price offering and that the portfolio manager receives sufficient information as input to the investment decision. Table 12.1 shows the typical number of trading counterparties for the individual portfolios.

Danmarks Nationalbank participates in the market for Danish bonds. In principle, the counterparties are members of CSE's bond market and the MTS market makers who are not CSE members (i.e. a total of 32 counterparties). The MTS market makers are Danmarks Nationalbank's government-bond trading counterparties, and via electronic trading it is ensured, that the trade takes place with the members offering the most attractive prices.

It is expected that most mortgage-credit bonds will continue to be traded via telephone, and most of the trading will be with the largest market participants. Although CSE has 27 bond members, the actual number of counterparties is significantly lower.

The number of counterparties for the foreign bond portfolios is lower than the level for the domestic portfolio. The exception is the money-

TYPICAL NUMBER OF COUNTERPARTIES — Table 12.1

Portfolio	
Danish bonds	32
Euro bonds	10
US bonds	10
UK bonds	5
Swedish bonds	4
Foreign money market	60

Note: It is sought to use the same counterparties for the yield-premium portfolio as for the government-bond portfolios.

market portfolio which involves the investment of considerably larger amounts. This portfolio is therefore distributed on several counterparties in order to limit the credit risk.

The portfolio manager selects the counterparties among those with an approved credit standing. In principle, the counterparty list can be changed on an ongoing basis, but in practice counterparty relationships of a more long-term nature are sought. A counterparty is thus rarely removed from the list without being informed in advance of the weaknesses in the relationship and possibly also being given an opportunity to eliminate the weaknesses.

When selecting counterparties for the foreign-exchange portfolio price offering is vital to the level of trading. If counterparties offer less favourable prices, they will lose the trade to one of the other counterparties. Another important factor is the analyses received from the counterparty. These may be a more detailed analysis of a specific topic, or assessments of the current market development. Other focus areas are the extent to which forecasts of the market-related and economic developments actually materialise.

EXTERNAL PORTFOLIO MANAGEMENT

Since the early 1990s the portfolio of US mortgage bonds has been managed externally. Danmarks Nationalbank finds it difficult to build up and maintain the same level of knowledge internally as can be achieved by an American manager. The use of an external portfolio manager also gives access to economic, financial and investment information, but it does require devotion of resources to e.g. reporting and monitoring.

The external portfolio manager's mandate is to maximise the return on the portfolio in relation to the benchmark. The neutral modified duration of the benchmark is 3.2 years, with a deviation margin of $\pm$ 2 years. The benchmark consists of US government bonds and is adjusted monthly. The external portfolio manager may invest in US government and mortgage bonds, as well as CMOs, and make bank deposits. The portfolio has realised an average higher return of 0.5 per cent per annum after payment of costs to the portfolio manager.

The portfolio management entails ongoing re-investment of interest and repayments. The market value was almost DKK 2 billion at end-2002.

All trades are reported to Accounting at Danmarks Nationalbank and the portfolio is included alongside the other portfolios in the compilation of the exposure and risk.

MANAGEMENT OF THE GOLD RESERVE

Gold lending is subject to more restrictive requirements of credit standing than normal bank deposits, cf. Chapter 10.

The interest on gold loans granted by Danmarks Nationalbank is settled in gold that is sold on the maturity date, so that the market value of the gold reserves is maintained. Gold loans run from one to 6 months, depending on the counterparty banks' rating, interest rates and the expected interest-rate development. The interest rates for gold loans fluctuate, and in certain periods they have been so low that Danmarks Nationalbank recalled the gold from the loan counterparties on maturity since the revenue did not match the administration costs and the credit risk on lending. At the end of 2002 more than half of the gold holding had been lent to commercial banks, while in 2003 gold lending was limited as a consequence of the low level of interest, cf. Chart 4.4 in Chapter 4.

TRANSFER OF THE CURRENCY RISK TO EURO

Almost the entire currency risk on the foreign-exchange reserve's investments is transformed to euro by means of a spot foreign-exchange trade and foreign-exchange swaps, cf. Chapter 6 on currency risk. Danmarks Nationalbank's activity in the foreign-exchange swap market consists primarily of new foreign-exchange swaps as a consequence of the expiry of previously concluded swaps. In other words, the foreign-exchange swaps are "rolled over".

Danmarks Nationalbank concludes 3-5 foreign-exchange swaps per day for an average value of approximately EUR 45 million. Danmarks Nationalbank's trading volume in the forward foreign-exchange market is, however, limited compared to the overall global activity. According to the latest BIS survey of the foreign-exchange market (2001) foreign-exchange swaps with a daily average turnover of more than USD 600 billion account for the largest daily turnover among the products on the global foreign-exchange market.

INDICATIVE BID-OFFER SPREADS ON FOREIGN-EXCHANGE SWAPS — Table 12.3

	EUR/USD	EUR/GBP	EUR/SEK
1 month	0.1	0.2	0.3
2 months	0.2	0.4	0.4
3 months	0.2	0.5	0.5

Note: A bid-offer spread is the difference between the bid and the offer price for the forward premium used to determine the forward rate from the spot price. A spread of 0.1 will imply that the forward premium e.g. trades at -9.2/-9.1. The negative premium is due to the lower 1-month interest rate in the USA than in the euro area. The forward price will thus be 108.008-108.009 if the spot price is 108.10.

Foreign-exchange swaps are typically concluded with a maturity of 1-2 months, since the very short-term segments are the most liquid, cf. Table 12.3. The allowed maximum maturity of a foreign-exchange swap is 100 days, cf. Danmarks Nationalbank's credit rules.

The low bid-offer spread for a foreign-exchange swap shows that the costs are low due to the high liquidity.

The favourable liquidity also ensures that Danmarks Nationalbank can transform the currency risk to euro without affecting the market. The counterparties are 25 domestic and foreign banks.

13. Measuring Performance

Performance is measured by comparing the return on the actual portfolios to the return on the benchmark portfolios. A higher return on the actual than on the benchmark portfolios entails positive performance.

Danmarks Nationalbank has measured the performance of the foreign-exchange reserve for a number of years and new calculation methods will soon be implemented. The new methods will, among other things, enhance the opportunities for attribution analysis and also expand the performance calculations to include the domestic securities portfolio. The plan is to implement the new performance module within the framework of Danmarks Nationalbank's new portfolio management system, PSS[1]. Attribution analysis makes it possible to identify the factors underlying performance. For example, this can show the impact of market development on performance and the performance attributable to variations in returns in unchanged market conditions. The performance calculations are therefore a tool for evaluating the investment process and for analysing and quantifying the individual contributions to performance.

When calculating performance it is important to consider any possible differences in risk between the actual and the benchmark portfolio. In more precise terms, the sole basis for assessment of the portfolio manager must be whether the manager has contributed to achieving a return beyond the expected risk-adjusted return on the portfolio.

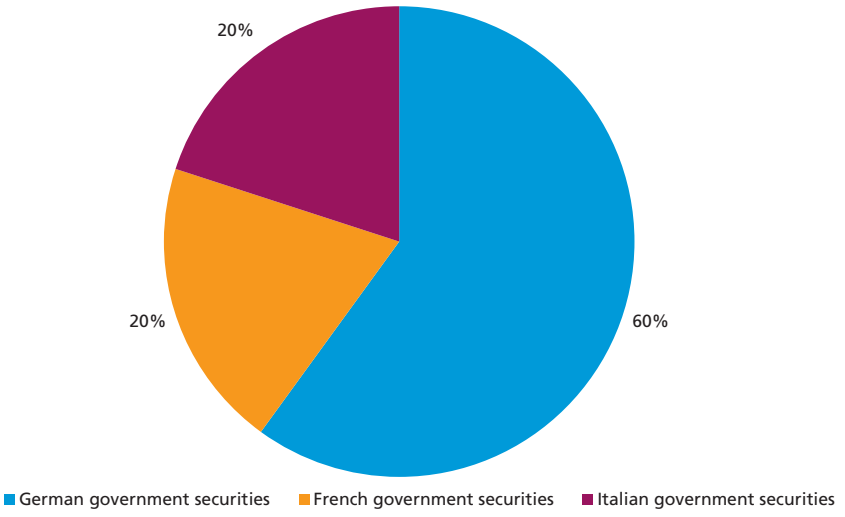
STRUCTURE OF BENCHMARK

Performance measurement is based on Danmarks Nationalbank's strategic benchmark portfolios. Chapter 7 on interest-rate risk describes how the structure of these benchmark portfolios is aimed to ensure sufficient diversification of the interest-rate risk, as well as an appropriate level of money-market investments for intervention purposes.

The benchmark portfolios are structured by selecting one or more bonds within each maturity range and then allocating them a suitable weight based on the total market value. The weights are determined so that the krone duration fulfils the required distribution of maturity. If a given maturity range comprises bonds from several countries, e.g. the

[1] PSS is described in Chapter 14.

STRUCTURE OF THE EURO BENCHMARK, KRONE DURATION IN PER CENT Chart 13.1



Note: The structure of the benchmark portfolio meets the krone-duration target. It should be noted that the contribution from the bank deposit to the krone duration is 0. Fluctuations in the bank deposit account for most of the fluctuations in the market value of the portfolio.
Source: Danmarks Nationalbank.

euro portfolio, a fixed country key is also applied to the distribution of the krone duration.

Only government bonds are included in the benchmark portfolio structure. An account at BIS[1] is applied as the benchmark for bank deposits.

The continuous reduction of the remaining maturity of the bonds means that duration is slowly reduced, so that the market value of an instrument must be increased gradually in order to keep the krone duration constant in the given maturity range. This re-balancing of instrument weights takes place on a daily basis. When an instrument approaches the lower end of the maturity range, a new instrument is found with a remaining maturity at the upper end of the range.

The composition of instruments in the euro benchmark portfolio is shown in Chart 13.1. 60 per cent of the krone duration is invested in German government bonds, 20 per cent in French government bonds, and finally 20 per cent in Italian government bonds. The portfolio also includes bank deposits at BIS with a krone duration of 0. Currently a total of 34 different government bonds from the three countries are included in the benchmark. These are all highly liquid bonds of high quality, and market data is easily accessible. The reason that only three

[1] See also Box 10.3 in Chapter 10 on credit risk.

euro area member states are chosen is primarily to keep the structure of the benchmark as simple and straightforward as possible.

On the other hand, the investment opportunities for the actual euro portfolio are somewhat more extensive than those applying to the benchmark portfolio. The actual portfolio allows for investment in government bonds from the euro area, and in bonds issued by government-guaranteed entities and supranational institutions. The bank deposits may be invested with institutions such as BIS, but also with commercial banks.

On assessment of the return on the foreign-exchange-reserve portfolios the actual return is compared to the return on the benchmark. The return is thus measured relative to the strategic benchmark, which reflects Danmarks Nationalbank's fundamental investment strategy. The difference between the return on an actual portfolio and a benchmark portfolio is hereafter called performance. It should be noted that performance can be positive, even though the return is negative, since performance is a relative measure.

The difference between the returns on benchmark and actual portfolios can be attributed to variations in interest-rate, credit and liquidity risk, as well as the instrument composition and the timing effects of the purchase and sale of bonds.

ORGANISATION AND POSITIONING

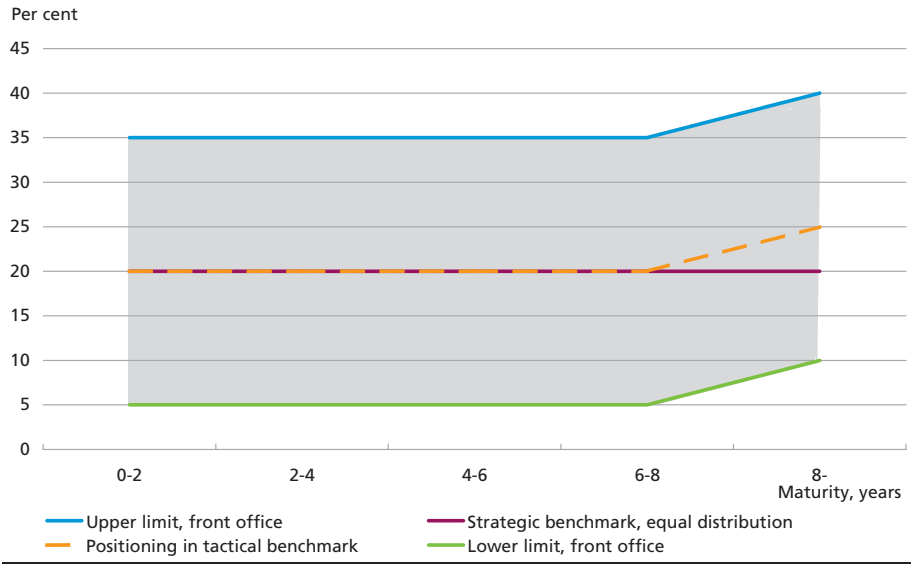
Interest-rate positions are taken at three levels at Danmarks Nationalbank, cf. Chapter 7 on interest-rate risk. At monthly investment meetings tactical-interest-rate positions in the 10-year segment are taken. In practice, a tactical benchmark portfolio is constructed whereby 10-year government securities are bought or sold against a reduction or increase of the portfolio of money-market investments. This increases or diminishes the krone duration relative to the strategic benchmark. The tactical benchmark forms an extra tier between the actual portfolio and the strategic benchmark. The tactical benchmark subsequently serves as the benchmark for the front office.

This is outlined in Chart 13.2, which shows the distribution of the strategic benchmark together with the tactical benchmark portfolio. In the tactical benchmark portfolio an interest-rate position of 5 percentage points is taken in the 10-year segment.

A krone-duration framework has been established around the maturity distribution for the tactical benchmark, cf. Chapter 7 on interest-rate risk. It is possible to take interest-rate positions within this framework across the entire yield curve.

DISTRIBUTION OF MATURITY AND POSITIONING, KRONE DURATION IN PER CENT

Chart 13.2



Note: Example with an equal maturity distribution of the krone duration in the strategic benchmark. The grey area shows the limits for the maturity distribution of the krone duration in the actual portfolio. The limits for the maturity distribution are supplemented by an overall framework for the krone duration of +/- 10 percentage points in relation to the krone duration for the tactical benchmark. The sum of the deviations for each maturity segment has to fulfil this overall framework.

Source: Danmarks Nationalbank.

As described above, the actual portfolio may also be invested in other bonds and bond types than those included in the benchmark. This may entail higher credit and liquidity risk in the actual portfolio than in the benchmark portfolios. In addition, purchases and sales during the day may yield gains or losses. Finally, the actual portfolio also includes other instrument types, including bond futures.

All in all, the above factors lead to variations in returns between respectively the strategic benchmark, the tactical benchmark and the actual portfolio. The differences in returns are quantified and can be broken down in the calculation of performance.

CALCULATION AND DECOMPOSITION OF PERFORMANCE

Danmarks Nationalbank is about to implement new performance calculation methods. The new calculation methods will e.g. help Danmarks Nationalbank to analyse the performance drivers and to include more portfolios in the calculations. The global investment performance standards (GIPS) for private firms' execution and reporting of performance calculations are of use in this respect. The GIPS standards are described further in Box 13.1.

The calculations to be included in the new system have not yet been finally determined. However, the methods reviewed below make it pos-

GLOBAL INVESTMENT PERFORMANCE STANDARDS Box 13.1

Global Investment Performance Standards (GIPS) apply to the compilation and measurement of performance conducted by portfolio managers[1]. Portfolio managers are all types of financial institutions responsible for management of portfolios vis-à-vis a customer segment. Even though central banks are not included in this category, it is natural for them to take inspiration from the requirements and standards applying to private capital managers in connection with the implementation of a new system for the central bank's performance measurement.

The purpose of the standard is to achieve global acceptance of methods to compile and present performance and thereby create transparency and comparability across firms and countries. GIPS are divided into five sections, each describing the basic elements and requirements of the performance data. An extract of the requirements[2] is presented below. Unless otherwise specified they are minimum requirements.

1. Input data. A firm must collect and maintain all data required for the calculation of performance. Assets must be valued at market value. The market value of the portfolios is as a minimum to be compiled as of the end of each month. As from 1 January 2010 the requirements will probably be tightened to include re-calculation on every instance of inflow or outflow of funds to or from the portfolio.

2. Calculation method. Performance must be based on total yield, including realised and unrealised capital gains plus interest and dividend net of trading costs. The calculation must be based on a geometrically connected time-weighted index (see Appendix D).

3. Structure of portfolio groups. Groups of portfolios must be defined to solely contain portfolios with uniform investment strategies and objectives. The managed portfolios must be kept separate from simulated portfolios such as benchmark portfolios, and must not be included in the same portfolio group.

4. Specific information. It must be possible to state the proportion of the firm's managed assets that are in compliance with GIPS. The percentage of the portfolio group invested in countries or areas not included in the benchmark must be stated. The use of gearing or derivatives must be stated.

5. Presentation and reporting. A total benchmark return must be stated for each portfolio group. The benchmark must reflect the investment strategy or mandate applying to the portfolio group, and must be compiled for the same period as performance for the portfolio group. Targets for the yield spread must be reported for portfolio groups. It is recommended (not a minimum requirement) to report relevant risk targets together with the presentation of performance, for example volatility targets, tracking errors, beta and adjusted duration.

If a firm complies with all GIPS requirements, it may submit a "compliance statement" to investors and customers in connection with reporting of performance. A firm's compliance with the GIPS standards can be verified by a third party if the firm so chooses. The verification enhances the credibility of a GIPS compliance statement, but is not a requirement so far. Verification is expected to become a GIPS minimum requirement after 2005.

1 Global Investment Performance Standards, The Danish Society of Investment Professionals, 31 July 1999.
2 The above is a summary of the GIPS requirements.

sible to construct a flexible performance system. The performance calculations are to be carried out within Danmarks Nationalbank's own risk management system, PSS.

Calculation of index

Both the new and the old performance calculations are based on the following portfolio return index:

$$(1)\ Index_t = (1 + r_{0,t}) = (1 + r_1)(1 + r_2)(1 + r_3).....(1 + r_{t-1})(1 + r_t)$$

where $r_1, r_2 \ldots, r_{t-1}, r_t$ are the daily returns on the portfolio, and $r_{0,t}$ is the return accumulated over the period. The index is a multiplicative time-weighted index (or a geometrically connected time-weighted index, cf. Box 13.1 on GIPS standards) in which the return on the portfolio is calculated on a daily basis and multiplied over time in order to provide an index for the return over a longer period.

The daily return is calculated as the change in the portfolio's market value – adjusted for holding fluctuations – relative to the market value at the start of the day. The adjustment for holding fluctuations during the day makes the index robust vis-à-vis changes in the size of the portfolio. This robustness is necessary since the size of the portfolios varies over time and is generally beyond the range of the portfolio manager. The characteristics and limitations of the index are described in further detail in Appendix D.

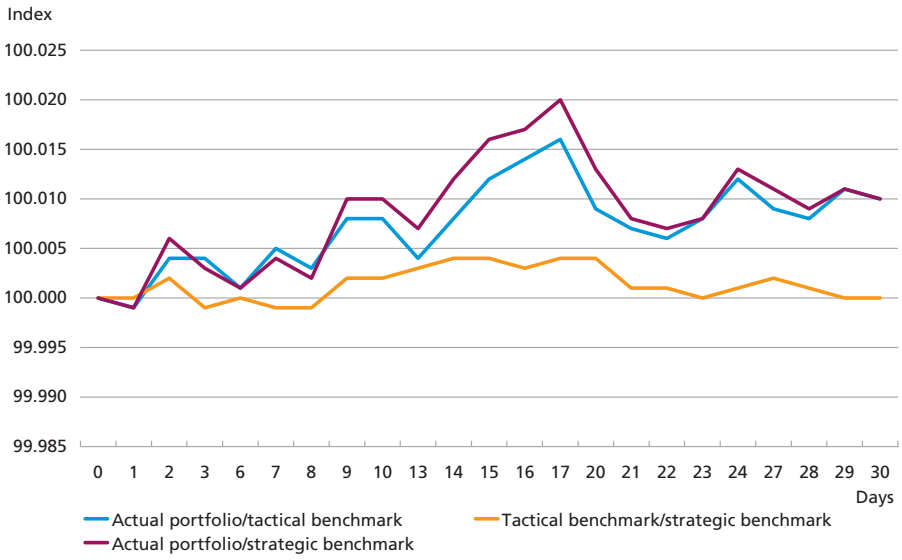
The index is calculated for both benchmark and actual portfolios. Performance is measured as the development in the index for the actual portfolio relative to the development in the index for the benchmark portfolios, cf. the example in Chart 13.3.

The portfolios and their respective benchmark portfolios are measured in the same currency, so that exchange-rate fluctuations do not impact on the portfolio performance.

Chart 13.3 shows that performance for the tactical benchmark has been neutral during the specific period, while performance for the actual portfolios is positive at its end. However, it is not explained which factors drives performance. What share of performance is attributable to interest-rate positions and market development? What is the significance of differing instrument compositions, including derived differences in credit and liquidity risk? Have purchase and sale at the right time yielded considerable gains?

To answer these questions, the calculations must be expanded to include a formalised decomposition of the return on and performance of the portfolio.

EXAMPLE OF EURO PORTFOLIO PERFORMANCE Chart 13.3



Note: Actual portfolio/tactical benchmark is the return index on the actual portfolio relative to the return index on the tactical benchmark.
Source: Danmarks Nationalbank.

Decomposition of return and performance

In the following, first the decomposition of the return on a single bond in a single period is given. This breakdown is then applied to the decomposition of performance at portfolio level.

In the first instance the return on a bond can be divided into the return on an unchanged market and the return after changes in the market. The first is here termed the direct return on the bond portfolio or the "carry", while the market development reflects capital gains and losses attributable to the development in the yield structure, etc. Table 13.1 presents a further breakdown of the direct return on the bond and the return attributable to market developments.

The detailed decomposition in Table 13.1 gives an accurate picture of the origins of the bond return. The columns explain the respective direct return and market development elements. The rows explain the size of the total extra return on investing in e.g. a corporate bond rather than a government bond. The various return components together comprise the total return on the bond.

Table 13.1 is best explained by an example: consider a corporate bond from General Motors. Assume first that the return structure remains unchanged in the period under review. The total return in this period is now the direct return comprising the coupon payment, as well as the

BREAKDOWN OF BOND RETURN, PER CENT Table 13.1

	Direct return		Return due to market development	Sum, total return
	Coupon	Maturity reduction (pull to par)		
General yield structure	$r_{\text{yield structure, coupon}}$	$r_{\text{yield structure, maturity reduction}}$	$r_{\text{yield structure parallel shift}} + r_{\text{yield structure, change in shape}}$	$r_{\text{yield structure}}$
Sectoral spread	$r_{\text{sectoral spread, coupon}}$	$r_{\text{sectoral spread, maturity reduction}}$	$r_{\text{sectoral spread, development}}$	$r_{\text{sectoral spread}}$
Instrument-specific spread	$r_{\text{specific spread, coupon}}$	$r_{\text{specific spread, maturity reduction}}$	$r_{\text{specific spread, development}}$	$r_{\text{instrument-specific spread}}$
Sum, total return	$r_{\text{total coupon}}$	$r_{\text{total maturity reduction}}$	$r_{\text{total market development}}$	r_{total}

Note: The effect of maturity reduction is also known as the pull to par effect, and here it includes the effect from the yield curve not being flat (roll down). See Appendix C on the effect of maturity reduction and Appendix D for a detailed description of decomposition of return.

share of the price development attributable to the maturity reduction of the bond, also known as the pull to par effect.

Comparison of the direct return on the General Motors bond with the return due to the general yield structure, e.g. represented by the government return curve and the return according to a relevant sector curve, e.g. a return curve for corporate bonds with the same rating as General Motors, allows decomposition of the direct return on the bond into the share attributable to the general yield structure; the extra return due to a sectoral spread; and the share attributable to an instrument-specific spread on the bond.

The direct return according to e.g. the government yield curve is the return on the General Motors bond had it been a government bond. This return can again be divided into the coupon payment and the pull to par effect along the government yield curve.

The extra return due to the sectoral spread comprises e.g. the payment for the higher credit risk for corporate bonds in general, while the contribution to the direct return from the instrument-specific spread is the payment for company-specific risks associated with buying a General Motors bond.

Gains and losses as a consequence of market developments can likewise be broken down into the part relating to the development in the general yield structure, as well as the development in the sectoral spread between the corporate-bond yield curve and the general yield structure, and finally, the change in the instrument-specific spread relative to the sectoral return curve, cf. Table 13.1.

An increase in government-bond yields will, for example, reduce the price of the General Motors bond, unless for example the sectoral

spread between the government and corporate yield curves narrows equivalently. While development in the sectoral spread is driven by sector-specific factors such as deteriorating cyclical prospects, company-specific information on General Motors will affect the development in the instrument-specific spread.

In Table 13.1 the effect of the change in the general yield structure is further divided into a parallel shift and a change in the shape of the yield structure. In practice, this can be achieved by e.g. calculating the parallel shift as the average of the change in the 2-, 5- and 10-year yields and then residually determining the change in the shape of the yield curve, cf. the example in Box 13.2. A more complex decomposition of the development in the yield structure can be achieved by applying an analysis of principal component, cf. Chapter 7 on interest-rate risk.

The breakdown in Table 13.1 is described in full detail in Appendix D.

In practice, the return on the total portfolio and the breakdown are achieved by calculating return components for the individual bonds and thereafter adding up the components to achieve the total return. Disregarding the effects of purchases and sales during the day, the performance, i.e. the difference between the return on the actual portfolio and the benchmark, from time *t* to *t+1* can be written as:

$$(2)\ P = r_{actual\ portolio} - r_{benchmark} =$$
$$\sum_S \Delta\omega_S r^S_{total\ coupon} + \sum_S \Delta\omega_S r^S_{total\ maturity\ reduction} +$$
$$\sum_S \Delta\omega_S r^S_{yieldstructure,\ parallelshift} + \sum_S \Delta\omega_S r^S_{yieldstructure,\ changein\ shape} +$$
$$\sum_S \Delta\omega_S r^S_{secoral\ spread,\ development} + \sum_S \Delta\omega_S r^S_{specificspread,\ development}$$

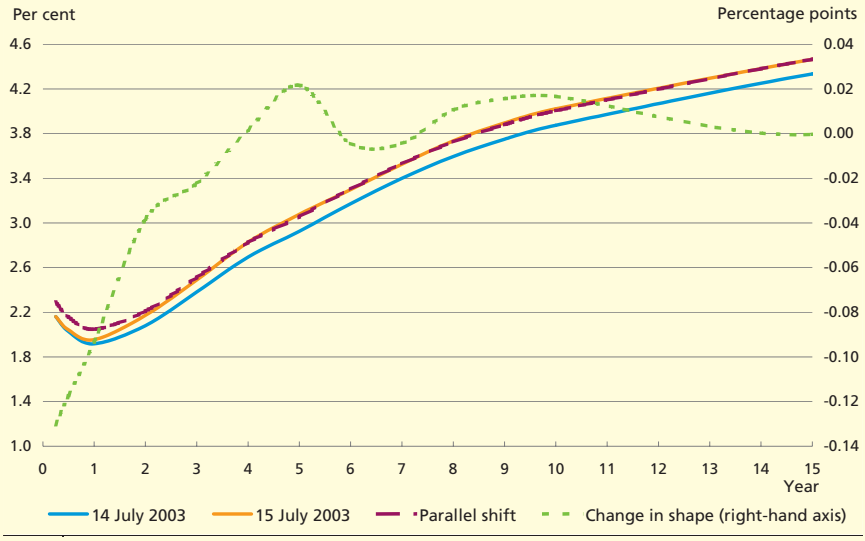
where $\Delta\omega_s$ is the difference between the weight of bond *s* in the actual portfolio and the benchmark portfolio respectively, and the *r's* stand for the decomposition of the total return into its various components, cf. Table 13.1. Equation (2) shows that performance is driven by the differences in the weights at which the individual instruments are included in respectively the actual and the benchmark portfolios. The decomposition can be further refined by e.g. breaking down performance by maturity, country or instrument type.

Danmarks Nationalbank's previous calculation of performance does not allow for decomposition as in equation (2) so there are currently no such results for Danmarks Nationalbank's portfolios. Instead, Box 13.2. gives an example of a performance calculation for a fictive mini-portfolio of two instruments.

DECOMPOSITION OF PERFORMANCE: A CALCULATION EXAMPLE Box 13.2

In the following the yield on a 10-year French government bond with one annual term and a 4 per cent coupon is broken down. The decomposition is then used to explain the performance of a portfolio consisting of the French government bond as well as a bank deposit. The market value decreases from 101.93623 to 100.70629 day-to-day from 14 to 15 July. No settlement payments fall due during this period, so the return on the bond corresponds to the change in market price, i.e. -1.22994. The Chart shows the development in the euro zero-coupon yield curve from 14 to 15 July broken down as parallel shift and shape. The parallel shift is calculated as the average change in the 2-, 5- and 10-year yields, and the change in the yield curve's shape is calculated on a residual basis.

DEVELOPMENT IN THE EURO ZERO-COUPON YIELD CURVE FOR GOVERNMENT BONDS



Note: The euro yield curve for government bonds is estimated on the basis of the European benchmark government bonds. Up to and including a maturity of one year these are French Treasury bills, while for longer maturities they are German government bonds. If "change in shape" is zero, the movement of the yield structure corresponds to a parallel shift.

The movement at the long-term end of the European yield structure corresponds to a parallel shift, i.e. the contribution from "change in shape" is around zero. In the 1 to 5-year segment the yield curve steepens a little. The yield on the French government bond can be broken down via the formulae in Appendix D. The Table shows the result.

The direct return on the bond, i.e. coupon plus reduction of maturity, is positive at DKK 0.013, of which DKK 0.0004 is attributable to a positive coupon spread. The market development entails a negative performance totalling DKK -1.24. The parallel shift of the yield structure contributes DKK -2.20, while the steepening at the short end of the curve has the opposite effect, with a positive contribution of DKK 1.04. Finally, the drop in the bond price is stronger than predicted by the theoretical model, which gives a negative return of DKK -0.08.

CONTINUED Box 13.2

DECOMPOSITION OF RETURN

	1993	DKK	Per cent
Direct return	Coupon according to euro yield structure ..	0.0106	0.0104
	Instrument-specific coupon premium	0.0004	0.0004
	Total reduction of maturity	0.0020	0.0019
	*Total direct return	*0.0130*	*0.0127*
Market development	Parallel shift of euro yield structure	-2.1993	-2.1575
	Change in the shape of the euro yield curve shape	1.0386	1.0189
	Change in the instrument-specific spread ...	-0.0821	-0.0806
	*Total market development	*-1.2428*	*-1.2192*
Total return		-1.2299	-1.2066

Note: Compiled per DKK 100 nominal.

This calculation can be applied to further analysis of performance. Assume, for example, that the benchmark portfolio consists of 50 per cent bank deposits at an annual interest rate of 2.2 per cent, and 50 per cent invested in the aforementioned government bond. In the actual portfolio a short-term interest-rate position has been taken with 60 per cent as bank deposits and the remainder invested in the government bond. The performance is calculated and broken down in the Table below.

PERFORMANCE

Per cent		Bench-mark return	Portfolio return	Perform-ance, pct. points
Direct return	Coupon according to euro yield structure	0.0082	0.0078	-0.0004
	Instrument-specific coupon premium	0.0002	0.0001	-0.0000
	Total reduction of maturity	0.0010	0.0008	-0.0002
	*Total direct return	*0.0093*	*0.0087*	*-0.0007*
Market development	Parallel shift of euro yield structure..	-1.0788	-0.8630	0.2158
	Change in the shape of the euro yield curve	0.5094	0.4075	-0.1019
	Change in the instrument-specific spread	-0.0403	-0.0322	0.0081
	*Total market development	*-0.6096*	*-0.4877*	*0.1219*
Total return		-0.6003	-0.4790	0.1213

Note: Performance is measured as the difference between the relative return in per cent on the actual portfolio and the benchmark portfolio respectively from 14 to 15 July. The relative return is not converted to annual return.

Performance measured as the difference in relative return is positive at 0.1213 percentage points. The direct return makes a negative contribution to performance due to the under-weighting of the long-term government bonds in the portfolio. The total effect from market development entails positive performance.

Decomposition for a longer period

In (2) return and performance are solely calculated from *t* to *t+1*, i.e. for a single period, but in practice the focus is not on day-to-day return and performance, but on return and performance over a longer period. It is therefore necessary to aggregate the daily contributions in order to e.g. explain the monthly performance. Appendix D shows how the decomposition can be adjusted so that the daily return components add up to the total return for the period.

INTERPRETATION OF PERFORMANCE RESULTS AND CHOICE OF HORIZON

The performance results must be interpreted with a degree of caution. The performance calculation described in Box 13.2 first and foremost illustrates the origins of performance and the key source of performance in the period measured. Secondly, the performance calculation can be used as an indicator of the quality of the day-to-day portfolio management.

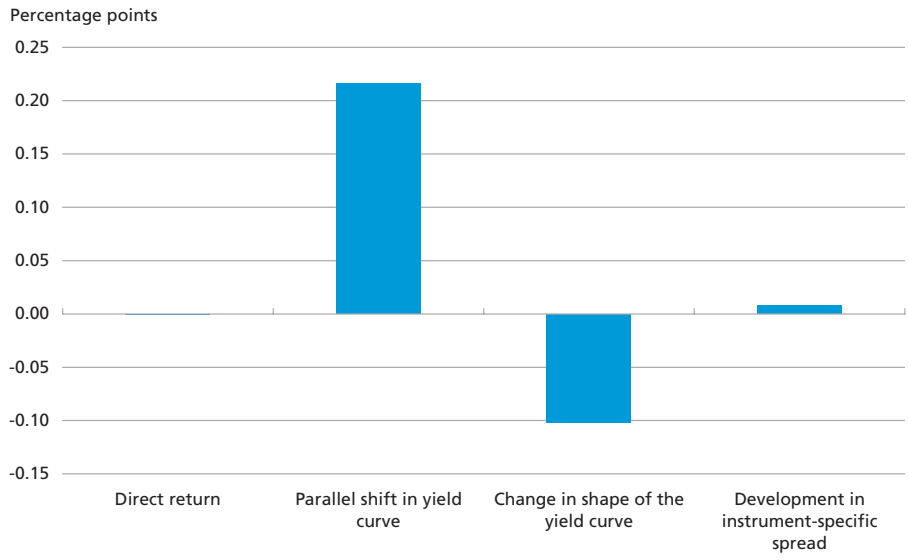
Positive performance in a particular period may be attributable to random factors such as positive market development. Performance calculations for a number of periods are therefore necessary to determine the quality of portfolio management. Furthermore, the calculations can be supplemented with statistical tests for performance significantly different from zero. These tests can be applied to both the overall performance and the individual performance components[1].

Assessment of the quality of portfolio management must also take account of any possible systemic differences in risk and return between the actual and the benchmark portfolio. If there is a generally higher credit risk and therefore a higher return in the actual portfolio than in the benchmark portfolio, this must be taken into account prior to the performance evaluation. In more precise terms, the sole basis for assessment of the portfolio manager must be whether the manager has contributed to achieving a return beyond the expected risk-adjusted return on the portfolio.

A decision on the frequency of performance reporting must include consideration of the possible effects on behaviour. Frequent performance reporting – e.g. on a daily basis – may reduce the willingness to take positions. On the other hand, longer intervals between performance assessments will reduce the value of the results.

[1] In Grinold (1989) and Kahn (1991) it is shown how the *information ratio* can be applied to testing whether the daily portfolio management makes a positive contribution to performance.

EXAMPLE OF DAY-TO-DAY PERFORMANCE Chart 13.4



Note: Results from the Table of performance results in Box 13.2.
Source: Danmarks Nationalbank.

This is best illustrated by an example. If a dealer takes a position in a credit bond, the return will be dominated in the short term by the volatility of the return spread, while the extra direct return, i.e. the compensation for the credit risk, will materialise slowly in the longer term. This observation is illustrated by the performance example in Box 13.2 where the return components attributable to the market development by far overshadow the contribution from the variations in the direct return, cf. Chart 13.4. Excessive focus on day-to-day performance may therefore lead to smaller interest-spread risks being taken because in the short term this will increase the risk of negative performance.

LITERATURE

Christensen, Michael (2003) "Performance Evaluation of Danish Investment Associations", *Finansinvest* 4/03.

The Danish Society of Investment Professionals (1999) "Global Investment Standards".

Grinold, Richard C. (1989) "The fundamental law of active management", *The Journal of Portfolio Management*.

Kahn, Ronald N. (1991) "Bond performance analysis: A multi-factor approach", *The Journal of Portfolio Management*.

Kjeldsen, Kristian (1996) "International Bond Portfolio Performance Evaluation a mark-to-market approach", *Working Paper 96-14*, Institute of Finance, Copenhagen Business School.

SimCorp (2003) "Fixed Income Performance Attribution, A flexible approach", Knowledge Sharing.

Unibank Markets (2000) "Unibank's Mortgage-Credit Index" (in Danish), Finansiel Analyse, Topical Issue No. 63.

14. IT Systems for Financial Management

In parallel with the development of risk management theory, advances within IT have made it possible to implement new risk management methods. At the same time, the range of financial products and the volume of transactions have increased, supported by technological innovation and the liberalisation of the financial markets. Since IT has thus become a direct prerequisite to operating as a modern financial institution, the use of IT is considered to be of high strategic importance to Danmarks Nationalbank, as is the case for many other organisations.

This chapter describes how Danmarks Nationalbank's IT systems support financial management, and the background to the existing structure. There is special emphasis on the description of the new portfolio management system (PorteføljeStyringsSystem, PSS), which has been developed in-house, and which provides a full overview of the portfolios of Danmarks Nationalbank and the central government. On a daily basis PSS calculates all relevant key figures that are used for control of compliance and further analysis. All results are made available to users by means of an internal web portal.

APPLICATION OF INFORMATION TECHNOLOGY IN DANMARKS NATIONALBANK'S PORTFOLIO MANAGEMENT

Danmarks Nationalbank's application of IT in its portfolio management is based on decentralised systems and responsibility for such systems. However, the departments still work closely together on IT projects, and staff from different departments may participate in each other's projects. Danmarks Nationalbank has so far decided to do without the large portfolio management systems used by many financial institutions. Instead, it has opted for smaller systems that to a large extent can be operated in-house, and that are based on standard technology, so that a broad-based, reliable knowledge base can be built up concerning the solutions used. The systems should be open and enable data exchange via standard methods.

Danmarks Nationalbank has had the opportunity to develop a new risk management system, PSS, that is tailored to the risk management concept of both Danmarks Nationalbank as well as the central govern-

ment[1]. The system has been developed in the SAS® program (from SAS Institute), which is in widespread use at Danmarks Nationalbank, and which allows for very flexible use of data. PSS also provides new opportunities for front-office data application for analysis and to support trading.

Technological advances have led to more and more trading in financial instruments taking place by means of electronic trading platforms/systems. Such systems are integrated with back-office systems on an ongoing basis in order to eliminate manual registration of trades. Finally, back-office functions are increasingly using standard systems at "Bankernes EDB Central" (BEC)[2], making the data easily accessible via the PSS risk management system.

DANMARKS NATIONALBANK'S PORTFOLIO MANAGEMENT SYSTEM, PSS

The day-to-day management of Danmarks Nationalbank's market risk is based on targets for exposure expressed as krone duration and convexity, and in some areas an absolute market value all of which are calculated in PSS on a daily basis.

With the introduction of PSS all portfolios – including derived products such as forward foreign-exchange contracts – are placed in the same system with the same key figures calculated according to uniform principles. Data for all portfolios is structured as a small number of uniform tables across feeding systems and instruments. This makes the data easier to access and understand than previously when data was stored and processed in several different systems.

As mentioned earlier, Denmark's government debt is managed by Danmarks Nationalbank, whereby the central government's portfolios are also included in PSS. Central-government debt is booked separately from Danmarks Nationalbank's bookkeeping, but data is retrieved by PSS, market values and key figures are calculated in the same way as for Danmarks Nationalbank, and all data is stored in tables structured according to the same principles as for Danmarks Nationalbank. For market and master data it has been taken into account that the data requirements are identical, and therefore data is shared by the central government and Danmarks Nationalbank. By combining the technical sides of the risk management of the central government and Danmarks Nationalbank considerable economies of scale have been achieved in terms of implementation and operation, as well as considerable gains

[1] The Danish government borrowing and debt is managed by Danmarks Nationalbank.
[2] BEC is an external IT centre used by Danmarks Nationalbank for a variety of IT services.

from staff working on the same system. All results and tools are accessible by means of a web portal.

Risk management is based on accounting entries by back-office functions. It is an important principle that holdings are calculated by trading date, and not by value date, since exposure to market fluctuations or credit events arises as soon as the trade has been concluded. Data should therefore be available by contract date with clear details of both trading and value date. Key figures are calculated on positions at the close of the previous banking day every morning before the markets open. To the extent possible, the calculations are based on closing prices from the various markets worldwide. PSS reports are used to check compliance vis-à-vis market risks. In this way the portfolio manager can start the day with a good overview of the investment position.

PSS technology

PSS is programmed in the SAS database program, which is already used by Danmarks Nationalbank, elsewhere in the financial sector and by universities. Among the many SAS modules is Risk Dimensions, which gives access to a number of functions that can be applied to financial risk management. PSS runs on an ordinary MS Windows server, and staff in risk management in cooperation with the IT department handles the day-to-day operations.

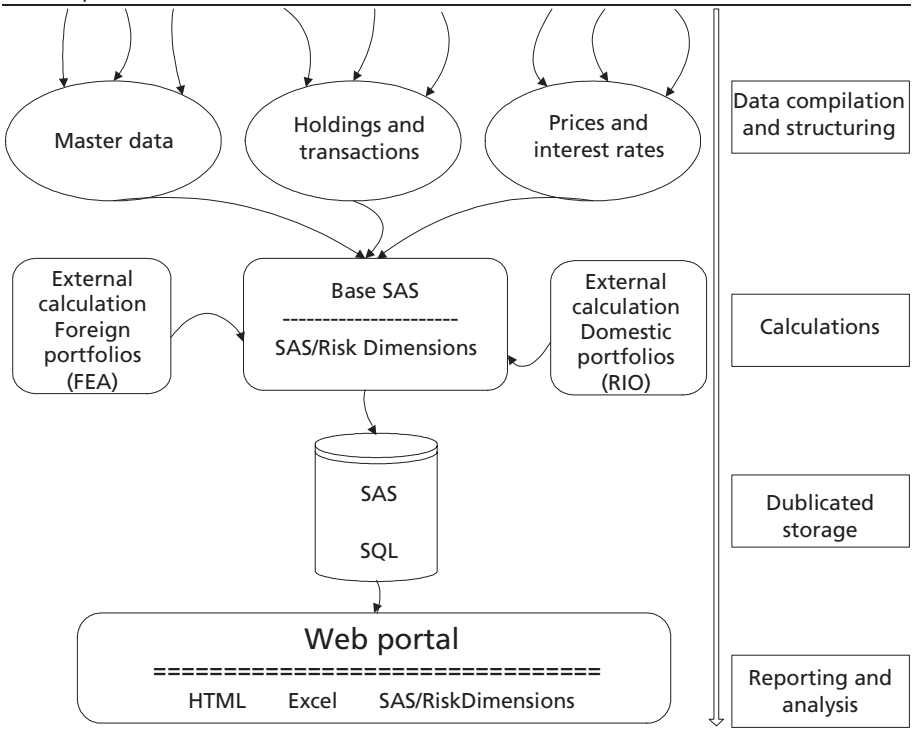
Implementation of PSS was mainly carried out by Danmarks Nationalbank's own staff and can be broadly divided into four main areas: data compilation and structuring, calculations, storage, and reporting and analysis, cf. Chart 14.1.

Data compilation and structuring are important and extensive elements of risk management since it is necessary to have access to and understand basic financial data in order to make the necessary and correct calculations, and because data restructuring ultimately becomes part of the result of risk management work. By analysing the data, knowledge is gained of how the financial transactions are carried out and registered. This is important for the actual implementation of risk management and the subsequent day-to-day operation.

Data processing is complicated by the fact that Danmarks Nationalbank, like most other organisations, requires a large number of data sources to gain a complete overview of its portfolios. PSS thus retrieves data from 15-20 different systems and tables, which requires the use of many different technologies and updating principles. In practice, the use of so many systems has proved to be a source of instability since there may easily be at least one system that presents problems.

STRUCTURE OF DANMARKS NATIONALBANK'S RISK MANAGEMENT SYSTEM, PSS

Chart 14.1



Calculations predominantly comprise the pricing methods that define the calculation of market values, krone durations and convexities for the portfolios of Danmarks Nationalbank and the central government. Prior to programming, the instruments of Danmarks Nationalbank and the central government were analysed so that common features and differences could be found and used in the programming. For instance, interest-rate swaps are implemented as a combination of fixed-rate and floating-rate bullet loans. The many instruments used by Danmarks Nationalbank are in the same way reduced to a far smaller number of specific pricing methods.

The actual calculation of key figures takes place in external functions. SAS/Risk Dimensions comprises among other things a supplementary programming language and integration technology for integration with calculation routines from other suppliers. The pricing-method programming thus consists of establishing relations between the organised input data and the external routines, and of submitting results back to the SAS database in the required format.

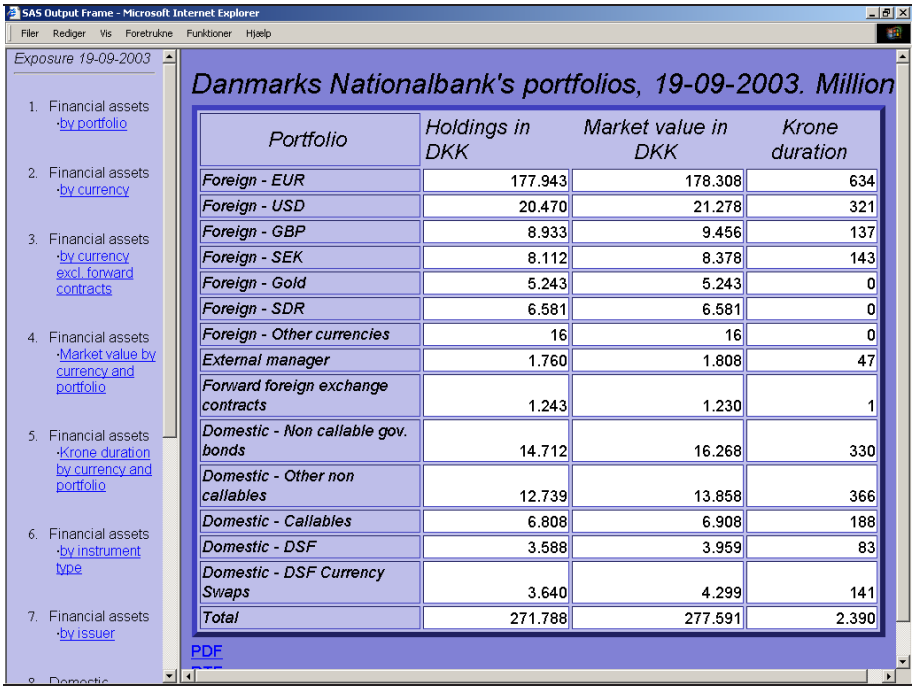
The calculations for the foreign portfolios are made in "Interest Library" from FEA (Financial Engineering Associates), which provides a number of key figures for many types of financial products. The choice

of FEA was based on the possibility of integration with SAS, coverage of instrument types and key figures, flexibility, and price. Calculations on the portfolio of domestic securities are made via RIO, developed by Scanrate. RIO has been used by Danmarks Nationalbank for some years and offers both calculation routines and data for Danish securities, in particular callable mortgage-credit bonds, which traditionally constitute a considerable portfolio management challenge. To create a single coherent risk management system, Scanrate has developed a technical interface from SAS to RIO, so that data and calculations in RIO can both be accessed from PSS.

A challenge in relation to price-method work is to ensure that the calculated cash flows are as correct as possible. Different trading conventions, interest-rate conventions, etc. make this work difficult and time-consuming, and it has proved difficult to ensure correct use of master data. Financing theory considerations were often overshadowed by these market- and instrument-specific considerations.

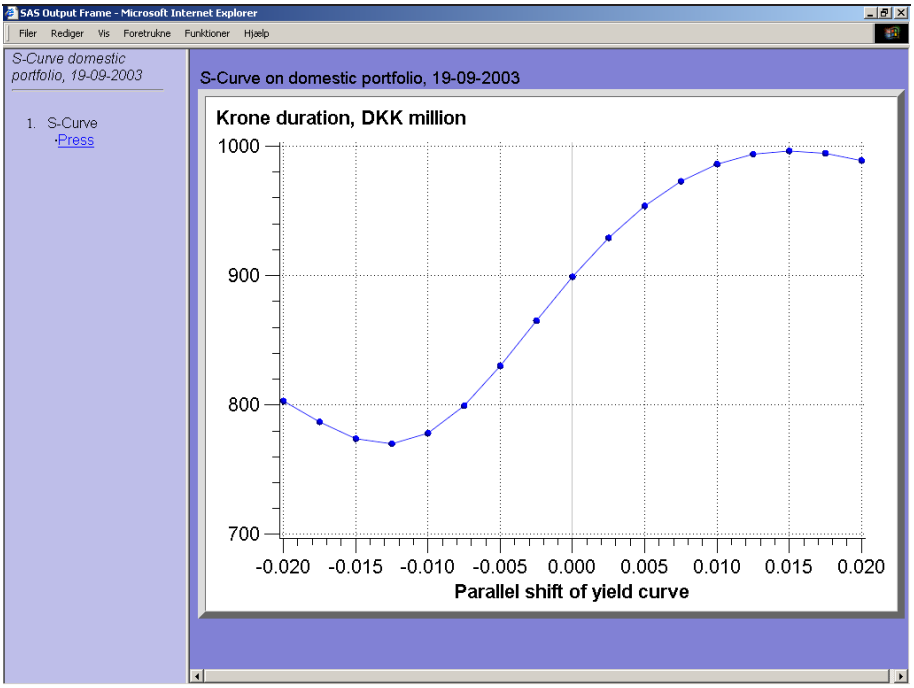
When *storing* and *reporting* data and results, importance is attached to simplicity and flexibility by providing several different methods to access PSS data and making these available via an internal web portal. The daily compliance statements for the krone-duration management and a wide range of reports with market values and interest-rate exposures are displayed directly as HTML reports, as illustrated in Chart 14.2.

EXAMPLE OF EXPOSURE OVERVIEW FROM PSS — Chart 14.2



Portfolio	Holdings in DKK	Market value in DKK	Krone duration
Foreign - EUR	177.943	178.308	634
Foreign - USD	20.470	21.278	321
Foreign - GBP	8.933	9.456	137
Foreign - SEK	8.112	8.378	143
Foreign - Gold	5.243	5.243	0
Foreign - SDR	6.581	6.581	0
Foreign - Other currencies	16	16	0
External manager	1.760	1.808	47
Forward foreign exchange contracts	1.243	1.230	1
Domestic - Non callable gov. bonds	14.712	16.268	330
Domestic - Other non callables	12.739	13.858	366
Domestic - Callables	6.808	6.908	188
Domestic - DSF	3.588	3.959	83
Domestic - DSF Currency Swaps	3.640	4.299	141
Total	271.788	277.591	2.390

KRONE DURATION AS A FUNCTION OF YIELD-CURVE SHIFTS Chart 14.3



Note: The Chart illustrates that the duration of the domestic portfolio is greatly affected by the level of interest rates, due to the callable mortgage-credit bonds in the portfolio. The graph was produced by calculating the krone duration for 17 different interest rate curves.

Predefined pivot tables in Excel allow for further breakdown of data or alternative layouts, and finally all data for each individual portfolio can be retrieved directly from SAS or Danmarks Nationalbank's SQL server, where data is also stored. The basic data is identical wherever it is stored, and is protected against editing and deletion.

A major advantage of the system is that all positions and key figures are available historically in their most decomposed form, i.e. per holding in each sub-portfolio. This makes it relatively easy for users to make long-term analyses, and it is possible to make retroactive changes in connection with adjustments of an overall nature, e.g. changes in portfolio structure or calculation methods. An example of a more complex calculation is given in Chart 14.3.

While day-to-day risk management is carried out by the use of exposure targets, exposure bands and the investment policy in general are also determined on the basis of risk calculations expressed as e.g. Value-at-Risk (VaR), or various types of stress test. For this purpose PSS data is used, but calculations are made in Risk Manager from RiskMetrics Group, while stress tests are made in Microsoft Excel.

To a large extent PSS comprises the transactions required to compile performance. PSS operates with a flexible portfolio and holding concept

that makes it relatively simple to build up and maintain a benchmark portfolio. Finally, PSS allows pricing on the basis of both theoretical and actual prices, and various yield curves can be applied to the theoretical pricing. These features comprises the technical foundation for the new performance module, cf. Chapter 13.

IT security considerations

Since IT is used for all major functions at Danmarks Nationalbank, an IT security policy and guidelines for Danmarks Nationalbank's use of IT have been developed, cf. Chapter 11 on operational risk. In connection with the introduction of PSS, and in particular with a view to its continued use and further development, emphasis is on the following aspects:

- *Access control*
  Access control is based on the PC network's normal user-identification system with passwords. In addition, users are assigned specific rights to read, edit and delete PSS data and code. Access control is intended to protect against unintentional editing of code and data so as to avoid errors and troublesome restoration.
- *Test*
  Risk management is a difficult discipline involving many complex calculations. Therefore results from several stages of the data flow were compared with data from existing systems as well as external sources such as Bloomberg. This test helped to disclose errors and develop tests for future use.
- *Separation of environments*
  To ensure a secure and flexible maintenance process in the future, considerable time was devoted to finding a suitable way to manage the separation of development, testing and production. It is now possible to handle decentralised in-house development of both small and large projects, while also maintaining centralised version and quality control of all software updates.

ANNEX: CONSIDERATIONS ON CHOOSING A NEW RISK MANAGEMENT SYSTEM

On planning the introduction of a new risk management system, a far larger project was considered whereby the front-, middle- and back-office systems were replaced by one comprehensive system. This strategy was rejected since the project would be very expensive and protracted and entail major project risks. The arguments for a comprehensive system solution are often easier maintenance, fewer interfaces, real-time processing, etc., but other institutions' experience in this area showed that it is often necessary to carry out follow-up projects and purchase extra products, and the final result is often more interfaces than expected and a large number of external consultant hours.

In addition, the departments involved had very different requirements and wishes regarding future system development. This was another reason that separate system modernisation projects would be an advantage.

On implementing portfolio-management systems the emphasis is often on concepts such as Straight-Through Processing (STP) and Real-Time Processing (RTP). STP means that the data flow must be as automatic as possible so as to eliminate manual processes, while RTP comprises ongoing position and key figure updates as transactions take place and interest rates and prices change. With the decision to only develop a new risk management system and to combine it with decentralised systems, the STP and RTP requirements were given lower priority. It was assessed that STP was not a top priority since the number of transactions conducted by Danmarks Nationalbank is not high, and because the manual functions involve very few errors. At the same time, it will be possible to introduce STP gradually between front- and back-office functions where there is the highest volume of manual work.

Danmarks Nationalbank also assessed that in terms of risk management it is justifiable to make the calculations only once a day, and that the primary consideration must be that the portfolio manager has an overview of the portfolio and can make the required analyses. This has been achieved without RTP, thereby avoiding a costly and complicating factor.

It was therefore decided that systems could be replaced gradually in the relevant departments, and that whenever possible the solutions should be based on standard programs, open technologies, PC-based solutions to a large extent, and a high degree of internal commitment to the solutions. The result is expected to be solutions that function together, a high knowledge level within Danmarks Nationalbank, and more flexible and less costly projects, involving fewer project risks.

In-house development?

An argument for accepting in-house development of PSS was the need for the risk management unit to understand all aspects of financial transactions. It is not sufficient merely to be familiar with general characteristics of the instruments selected. The risk management unit should also know about back-office processing, understand cash flows, be able to calculate key figures, and understand the development in the aggregated portfolios that are managed on a day-to-day basis. This is an important prerequisite to maintaining a close day-to-day dialogue with the back and front offices.

The drawback of this strategy is the risk that specific, critical knowledge is held by individual staff members who may leave their positions for one reason or another. Consequently, priority has been given to ensuring broad-based knowledge of the system's functionality, operations and maintenance.

Appendices

A. Callable Mortgage-Credit Bonds

Callable Danish mortgage-credit bonds constitute a significant proportion of the portfolio of domestic securities and account for most of the volatility in the krone duration of the portfolio.

The reason is that the interest-rate exposure of a callable bond is greatly influenced by the level of interest rates in relation to the bond's coupon rate. The closer the bond gets to par value, the greater the probability that it will be redeemed prematurely, meaning that investors will not pay a higher price for the bond. The price thus becomes less sensitive to falling interest rates, and the price/yield ratio shows negative convexity.

This must be taken into account in risk management, and the trade-off between expected returns and risk must be based on option-adjusted key figures, where the price of the call-option is estimated and incorporated in the key figures.

THE DANISH MORTGAGE-CREDIT MARKET

In Denmark the purchase and construction of real property are traditionally financed by issuing mortgage-credit bonds. The mortgage-credit institutes grant loans against real property as collateral based on the proceeds from selling bonds in the financial market.

The borrower receives the proceeds from the bonds sold. The yield to maturity on the loan is thus the same for the borrower and the owner of the bond. For the mortgage-credit institute there is therefore no immediate market risk related to the development in interest rates, since the interest payments and loan repayments received from the borrowers are counterbalanced by the mortgage-credit institute's payments to the bond owners, called the *balance principle*. In addition, the borrowers pay a fee to the mortgage-credit institute.

Since the loan is granted within statutory limits against real property as collateral, the credit risk incurred by the mortgage-credit institute is very small, provided that the property has been valued on a realistic basis. If the borrower does not service the loan as agreed, the mortgage-credit institute may effect the enforced sale of the property according to a specific procedure.

THE MORTGAGE-CREDIT INSTITUTES' DOMESTIC LENDING BY LOAN TYPES, YEAR-END

Table A.1

DKK billion	Adjustable-rate loans	Other nominal loans	Index-linked loans	Total
1999	59.7	877.5	113.7	1,050.9
2000	99.8	882.4	113.1	1,095.4
2001	245.7	836.5	109.6	1,191.8
2002	365.0	816.0	103.6	1,284.6
2003 July	434.2	822.8	102.0	1,359.1

Note: Comprises loans in DKK and foreign exchange.
Source: Danmarks Nationalbank, *Financial Statistics*, 3rd Quarter 2003.

The mortgage-credit institute will only incur a loss if the property is sold at a lower value than the loan from the mortgage-credit institute.[1] If the mortgage-credit institute is subject to compulsory liquidation, the bond owners rank before other creditors, i.e. they have a preferential position.[2]

Until the latter part of the 1990s the bonds issued were primarily *callable* bonds with a fixed coupon throughout the maturity of the loan.[3] If the price of the callable bond exceeds its par value, the borrower is entitled to redeem the loan prematurely at par (i.e. to prepay the loan). If the price is below par, the borrower may also redeem the loan by delivering the bonds, i.e. purchasing them at market price.[4] The fixed-rate callable bonds are still predominant, but adjustable-rate loans with underlying *uncallable* fixed-rate bonds have come into widespread use in recent years, cf. Table A.1.[5]

Since 1 October 2003 it has also been possible to obtain deferred-amortisation mortgage-credit loans. The underlying bonds are either uncallable bonds, which are also applied to adjustable-rate loans, or new 10- or 30-year callable bonds. The callable bonds are similar to the existing 30-year bonds, but the borrower has the additional option to defer amortisation for up to 10 years.

1 In addition, internal guarantee systems often apply between a bank acting as intermediary for the loan and the mortgage-credit institute issuing the loan. The bank guarantees the lowest/last-ranking part of the mortgage-credit loan for a limited number of years. For an owner-occupied home financed by mortgage-credit for 80 per cent of the property value, the banking institution may e.g. guarantee the last-ranking 20 percentage points of the loan, cf. *Financial Stability*, page 36, Danmarks Nationalbank, 2003.

2 See Gjede, Houman and Pedersen (2001) for an elaboration on the Danish mortgage-credit system.

3 Disregarding index-linked loans, which previously dominated the financing of subsidised housing projects.

4 In this respect the Danish mortgage-credit market differs from e.g. the US market, where borrowers cannot redeem loans by delivering the bonds at their market price.

5 For details, see Christensen and Kjeldsen (2002).

CALLABLE BONDS

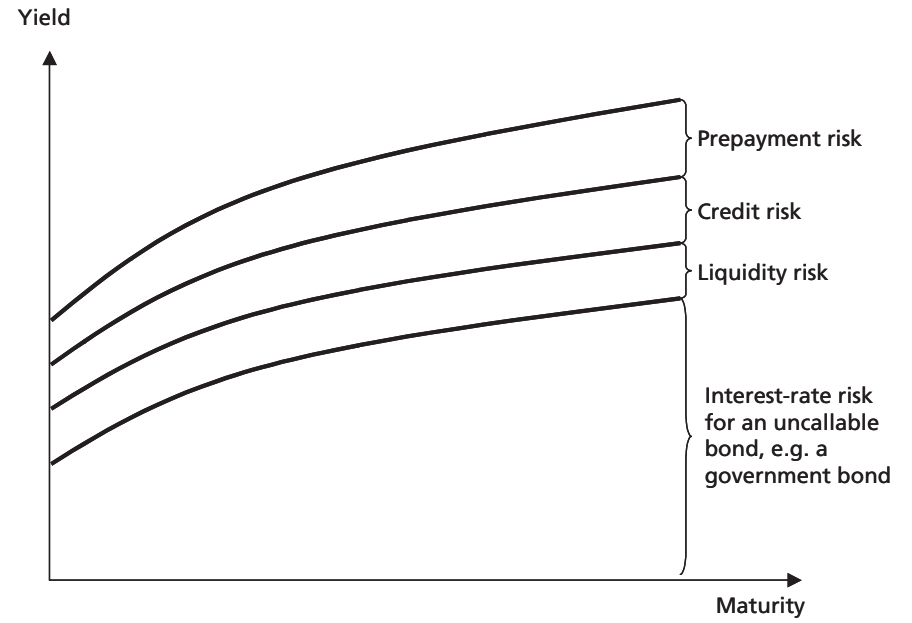
A callable bond can be seen as a purchased uncallable bond and a sold option entitling the borrower to redeem the loan at par value. This bond entails not only interest-rate, credit and liquidity risk, but also a *prepayment risk*, which must be compensated for, cf. Chart A.1. Prepayment risk is the risk that the borrower redeems a bond yielding a high return compared to the market level, so that the funds would be reinvested at a lower yield.

Compared to a government bond, a callable mortgage-credit bond thus contributes liquidity, credit and prepayment risk, which must be set against the expected excess return vis-à-vis a government bond. The prepayment risk is normally the most important of the three risks and depends on the level of interest rates in relation to the bond's coupon rate, as well as the volatility of the interest rate.

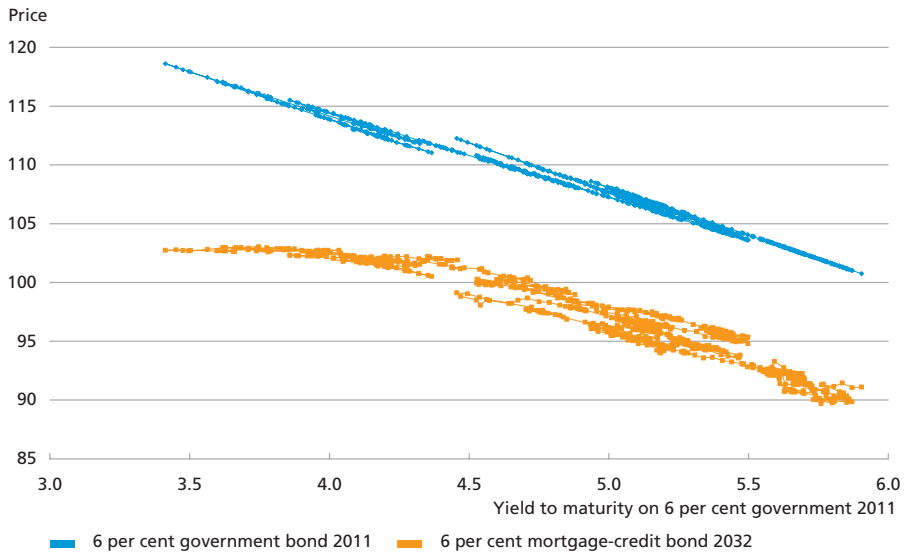
Level of interest rates in relation to coupon rate

The lower the market interest rate in relation to the bond's coupon rate, the higher the probability of the borrower to prepay and renew the loan at a lower interest rate. This means that the price increases less and less when interest rates are falling, and it is therefore unlikely that the price of a callable bond will rise much above par. This is illustrated in

PRICE FORMATION ON A CALLABLE BOND — Chart A.1



THE IMPACT OF THE OPTION ELEMENT ON PRICE FORMATION Chart A.2



Note: Yields and prices for the period 4 May 2000-23 September 2003.
Source: Danmarks Nationalbank.

Chart A.2. The price can exceed par value due to behavioural effects, transaction costs, tax, notice periods, etc.

Interest-rate exposure, expressed as the slope of the curves, is virtually constant for the government bond. For the mortgage-credit bond, however, interest-rate exposure declines significantly when interest rates are falling, i.e. the convexity of the curve is negative.[1] At a very low level of interest rates there may even be a positive relation between yield and price, i.e. the interest-rate exposure of the bond becomes negative.

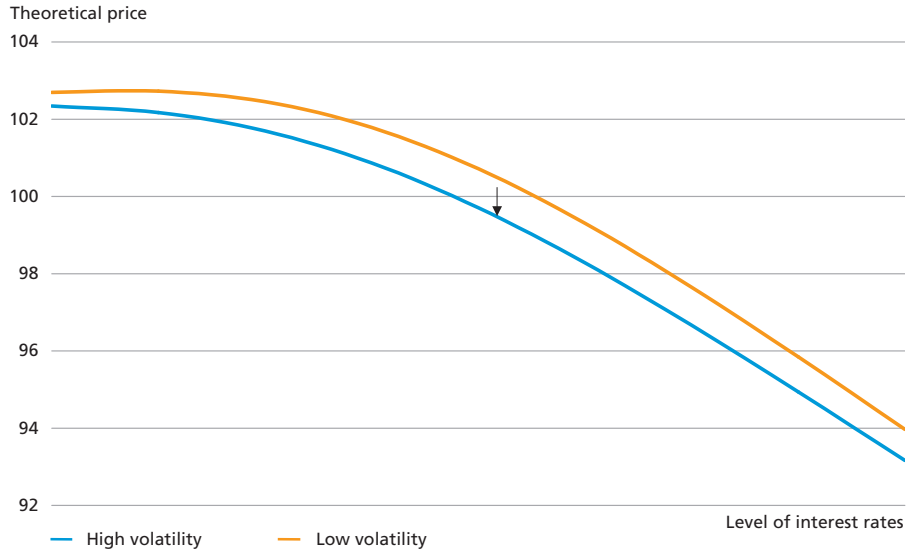
Interest-rate volatility

Volatility is a risk factor just like interest and exchange rates. The greater the interest-rate volatility, the higher the probability that it will be favourable to exercise the option, and the higher the value of the option/prepayment right. In other words, in periods of high volatility in interest rates an investor does not wish to pay such a high price for the bond, since the option sold by the investor has become more valuable to the borrower.

This means that if the option is sold at a given volatility level, a loss is incurred if the volatility subsequently increases, since the price of the bond decreases, cf. Chart A.3.

[1] In mathematical terms interest-rate exposure corresponds to the 1st derivative on the price/yield curve, while the exposure of the interest-rate exposure to changes in interest rates corresponds to the 2nd derivative on the curve.

IMPACT OF INTEREST-RATE VOLATILITY ON THE THEORETICAL PRICE Chart A.3



Note: Calculated for a 5 per cent mortgage-credit bond with term date in 2029.
Source: Danmarks Nationalbank.

MODEL FOR CALCULATING KEY FIGURES FOR CALLABLE BONDS

Due to the option element, there is uncertainty regarding the future cash flow for the mortgage-credit bond. An option is in itself difficult to manage, and an option to prepay is further complicated by a number of circumstances. For instance, the borrower's behaviour depends on the refinancing alternative, i.e. the terms for the new loan. In addition, there are costs related to prepayment, and the borrower may also be influenced by other factors such as hearing about prepayments in the media. Estimating the price of the option is also complicated by the so called "burn-out" factor. The burn-out factor is related to the fact that prepayments typically are lower for a bond series, if the bond series earlier on has been through periods with prepayments.

It is thus difficult to set the price of a callable mortgage-credit bond and to calculate key figures such as interest-rate exposure. This requires a mortgage-credit model which, in simple terms, comprises two components: a interest-rate model and a prepayment model. The *interest-rate model* describes the dynamics of the yield structure and creates scenarios for future interest rates. The *prepayment model* describes the borrowers' prepayment behaviour as a function of the level of interest rates and various background variables.

With a mortgage-credit model key figures can be calculated for the bonds, taking into account the option element. For instance, the option-

OPTION-ADJUSTED KEY FIGURES FOR SELECTED BONDS Table A.2

	Danske Bank		Nordea		Nykredit Bank	
	OAS	OABPV	OAS	OABPV	OAS	OABPV
4 per cent mortgage credit 2035	-7	8.88	-4	9.44	-8	8.41
5 per cent mortgage credit 2035	30	7.87	50	8.95	28	7.33
6 per cent mortgage credit 2035	43	4.90	42	3.21	33	3.33

Note: OAS is the option-adjusted spread to the swap-yield curve in basis points. OABPV is the option-adjusted duration as the change in price on a change in the yield curve by 100 basis points. Key figures for 8 October 2003.
Sources: Danske Bank, Nordea and Nykredit Bank.

adjusted duration indicates a bond's interest-rate exposure, taking into account the possibility that the bond may be redeemed prematurely at a low level of interest rates compared to the bond's coupon rate.

There are several models for calculating key figures for callable bonds, and some financial analysts/institutions have developed their own models. To calculate the duration of the callable mortgage-credit bonds, Danmarks Nationalbank applies an external model, RIO, which is also used by other market participants. The model is outlined in an Annex to this Appendix.

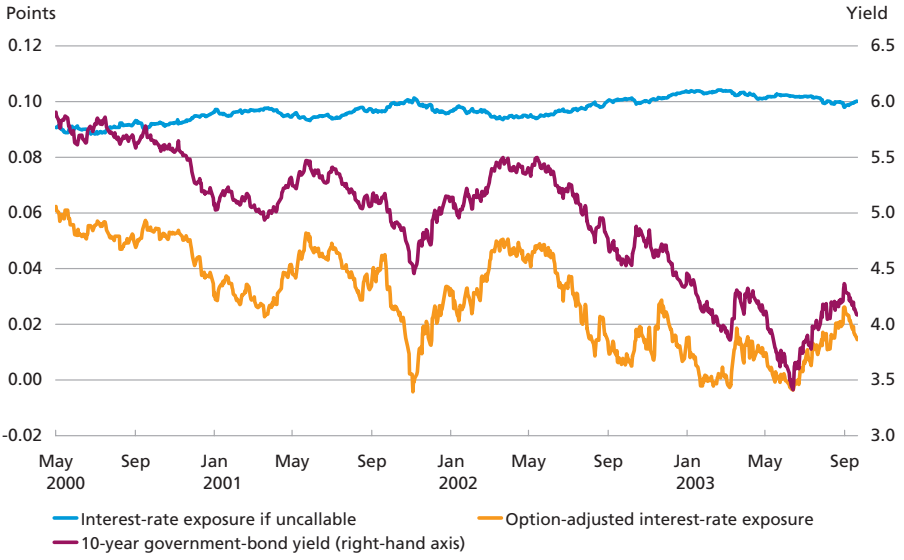
The calculation for callable mortgage-credit bonds thus involves a *model risk*, since the calculated key figures are greatly dependent on the model's assumptions, e.g. the borrower's behaviour. Key figures for a bond may thus vary among market participants as a result of different models and assumptions, cf. Table A.2, which shows three banks' option-adjusted key figures for three callable bonds. The calculations should be viewed critically and possibly compared with other calculations. Moreover, it might be useful regularly to test the model's results against the actual development.

Example of use of a mortgage-credit model

Despite the model risk, calculations that take account of the option element give a far more correct picture of the bond risk than if the bond is merely regarded as uncallable. Chart A.4 shows the interest-rate exposure for a callable mortgage-credit bond, calculated as the change in price on a change in the yield curve by 1 basis point. The Chart shows the exposure both when the bond is regarded as uncallable and when the option element is taken into account.

If the bond is regarded as uncallable, the interest-rate exposure increases marginally as a result of the falling interest rate. At end-September 2003 the interest-rate exposure was 0.10 points, i.e. the price would fall by 0.10 points on an increase in interest rates by 1 basis point at the given level of interest rates.

INTEREST-RATE EXPOSURE FOR A CALLABLE MORTGAGE-CREDIT BOND Chart A.4



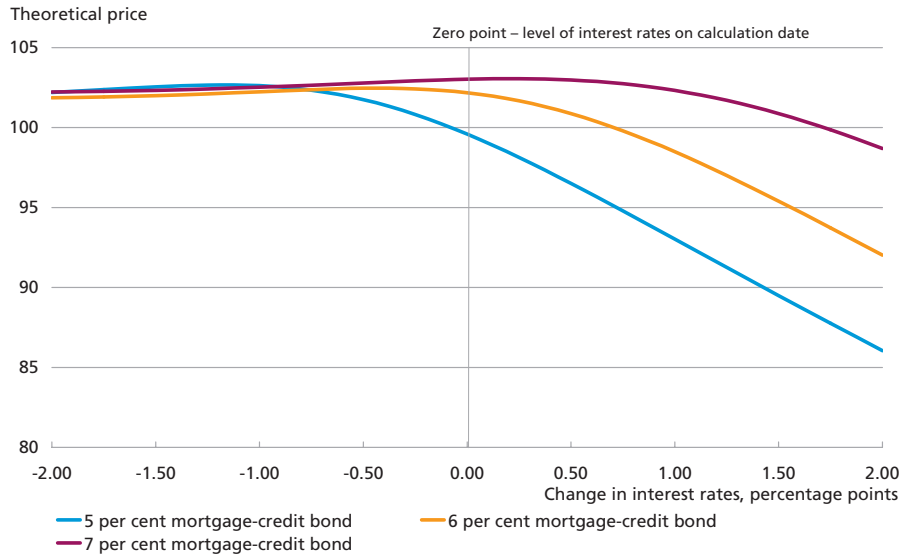
Note: Interest-rate exposure is calculated as the change in the price on a change in the yield curve by 1 basis point.
Source: Danmarks Nationalbank.

Chart A.2 shows that the interest-rate exposure for a callable bond declines when interest rates are falling. That is indicated by the option-adjusted interest-rate exposure. The low market rate in relation to the bond's coupon rate has reduced the interest-rate exposure of the bond significantly. At end-September 2003 the option-adjusted interest-rate exposure was 0.01 points, i.e. only 1/10 of the non-option-adjusted interest-rate exposure.

CONVEXITY

The declining interest-rate exposure in connection with falling interest rates corresponds to the curvature of the price/yield curve, cf. also Chart A.2. This is known as "*negative convexity*". The curvature means that the exposure measure cannot just be scaled to different interest-rate changes. Calculation of the capital loss in connection with a change in interest rates is only "correct" for a marginal change in interest rates. If the calculated interest-rate exposure is merely multiplied by a larger change in interest rates, the actual capital loss in connection with an increase in interest rates is underestimated, while the capital gain in connection with falling interest rates is overestimated. The greater the curvature, the greater the error. In order to calculate the precise interest-rate exposure for a given change in interest rates, the price change at this change in interest rates must be calculated directly.

THEORETICAL PRICES CALCULATED ON CHANGES IN INTEREST RATES Chart A.5



Source: Danmarks Nationalbank.

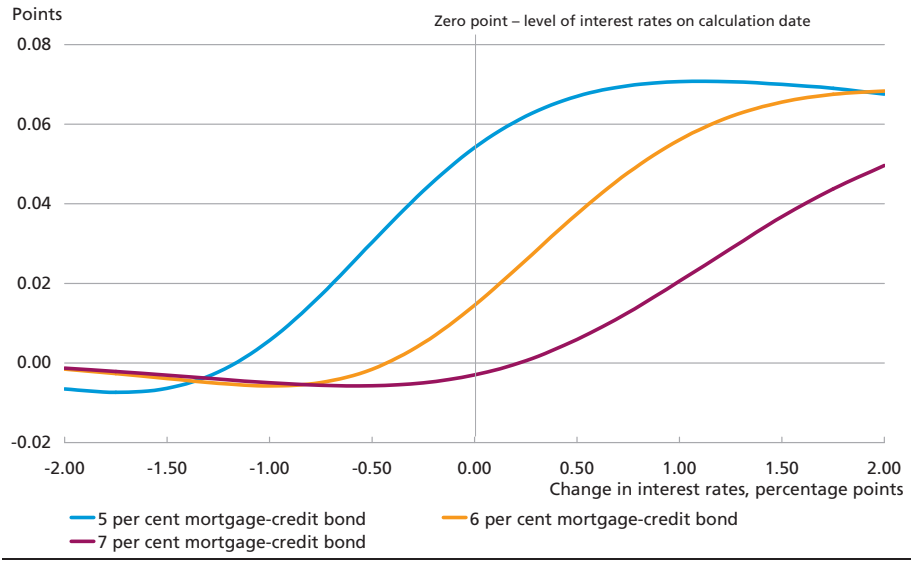
For an uncallable bond the curvature is reversed. In other words, convexity is positive, and the capital loss will be overestimated on an increase in interest rates, while the capital gain will be underestimated on a decrease in interest rates. Typically, the positive convexity for uncallable bonds is insignificant, however, compared to the negative convexity for callable bonds close to their par value.

As a consequence of the convexity, the interest-rate exposures for two bonds with the same interest-rate exposure at the given level of interest rates may develop differently on a change in interest rates. How sensitive the interest-rate exposure of a bond is to changes in interest rates, depends on the level of interest rates in relation to the bond's coupon rate. In Chart A.5 the theoretical price for three callable bonds has been calculated for different changes in interest rates.

All three curves show the observed relation between the interest rate and the price of callable bonds (negative convexity). At the given level of interest rates, the 5 per cent bond will "behave" like an uncallable bond in connection with minor interest-rate changes, but on large decreases in interest rates the bond will be "prepayment threatened" and the price will become less sensitive to interest-rate changes. The interest-rate exposure of the 6 per cent bond is very low at the given level of interest rates, where the price is above par, and the bond is "prepayment threatened". On a large increase in interest rates, the interest-rate exposure will increase significantly, since the bond will then be less

OPTION-ADJUSTED INTEREST-RATE EXPOSURE TO CHANGES IN INTEREST RATES

Chart A.6



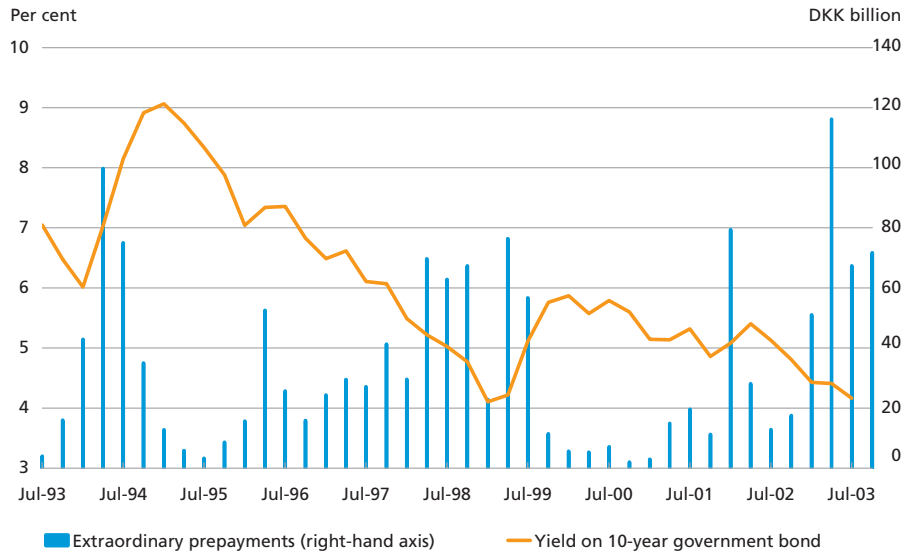
Source: Danmarks Nationalbank.

threatened by prepayment. The interest-rate exposure for the 7 per cent bond is negative. This reflects that the bond is so threatened by prepayment at the given level of interest rates that a further drop in interest rates will entail a lower price. The relation can also be illustrated via an "S curve", cf. Chart A.6.

In Chart A.6 the option-adjusted interest-rate exposures to different changes in interest rates have been calculated. The zero point shows the bonds' interest-rate exposure at the given level of interest rates on the calculation date. For the 5 per cent and 6 per cent bonds these are respectively 0.05 and 0.01 points on a change in interest rates by 1 basis point. The interest-rate exposure of the 7 per cent bond is negative since the risk that the bond is prepaid at par if interest rates fall is very high, cf. also Chart A.5.

The impact on exposure to changes in interest rates is not identical for the three bonds. On a drop in interest rates by 0.5 percentage point the interest-rate exposure of the 7 per cent bond will remain more or less unchanged, while the interest-rate exposures of the 5 per cent and 6 per cent bonds will be reduced since they become more threatened by prepayment. Particularly the interest-rate exposure of the 5 per cent bond will decline significantly on a drop in interest rates.

EXTRAORDINARY PREPAYMENTS AND THE INTEREST-RATE DEVELOPMENT Chart A.7



Sources: Copenhagen Stock Exchange, Danmarks Nationalbank and own calculations.

EMPIRICS OF EXTRAORDINARY PREPAYMENTS

The duration of the 30-year mortgage-credit bonds would typically be 8-10 years if the prepayment option were not taken into account. During the past 10 years the market has seen extraordinary prepayments of mortgage-credit bonds for DKK 1,455 billion, cf. Chart A.7.[1] The average duration of the 30-year bonds can thus be considerably lower than 8-10 years, depending on the interest-rate development in relation to the bonds' coupon rates.

One effect of these prepayments has been that a large proportion of the 30-year mortgage-credit bonds with a coupon of 6 or 7 per cent issued within the past 10 years have already disappeared from the market again. They have either been purchased in the market or prepaid extraordinarily. For instance, the outstanding volume of 30-year mortgage-credit bonds with a coupon of 6 per cent maturing in 2026 has by the end of October 2003 been reduced to only 22 per cent of the highest outstanding volume. If the only reductions had been the ordinary redemptions, the circulating volume in the series would have been 86 per cent at the end of October 2003.[2]

[1] For comparison, the circulating volume of mortgage-credit bonds was DKK 1,518 billion in September 2003.

[2] For further details, see Knudsen (2003).

LITERATURE

Black, Fischer, Emanuel Derman and William Toy (1990), A One-Factor Model of Interest Rates and Its Application to Treasury Bond Options, *Financial Analyst Journal*, January-February, pages 33-39.

Danmarks Nationalbank, 2003, *Financial Stability*, p. 36.

Christensen, Anders Møller and Kristian Kjeldsen (2002), Adjustable-Rate Mortgages, Danmarks Nationalbank, *Monetary Review*, 2nd Quarter.

Gjede, Torben, Mette-Lise Houman and Mette Saaby Pedersen (2001), National reports: Denmark, *Mortgage Banks and the Mortgage Bond in Europe*, pages 91-110, European Mortgage Federation, 3rd edition.

Knudsen, Ulrik (2003), Conversions of 30-year Mortgage-Credit Bonds During the Last 10 Years, Danmarks Nationalbank, *Monetary Review*, 2nd Quarter.

ANNEX: DANMARKS NATIONALBANK'S MORTGAGE-CREDIT MODEL IN RIO[1]

In simple terms, a mortgage-credit model comprises two components: a interest-rate model and a prepayment model. Nationalbanken use a BDT-model as a interest-rate model.[2] The calculations can be broken down into the following five steps:

- A number of interest-rate scenarios are created.
- The present value of the mortgage-credit bond is calculated for the borrower on the basis of the interest-rate scenarios, assuming that the loan runs until maturity.
- On the basis of the present value the borrower's prepayment gain is calculated.
- On the basis of the prepayment gain, etc. a redemption ratio is calculated for the mortgage-credit bond in question.
- On the basis of the estimated redemption a new cash flow for the bond is determined, from which the theoretical price, etc. can be determined.

The structure of Danmarks Nationalbank's mortgage-credit model is illustrated in Chart A.8.

Interest-rate model

The first stage is to set up the current yield structure and a volatility assumption for the interest rate. Both of these are required to create a binomial tree, which is used to indicate possible scenarios for the future development in interest rates, cf. Chart A.9.

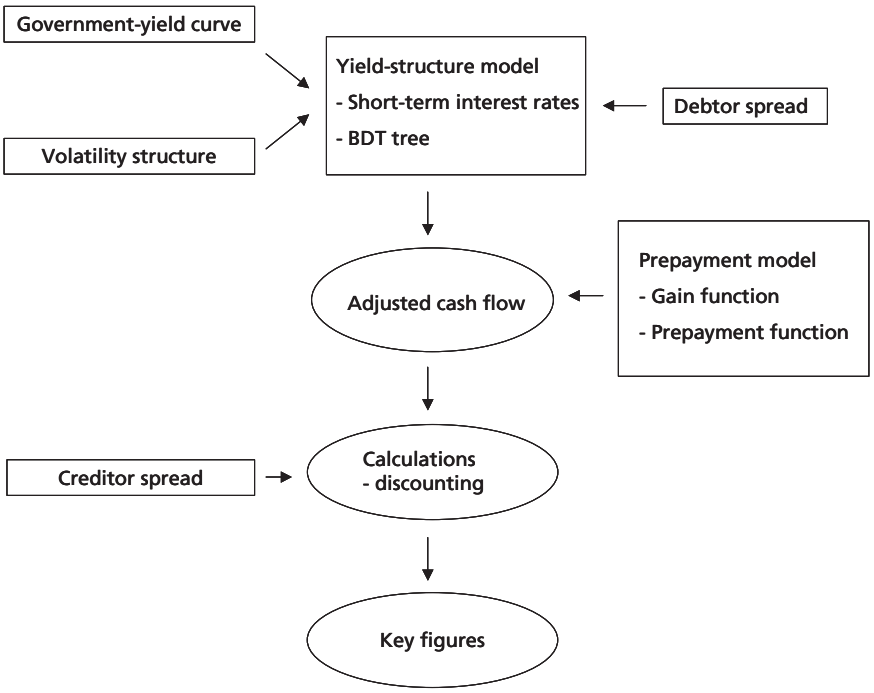
At a given time, t, the rate of interest equals r. At time t+1 the rate of interest may be higher, r(u), or lower, r(d), and so forth for the subsequent periods. In the mortgage-credit model the binomial tree is created using a BDT model.

The assumption as to the volatility of the interest rate affects the shape of the binomial tree. Higher/lower volatility will make the tree wider/narrower, i.e. higher volatility means that the development in interest rates may be more extreme.

The yield structure may have been created on the basis of the government-yield curve. In that case a debtor spread is added to the interest-rate tree, indicating the premium that the borrower must pay on top of the government yield on raising a new mortgage-credit loan. The

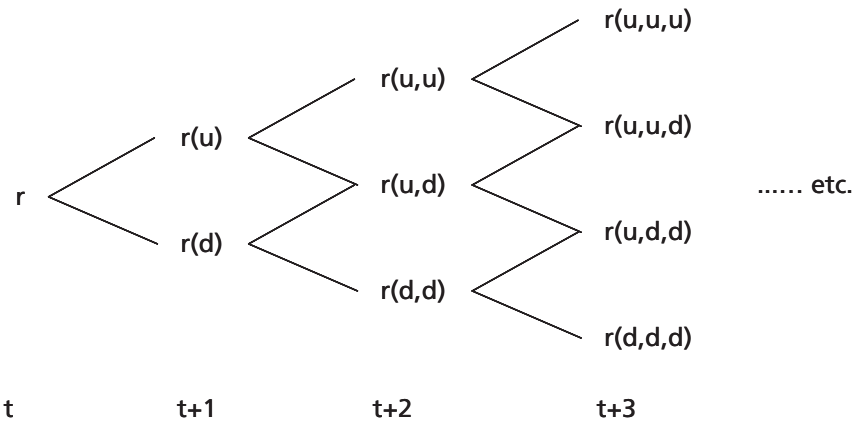
[1] The RIO-system is managed by Scanrate financial systems. See www.scanrate.dk for further details on the RIO-system and alternatives to the BDT-model.
[2] See Black, Derman and Toy (1990).

ORDER OF CALCULATION IN DANMARKS NATIONALBANK'S MORTGAGE-CREDIT MODEL — Chart A.8



borrower cannot refinance directly at the government yield, but must issue mortgage-credit bonds, which are often traded with a credit and liquidity spread to government bonds. Alternatively, the yield structure may be based on the swap curve. The swap spread to the government-yield curve is thus assumed to be equal to the debtor spread. This has the advantage that the spread across the curve is not constant.

EXAMPLE OF INTEREST-RATE TREE — Chart A.9



Prepayment model

The borrower's interest-rate tree is used as the discount factor to determine the present value of the loan, which is subsequently used to calculate the *prepayment gain*. This is found as the ratio of the current value of the loan to its outstanding debt plus prepayment costs. The lower the present value of the loan, the lower the prepayment gain.

The prepayment gain is used to estimate a redemption ratio using a *gain-requirement model*, i.e. a model for the required gain if a borrower is to prepay a loan. In RIO's gain-requirement model borrowers are grouped by the size of the loan.

Discounting adjusted cash flow

When the borrower's prepayment behaviour has been determined, the prepayment-adjusted cash flow can be set up for each node in the interest-rate tree. These cash flows are discounted by either the government-yield curve plus a creditor spread, or the swap curve. This results in the present value of the bond, i.e. the theoretical price, taking the prepayment option into account.

The creditor spread is the spread required by investors in return for taking the risk of purchasing a mortgage-credit bond rather than a government bond. The spread thereby illustrates the compensation required by investors for both credit and liquidity risk. Since the prepayment rates in the future interest-rate scenarios have already been determined in the prepayment model, the effect of the creditor spread is a pure discounting effect.

In a pricing model the debtor and creditor spreads can be expected to be equal. The spread which the borrowers encounter when refinancing must be equal to the spread that investors require in order to invest in a mortgage-credit bond. By using the swap curve, the debtor and creditor spreads are assumed to be equal.

B. Ship Finance Schemes

Historically, Danmarks Nationalbank has played a role in connection with support for various industries. This is no longer the case, and most of the schemes have now been terminated. Although the acceptance of new commitments under the agreements ceased long ago, a few agreements concerning shipbuilding finance are of such long maturity that they will continue to affect Danmarks Nationalbank's market and credit risks and the management of the portfolio of domestic securities for some years to come. The two most important schemes are the index-linked and swap agreements.

INDEX-LINKED SCHEME

As an element of the political agreement on shipyards of 1986, Danmarks Nationalbank acquired index-linked bonds issued by Danish Ship Finance (DSF) to finance newbuildings.[1] The index-linked bonds have a coupon of 2.5 or 4 per cent, and they are serial loans. The government support primarily consisted of a guarantee that the borrower would not have to pay a yield exceeding 5.5 per cent, regardless of the development in prices. Any difference between the indexation premium for the bond owner and borrower is paid by the central government. The last loan under this scheme matures in January 2010.

Danmarks Nationalbank acquired the index-linked bonds at par and has subsequently sold most of the bonds in the market. On acquisition Danmarks Nationalbank made a commitment that, irrespective of the market value of the equivalent bonds, the index-linked loans can be redeemed prematurely at par.

The borrower's right to redeem the index-linked loan prematurely corresponds to a homeowner's option to prepay a callable mortgage-credit loan. This option is typically exercised if the borrower can refinance on better terms. In contrast to the "house analogy", however, the bond owner is not the issuer of the (call) option, since the index-linked bonds are not callable. The structure of the scheme means that the option is issued by Danmarks Nationalbank instead.

[1] The Danish market for index-linked bonds was introduced in 1982 in an economy with a very high rate of inflation. The aim was to create an asset whereby the investor received compensation for inflationary erosion of the future nominal payments. Consequently, the payments on the index-linked bonds are written up by a factor corresponding to the development in prices, so that the payments are made in real terms.

Danmarks Nationalbank does not hedge the prepayment option as an element of its risk management. Since the market value of the bonds is typically higher than their nominal value, prepayments entail a loss.

In the event of prepayments Danmarks Nationalbank must deliver the underlying bonds. This means that a certain number of Ship Finance bonds are maintained in the portfolio of domestic securities, cf. Chapter 4 on Danmarks Nationalbank's portfolios. Alternatively it is assessed whether the bonds can be purchased at a favourable price in the market.

If it is not possible to deliver the bonds, a debenture may be created. In that case Danmarks Nationalbank takes over the debtor's and the central government's total obligations vis-à-vis the bond owners and covers the future payments on the bond. If, at a later time, it becomes advantageous to purchase the underlying bonds in the market, the debenture may be cancelled. The Board of Governors has approved a ceiling for the nominal value of the debentures issued.

The interest-rate risk on the index-linked bonds is hedged by purchasing nominal bonds for the amount received upon prepayment. The aim is for the bonds to have approximately the same payment flow, at a given inflation scenario, as the index-linked bonds underlying the redeemed loan. When debentures are cancelled, the hedging is reduced again by selling bonds. The interest-rate risk is thus not included in the normal risk management.

The issue of debentures increases Danmarks Nationalbank's total balance sheet by an amount corresponding to the index-linked value of the outstanding debt on the loan that is redeemed prematurely. Table B.1 shows the effect of a debenture on Danmarks Nationalbank's balance sheet. It is assumed that the loan redeemed prematurely has an index-linked outstanding debt of DKK 100 million.

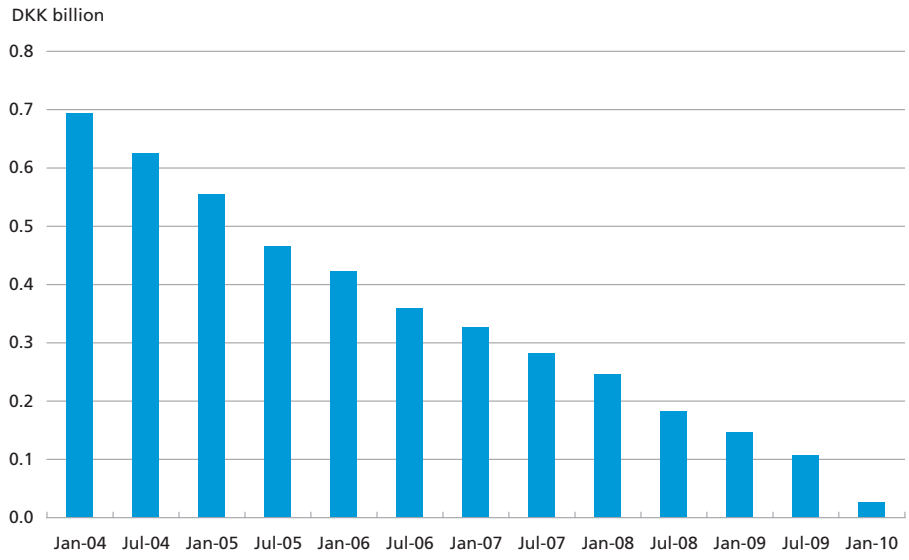
The scheme does entail some particular risks. For instance, a higher rate of inflation will increase Danmarks Nationalbank's obligations, since the payments on the index-linked bonds are adjusted upwards in step with prices. Another risk is a relative change in the prices of index-linked bonds and nominal bonds, e.g. in connection with tax reforms.

BALANCE-SHEET IMPACT OF ISSUE OF DEBENTURES — Table B.1

DKK million	Assets	Liabilities
Domestic bonds	+100	
Debentures		+100

Source: Danmarks Nationalbank.

OUTSTANDING DEBT FOR DEBENTURES (INDEX-LINKED) Chart B.1



Note: The index-linked payments are calculated for a future inflation rate of 2 per cent.
Source: Danmarks Nationalbank.

In recent years some of the index-linked loans have been redeemed prematurely. The many prepayments may be related to the low level of interest rates, which has increased the value of the prepayment option.

Since 1997 debtors have redeemed 150 loans with a total index-linked value of DKK 11.5 billion. Of these, DKK 2.2 billion have been delivered, while a total of 121 debentures have been issued for the outstanding amount. [1] Chart B.1 shows the payment distribution for the outstanding debentures.

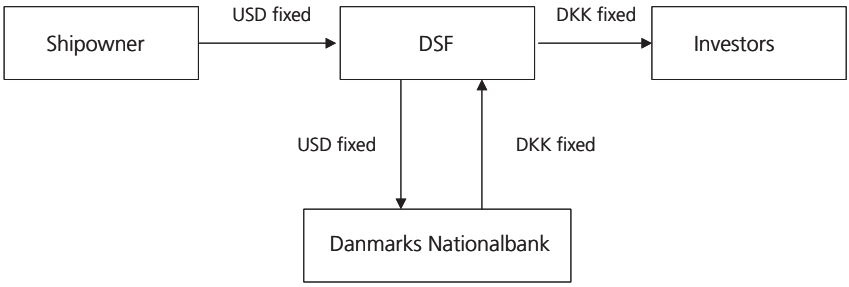
The potential for further prepayments may be calculated as the circulating volume of index-linked bonds from DSF less the outstanding debt on the debentures already issued by Danmarks Nationalbank. At end-2002 the potential was DKK 1.8 billion.

SWAP LOANS

In 1993 a government interest-subsidy scheme was introduced to reduce the financing costs of newbuildings at Danish shipyards. The scheme enabled DSF to borrow in dollars by issuing nominal krone-denominated bonds. The scheme was made possible by the conclusion of a swap agreement with Danmarks Nationalbank. No new commitments are

[1] Of the 121 debentures 46 have been cancelled and 21 have expired. Therefore 54 debentures remain.

PAYMENT FLOWS IN THE SWAP SCHEME Chart B.2



Source: Danmarks Nationalbank.

accepted today, and the last loan is to be repaid in 2012. The scheme is outlined in Chart B.2.

DSF lends dollars by selling nominal krone-denominated bonds at a fixed yield. The shipowner obtains a dollar loan based on the CIRR interest rate[1]. DSF remits the payment to Danmarks Nationalbank as the dollar leg of the swap. The other leg of the swap agreement consists of Danmarks Nationalbank's fixed-rate krone payments to DSF. These payments correspond to the payments on the underlying Ship Finance bonds. At end-2002 the market value of the krone leg was DKK -4.1 billion and DKK 5.0 billion of the dollar leg.

Danmarks Nationalbank's interest-rate risk in connection with the swap scheme is part of the normal risk management. If interest rates increase, the fixed payments on the krone leg decrease in value, which is a gain for Danmarks Nationalbank. The krone leg thereby contributes negatively to the krone duration. On the other hand, the dollar leg contributes positively to the krone duration. At end-2002 the krone duration of the krone leg was negative by DKK 160 million and that of the dollar leg positive by DKK 185 million.

The foreign-exchange exposure in dollars is included in the foreign-exchange management and hedged via transformation to euro.

Originally Danmarks Nationalbank acquired the issued bonds at market price with a view to ongoing resale of the bonds to the market. In connection with prepayments Danmarks Nationalbank must deliver the underlying bonds, corresponding to the krone leg of the swap contract.

[1] The CIRR interest rate is an OECD interest rate determined for one month at a time on the basis of the preceding month's average interest rate on government securities plus 1 percentage point. It applies with half a month's delay. The CIRR interest rate is published for three maturities: 0-5 years, 5-8½ years and 8½ years or more. The CIRR interest rate to be applied is determined by the maturity of the loan.

As with index-linked loans, it is possible to issue a debenture, however. This option has not been exercised so far. In risk terms the prepayments contribute to reducing the interest-rate exposure of the swap.

Originally, 30 swap contracts were concluded with a principal of DKK 8.4 billion. 18 of the 30 loans have been redeemed prematurely. The outstanding principal was DKK 3.8 billion at end-2002.

C. Mathematical Price Adjustment (Pull to Par)

Like the commercial Danish banks, Danmarks Nationalbank states bonds and financial instruments at market value on its balance sheet. Mainly two factors may influence the market value of a bond: changes in the market interest rate, and reduction of maturity. The latter is also known as the pull to par effect and is a result of the fact that the nominal yield on the bond is different from the market interest rate. The current coupon structure of Danmarks Nationalbank's portfolios exceeds the market interest rate. At unchanged interest rates, Danmarks Nationalbank will thus suffer a capital loss as a consequence of the reduction of maturity. However, this will be offset by the fact that the income from coupon payments will be higher than the current market interest rates.

EFFECTS OF MATURITY REDUCTION

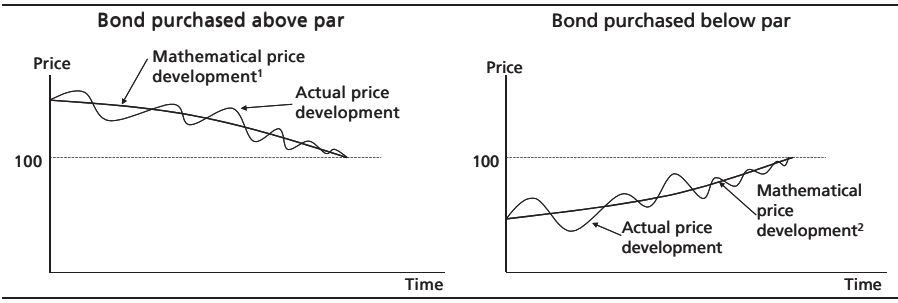
The breakdown of the financial result on yields and capital gains is affected by the reduction of maturity. Mainly two factors affect the price of a bond: changes in the market interest rate and reduction of maturity.

A drop in the market interest rate will typically entail an increase in the bond price, and vice versa. The effect of reduction of maturity, on the other hand, is a result of the fact that the nominal yield on the bond differs from the market interest rate. When a bond approaches its maturity date, the price of the bond will approach par. This price adjustment is known as the reduction of maturity or mathematical price adjustment, cf. Chart C.1 and Box C.1.

Danmarks Nationalbank's portfolio is currently placed in instruments with an average nominal yield exceeding the market interest rate. At unchanged interest rates Danmarks Nationalbank will thus suffer a capital loss as a consequence of the reduction of maturity. However, this is offset by the fact that the income from interest is higher than could be achieved on the basis of the current market interest rates.

In recent years, when interest rates have predominantly been falling, Danmarks Nationalbank has achieved capital gains. Mathematical price adjustments have, however, resulted in lower capital gains than if the coupon structure of the portfolios had been closer to the market inter-

MATHEMATICAL PRICE ADJUSTMENT Chart C.1



[1] This effect is also known as depreciation of premium. The premium is determined as the actual price less par.
[2] This effect is also known as accretion of discount. The discount is determined as par less the actual price.

est rate. On the other hand, the income from interest has been correspondingly higher, so that the total return on the portfolios has not been affected by the fact that the market interest rate has been lower than the average coupon rate on Danmarks Nationalbank's portfolios.

Price adjustments and income from interest are not treated in the same way as regards allocation of profit. It is therefore of importance to the transfers to the central government and to the build-up of the Danmarks Nationalbank's Value Adjustment Reserve whether the market interest rate is higher than, lower than or on a par with the average coupon rate on Danmarks Nationalbank's portfolios.

In view of the current coupon structure of Danmarks Nationalbank's portfolios, the mathematical price adjustment entails that the Value Adjustment Reserve is not as large as could be expected on the basis of the market development.

MATHEMATICAL PRICE ADJUSTMENT Box C.1

The mathematical price adjustment can be illustrated by an example. It is assumed that Danmarks Nationalbank on 1 January purchases a 4-year bond, bullet loan, with a coupon rate of 10 per cent. The yield structure is assumed to be flat at 8 per cent. When the accounts are presented that year, the bond will have a price of DKK 105.15.[1] It is now assumed that interest rates are unchanged. The following year the price of the bond will be DKK 103.57.[2] The mathematical price adjustment is thus: DKK 103.57-105.15 = DKK -1.59. This means that the price of the bond has decreased despite the unchanged level of interest rates. The reason for the decrease in price is that the bond's coupon rate is higher than the market interest rate.

[1] $10 * ((1- (1.08)^{3})/0.08) + 100 * (1.08)^{-3}$ = DKK 105.15.
[2] $10 * ((1- (1.08)^{2})/0.08) + 100 * (1.08)^{-2}$ = DKK 103.57.

D. Index for Performance and Decomposition

The following reviews the key calculations in connection with the compilation and decomposition of performance. This supplements Chapter 13 on measuring performance.

CALCULATION OF INDEX

Both the old and the new performance calculations are based on the following type of return index:

$$(1)\ Index_T = (1 + r_{0,T}) = \prod_{t=1}^{T}(1 + r_t) = \prod_{t=1}^{T}\frac{MV_t + C_t - T_t}{MV_{t-1}} \quad , where$$

MV_t = *market value in period t*

C_t = *coupon payments in period t*

T_t = *net changes in holding on day t calculated at exercise price*

r_t = *relative return in period t*

$r_{0,T}$ = *relative return over the entire period*

The index is a multiplicative time-weighted index, cf. Chapter 13 on performance. The return on the portfolio is calculated on a daily basis and multiplied over time to give an index for the return over the entire period. The index is robust vis-à-vis flows of funds to and from the portfolio, cf. below. The percentage return r_t from *t-1* to *t* can be re-written from (1) to the following expression:

$$(2)\quad r_t = \frac{\sum_s N_{t-1}^s (P_t^s - P_{t-1}^s) + \sum_s C_t^s + \sum_s (P_t^s \Delta N_t^s - T_t^s)}{\sum_s N_{t-1}^s P_{t-1}^s} \quad , where$$

N_{t-1}^s = *nominal holding of instrument s time* $t-1$

ΔN_t^s = *change in nominal holding of instrument s*

C_t^s = *coupon payments on instrument s day t*

P_t^s = *dirty price on instrument s day t*

T_t^s = *sum of transactions at exercise price for instrument s*

On the basis of (2) it is possible to describe the calculation of the index by considering the following situations:

- If no instruments are traded, $\Delta N^s_t = T^s_t = 0$, and the return stems solely from changes in the dirty price and any coupon payments on the instrument on a settlement date.
- If $\Delta N^s_t = 0$, i.e. no change in any of the nominal holdings, but $T^s_t \neq 0$, the same paper has been bought and sold during the day and the contribution to the return is the result of price changes during the day.
- If $\Delta N^s_t \neq 0$ and $T^s_t \neq 0$, the nominal holdings have changed, and the return is affected if the closing price P^s_t deviates from the bid or offer prices for the instrument during the day. This means that purely nominal changes in the holdings from time *t-1* to *t* do not affect the return index. The index can therefore resist changes in the holdings over time.
- If all holdings of an instrument *s* are removed from the portfolio, i.e. $\Delta N^s_t = -N^s_{t-1}$, the numerator is reduced to $-T^s_t - N^s_{t-1} P^s_{t-1}$ for the instrument in question. In this case, the numerator equals the proceeds from the sale less the holding's market value on the previous day.
- If a new instrument is bought for the portfolio, the numerator equals $N^s_t P^s_t - T^s_t$, which is the gain from the time of purchase until closing.

The last term in the numerator in (2) can be called the timing effect. It is positive if the dealer has bought or sold at the right time during the day.

It is important to note that the denominator in (1) and (2) assumes that changes in the portfolio size during day *t* cannot generate a return on the same day, i.e. interest or capital gains, and/or the portfolio change is not at the disposal of the dealer until time *t+1*.

This is best illustrated by means of an example. Assume that the holding doubles from DKK 100 million to DKK 200 million from time *t-1* to *t*. The denominator equals MV_{t-1}=DKK 100 million. If the dealer can invest the increase in the holding during the day and generate a positive return, e.g. as a result of favourable price development, this return will be included in the numerator via the element $P^s_t \Delta N^s_t - T^s_t$. If this is the case, the denominator is too low, since the return on the portfolio is generated by invested capital exceeding DKK 100 million at time *t-1*, so the return on the portfolio is overestimated. Kjeldsen (1996) gives a detailed discussion of this problem and its solutions, cf. the literature reference list for Chapter 13.

DECOMPOSITION OF RETURN AS DIRECT RETURN AND MARKET DEVELOPMENT

The following example considers a portfolio with no movement in the holding comprising one bond of the bullet issue type, i.e. the entire bond is redeemed on expiry. (2) can be reduced to the following formula (the index *s* is dropped initially, and it is explicitly stated that the market value equals the dirty price of the bond):

$$(2') \; r_t = \frac{(P_t^{dirty} - P_{t-1}^{dirty}) + C_t}{P_{t-1}^{dirty}}$$

The return can be written as the change in the dirty price plus any coupon payments C_t as a ratio of the dirty price on the previous day. The focus in the following is first on the absolute return ΔV (in DKK) expressed as:

$$(3) \; \Delta V = P_t^{dirty} - P_{t-1}^{dirty} + C_t$$

This return can be decomposed in various ways, initially as:

- direct return "carry", ΔV_{direct}
- market development, ΔV_{market}

ΔV_{direct} is here defined as the coupon payment with the addition of the mathematical price adjustments due to the reduction of maturity. ΔV_{direct} can be written as:

$$(4) \; \Delta V_{direct} = (AI_t - AI_{t-1} + C_t) + (P^{clean}(M_{t-1}, t) - P^{clean}(M_{t-1}, t-1))$$
$$\Rightarrow \Delta V_{direct} = \Delta V_{coupon} + \Delta V_{maturity\ reduction}$$

The first term is the change in accrued interest *AI* with the addition of any settlement payments C_t on day *t*. The last term is the change in the theoretical clean price P_t from *t-1* to *t* under unchanged market conditions, the so-called maturity reduction. This term is determined by pricing the bond at time *t* and *t-1* assuming unchanged yield curves and spreads via the function $P^{clean}(M_t, t)$, where M_t represents the chosen input of market data and *t* the time of the pricing. Note that, maturity-reduction (also known as pull to par) as defined here contains both the effect of pure maturity reduction and a possible effect of changes in interest rates, if the yield curve is not flat (roll-down). For example, if

the yield curve has a positive slope and the bond is priced under par, both the maturity reduction in isolation, and the effect of roll-down will draw towards a higher price[1].

The part of the return attributable to the market development is calculated as the difference between the theoretical clean price at time *t* and *t-1* less the effect of the maturity reduction, i.e.:

$$(5)\ \Delta V_{market} = P_t^{clean} - P_{t-1}^{clean} - \Delta V_{maturity\ reduction}$$

It should be noted that the prices in (5) are the observed stock-exchange prices (not the theoretical prices). That (4) + (5) equals (3) can be seen from the following:

$$(6)\ \Delta V = \Delta V_{market} + \Delta V_{direct} = (P_t^{clean} + AI_t) - (P_{t-1}^{clean} + AI_{t-1}) + C_t = P_t^{dirty} - P_{t-1}^{dirty} + C_t$$

DETAILED DECOMPOSITION OF RESPECTIVELY DIRECT RETURN AND MARKET DEVELOPMENT

The coupon payment ΔV_{coupon}, the maturity reduction $\Delta V_{maturity\ reduction}$ and the return due to the market development ΔV_{market} can be broken down into several components, cf. below.

The coupon payment ΔV_{coupon} can be broken down as:

- coupon according to the general yield structure $\Delta V_{yield\ structure,\ coupon}$
- coupon premium due to sectoral spread $\Delta V_{sectoral\ spread,\ coupon}$
- coupon premium due to instrument-specific spread $\Delta V_{instrument\text{-}specific\ spread,\ coupon}$

The maturity reduction $\Delta V_{maturity\ reduction}$ can be broken down as:

- maturity reduction across the general yield structure $\Delta V_{yield\ structure,\ maturity\ reduction}$
- a premium due to maturity reduction along the sectoral curve $\Delta V_{sectoral\ spread,\ maturity\ reduction}$

[1] Unchanged market conditions are here defined as a situation where the yield curves are unchanged. Alternatively it could be defined as where the forward curves are realised. If the last definition is used the "maturity-reduction" could fx be calculated as $P^{clean}(M_{t-1,t}, t) - P^{clean}(M_{t-1}, t)$, where $M_{t-1,t}$ represent the forward curves at time *t* implied from the yield curves at time *t-1*. In such a context "maturity-reduction" contains both effects from pure maturity-reduction, roll-down on the curve and development in forward curves.

- a premium due to maturity reduction along the instrument-specific curve $\Delta V_{\text{instrument-specific spread, maturity reduction}}$

The market development ΔV_{market} can be broken down as:

- contribution from parallel shift in the general yield structure, $\Delta V_{\text{yield structure, parallel shift}}$
- contribution from change in the shape of the general yield structure, $\Delta V_{\text{yield structure, change in shape}}$
- contribution from development in the sectoral spread, $\Delta V_{\text{sectoral spread, development}}$
- contribution from development in the bond-specific spread, $\Delta V_{\text{instrument-specific spread, development}}$

The breakdown of the *coupon payment* ΔV_{coupon} into a coupon according to a general yield structure, e.g. the government-yield curve, and subsequent coupon premiums attributable to a sectoral or instrument-specific spread is as follows. First the coupon $k_{\text{yield structure, derived}}$ that, at the current general yield structure equals the theoretical stock-exchange price to the observed stock-exchange price, is calculated. This means that the coupon $k_{\text{yield structure, derived}}$ is found by solving the following equation:

$$(7)\ P^{clean}(M_{t-1}^{\text{yield structure}}, t-1, k_{\text{yield structure, derived}}) = P_{t-1}^{clean}$$

The calculation is then repeated using the relevant sectoral curve. For a corporate bond the yield structure for corporate bonds with the same rating is used. The difference between the two calculated coupons is the coupon premium attributable to the spread between the government and corporate bond curves:

$$(8)\ k_{\text{sectoral spred, coupon premium}} = k_{\text{sectoral curv, derived coupon}} - k_{\text{yield structure, derived coupon}}$$

The coupon premium due to the sectoral spread is most often positive and can be interpreted as the extra coupon payment to an investor as compensation for investing in e.g. a corporate bond with a higher credit risk rather than in a government bond. In addition, the corporate bond will include an instrument-specific coupon premium, since in practice the bond is never traded on the corporate-bond curve. This instrument-specific premium can be positive or negative and may be the result of company-specific factors such as gain or a possible liquidity premium on the bond. The instrument-specific premium is determined residually as:

$$(9)\ k_{\text{instrument-specific spread, coupon premium}} = k - k_{\text{sectoral spread, coupon premium}} - k_{\text{yield structure, derived coupon}}$$

where k is the actual coupon on the corporate bond. The two coupon premiums and the coupon according to the general yield structure add up by construction to the total coupon. The total coupon payment in absolute terms can therefore be written as:

$$(10)\ \Delta V_{\text{coupon}} = \Delta V_{\text{yield structure, coupon}} + \Delta V_{\text{sectoral spread, coupon}} + \Delta V_{\text{instrument-specific spread, coupon}}$$

where the individual payments are calculated on the basis of the calculated coupons. Besides the coupon payment the direct return also comprises the price development due to the reduction of maturity, cf. (4). The *maturity reduction* can be calculated along various yield curves. The starting point is again a general yield structure such as the zero-coupon yield curve for government bonds. The price development along this curve can be calculated as:

$$(11)\ \Delta V_{\text{yield structure, maturity reduction}} = (P^{clean}(M_{t-1}^{\text{yield structure}}, t) - P^{clean}(M_{t-1}^{\text{yield structure}}, t-1))$$

It should be noted that the calculated reduction of maturity comprises two effects. Firstly, the bond is brought closer to maturity, and secondly other discounting factors are applied if the curve is not flat. Viewed in isolation, the first effect will push the price towards par, while the price effect of changed discounting factors depends on the shape of the yield curve. The calculation in (11) can be repeated using a relevant sectoral curve, cf. above, and finally by using an instrument-specific curve. The instrument-specific curve can be determined residually by means of parallel shift of the sectoral curve whereby the bond is priced on the curve. The maturity reduction along the instrument-specific curve is an estimate of the bond's true price development as a consequence of the maturity reduction, and can likewise be written as a sum of 3 factors:

$$(12)\ \Delta V_{\text{maturity reduction}} = \Delta V_{\text{yield structure, maturity reduction}} + \Delta V_{\text{sectoral spread, maturity reduction}} + \Delta V_{\text{instrument-specific spread, maturity reduction}}$$

The only remaining element to be decomposed is the *market development* ΔV_{market}. The market development can first be written as follows, cf. (5) and (12) :

$$
\begin{aligned}
&(13)\ \Delta V_{market} = P_t^{clean} - P_{t-1}^{clean} - \Delta V_{maturity\ reduction} \\
&= \left(P^{clean}(M_t^{yield\ structure}, t) - P^{clean}(M_{t-1}^{yield\ structure}, t-1)\right) \\
&- \Delta V_{yield\ structure,\ maturity\ reduction} \\
&+ \left(P^{clean}(M_t^{sectoral\ curve}, t) - P^{clean}(M_t^{yield\ structure}, t)\right) \\
&- \left(P^{clean}(M_{t-1}^{sectoral\ curve}, t) - P^{clean}(M_{t-1}^{yield\ structure}, t-1)\right) \\
&- \Delta V_{sectoral\ spread,\ maturity\ reduction} \\
&+ \left(P_t^{clean} - P^{clean}(M_t^{sectoral\ curve}, t)\right) - \left(P_{t-1}^{clean} - P^{clean}(M_{t-1}^{sectoral\ curve}, t-1)\right) \\
&- \Delta V_{instrument-specific\ spread,\ maturity\ reduction} \\
&= \Delta V_{yield\ structure,\ development} + \Delta V_{sectoral\ spread,\ development} \\
&+ \Delta V_{instrument-specific\ spread,\ development}
\end{aligned}
$$

In (13) the market development is divided into the share attributable to the development in the general yield structure, the share attributable to the development in the sectoral spread and finally, the share attributable to the development in the instrument-specific spread. It should be noted that the individual contributions from the reduction of maturity, cf. (12) are deducted in the calculation of the contributions from the market development. That way the reduction of maturity is included in the calculation of the direct return on the bond.

The effect of the development in the general yield structure, $\Delta V_{yield\ structure,\ development}$ can be further broken down as parallel shift and shape:

$$
\begin{aligned}
&(14)\ \Delta V_{yield\ structure,\ development} = \left(P^{clean}(M_t^{parallel}, t) - P^{clean}(M_{t-1}^{yield\ structure}, t-1)\right) \\
&- \Delta V_{yield\ structure,\ maturity\ reduction} + \left(P^{clean}(M_t^{yield\ structure}, t) - P^{clean}(M_t^{parallel}, t)\right) \\
&= \Delta V_{yield\ structure,\ parallel\ shift} + \Delta V_{yield\ structure,\ development\ in\ shape}
\end{aligned}
$$

where $P(M_t^{parallel}, t)$ is the notional stock-exchange price on a parallel shift in the general yield structure from *t-1* to *t*. The parallel shift can be calculated in several ways. Box 13.3 in Chapter 13 shows an example of parallel shift of the curve by the average yield change in the 2-, 5- and 10-year segments from time *t* to *t-1*. ΔV_{shape} is finally calculated residually as the difference between the notional stock-exchange price at the actual yield curve and at the parallel-shifted curve.

The total decomposition of the return can be written as:

$$(15)\ \Delta V = \Delta V_{direct} + \Delta V_{market} = \Delta V_{general\ yield\ structure,\ coupon}$$
$$+ \Delta V_{sectoral\ spread,\ coupon} + \Delta V_{instrument-specific\ spread,\ coupon}$$
$$+ \Delta V_{yield\ structure,\ maturity\ reduction} + \Delta V_{sectoral\ spread,\ maturity\ reduction}$$
$$+ \Delta V_{instrument-specific\ spread,\ maturity\ reduction} + \Delta V_{yield\ structure,\ parallel\ shift}$$
$$+ \Delta V_{yield\ structure,\ development\ in\ shape} + \Delta V_{sectoral\ spread,\ development}$$
$$+ \Delta V_{instrument-specific\ spread,\ development}$$

Written as a relative return, (15) is as follows:

$$(15')\ r = \frac{\Delta V}{V} = r_{direct} + r_{market}$$
$$= r_{general\ yield\ structure,\ coupon} + r_{sectoral\ spread,\ coupon} + r_{instrument-specific\ spread,\ coupon}$$
$$+ r_{yield\ structure,\ maturity\ reduction} + r_{sectoral\ spread,\ maturity\ reduction}$$
$$+ r_{instrument-specific\ spread,\ maturity\ reduction} + r_{yield\ structure,\ parallel\ shift}$$
$$+ r_{yield\ structure,\ development\ in\ shape} + r_{sectoral\ spread,\ development}$$
$$+ r_{instrument-specific\ spread,\ development}$$

The total result of the decomposition is presented as a table and described in further detail in Chapter 13.

The decomposition in (15) is additive in the individual components. Alternatively a multiplicative decomposition of the return can be applied. The multiplicative decomposition instead gives the following expression (the calculations are not described in further detail here):

$$(15'')\ 1 + r = \frac{V + \Delta V}{V} = (1 + r_{direct})(1 + r_{market})$$

DECOMPOSITION OF TOTAL RETURN AND PERFORMANCE

The decomposition of the return on the individual bond can now be used in a decomposition of the return on the total portfolio. The total return in DKK from *t-1* to *t* can be written as:

$$(16)\ \Delta V =$$
$$\sum_s \left(\Delta V^s_{general\ yield\ structure,\ coupon} + \Delta V^s_{sectoral\ spread,\ coupon} \right.$$
$$+ \Delta V^s_{instrument-specific\ spread,\ coupon} + \Delta V^s_{yield\ structure,\ maturity\ reduction}$$
$$+ \Delta V^s_{sectoral\ spread,\ maturity\ reduction} + \Delta V^s_{instrument-specific\ spread,\ maturity\ reduction}$$
$$+ \Delta V^s_{yield\ structure,\ parallel\ shift} + \Delta V^s_{yield\ structure,\ development\ in\ shape}$$
$$\left. + \Delta V^s_{sectoral\ spread,\ development} + \Delta V^s_{instrument-specific\ spread,\ development} \right)$$

where ΔV is now the return on the entire portfolio, and *s* refers to the individual bonds/instruments in the portfolio. (16) can be re-written as a relative return from *t-1* to *t* :

$$(17)\ r = \frac{\Delta V}{V} = \sum_S \omega_S \Big(r^s_{\text{general term structure, coupon}} + r^s_{\text{sectoral spread, coupon}} + r^s_{\text{instrument-specific spread, coupon}} + r^s_{\text{yield structure, maturity reduction}} + r^s_{\text{sectoral spread, maturity reduction}} + r^s_{\text{instrument-specific spread, maturity reduction}} + r^s_{\text{yield structure, parallel shift}} + r^s_{\text{yield structure, development in shape}} + r^s_{\text{sectoral spread, development}} + r^s_{\text{instrument-specific spread, development}} \Big)$$

where ω_s is now the weight of bond *s* in the portfolio at the time *t-1*. The weight is calculated as the bond's share of the market value of the portfolio. The relative return *r* on the portfolio can thus be calculated as a weighting together of the individual components of the return. The performance *P*, i.e. the difference between the return on the actual portfolio and on the benchmark portfolio, from *t-1* to *t* can be calculated as follows:

$$(18)\ P = r_{\text{actual portfolio}} - r_{\text{benchmark}} = \sum_S \Big(\Delta\omega_S r^s_{\text{general yield structure, coupon}} + \Delta\omega_S r^s_{\text{sectoral spread, coupon}} + \Delta\omega_S r^s_{\text{instrument-specific spread, coupon}} + \Delta\omega_S r^s_{\text{yield structure, maturity reduction}} + \Delta\omega_S r_{\text{sectoral spread, maturity reduction}} + \Delta\omega_S r^s_{\text{instrument-specific spread, maturity reduction}} + \Delta\omega_S r^s_{\text{yield structure, parallel shift}} + \Delta\omega_S r^s_{\text{yield structure, development in shape}} + \Delta\omega_S r^s_{\text{sectoral spread, development}} + \Delta\omega_S r^s_{\text{instrument-specific spread, development}} \Big) + r_{\text{timing-effect}}$$

where $\Delta\omega_s$ is the difference between the weight of instrument *s* in respectively the actual portfolio and the benchmark portfolio. The performance from *t-1* to *t* can in other words be calculated as a weighted average of the components of the return on the individual instruments. Performance is the result of differences in the weights of the individual instruments in respectively the actual portfolio and the benchmark portfolio. Furthermore, the timing effect is added in (18) for the sake of completion, cf. (2). As stated, the timing effect is the effect of gains/losses from intraday sales/purchases.

AGGREGATION OF SUB-COMPONENTS OVER TIME

The calculations above show how the total return from period *t-1* to *t* can be broken down into various sub-components which together add up to the total return r_t in the period. However, the measurement of performance focuses on the return over a longer period, for which the return is measured via the time-weighted index. The time-weighted index can be written as follows, cf. (1):

$$(1')\ Index_T = (1 + r_{0,T}) = \prod_{t=1}^{T} (1 + r_t) \ \Leftrightarrow \ r_{0,T} = \prod_{t=1}^{T} (1 + r_t) - 1$$

In (1') the period returns are multiplied over time, leading to the return over the entire period, i.e. $r_{0,T}$. The question is now whether the total return for the period can be decomposed like the returns for individual periods. The return for an individual period from *t-1* to *t* can be written as follows (17'):

$$\begin{aligned}(17')\ r_t = \sum_S \big(& rc^{s,t}{}_{\text{general yield structure, coupon}} + rc^{s,t}{}_{\text{sectoral spread, coupon}} \\ & + rc^{s,t}{}_{\text{instrument-specific spread, coupon}} + rc^{s,t}{}_{\text{yield structure, maturity reduction}} \\ & + rc^{s,t}{}_{\text{sectoral spread, maturity reduction}} + rc^{s,t}{}_{\text{instrument-specific spread, maturity reduction}} \\ & + rc^{s,t}{}_{\text{yield structure, parallel shift}} + rc^{s,t}{}_{\text{yield structure, development in shape}} \\ & + rc^{s,t}{}_{\text{sectoral spread, development}} + rc^{s,t}{}_{\text{instrument-specific spread, development}} \big)\end{aligned}$$

where $rc^{s,t}_j$ is the return component *j* on bond *s* in period *t* weighted using the bond's portfolio share, i.e. $rc^{s,t}_j = \omega_s r^{s,t}_j$.

A first attempt to decompose the total return over time $r_{0,T}$ would be to sum up the sub-components in (17') for the entire period. However, the problem is that the time-weighted index is a multiplicative index, whereby simply summing up the sub-components in (17') does not yield $r_{0,T}$. This problem can be solved by scaling the individual sub-components in the following way:

$$(19)\ \tilde{rc}^{s,t}{}_j = rc^{s,t}{}_j (1 + r_{0,t-1})$$

In (19) the sub-components from each period *t* are scaled using the return index up to and including the preceding period, i.e. $(1+r_{0,t-1})$. The following is shown to apply:

$$(20)\ r_{0,T} = \sum_{t=1}^{T} \sum_{S} \left(\widetilde{rc}^{\,s,t}_{\text{general yield structure, coupon}} + \widetilde{rc}^{\,s,t}_{\text{sectoral spread, coupon}} + \widetilde{rc}^{\,s,t}_{\text{instrument-specific spread, coupon}} + \widetilde{rc}^{\,s,t}_{\text{yield structure, maturity reduction}} + \widetilde{rc}^{\,s,t}_{\text{sectoral spread, maturity reduction}} + \widetilde{rc}^{\,s,t}_{\text{instrument-specific spread, maturity reduction}} + \widetilde{rc}^{\,s,t}_{\text{yield structure, parallel shift}} + \widetilde{rc}^{\,s,t}_{\text{yield structure, development in shape}} + \widetilde{rc}^{\,s,t}_{\text{sectoral spread, development}} + \widetilde{rc}^{\,s,t}_{\text{instrument-specific spread, development}} \right)$$

$$\Rightarrow$$

$$r_{0,T} = rc^{0,T}_{\text{general yield structure, coupon}} + rc^{0,T}_{\text{sectoral spread, coupon}} + rc^{0,T}_{\text{instrument-specific spread, coupon}} + rc^{0,T}_{\text{yield structure, maturity reduction}} + rc^{0,T}_{\text{sectoral spread, maturity reduction}} + rc^{0,T}_{\text{instrument-specific spread, maturity reduction}} + rc^{0,T}_{\text{yield structure, parallel shift}} + rc^{0,T}_{\text{yield structure, development in shape}} + rc^{0,T}_{\text{sectoral spread, development}} + rc^{0,T}_{\text{instrument-specific spread, development}}$$

Where $rc^{0,T}_{j}$ is now the total contribution to the return over the period from sub-component *j*. (20) shows that the total return for the entire period is the sum of the new scaled sub-components, which can also be summed up over the period. Scaling the original return contributions thus makes it possible to achieve a decomposition that sums up to the total return for the period over time.