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March 12, 2007

To: Members of the Executive Board

From: The Acting Secretary

Subject: **Denmark—Publication of Financial Sector Assessment Program—Technical Note—Stress Testing**

Attached for the **information** of Executive Directors is a technical note for Denmark, on stress testing, in connection with the Financial Sector Assessment Program (FSAP). The FSAP technical note supplements the Financial System Stability Assessment for Denmark, which was circulated as SM/06/301 (9/8/06).

It is intended that this technical note be published on the Fund's extrnal website as requested by the authorities of Denmark and approved by management.

Questions may be referred to Mr. Wajid, MCM (ext. 39620).

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FINANCIAL SECTOR ASSESSMENT PROGRAM

DENMARK

TECHNICAL NOTE
STRESS TESTING

SEPTEMBER 2006

INTERNATIONAL MONETARY FUND
MONETARY AND CAPITAL MARKETS DEPARTMENT

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GLOSSARY

AVGR	Interest rates
BLS	Baseline scenario
BU	Bottom-up
CAR	Capital adequacy ratio
CAR-S	Adjusted CAR after a shock
CAR-decrease	Marginal decrease of CAR due to a shock
CIMDO	Consistent information multivariate density optimizing
CoPoD	Conditional probability of default
CREOVGDP	Credit over GDP
DFSA	Danish Financial Supervisory Agency
DGP	Data generation processes
DNB	Danmarks Nationalbank
EC	Economic capital
ECB	European Central Bank
EL	Expected losses
EL-buffer	Expected loss buffer
EU	European Union
EX	Exposures
FSAP	Financial Sector Assessment Program
FXDU	Foreign exchange rate
HOUP	House prices
LD	Loss distribution
LGD	Loss given default
MXED	Minimum cross entropy approach
NFI	Net foreign investment
NPL	Nonperforming loan
OLS	Ordinary least squares
PIT	Probability integral transformation
PLD	Portfolio loss distribution
PMD	Portfolio multivariate density
PoDs	Probability of defaults
RWA	Risk-weighted assets
TD	Top down
UL	Unexpected losses
UNEM	Unemployment
VaR	Value at risk

I. Introduction[1]

1. **This note describes the stress testing exercises carried out for the Danish commercial banking system and the insurance sector.** The tests were conducted as part of the Financial Sector Assessment Program (FSAP) for Denmark and were developed in collaboration with the Danish Financial Supervisory Agency (DFSA) and Danmarks Nationalbank (DNB). The general objective of the exercises was to assess the resilience of the banking and insurance sectors to a variety of relevant risks. The single factor shocks and macroeconomic scenarios considered were low probability, severe, but plausible events.

2. **Two approaches—bottom-up (BU) and top-down (TD)—were employed in the analysis.** Under the BU approach, stress tests were carried out by the major financial institutions, using their own internal risk models. The DFSA coordinated and oversaw individual institution's stress tests, which were based on December 2005 data. The DFSA also compiled and aggregated the results in order to protect the confidentiality of the information on individual institutions. The TD stress tests were performed by the mission and the DNB using a risk-based methodology.[2] The exercises were based on two databases, namely aggregated supervisory data provided by the DFSA and aggregated financial surveillance data produced by the DNB.[3] The TD stress tests, which were based on December 2004 data, also served as a consistency check on the results obtained by individual institutions.

II. Coverage

3. **Stress tests were performed on the five largest financial groups, representing roughly 80 percent of the system's assets on a consolidated basis.** Within this group, Danske Bank holds some 46 percent of the assets, Nordea Bank 26 percent, Jyske Bank 13 percent, FIH 8 percent, and Sydbank 7 percent. The analysis was done at the consolidated group level covering the most important risk exposures in trading and banking books, with shocks applied to domestic portfolios.

4. **Stress tests aim to cover the major risks stemming from macroeconomic sources faced by financial institutions.** For both banks and insurance companies, these consisted of market and credit risks. For the former, liquidity, concentration, and contagion risks through

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[1] The primary author of this document is Miguel Angel Segoviano (msegoviano@imf.org). The author and his colleagues would like to thank the Danish authorities for their exemplary cooperation and hospitality before, during, and after the mission. Special thanks are given to Kenneth Juhl Pedersen at the DNB for his support in data preparation.

[2] The risk-based methodology was developed and implemented by Miguel Angel Segoviano. For technical details, please refer to Segoviano (2006a,b). For implementation details please refer to Segoviano and Padilla (2006).

[3] Please see paragraph 10 for a description of the databases that were available to perform the TD stress test.

the interbank market were also assessed, but not operational risk.[4] Market risks were analyzed by applying shocks to interest rates, equity prices, foreign exchange rates, and real estate prices and tracing the effect on the balance sheets of the relevant institutions.[5] Credit risk was assessed by applying multi-factor or macroeconomic scenarios. Stress tests for market and credit risks spanned a three-year horizon, while those for liquidity, concentration, and contagion risks had a shorter horizon. The three-year horizon was chosen because it usually takes more than two years for the effect of shocks to completely materialize.[6] Shocks to liquidity, concentration, and contagion risks were considered to be single events, since these shocks tend to hit the system suddenly, rather than developing over time.

III. Methodology

A. Definition of Shocks and Macroeconomic Scenarios

5. **To ensure consistency across institutions, the mission and the DNB defined the single factor shocks and macroeconomic scenarios to be used in the two approaches.** The magnitudes of the shocks were based on historical information, with a time frame long enough to cover at least one economic cycle and episode of financial distress. A baseline scenario, given the current macroeconomic situation was forecast and three additional scenarios were developed. These were based on: (i) assumptions about key variables to be shocked; and (ii) the estimated effect on a set of endogenous macroeconomic variables determined by MONA—the macroeconomic model developed by the DNB.

B. The Bottom-Up Approach

6. **The DFSA provided guidance, coordinated, and oversaw the individual institutions' stress tests.** These took into account the expertise of the individual financial institutions, since each institution was given the freedom to use its own methodology to perform the stress tests. For both the banks and insurance companies, the tests on credit and market risks were performed using the institution's own internal risk models. As banks routinely test for market risks in their portfolios, such models are quite well developed and hence exhibit a high degree of consistency across institutions. Although tests for credit risk are also performed routinely, the models used by financial institutions in this area are less uniform.

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[4] FSAPs are designed to assess the stability of the financial system as a whole and not that of individual institutions. They have been developed to help countries identify and remedy weaknesses in their financial sector structure, thereby enhancing resilience to macroeconomic shocks and cross-border contagions. FSAPs do not cover risks specific to individual institutions such as operational, or legal risks or fraud.

[5] The institutions participating in the exercise excluded credit risk effects from the single factor shocks, except in the shock to real estate prices.

[6] See Goodhart, Hofmann, and Segoviano (2004) and Segoviano (2006a).

7. **The DFSA compiled and aggregated the results to ensure reporting uniformity across institutions and for reasons of confidentiality.** All banks reported the impact of the shocks on their portfolios' expected losses (EL), but employed different approaches to estimate the impact of the shocks on their capital. ELs were estimated as: EL = probability of default (PoD) x exposure (EX) x loss given default (LGD). Most of the banks computed the impact of macroeconomic shocks on the PoDs of each type of loan in their portfolios. They used their own databases on EX and applied conservative assumptions to determine LGD rates. Once PoDs, EX, and LGDs were determined, banks computed the EL from the shocks. Only one bank estimated EL directly as a function of macroeconomic variables. Banks used different frameworks to estimate the impact of the shocks on their capital. Two banks used their internal models to estimate unexpected losses (UL). The ULs correspond to the 99.5 percent value at risk (VaR) of the loan portfolio loss distribution (PLD). ULs also correspond to economic capital (EC), since it is the capital that a bank would need to hold in order to cover its ULs. Two other banks followed an "accounting approach" to estimate their capital adequacy ratio (CAR) after the shock.

8. **The stress test exercise was also carried out by the five largest insurance companies in Denmark.** Danica Pension (Danske Bank subsidiary), Nordea Pension (Nordea subsidiary), SEB Pension (SEB subsidiary), PFA Pension, and Kommunernes Pensionsforsikring. Together, these insurance companies represent slightly more than 50 percent of the insurance sector assets in Denmark.

C. The Top-Down Approach

9. **The TD approach mainly focused on estimating banks' portfolio credit risk, since this was perceived to be the major source of risk.** The TD approach helped to validate the results obtained by the participating institutions in the BU approach. Data limitations prevented conducting tests at the conglomerate level—e.g., joint banking and insurance portfolios—and testing for operational risk.

10. **The portfolio credit risk stress tests were performed using data provided by the DFSA and the DNB.** The DFSA provided data included information on (i) ratios of provisions (flow) to loans grouped by economic sectors; and (ii) the percentage loan exposure to each economic sector. These variables corresponded to the loan portfolio of banks making up "Group 1" in the Danish Financial System.[7] For each variable, the data included annual observations from 1991 to 2004. The DNB data included information on two variables: (i) PoDs of loans grouped by risk-rating categories;[8] and (ii) the proportion of total EX to each risk-rating category. For each variable, the data included annual observations from 1996 to 2003. For confidentiality reasons, data were not available on individual banks'

7 The DFSA categorizes banks operating in Denmark in four groups. Group 1 comprises Danske Bank, Nordea Bank, FIH, Jyske Bank, and Sydbank. See Financial Stability Report, Danmarks Nationalbank 2005.

8 The PoDs estimates are based on the DNB failure-rate model described in Lykke, Pedersen, and Vinter (2004).

portfolios, or on loan by loan basis. These limitations did not allow the mission to estimate individual banks' portfolio credit risk and the estimates obtained correspond to the "average" credit risk of banks in "Group 1."

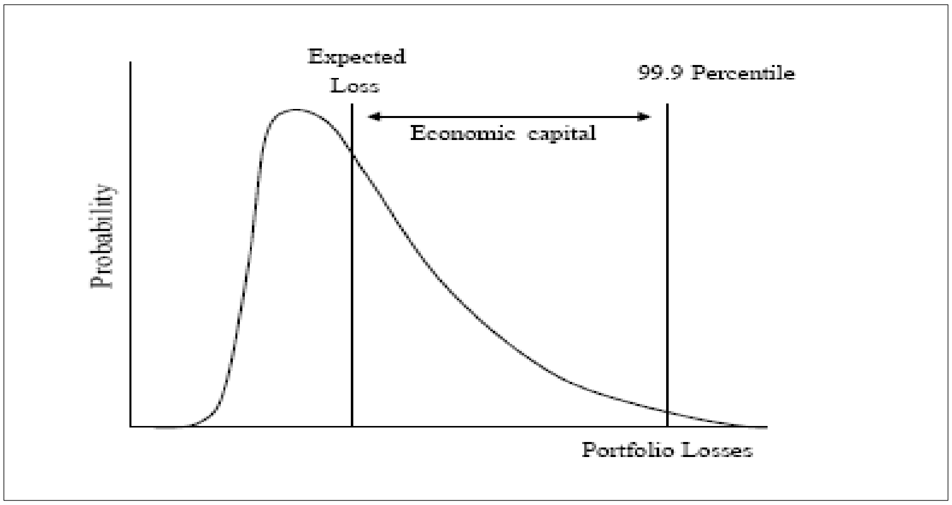
11. **A risk-based approach was used to perform the TD stress test.** The objective of any risk-based approach is to estimate the portfolio loss distribution (PLD) from which the economic capital that a bank should hold in order to withstand shocks is defined. Since the quality of the credit portfolio of a bank can change at any time in the future, there is a need to calculate the expected losses the bank could suffer under different risk situations. Measuring the uncertainty or variability of losses—ULs in the risk measurement literature—and the related likelihood of the possible levels of unexpected losses in a bank's portfolio is fundamental to the effective management of credit risk. Sufficient earnings should be generated through adequate pricing and provisioning to absorb any expected loss. However, economic capital should be available to cover unexpected credit default losses, because the actual level of credit losses suffered in anyone period could be significantly higher than the expected level. The estimation of the loss distribution PLD of credit portfolios, from which a level of unexpected losses can be identified—e.g., 99.9 percentile loss level—and thus, the level of EC that a bank should put aside represents the main objective of risk-based approaches. The PLD summarizes the credit risk of the loan portfolio by indicating the possible losses in the value of the portfolio and the related likelihood of such events (Figure 1).

12. **In order to estimate the PLD of a loan portfolio, it is necessary to infer the portfolio multivariate density (PMD).** The estimation of the PLD of a loan portfolio requires simulation of the possible losses that the portfolio can experience, given the characteristics of the loans held in the portfolio. The PMD describes the joint likelihood of changes in the credit risk quality of the loans that make up the portfolio.

13. **The risk-based technique employed to model PMDs is based on the joint implementation of the Conditional Probability of Default (CoPoD) Methodology and the Consistent Information Multivariate Density Optimizing (CIMDO) Methodology.** These methodologies are designed to improve the measurement of portfolio credit risk in data constrained environments. The CoPoD and the CIMDO facilitate back-testing and policy recommendations. This approach is an improvement over purely statistical or mathematical models that are economically a-theoretical.

14. **The CoPoD allows the modeling of PoDs as functions of macroeconomic and financial variables and produces efficient estimators.** The process of modeling PoDs represents a challenging task, since time series of PoDs usually contain few observations, making ordinary least squares (OLS) estimation imprecise or unfeasible. With few PoD observations, the CoPoD produces smaller-variance estimators than OLS techniques. A summary and key features of the CoPoD is presented in Appendix 1.

Figure 1. Portfolio Loss Distribution



Source: Segoviano (2006b).

15. **Intuitively, the CoPoD produces efficient estimators because it assigns different weights to data observations and infers their distribution based on data.** Under maximum likelihood (ML) estimation, implicitly, equal weights to each sample observation are assigned and a parametric distribution (usually the normal distribution), is assumed to represent the stochastic behavior of the data. Then, the unknown parameters are solved by maximizing the probability of observing the data; i.e., their likelihood functions. The CoPoD criterion weighs sample observations using different estimates of their probabilities, which are based on observed data and infers the distribution of probability weights from data itself rather than fixing it ex-ante. The CoPoD criterion thus makes a more efficient use of the data than OLS (which is equivalent to ML assuming that observations are normal (Appendix 2).

16. **The CIMDO allows recovering PMDs from very limited information—the PoDs of each type of loan making up a portfolio.**[9] In comparison to standard credit risk models, CIMDO does not need stock prices, market, or financial variables of individual firms to model their credit risk. Nor is information on the loans' dependence structure (correlations) needed. Moreover, the PMDs recovered with CIMDO are better specified than parametric PMDs when the information necessary to calibrate them is not available. A summary of the CIMDO is presented in Appendix 3. In Appendix 4, we provide an intuitive explanation of the density specification improvements achieved by CIMDO.

[9] The specification improvements of the PMDs are measured under the probability integral transformation (PIT) criterion. For technical proofs see Segoviano (2006b).

17. **The stress test exercises involved a four-step procedure (Figure 2):**

(i) **The definition of macroeconomic scenarios.** The mission and the DNB defined the macroeconomic scenarios used in both TD and BU approaches.

(ii) **The incorporation of macroeconomic shocks into the PoDs of the loans making up the portfolios.** The effects of the macroeconomic shocks in the scenarios were incorporated into the probabilities of default of loans grouped by sector or rating with the CoPoD.

(iii) **The modeling of the portfolio multivariate density.** Once such effects were incorporated into PoDs, the multivariate density that describes the joint likelihood of changes in the credit risk quality of the loans that make up the loan portfolio was generated with the CIMDO.

(iv) **The simulation of portfolio loss distribution and estimation of economic capital.** The portfolio multivariate density was used to simulate the possible losses/gains that the loan portfolio can experience. The losses/gains obtained from this simulation were used to construct the PLD of the portfolio. From the PLD distribution the EC that a bank should put aside, given the risk profile of its loan portfolio was determined.

18. **The stress testing framework employed allows explicit linkage of macroeconomic shocks to estimation of EC and therefore evaluation of the banks' vulnerability under different shocks.** It ensures the economic consistency of the estimated risk measurements. The analysis facilitates policy recommendations since the relevant explanatory variables are based on identified data and economic theory.

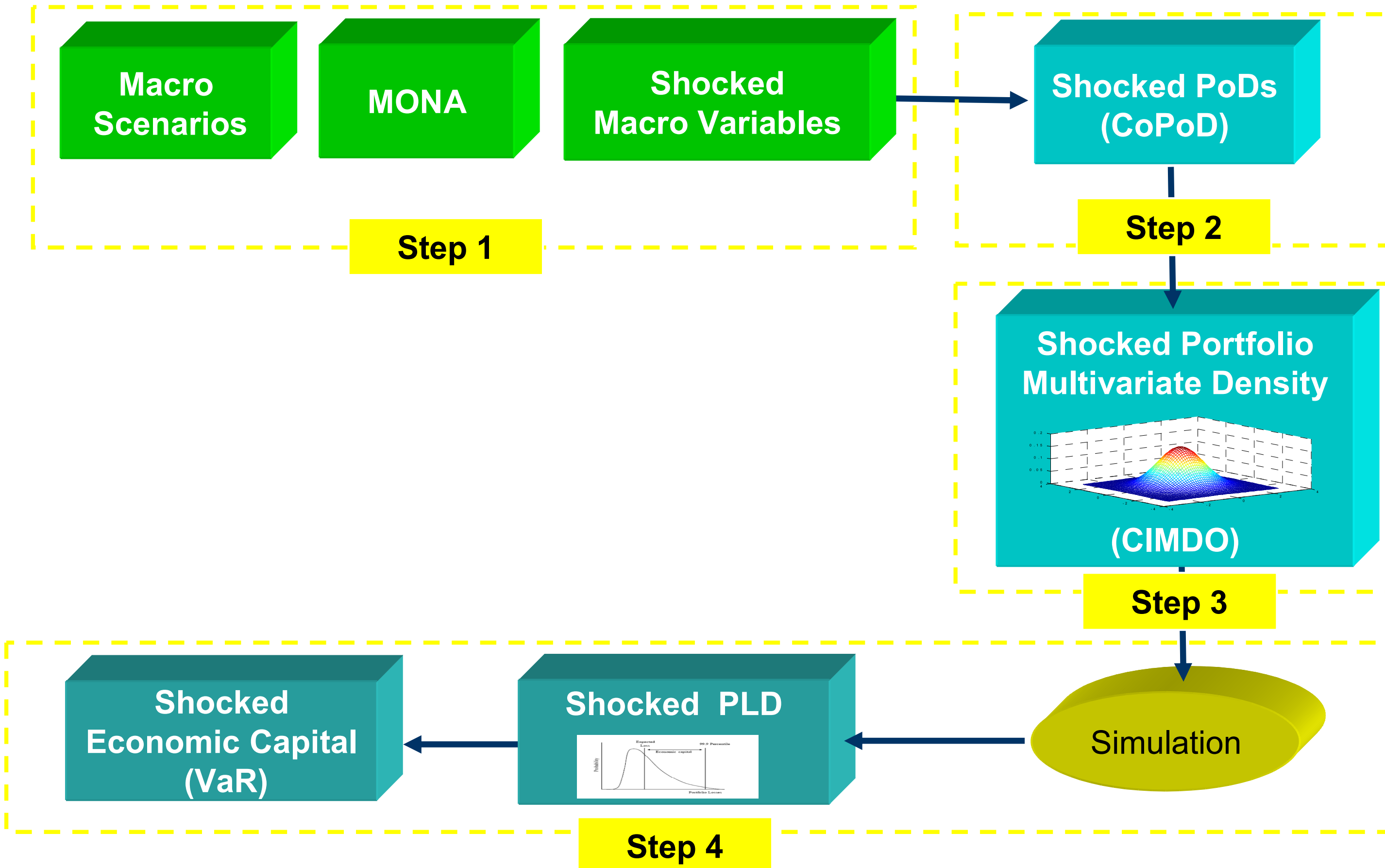
19. **Vulnerability assessments of liquidity, contagion risk in the interbank market, and concentration were incorporated into the TD approach.** Liquidity and concentration risks were assessed by analyzing liquidity and exposures in banks' portfolios. Tests for contagion risk were performed by employing a model developed by the DNB.[10]

D. Excercise Caveats

20. **A key caveat in any stress testing is fully addressing secondary feedback effects in the financial system.** The exercise does not provide a general equilibrium model that takes into account the externalities resulting from weaknesses in the financial system. In the TD analysis, an attempt was made to deal with this issue on a limited basis. The PoDs in the macroeconomic stress scenario were adjusted to simultaneous (single factor) shocks and scenarios were run in which assets (financial and real estate) lose value due to adverse economic conditions.

[10] The model is defined in Abildgren and Arnt (2004).

Figure 2. Stress Test Procedure



Source: Segoviano (2006c).

21. **Data limitations impeded the modeling of adjustments to banks' profitability and LGDs through-time under the stressed scenarios.** Therefore, profitability was assumed to remain at the levels reported in 2004. Thus, to this extent the shocks' impact on capital may be understated. This "second best" approach was taken in the absence of sufficient data and consensus for modeling adjustments to profitability. It was also not possible to access data on LGDs, and assumptions about this variable were made.[11]

22. **The use of bank-grouped data in the TD stress test prevented the estimation of individual banks' portfolio credit risk.** Since bank concentration is high in Denmark, stress tests on bank-grouped data have to be interpreted with caution. Individual institutions, including systemically important ones, can have portfolios that might make them more vulnerable to certain shocks than the system on average.

IV. Definition of Shocks and Macroeconomic Scenarios

A. Economic Outlook and Vulnerabilities

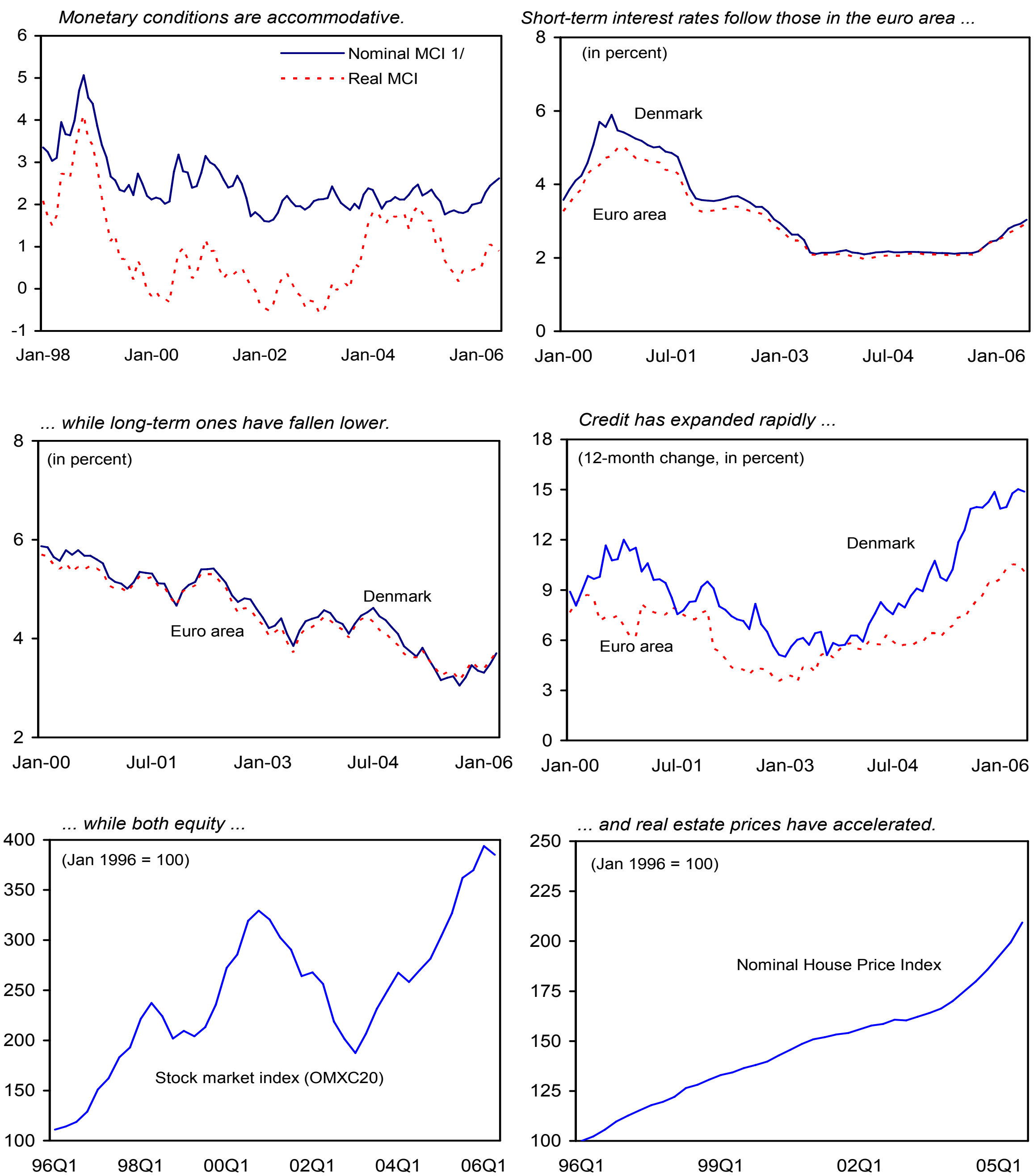
23. **Recent economic and financial developments in the Danish economy suggest emergence of risks that could impact financial stability (Figure 3).** Over the last year, the rate of house price increases has been particularly strong, with prices rising at double-digit rates over 20 percent in 2005, the largest increase in nearly 20 years.[12] Credit growth has accelerated in parallel, reaching above 21 percent in 2005.[13] The housing finance structure has also changed considerably in recent years. The level of total household debt to disposable income has increased substantially along with the share of adjustable rate loans that have become prominent in the mortgage markets. Households are thus more vulnerable to fluctuations in interest rates and given the importance of mortgage loans in the economy, the new structure has the potential to amplify interest rate effects on the economy.

[11] We assumed a LGD equal to 50 percent, as indicated in the Basel II IRB approach guidelines.

[12] The ratio of house prices to disposable income has risen 70 percent from 1970 to date. This is due to the fact that, from 1995, house prices have increased considerably with an average yearly growth rate of 8 percent. While there are good fundamental reasons to believe that house prices should be higher today than in 1995, the recent growth rates look excessive. From Q1 2005 to Q1 2006, prices of family houses increased 24.4 percent and of condominiums 31.0 percent, while prices of summer houses increased by 19.5 percent.

[13] Low interest rates imported from the Euro is one of the main factors explaining the surge in house prices and excessive credit growth in Denmark. Due to the restriction on Denmark's conduct of its monetary policy, it is expected that low interest rates will continue to boost credit growth and house prices. In addition, the tax freeze in real estate have further invigorated the housing market.

Figure 3. Recent Economic and Financial Developments in Denmark

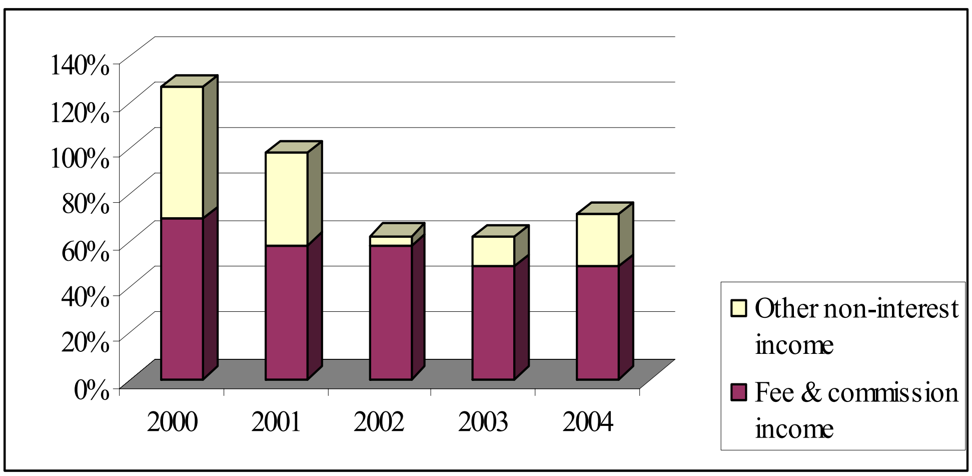


Sources: Danmark National Bank, International Financial Statistics.
Monetary conditions indices are calculated as weighted averages of the 3-month interest rates and the detrended effective exchange rates, with respective weights of 0.75 and 0.25.

24. **Temporary factors have clouded the information content of some of the financial indicators.** In particular, figures on the profitability of the banking sector should be interpreted carefully. An increasing proportion of the gross income of Danish banks has been derived in recent years from non-interest income, which is unlikely to be sustainable over the longer term (in particular, refinancing of houses, securities, and foreign exchange income, or income attributable to equity investments in associates and unconsolidated subsidiaries).[14] Growth in the fee and commission income has been moderate in both gross and net terms, and the share of this income in total assets has been broadly stable. This ratio is similar to that of banks operating in other EU countries (Figure 4).

25. **As any small open economy, Denmark seems prone to vulnerabilities to developments in the larger partner economies.** Because of its openness and the limited scope for monetary policy in the context of the pegged exchange rate arrangement, the Danish economy is exposed to developments in foreign economies.

Figure 4. Fee Income as a Percentage of Pretax Income



Source: IMF's estimation.

B. Single Factor Shocks and Macroeconomic Scenarios

26. **On the basis of the current macroeconomic situation and vulnerabilities in the Danish economy, extreme but plausible single factor shocks and macroeconomic scenarios were defined**. In all cases, the sizes of the shocks draw from historical information, taking into account a time frame long enough to cover at least an entire economic cycle and episodes of financial distress (Table 1).

[14] Total profit for most regional and local banks in 2004 and 2005 was positively affected by payments received from Nykredit Realkredit for the purchase of Totalkredit—similar one-off income will affect these banks' results in 2006 as well.

Table 1. Macroeconomic Scenarios—Percentage Deviations From Baseline Scenarios

Variable	Baseline			Scenario 1			Scenario 2			Scenario 3		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
GDP % y/y	2.4	2.2	2.2	-1.8	-5	-6.8	-1.4	-3.2	-4.1	-2.4	-6.7	-9.2
Unemployment 1/	5.1	5	5	0.5	2.2	3.8	0.6	2	3.2	0.7	2.9	5.1
Private consumption % y/y	2.5	2.2	2.2	-2.8	-6.9	-9.1	0.4	-0.5	-1.2	-3.5	-8.8	-11.7
House price % y/y	7	3	3	-7.2	-17.8	-27	-0.6	-2.9	-5.5	-15.6	-29.8	-41.9
Business investment % y/y	5.9	4	4	-5.7	-12.6	-17.1	-1.8	-4.9	-7.7	-8	-19.5	-26.5
Exports % y/y	4.6	5.5	5.5	-2.4	-3.4	-3.1	-5.9	-8.3	-8.6	-3.3	-3.8	-3.1
Manufacturing output % y/y	3.5	3.2	3.2	-3.5	-9.7	-12.9	-3.6	-7.9	-9.9	-4.6	-13	-17.5
Consumer price % y/y	2.1	1.9	1.9	-0.1	-0.4	-0.8	-2	-3.1	-4	0.2	0	-0.4
Hourly wage % y/y	3.7	3.8	3.8	-0.1	-0.9	-2.7	-0.3	-1.5	-3.2	-0.1	-1.1	-3.5
Oil price $/barrel	56.4	56.4	56.4	0	0	0	0	0	0	30	30	30
DKK/USD	638	638	638	0	0	0	-29	-29	-29	0	0	0
Bond yield % points	3.9	3.9	3.9	0	0	0	0	0	0	2.5	2.5	2.5
Discount rate % points	2.2	2.2	2.2	0	0	0	0	0	0	2.5	2.5	2.5
Share price % y/y	8	5	5	-0.7	-6.5	-11.5	-1.9	-9.6	-14.6	-23.7	-31.6	-30.8
Loans to private sector % y/y	8	5	5	-1.5	-7.0	-14.2	0	-1	-2.7	-1.8	-9.5	-19.5

Sources: Danmarks' Nationalbank; and IMF's staff estimations.

Notes: The shocks are reported as percentage deviations from the baseline scenario (BLS); thus, need to be interpreted with caution. For example, a shock to GDP in 2008 under Scenario 3 is equal to -9.2 percent from the BSL in 2008. However, this shock corresponds to -2.4 percent from the BSL level in 2005. This result is equal to the accumulated percentage increase in GDP under the BSL from 2005 to 2008 (6.8 percent) minus the percentage deviation from the BSL in 2008 (-9.2 percent).

[1] Percent of labor force national definition

27. **The exercises based on single factor tests comprise three sources of market risks: (i) interest rate; (ii) equity and real estate prices; and (iii) foreign exchange.** Banks included derivatives exposures in assessing market risk and used assumptions about shocks to implied volatilities. The single factor shocks are specified as follows:

- Shock 1: Parallel shifts in the yield curve: +250 and -100 basis points.
- Shock 2: Equity prices: -30 percent.
- Shock 3: Foreign exchange DKr/non-euro currencies: appreciation/depreciation 40 percent.[15]
- Shock 4: Real estate prices: -30 percent.

28. **Three macroeconomic scenarios were defined relative to a baseline scenario, capturing the main risks to the Danish economy.** The scenarios are:

- **Scenario 1: Boom-bust in real estate prices and credit**—the low interest rate environment in recent years has increased the value of collateralizable assets (stocks and real estate). As the borrowing capacity of borrowers depends on the value of their collateralizable assets, higher asset values have contributed to higher lending, which in turn has further fuelled economic activity and asset prices. The increased value of assets has raised households' borrowing capacity and wealth and boost consumption. Higher consumption has increased aggregate demand and lowered unemployment, with further knock-on effects on asset prices, competitiveness, and economic activity. In this way, the levels of indebtedness in the economy have increased quickly. Eventually, decreases in asset returns—resulting from the sharp increase in asset prices and high levels of indebtedness in the economy—can make economic agents revise their expectations about asset prices and the boom can turn into a bust. Asset prices then start falling and credit growth decreases, downplaying economic activity. Expectations of wealth decrease, consumption falls, aggregate demand falls, GDP falls, and unemployment increases. Depressed collateral prices, higher unemployment, and decreasing GDP have a negative impact on banks' assets, increasing the proportion of nonperforming loans (NPLs).

- **Scenario 2: Foreign shock due to a correction in U.S. imbalances**—under this scenario, investors around the world become nervous of global imbalances and withdraw their assets, looking for a "safe haven" in Europe. This results in a reduction of European Net Foreign Investment (NFI). A downward shift in European NFI reduces the demand for loans and therefore reduces the equilibrium interest rate.[16] The reduced level of NFI in Europe reduces the supply of euros in the market for foreign exchange; therefore, the euro appreciates. The Danish Kroner, pegged to

[15] This is the foreign exchange DKr/non-euro currencies. An increase implies depreciation.

[16] The lowering of interest rates in Europe tends to raise NFI, but this only partly mitigates the shift in the NFI curve.

the euro, appreciates against the U.S. dollar and other currencies as well, leading to a loss of competitiveness and lower demand for Danish goods. The trade balance deteriorates, GDP falls, and unemployment rises in Denmark. There is a shift in expectations, negatively affecting private consumption and depressing economic activity further. These effects have a negative impact on banks' NPLs, increasing banks' losses.

- **Scenario 3: Boom-bust in real estate prices and credit plus an increase in European interest rates—t**he background leading up to this scenario is similar to that described in Scenario 1 above—a boom in asset prices and credit. However, in this Scenario, we also assume that the continuation of high oil prices increases inflationary pressures in Europe, prompting the European Central Bank to increase interest rates. The DNB follows suit and increases the policy interest rate. The reassessment of asset values is reinforced by higher interest rates and higher debt servicing, making the boom turn into a bust. As in Scenario 1, asset prices start falling, consumption decreases, aggregate demand contracts, GDP falls, credit growth decreases, and unemployment increases. Higher interest rates, depressed collateral prices, higher unemployment, and decreasing GDP have a negative impact on banks' assets and NPLs.

V. Results: Top Down Approach

A. Credit Risk

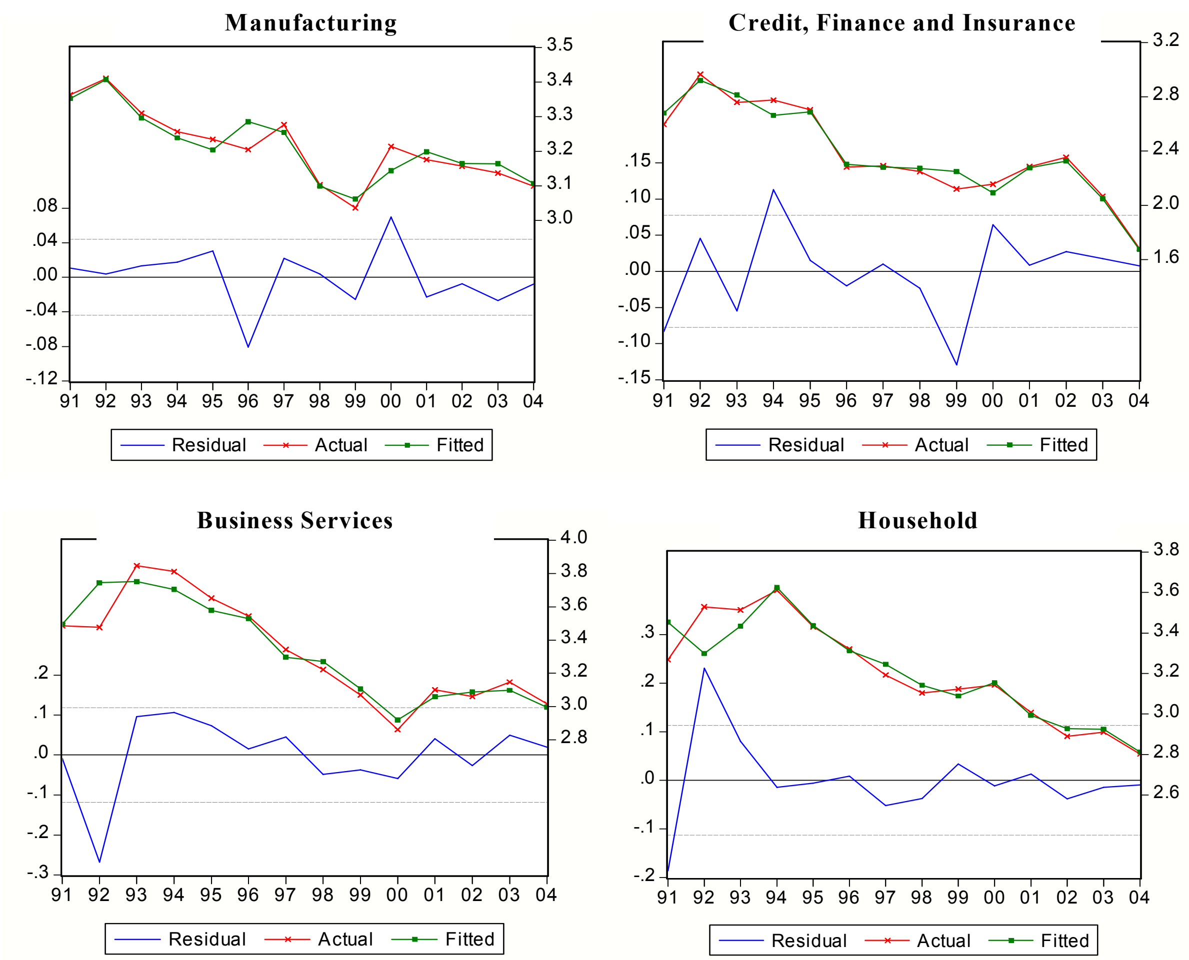
29. **Once the macroeconomic scenarios were defined, the modeling of PoDs as functions of macroeconomic variables were performed.** For this purpose, the CoPoD methodology is used to estimate the coefficients of the explanatory variables that are significant in explaining the evolution over time of the PoDs of loans grouped by risk-rating category and by economic sector.[17] Equations for 8 risk-rating categories and 11 economic sectors were estimated. Figure 5 shows estimated values for a selected group of economic sectors. Table 2 shows the significant explanatory variables, their lags and signs for all the economic sectors that were estimated. In all these cases, credit over GDP (CREOVGDP) and house prices (HOUP) are significant.[18] Because of the impact of the value of collateral assets on the level of credit, wealth effects and economic activity, the evolution of these variables has a significant effect on the relevant economic sectors. It is also noteworthy that there are specific variables that are more relevant to specific sectors due to the nature of their economic activity. For example, interest rates (AVGR) and unemployment (UNEM) are highly significant in explaining the default behavior of the credit, finance, and insurance sectors and households, respectively. The foreign exchange rate (FXDU) is highly significant for manufacturing, since in Denmark, this sector is strongly focused on export markets, while

[17] After analyzing the database provided by the DFSA, which contained NPL ratios of loans grouped by economic sector, we considered such NPLs to be good proxies for PoDs. Hereafter, we refer to these NPLs as PoDs.

[18] These results are consistent with theoretical credit cycles à la Kiyotaki and Moore (1997), as well as the results reported by Kaminsky and Reinhart (1999); Eichengreen and Areta (2000); Borio and Lowe (2002); Goodhart, Hofmann and Segoviano (2004); and Segoviano (2006a).

GDP is highly important for business and services, which is a sector that is mainly focused on the domestic sector.

Figure 5. Probability of Defaults as Functions of Macroeconomic Variables



Source: IMF estimation

Table 2. Significant Explanatory Variables

Sector	CREOVGDP		HOUP		GDP		UMEM		AVGR		MTGR		FXDU		R^2
	Sign	Lag	Sign	Lag	Sign	Lag	Sign	Lag	Sign	Lag	Sign	Lag	Sign	Lag	
Public	+	3	+	2			+	2					-	0	0.83
Agriculture	+	5	+	4	-	3							-	3	0.81
Fisheries	+	5	+	4			+	2	+	1					0.78
Manufacturing	+	4	+	1	-	1			+	0			-	2	0.74
Building	+	5	- , +	0, 5									-	3	0.68
Trade	+	4	-	0	-	3					+	0	-	0	0.72
Transport	-	1	-	0	-	0			+	0					0.69
Finance & insurance	-	0	+	3					+	0					0.73
Business	+	6	-	0	-	3									0.74
Households	+	4	-	0			+	1	+	1			-	2	0.71

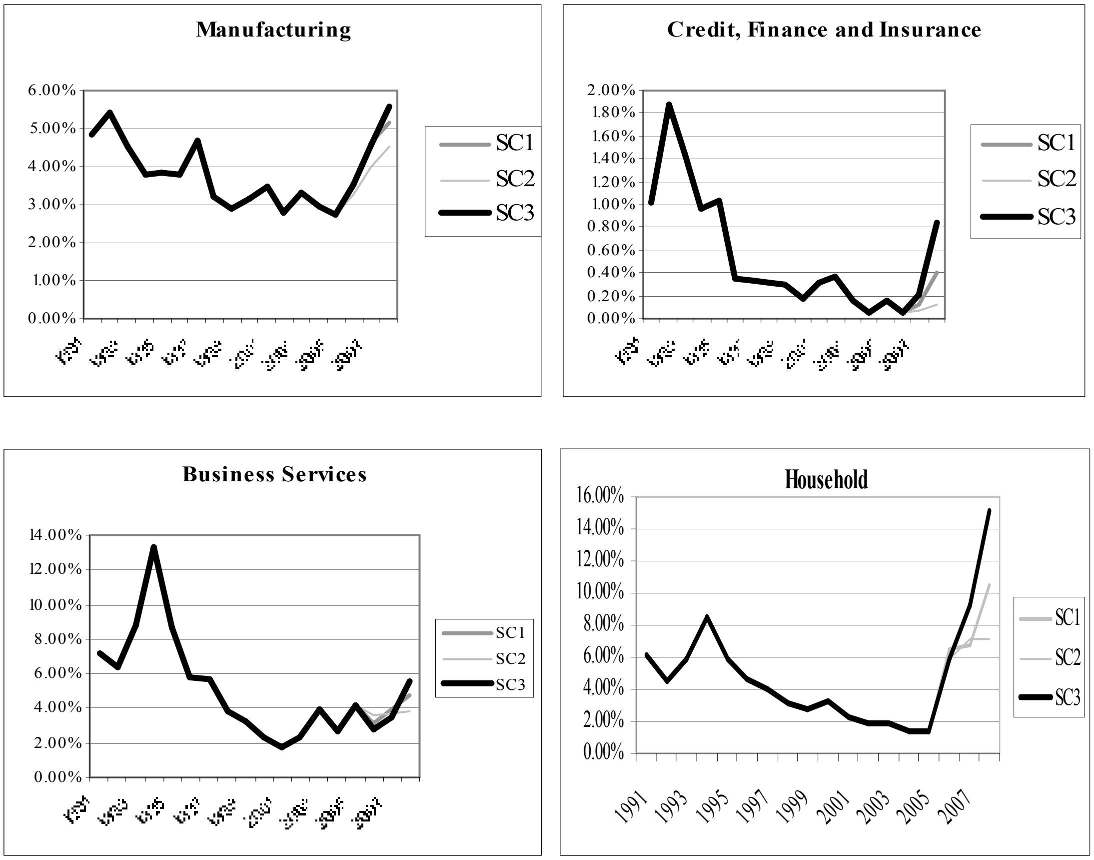
Source: Author's estimation.

30. **The effects of macroeconomic shocks on credit risk are gauged by estimating stressed PoDs.** The selected model specifications—for each risk-rating category and each economic sector—are used together with the values of the key macroeconomic variables to estimate stressed PoDs under each scenario. Estimates of stressed PoDs are entered as exogenous variables in order to recover the PMD, which describes the joint likelihood of changes in the credit risk quality of the loans that make up a bank's portfolio. Figure 6 shows the paths taken by selected PoDs under the three scenarios that were considered.[19]

31. **The Expected Losses under each scenario were estimated (ELs are defined as EL = PoD x exposure x LGD).** Stressed PoDs for each risk-rating category and economic sector, under each scenario were used. Information on LGDs was not available. As a result, the Basel II guidelines were applied and this variable was set to 50 percent. Table 3a shows the ELs as a ratio of risk-weighted assets (RWA), i.e., the EL ratio.

[19]The CIMDO-recovered multivariate density embeds the effects that macroeconomic shocks have on the credit risk quality of the loans held by the banks Segoviano and Padilla (2006) describe in detail the mathematical set-up used to recover multivariate distributions.

Figure 6. Stressed Probability of Defaults



Source: Author's estimation.

32. **The potential losses that can be experienced by a bank (given the composition of its portfolio) are simulated using the PMD.** Such losses are used to construct the PLD from which the ULs are estimated. The joint likelihood of credit quality migrations of the loans making up a portfolio is embedded in the PMD. This density is used to simulate the different credit qualities that loans in the portfolio can take on. Thus, if a macroeconomic shock causes the quality of the loans in the portfolio to decrease (making loans riskier), losses are incurred. The losses obtained from such simulation process are used to build a histogram, which summarizes the distribution of the portfolio losses under each scenario. The EC is set to be equal to the loss level corresponding to the 99.5 percentile of the PLD. Equivalently, ULs that could be suffered by a bank under a specific macroeconomic scenario will be covered 99.5 percent of the time; however, with a probability of 0.5 percent, there will be (extreme) unexpected losses higher than the EC. Table 3b shows the total ULs as a ratio of RWA; i.e., UL ratio.

Table 3a. Expected Losses as a Percentage of Risk-Weighted Assets

	Scenario 1	Scenario 2	Scenario 3
2006	1.45	1.37	1.34
2007	1.66	1.63	2.00
2008	2.32	1.73	3.07

Table 3b. Unexpected Losses as a Percentage of Risk-Weighted Assets

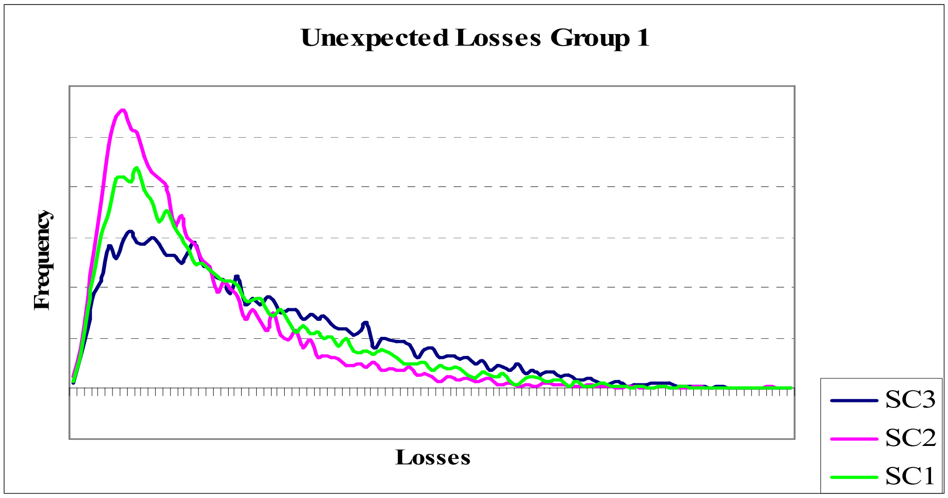
	Scenario 1	Scenario 2	Scenario 3
2006	11.94	11.89	11.82
2007	12.16	12.12	12.39
2008	13.76	12.28	14.71

Source: Staff estimates.

33. **Banks' financial performance has been very solid, especially during the favorable macroeconomic environment enjoyed over the last two years. However, results of the stress test show that under changing macroeconomic conditions, credit risk could materialize, causing a substantial deterioration in banks' results.** Credit portfolios are highly concentrated in loans to the credit, finance, and insurance, household, manufacturing, and business services sectors. Together, loans to these sectors constituted over 82 percent in 2004 and between 1991 and 2004, they averaged over 73 percent. Note that loans to the private sector, house prices, unemployment, and GDP are the macroeconomic variables that deteriorate faster under the assumed scenarios (see Table 1). Deterioration is especially drastic under scenario 3 (followed by scenarios 1 and 2 respectively) as can be seen in Figure 7. These are also the variables that are significant in explaining the default behavior of the sectors to which the banks are more exposed.[20] These effects are captured in the forecasts of the sectors' PoDs and passed on to the estimated ELs and ULs (Tables 3a, 3b).

[20] Credit over GDP and house prices are significant explanatory variables in all these sectors. In addition to these variables, the credit, finance, and insurance sector is highly sensitive to interest rates, the household sector is highly sensitive to employment levels and interest rates, the manufacturing sector is highly sensitive to foreign exchange, since it is highly concentrated on the export markets and the business services sector to GDP.

Figure 7. Portfolio Loss Distribution Under Scenarios 1–3



Source: Author's estimations.

34. **The increase in PoDs, ELs, and ULs is consistent across the scenarios (scenario 3 is the most severe, followed by scenarios 1 and 2) and over time (the cumulative effects of the macroeconomic shocks over the three-year horizon are reflected in the increasing PoDs, ELs, and ULs over the three-year period).** These results indicate that credit risk could materialize quickly, if the accelerated and acute increase in house prices and levels of leverage in the economy developed into macroeconomic imbalances, leading to a boom-bust in real estate prices and credit. Moreover, results clearly indicate that current developments in the market, which seem to increase the vulnerability of households to interest rate fluctuations,[21] as well as foreign shocks (as indicated by Scenario 3), could reinforce the stress to the banking system. The macroeconomic shocks that were considered (and as a result, the simulated increases in PoDs, ELs, and ULs) may be extreme; but they are plausible. Thus, credit risk clearly remains a major risk factor for the Danish banking system.

35. **A buffer large enough to absorb ELs should be generated through adequate pricing and provisioning.** The expected loss buffer (EL buffer) was defined as the ratio of pre-tax income plus provisions to RWA. The CAR represents the buffer to cover ULs, since the realized level of credit losses experienced under a specific shock could be significantly higher than the expected level. The EL buffer and the CAR constitute the banking institutions' total buffer to withstand losses.

36. **Overall, the Danish banking institutions' total buffer as a ratio of RWA has been reduced from 2004.** This trend is likely to continue. The reduction in the total buffer is the result of a fall in accumulated provisions and lower solvency ratios (especially during the last two years), both in absolute levels and as a ratio of RWA. The new International Accounting Standards/International Financial Reporting Standards, effective from January 2005 have had a significant impact on the EL buffer via large reductions in provisions (Table 4a). From

[21] The accelerated increase in the levels of debt to disposable income and in the share of adjustable-rate loans, represent a contingent risk to households that can materialize as soon as interest rates increase.

2004, pretax income increased but the increase in pretax income was lower than the decrease in provisions. An increasing proportion of the gross income of Danish banks has been derived in recent years from non-interest income, which is unlikely to be sustainable over the longer term (Table 4b).[22] Moreover, future capital adequacy rules under Basel II will likely influence the size and composition of the future buffers of the banking institutions.

Table 4a. Expected Loss Buffer and Capital Adequacy Ratio for Group 1

	2000	2001	2002	2003	2004
Total loan-loss provision	1,217	3,364	2,508	3,213	410
Total pre-tax income	13,582	15,950	16,549	20,338	22,075
Total provisions + pretax income	**14,799**	**19,314**	**19,057**	**23,551**	**22,485**
Total capital (capital adequacy)	110,460	117,205	122,496	125,752	126,958
Total risk-weighted assets	1,135,287	1,141,915	1,174,840	1,168,680	1,243,096
EL buffer/Risk-weighted assets	1.30	1.69	1.62	2.02	1.81
Capital adequacy ratio	9.723	10.26	10.43	10.76	10.21

Sources: Financial Soundness Indicators reported by Moody's Investor Services; the Danish Financial Supervisory Authority; and author's estimation.

Table 4b. Noninterest Income Items as a Percentage of Pre-Tax Income for Group 1

	2000	2001	2002	2003	2004
Trading income	33.88	14.20	-17.37	-14.37	-6.31
Dividend and other operating income	15.81	16.99	13.95	15.26	16.03
Results of subsidiaries and associates	8.20	9.07	7.79	11.97	12.70
Total	**57.90**	**40.26**	**4.36**	**12.86**	**22.42**

Sources: Financial Soundness Indicators reported by Moody's Investor Services; the Danish Financial Supervisory Authority; and author's estimation.

37. **In order to quantify the magnitude of ELs that banks in group 1 can take without affecting their capital, the EL buffer after the shocks (EL-buffer-S) is estimated.** The EL-buffer-S is computed as the difference between the EL buffer at the end of 2004 (i.e., 1.81 percent) and the EL ratio under each scenario. Under scenario 1, the ELs during 2006 and 2007 would be covered by pricing and provisioning but in 2008, pricing and provisioning would not provide the coverage of ELs (Table 5a). Under scenario 3, ELs would not be covered during 2007 and 2008.

38. **Under the current regulatory guidelines and the Basel II proposal, a minimum CAR of 8 percent should always be kept in order to guarantee the regular operations and solvency of a bank.** In order to check whether this requirement is met, we estimated the adjusted CAR after the shocks (CAR-S). The decrease that the CAR can suffer after the shocks (CAR-decrease) is defined as the difference between the UL ratio under each scenario

[22] In particular, securities and foreign exchange income, or income attributable to the equity investments in associates and unconsolidated subsidiaries.

minus the CAR at the end of 2004 (i.e., 10.21 percent). Then the CAR-S is estimated as the difference between the CAR at the end of 2004 minus the CAR-decrease (Table 5b). The estimates show that the required minimum CAR of 8 percent would be breached under Scenarios 1 and 3 in 2008. Note that if we assume that the uncovered ELs are absorbed by capital, then the CAR-decrease would also have to include uncovered ELs; thus, the CAR-S would further be reduced. The CAR after the shocks net of EL buffer is denoted CAR-S net. The latter is presented in Table 5c, which shows that the minimum CAR requirement of 8 percent would also be breached in 2007 under scenario 3. In these situations, on average, the solvency of the banks in group 1 would be threatened.

Table 5a. Expected Loss Buffer-S
(In percent)

	Scenario 1	Scenario 2	Scenario 3
2006	0.35	0.43	0.46
2007	0.14	0.18	-0.19
2008	-0.51	0.07	-1.26

Source: Staff estimates.

Table 5b. CAR-Decrease and CAR-S
(In percent)

	CAR-Decrease				CAR-S		
	Scenario 1	Scenario 2	Scenario 3		Scenario 1	Scenario 2	Scenario 3
2006	-1.72	-1.68	-1.61	2006	8.49	8.54	8.60
2007	-1.95	-1.91	-2.17	2007	8.26	8.31	8.03
2008	-3.55	-2.07	-4.50	2008	6.66	8.14	5.71

Source: Staff estimates.

Table 5c. CAR-S-Net

	Scenario 1	Scenario 2	Scenario 3
2006	8.84	8.97	9.07
2007	8.41	8.48	7.85
2008	6.15	8.22	4.45

Source: Staff estimates.

39. **Individual institutions could suffer from much higher losses, than the losses estimated in the stress test.** The results presented here represent the results of the "average effect" of the shocks to banks in group 1. Individual bank's portfolio credit risk was not assessed due to the use of bank-grouped data.

40. **The credit portfolios of banks in group 2 and group 3 seem to be riskier.** Therefore, the impact of the assumed shocks on the banks' CAR would probably be higher. The stress test did not cover banks in groups 2 and 3. The exposure of lending to somewhat more risky agriculture and fisheries is the highest among the smaller banks, some of which have grown rapidly. During the challenging times in the late 1980s and early 1990s, it was

typically the banks that had grown fastest that also experienced the largest losses. The potential impact (ELs and ULs) of the assumed shocks may thus be larger among smaller banks, given their more concentrated and risky loan portfolios.

41. **The effects of shocks to unemployment and interest rates might be larger than they appeared.** Lending by banking institutions to households has increased significantly during recent years. In 2005, the annual growth rate exceeded 21 percent. Growth in this sector has mainly been attributable to the introduction of adjustable-rate bank mortgage loans to homeowners as an alternative to traditional capital-market financing via mortgage-credit institutions. The introduction of mortgage-credit loans with an option to defer amortization has had a significant impact on the composition of loan portfolios.[23] The total debt of the households continued to rise at a higher rate than their disposable income; thus, the burden of the households has increased.[24] However, recent periods' low interest rates have temporarily neutralized the budget impact of the growing debt levels. Nonetheless, all these factors will likely make households more vulnerable to fluctuations in interest rates and unemployment.

42. **The results of the TD stress test are consistent with DNB's analysis of banks losses under the three scenarios.** The DNB used a highly simplified model to estimate the path followed by a proxy of ELs under each of the three macroeconomic scenarios. The analysis shows that over time, losses increase from 2006 to 2008 and across scenarios. The DNB used a database containing information of aggregate write-offs in the system as a proxy for PoDs.[25] They regressed this variable with shocked macroeconomic variables and forecasted a proxy of ELs under each macroeconomic scenario.[26] Notwithstanding the limitations of this analysis, the exercise confirms the consistency of the mission estimates (Figure 8).

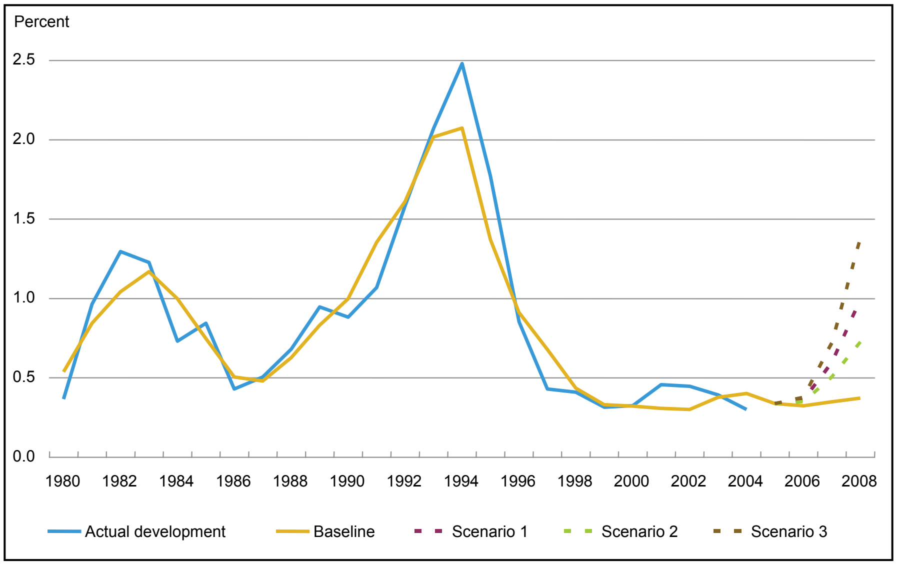
[23] Traditional fixed-rate mortgage-credit loans now account for less than half the total mortgage-credit volume, while fixed-rate and adjustable-rate mortgage-credit loans with the option to defer amortization are gaining ground and constituted 17 percent at end of February 2005. (DNB Financial Stability Report, 2005).

[24] As of end February 2005, the homeowners' average mortgage debt was 2.1 times the gross household income. However, the average mortgage debt for homeowners in the lowest income bracket was 2.9 times the annual household income. Moreover, 10 percent of this group had mortgage debt that was at least 4.5 times the annual household income. (DNB, Financial Stability Report, 2005).

[25] The level of write-offs is much lower than the empirically observed levels of PoDs; therefore, the proxy of ELs that is obtained using this model is much lower than the empirically observed ELs.

[26] The database includes annual observations from the mid-1990s; however, since in this estimation only standard OLS regressions were performed, the lack of robustness (large variances) of the estimators appears to be a problem.

Figure 8. Banks Expected Losses Estimated by the Danmarks Nationalbank

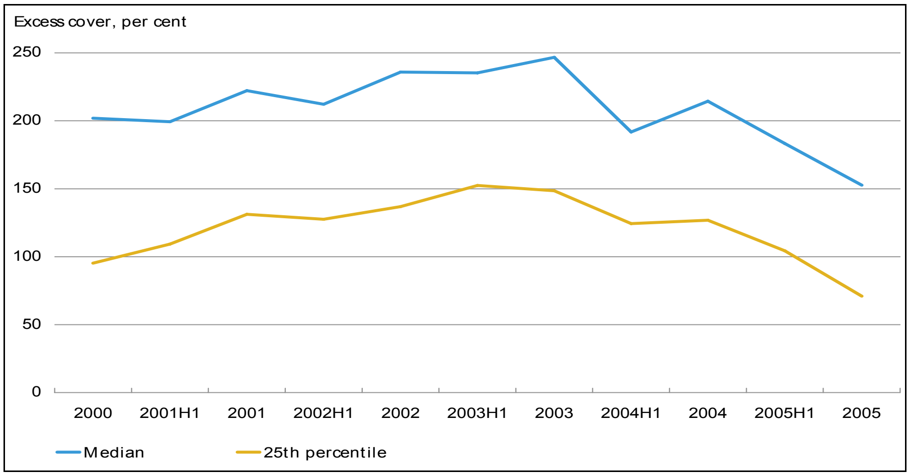


Source: Danmarks Nationalbank's estimation.

43. **Liquidity in Danish banks is judged to be adequate.** The stock of liquid assets is higher than the regulatory minimum although it has declined somewhat in the most recent years. The Danish FSA supervises individual banks and ensures they have adequate liquidity and contingency plans (Figure 9).[27] Regulations require banks to have liquid assets (broadly defined) to cover 15 percent of call deposits and liabilities falling due within one month and 10 percent of all liabilities other than core capital. The DFSA publishes indicators for the banks excess liquidity, over and above the regulatory minimum. This is shown in Figure 10 below. The median and the lower quartile in this figure show that most banks have far more liquidity than the regulatory minimum. The excess cover has declined somewhat in the most recent years, but remains plentiful for most of the banks. The stock-based liquidity requirement, including the requirement promptly to report and rectify shortfalls, appears to function as a benchmark which the banks avoid getting too close to.

[27] Liquidity in the payment systems is discussed in "Protection of Settlement in Danish Payment Systems" in Danmarks Nationalbank Financial StabilityReport, 2005.

Figure 9. Danish Banks' Excess Liquidity

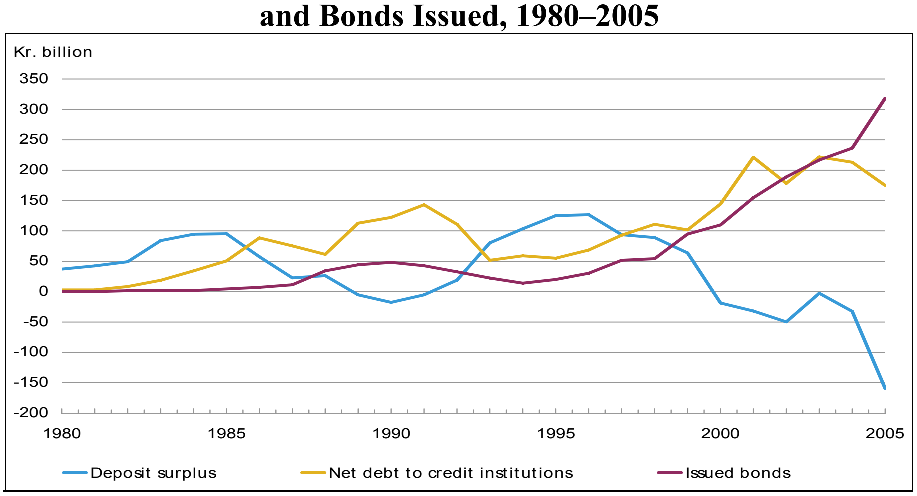


Sources: The Danish Financial Supervisory Agency; and Danmarks Nationalbank.

Note: Key ratios for the excess liquidity cover at unconsolidated level. Figures for 2005 are estimates based on the banks' accounts.

44. **Sources of banks funding and liquidity may become volatile in the event of a crisis.** Banks in recent years experienced stronger loan than deposit growth, and have increasingly relied on issuance of bonds and borrowing from other financial institutions for funding (Figure 10). The later is partly accounted for by intragroup lending from parents of foreign-owned banks and borrowing from foreign banks, which may turn out to be a less stable source of funding and liquidity, especially in the event of a financial crisis. Thus, it is important to maintain market access and avoid potential changes in own credit spread—as illustrated for Icelandic banks in Spring 2006.

Figure 10. Banks Deposit-Lending Shortfall, Net Debt to Other Financial Institutions and Bonds Issued, 1980–2005

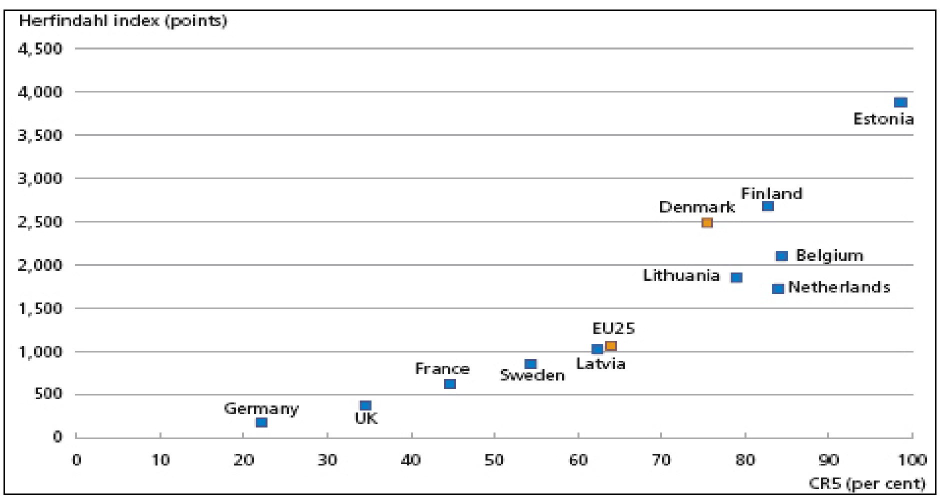


Sources: The Danish Financial Supervisory Agency; and Danmarks Nationalbank.
Note: All banking institutions comprise the Danish Financial Supervisory Authority's categories 1, 2 and 3.

45. **DNB contagion model suggests that contagion risk in the Danish interbank market currently seems to be limited.** However, 2004 was a year characterized by very high earnings for the banks (though outdone by 2005). Thus, it is important that the banks are aware of possible implications of their exposure, also in case of a deteriorating economic climate. The DNB has developed a methodology to analyze contagion risk on the Danish interbank market.[28] The stability of the Danish interbank market is analyzed by simulating unexpected failures of the largest debtor. Failure of the largest debtor would cause another bank to fail on 11 out of 253 banking days in 2004 if the LGD was 100 percent. Reducing the LGD to 50 percent greatly decreased the contagion risk, as only one bank on one day would fail. Only first order contagion took place, as no more than one bank would fail on any day by the failure of the largest debtor.

46. **Denmark shows higher concentration in the banking sector than many other EU member states.** Market share concentration, as measured by the CR5 and the Herfindahl index[29] show a higher concentration in the banking sector in Denmark than in many other EU member states (Figure 11). The concentration may have implications for financial stability**.** A highly concentrated banking system may be more vulnerable to systemic crises since; all other things being equal, banks with substantial market shares present a greater risk of contagion, both via the interbank market and via macroeconomic feedback effects. In a financial system with a high concentration of market shares, it is therefore particularly important that banks with large market shares are sufficiently robust to withstand potential shocks.

Figure 11. Concentration Measures in Selected European Union Member States, End-2004.



Source: Danmarks Nationalbank.

[28] The methodology is explained in more detail in Amundsen and Arnt (2005). Results are presented in DNB' Financial Stability Report, 2005.

[29] The CR5, e.g., the top-five concentration ratio, is the sum of the market shares of the five largest banks in the system. The Herfindahl index is defined as the sum of individual banks' squared market shares.

VI. RESULTS: BOTTOM UP APPROACH

A. Credit Risk

47. **Banks participating in the BU stress test on credit risk reported their results to the DFSA.** The DFSA aggregated those results and presented them to the mission.

48. **The ELs reported by the participating banks are consistent with the TD estimates.** This consistency is observed across the scenarios (Scenario 3 is the most severe, followed by scenarios 1 and 2) and over time (the ELs increase from 2006 to 2008) (Table 6). However, the level of ELs is lower than the TD estimates. The main reason behind these differences lies on the assumed levels of LGDs. Banks assumed lower levels of LGDs than the 50 percent assumed in the TD approach, even after the shocks materialized. Due to data constraints and due to the fact that the models that are used by the banks to estimate LGDs have not been validated by the DFSA, we considered the 50 percent assumed in the TD approach to be a conservative and appropriate assumption.

Table 6. Bottom-Up Results: Expected Losses
(As a percentage of risk-weighted assets)

	Scenario 1	Scenario 2	Scenario 3
2006	0.31	0.28	0.45
2007	0.49	0.42	0.72
2008	0.78	0.57	1.10

Source: Banks' staff estimations.

49. **The CAR-S obtained in the BU stress tests are consistent with the mission estimates.** [30] The BU results (Table 7) and the TD results show that commercial banks can withstand moderate shocks, but will experience capital shortfalls if subjected to severe shocks. The results of both approaches show that by the third year the mandatory capital adequacy ratio of the system is breached, although only in the worst case scenario is the shortfall substantial. Thus, credit risk remains a major risk factor for the Danish banking system.

[30] The BU results had to be aggregated to make them comparable with the TD results. For this purpose, the results were standardized by the specific banks' RWA.

Table 7. Bottom-Up Results: CAR-S

(In percent)

	Scenario 1	Scenario 2	Scenario 3
2006	10.50	10.08	9.32
2007	8.96	9.17	7.38
2008	6.65	7.73	4.50

Source: Banks' staff estimations.

B. Market Risk

50. **On average, market risk seems relatively modest but may vary significantly among institutions.** The impact of individual shocks (see paragraph 27) to interest rates, equity prices, real estate prices, and the exchange rate on capital of banks is modest. Most of the loans in banks' portfolios have flexible interest rates, so that the effects of the single factor shocks are transmitted primarily through credit risk. These shocks can potentially result in losses on banks' holdings of financial instruments, mainly mortgage bonds. However, banks dynamically hedge most of this portion of their portfolio, adjusting it in response to changes in interest rates so as to maintain a matched duration. Banks' net open position in foreign exchange (including the Euro) is also modest, so that even a substantial exchange rate shock results in only limited impact on banks' capital adequacy. The BU results reported by the DFSA are presented in Table 8.

Table 8. Bottom-Up Results of Single Factor Shocks

(In percent)

CAR-S						
2005	Yield Curve Up 250 bp	Yield Curve Down 100 bp	Property Prices Down 30 Percent	Equity Prices Down 30 Percent	Appreciation 40 Percent	Depreciation 40 Percent
10.23	9.46	9.89	9.87	9.66	10.16	10.25

Source: Banks' staff estimations.

51. **A simplified approach used by the mission confirmed the consistency of the results presented by the banks.** It suggested that market risk may vary significantly among institutions. Based on publicly available information (Table 9), the mission used a simplified approach to check for the consistency of the results presented by the banks. Table 10 shows the estimation results obtained by the mission. These results are consistent with those presented by the banks.

Table 9. Danish Banking System Market Risk Indicators, 2000–2004
(In percent)

Interest Rate Risk Over Tier 1 Capital [1]					
	2000	2001	2002	2003	2004
Group 1	3.10	3.50	2.10	3.50	1.60
Group 2	4.20	4.80	4.60	4.20	3.10
Groups 1-4	3.30	3.80	2.60	3.70	2.00
Foreign Exchange Exposure Over Tier 1 Capital [2]					
	2000	2001	2002	2003	2004
Group 1	4.90	7.10	9.00	7.90	3.70
Group 2	8.80	9.00	7.90	5.70	5.90
Groups 1-4	5.60	7.40	9.10	7.90	5.20
Net Open Position of Equities to Total Capital					
	2000	2001	2002	2003	2004
Groups 1-4	36.92	31.17	24.07	28.11	29.86

Source: Financial soundness indicators prepared by the Danish Financial Supervisory Authority.

1 Loss as a percent of Tier I capital due to an increase in interest rates by 100 bps.
2 The FX indicator is calculated as the largest amount of the short-term currency exposures and the long-term currency exposures.

Table 10. Results of Single Factor Shocks estimated by the Mission
(In percent)

CAR-Decrease			
	Yield Curve Up 250 bp	Equity Prices Down 30 Percent	FX Movement 40 Percent
	Mean	Mean	Mean
Group 1	0.31	0.91	0.11
CAR-S			
	Yield Curve Up 250 bp	Equity Prices Down 30 Percent	FX Movement 40 Percent
	Mean	Mean	Mean
Group 1	9.89	9.29	10.09

Source: Staff estimates.

C. Insurance Sector

52. **Danish insurance companies allocate the economic losses of shocks between owners and policyholders in accordance with the Danish "contribution principle."** The losses allocated to owners should be absorbed by the capital base and the required-solvency-margin, while the losses allocated to policyholders should be absorbed by the "collective bonus component", which comprises excess premiums and retained earnings.

53. **Stress tests conducted for the FSAP show that much of the impact of shocks would be absorbed by the "bonus component" of companies' reserves with marginal effects on the capital base.** The exercise covered the largest companies which were asked by the DFSA to estimate the consequences of the single factor shocks with magnitudes consistent with those applied for the banks for market risk.[31] The sizable "bonus component" and some degree of hedging cushions the impact of the shocks on the capital base. Thus, the impact of single factor shocks on the solvency-margin-ratios of the Danish insurance companies appear to be modest. On one hand, the required-solvency-margin (numerator of the solvency-margin-ratio) is only affected by shocks to interest rates. On the other, the effects of the single factor shocks on the capital base (denominator of the solvency margin ratio) as already mentioned are only marginally affected by the shocks. Table 11 shows that an upward shift in the yield curve reduces the value of the liabilities, improving the solvency position; thus, reducing the required solvency capital. It also shows that the largest market risk effect is caused by a 30 percent drop in property prices and a downward shift in the yield curve. The foreign exchange rate movement and equity price drop only have minor impacts on the capital base.

Table 11. Bottom-Up Insurance Sector Results

In Millions of DKK	2005	Yield Curve Up 250 bp	Yield Curve Down 100 bp	Property Prices Down 30 %	Equity Priced Down 30%	Appreciation 40 %	Depreciation 40 %
Capital base	40,987	39,282	41,437	37,912	40,536	40,276	41,210
Required-solvency-margin	24,255	22,189	26,191	24,255	24,255	24,255	24,255
Solvency-Margin-Ratio (percent)	170	179	159	158	168	167	171

Source: Insurance companies staff estimations.

54. **The DFSA's own monitoring system also suggests a generally resilient insurance sector.** The DFSA maintains a "traffic light" system based on two (red and yellow light) scenarios. The red light scenario assumes a combination of a decrease of 12 percent in the price of stocks, a decrease of 8 percent in the price of real estate, and a change of the interest rate level of 0.7 percentage points. The yellow light scenario assumes a decrease of 30 percent in the price of stocks, a decline of 12 percent in the price of real estate and a change of the interest rate level of 1.0 percentage point. The results indicate that at end -2005, there were six companies in yellow light and no companies in red light. The system complements the required capital margin. If a company cannot meet the red scenario, the DFSA may use

[31] The stress test exercise was carried out by the five largest insurance companies in Denmark: Danica Pension (Danske Bank subsidiary), Nordea Pension (Nordea subsidiary), SEB Pension (SEB subsidiary), PFA Pension, and Kommunernes Pensionsforsikring. Together, these insurance companies represent slightly more than 50 percent of the insurance sector assets in Denmark.

measures such as require monthly reporting and the company in question will not be not allowed to increase its overall risk.[32]

VII. Technical Recommendations

55. **Based on the stress test exercise, listed below are the mission's technical suggestions aimed at strengthening the DFSA's offsite risk analysis and framework for banks' model-validation.** Banks were given the freedom to use their own methodologies to perform the stress tests. For both the banks and the insurance companies, the tests on market and credit risks were performed using the institution's own internal risk models. As banks routinely test for market risks in their portfolios, such models are quite well developed and hence exhibit a high degree of consistency across institutions. Although tests for credit risk are performed by some banks routinely, the models used by financial institutions in this area are less uniform. Moreover, some banks are still in a model-developing stage. Therefore, in order to check for the consistency of banks' credit risk measurements and develop the process of banks' model validation, which will be necessary when the Basel II regulatory framework is implemented, the mission recommends the following:

- **Performing stress test exercises on a regular basis should be considered.** The FSAP stress test exercise yielded useful insights and demonstrated cooperation between supervisors, commercial banks and insurance companies. The DFSA should use the experience gained in this exercise to further develop the process of off-site supervision and model-validation of banks' internal models.

- **Standardize the reporting of PoDs or empirical frequencies of default and require the reporting of recovery rates.** When performing the credit risk TD stress test, we used different databases (see Section III.C) with proxy variables for PoDs. Although it was possible to check for the consistency and robustness of the different proxies, the exercise became burdensome. In order to facilitate future credit risk measurement exercises, it is recommended to standardize the reporting of PoDs or frequencies of default of banks' loan exposures. Information on recovery rates was not available to the regulators; therefore, we also suggest that recovery rates should be requested in a regular basis.

- **Model the impact of various shocks on the PoDs of banks' loan exposures and banks' profits.** The modeling of PoDs would prove useful to improve the understanding of the transmission mechanisms between macroeconomic shocks and credit risk. The modeling of profits is necessary to have a better understanding of the

[32] All life insurers and pension funds have to estimate the consequences of the changes in the assumed levels of mortality and disability used in the annual report. The test assumes both a decrease and an increase in the mortality intensity of 10 percent. It corresponds roughly to change in longevity of one year. Further, the test assumes an increase in the disability intensity of 10 percent. The result of these stress tests is required to be disclosed in the annual report.

effects of shocks on capital adequacy ratios; particularly, when macroeconomic scenarios develop through many years.[33]

- **Develop risk-based methodologies to measure banks' unexpected losses and their impact on banks' economic capital.** Currently, the DFSA does not have a risk-based methodology that could be implemented to check for the consistency of banks' portfolio credit risk measurements. We believe that developing such methodology is imperative since the results of the stress test indicate that credit risk may become substantial if the system was subjected to severe shocks. Furthermore, the development of such methodology will become pressing once that Basel II is implemented, since regulators will face the task of banks' model validation.

- **Perform interbank contagion risk analysis on a regular basis and continue with the close monitoring of banks' liquidity.** Contagion risk appears to be limited. Liquidity is judged to be adequate. However, since contagion risk and liquidity can change drastically in the event of a shock, we recommend assessing them on a regular basis.

- **Continue with the close monitoring of the insurance and pension sector.** The insurance sector appears to be resilient.

- **Attempt to assess second-round effects of macroeconomic shocks**. This is a difficult task that to our knowledge, no stress test methodology has achieved yet. Nonetheless, we encourage the regulators to join other colleagues around the world on their effort to develop methodologies for this purpose.

[33] Wrong assumptions of the development of profits through time can create large inconsistencies in the estimates of capital adequacy ratios.

Appendix 1. The Conditional Probability of Default Methodology

In this Appendix, a summary of the CoPoD methodology econometric setting is presented. Interested readers in the detailed development may refer to Segoviano (2006a).

CoPoD: Rationale

Under the Merton (1974) model, a borrower is assumed to default at time $T >$ t, if, at that time, the value of his assets, S_t^i, fall below a pre-specified barrier, a_t^i, which is modeled as a function of the borrower's leverage structure. Therefore, default can be characterized by $s(T) \leq$. a_t^i. Thus, at time t, the PoD at time T is given by:

$$PoD_t = \Phi(a_t^i), \qquad (1)$$

where Φ ( ) is the standard normal cumulative distribution function *cdf*.

If we group the PoDs of loans classified under the sectoral activity of the borrower to whom the loans are granted or their risk-rating category in a T-dimensional vector, **PoD**, each observation in the vector of frequencies of loan defaults **PoD** represents the empirical measure of **PoD** for the i_{th} type of borrower at each point in time t. Since each observation in the vector of PoDs is restricted to lie between 0 and 1, we make the following transformation: $\mathbf{a}^{\mathrm{i}} = \Phi^{-1}$ (**PoD**), where Φ (.) is the inverse standard normal *cdf*.

We are interested in modeling the PoDs as functions of identifiable macroeconomic and financial developments X, therefore we can formalize the problem as

$$\mathbf{a} = X\beta + \mathbf{e}, \qquad (2)$$

where **a** is a T-dimensional vector of noisy observations (transformation of the PoDs), X is a known (T x K) matrix of macroeconomic and financial series and β is a K-dimensional vector of unknown coefficients that we are interested in estimating.

Consequently, we know X, observe **a** and wish to determine the unknown and unobservable parameter vector β.

CoPoD: formulation

As detailed in Segoviano (2006a), we reformulate the model set in equation (2) as follows. We express our uncertainty about β and **e** by viewing them as random variables on supports **Z** and **V**, respectively; where **p(**λ**)** and **w (**λ**)** represent families of probability density functions for these random variables. Accordingly, the model set in equation (2) can be written in terms of random variables, and the estimation problem is to recover the probability distributions for β and **e**; e.g., **p(**λ**)** and **w (**λ**)**.

As a result, we treat each β_k as a discrete random variable with a compact support 2≤M< ∞ possible outcomes. For example if $M = 2, z_{k1}$ and z_{kM} represent the plausible extreme values (upper and lower bounds) of β_k. Therefore, we can express as β_k a convex combination of

Appendix 1. The Conditional Probability of Default Methodology (continued)

these two points. That is, there exists $p_k \in [0,1]$ such that, for $M = 2, \beta_k = p_k z_{k1} + (1 - p_k) z_{kM}$. We can do this for each element of β. However, M≥2 may be used to express the parameters in a more general fashion. In this case we also restrict the weights p_k to be strictly positive and to sum to 1 for each *k*. Therefore, we are in a position to rewrite each β_k as a convex combination of *M* points. These convex combinations may be expressed in matrix form as β=**Zp**. We can also reformulate the vector of disturbances, **e**. Accordingly, we represent our uncertainty about the outcome of the error process by treating each e_t as a finite and discrete random variable with $2 \leq J < \infty$ possible outcomes.

We also suppose that there exists a set of error bounds, v_{t1} and v_{tj}, for each e_t. For example, for J=2, each disturbance may be written as $e_t = w_t v_{t2} + (1 - w_t) v_{tJ}$ for $w_t \in [0,1]$. However, J≥2 may be used to express the parameters in a more general fashion. As before, we restrict the weights so as to be strictly positive and to sum to 1 for each t. The *T* unknown disturbances may be written in matrix form as **e=Vw**. Using the reparameterized unknowns, β= **Zp** and **e** =**Vw**, we can rewrite the model presented in equation (2) as:

$$\mathbf{a} = X\mathbf{Z}\mathbf{p} + \mathbf{V}\mathbf{w}, \qquad (3)$$

This model incorporates the effects of macroeconomic and financial developments into the PoDs at each point in time. It also accounts for possible noise in the data. The information represented by this set of equations is incorporated into the entropy decision rule that is used to recover the distributions **p** and **w**. Such information is formulated as a set of moment-consistency constraints that has to be fulfilled by the distributions **p** and **w**. The objective of the entropy decision rule is to choose the set of relative frequencies, **p** and **w**, that could have been generated in the greatest number of ways consistent with what is known; e.g., the moment-consistency constraints. Thus, following Segoviano (2006a), the probability vectors **p** and **w**, are recovered by maximizing the functional:

$$\begin{aligned} L = &-\left[\sum_{k=1}^{K}\sum_{m=1}^{M} p_m^k \ln p_m^k\right] - \left[\sum_{t=1}^{T}\sum_{j=1}^{J} w_j^t \ln w_j^t\right] \\ &+\sum_{t=1}^{T}\lambda_t\left[a_t - \sum_{k=1}^{K}\sum_{m=1}^{M} x_{tk} z_m^k p_m^k - \sum_{j=1}^{J} v_j^t w_j^t\right] \\ &+\sum_{k=1}^{K}\theta_k\left[1 - \sum_{m=1}^{M} p_m^k\right] + \sum_{t=1}^{T} T_j\left[1 - \sum_{j=1}^{J} w_j^t\right] \end{aligned} \qquad (4)$$

where $\gamma \in \mathbb{R}^T$ represents the Lagrange multipliers corresponding to the moment-consistency constraints that embed the information provided by the data and $\theta \in \mathbb{R}^K$ and $\tau \in \mathbb{R}^T$ represent the Lagrange multipliers corresponding to the additive restrictions that are imposed on **p** and **w**, since those distributions represent densities; thus, they must add to one.

Appendix 1. The Conditional Probability of Default Methodology (concluded)

The entropy solution is given by:

$$\hat{p}_m^k(\hat{\lambda}) = \frac{\exp\left[-\sum_{t=1}^{T} \hat{\lambda}_t \, x_{tk} \, z_m^k\right]}{\sum_{m=1}^{M}\left[\exp\left[-\sum_{t=1}^{T} \hat{\lambda}_t \, x_{tk} z_m^k\right]\right]} \qquad (5)$$

and by

$$\hat{w}_j^t(\hat{\lambda}) = \frac{\exp\left[-\hat{\lambda}_t \, v_j^t\right]}{\sum_{j=1}^{J}\left[\exp\left[-\hat{\lambda} \, v_j^t\right]\right]} \qquad (6)$$

Once we recover the optimal probability vector $\hat{p}$ we are in a position to form point estimates of the unknown parameter vector $\hat{\beta}$ as follows $\hat{\beta}\,\mathbf{Z}\,\hat{p}$ Equally, the optimal probability vector $\hat{w}$, may also be used to form point estimates of the unknown disturbance $\mathbf{e}$=$\mathbf{V}\,\hat{w}$.

Thus, the CoPoD provides a rationale for choosing a particular solution vector **p**, which is the density that could have been generated in the greatest number of ways consistent with what is known (without imposing arbitrary distributional assumptions). Because we do not want to assert more of the distribution **p** than is known, we choose the **p** that is closest to the uniform distribution and also consistent with the available information, expressed as constraints in equation (4).

Appendix 2. The Conditional Probability of Default Efficiency

This Appendix presents a heuristic explanation of the robustness of the CoPoD-estimators in small sample settings. The large and small sample properties of the CoPoD estimators and a Monte Carlo experiment that proves their robustness are presented in Segoviano (2006a). The objective of the Kullback (1959) minimum cross entropy approach (MXED) is to minimize the cross entropy distance between the posterior **p** distribution and the prior **q** distribution. The MXED objective function is defined as $C[p_k, q_k] = \sum_k^K pk \ln\left[\frac{p_k}{q_k}\right]$. Note that this can be interpreted as the expectation of a log-likelihood ratio. This interpretation is useful to illustrate the efficiency gains provided by the CoPoD estimation framework. Let θ_1 and θ_2 be two alternative values of the parameter vector defining two alternative discrete probability distribution characterizations $f(y;\theta_1)$ and $f(y;\theta_2)$ for the distribution of **y**. The MXED information in $f(y;\theta_1)$ relative to $f(y;\theta_2)$ is given by:

$$C[f(y;\theta_1), f(y;\theta_2)] = \sum_y \left[\ln\left[\frac{f(y;\theta_1)}{f(y;\theta_2)}\right]\right] f(y;\theta_1) \qquad (7)$$

$$= \mathrm{E}_{\theta_1}\left[\ln\left[\frac{L(y;\theta_1)}{L(y;\theta_2)}\right]\right],$$

where $\mathrm{E}_{\theta_1}[]$ denotes an expectation taken with respect to the distribution $f(y;\theta_1)$. It is clear that the MXED functional in equation (7) can be interpreted as a mean log-likelihood ratio, where averaging is done using weights provided by the distribution $f(y;\theta_1)$.

If $\ln\left[\frac{f(y;\theta_1)}{f(y;\theta_2)}\right] = \ln\left[\frac{L(y;\theta_1)}{L(y;\theta_2)}\right]$ is interpreted as the information in the data outcome y in favor of the hypothesis θ_1 relative to θ_2, then equation (7) can be interpreted as the *mean information* provided by sample data in favor of θ_1 relative to θ_2 under the assumption that $f(y;\theta_1)$ is actually true.

Now, consider the MXED criterion when the distribution $f(y;\theta_2)$ is some discrete distribution p(y) having discrete and finite support $y \in \Gamma$ and the distribution $f(y;\theta_1)$ is $n^{-1}\ \forall\ y \in \Gamma$. Thus, the MXED is given by:

$$C[n^{-1}1, p] = \sum_{i=1}^n \frac{1}{n}\left[\ln\left[\frac{\frac{1}{n}}{p(y_i)}\right]\right] \qquad (8)$$

$$= -n^{-1}\sum_{i=1}^n \ln(p_i) - \ln(n), \qquad (9)$$

where **1** represents a (nx1) vector of ones so that $n^{-1}1 = \left[n^{-1}, ..., n^{-1}\right]'$ denotes a discrete uniform distribution, n is the number of elements in Γ, $\mathbf{p} = (p_1, p_2, ..., p_n)$' and $p_i \equiv p(y_i)$. It is

Appendix 2. The Conditional Probability of Default Efficiency (concluded)

evident that minimizing equation (8) is equivalent to maximizing the scaled (by n^{-1}) function $\ln(p_i)$ in equation (9), equivalently, maximizing the likelihood function in equation (9).

If we reverse the roles of the distributions the MXED function is defined

$$\text{as: } C[p,n^{-1}1]=\sum_{i=1}^{n} p_i\left[\ln\left[\frac{p_i}{\frac{1}{n}}\right]\right] \qquad (10)$$

$$=\sum_{i=1}^{n} p_i \ln(p_i)+\ln(n),$$

where $\mathbf{p} = (p_1, p_2, \ \ , p_n)'$ denotes probability weights on the sample observations. Thus minimizing equation (10) is equivalent to maximizing $-\sum_{i=1}^{n} p_i \ln[p_i]$, which is precisely Shannon's (1948) entropy measure, defined in equation (17). Therefore, the difference between minimizing equation (8) and equation (10) lies in the calibration of the mean information provided by sample data.

In the former case, $C[n^{-1}1, p]$, averaging is performed with respect to predata weights $n^{-1}$for each Y_i. Then assuming the uniform distribution to be true, the mean information is interpreted in the context of the expected information in favor of the uniform distribution relative to the postdata estimated probability distribution **p**. Equivalently, we choose the distribution p(**y**) that minimizes mean information in favor of the empirical distribution weights, n^{-1}(e.g., assuming that weights n^{-1} are actually true).

This interpretation is consistent with the idea of drawing the distribution p(**y**) as closely as possible to the uniform distribution, which will concomitantly minimize the expected log-likelihood ratio. Note that this is what we implicitly do when computing ML estimation. From this generic representation, we can see that when we perform standard maximum likelihood estimation, we implicitly give equal weights n^{-1} to each Y_i. Then, given an ex-ante fixed (normal) distribution, we choose the distribution's parameters in a way that the probability of observing the given Y_i is as high as possible; e.g., we maximize the likelihood function.

In the latter case, $C[p,n^{-1}1]$ e.g., the CoPoD approach, averaging is performed with respect to the postdata probability distribution p; where the p estimates of the probabilities of the Y_i, are based on observed data information rather than on fixed predata uniform weights. Assuming that the information contained in the moment-consistency constraints is valid, one would anticipate that the expected log-likelihood ratio is estimated more efficiently in the CoPoD approach because it is calculated with respect to probability weights inferred from data information. Then, assuming the p distribution to be true, the mean information is interpreted in the context of the expected information in favor of the p distribution relative to the predata weights, $n^{-1}$for each Y_i.

Appendix 3. The Consistent Information Multivariate Density Methodology

The detailed formulation of CIMDO is presented in Segoviano (2006b). CIMDO is based on the Kullback (1959) minimum cross-entropy approach (MXED). For illustration purposes, we focus on a portfolio containing loans given to two different classes of borrowers, whose logarithmic returns are characterized by the random variables x and y, where $x,y \in \mathbb{R}^{i}$ s.t. $i=1,..,M$. Therefore, the objective function can now be defined as:

$$C[p,q]=\int\int p(x,y)\ln\left[\frac{p(x,y)}{q(x,y)}\right]dxdy,$$

where q(x,y) and $p(x,y) \in \mathbb{R}^2$.

It is important to point out that the initial hypothesis is taken in accordance with economic intuition (default is triggered by a drop in the firm's asset value below a threshold value) and with theoretical models but not necessarily with empirical observations. Thus, the information provided by the frequencies of default of each type of loan making up the portfolio is of prime importance for the recovery of the posterior distribution. In order to incorporate this information into the recovered posterior density, we formulate moment-consistency constraint equations of the form:

$$\int\int p(x,y)\,\chi_{\left(x_d^x,\infty\right)}dxdy=PoD_t^x,\ \int\int p(x,y)\,\chi_{\left(x_d^y,\infty\right)}dydx=PoD_t^y,$$

where $p(x,y)$ is the posterior multivariate distribution that represents the unknown to be solved. PoD_t^x and PoD_t^y are the empirically observed frequencies of default (PoDs) for each borrower in the portfolio and $\chi_{\left(x_d^x,\infty\right)}, \chi_{\left(x_d^y,\infty\right)}$ are the indicating functions defined with the default thresholds for each borrower in the portfolio. In order to ensure that $p(x,y)$ represents a valid density, the conditions that, $p(x,y)\geq 0$ and the probability additive constraint, $\iint p(x,y)\,dxdy=1$, also need to be satisfied.

Imposing these constraints on the optimization problem guarantees that the posterior multivariate distribution contains marginal densities with probabilities of default that are equalized to each of the borrowers' empirically observed frequencies of default. The CIMDO density is recovered by minimizing the functional:

$$L[p,q]=\int\int p(x,y)\ln p(x,y)dxdy-\int\int p(x,y)\ln q(x,y)\,dxdy+ \qquad (11)$$

$$\lambda_1\left[\int\int p(x,y)\,\chi_{[x_d^x,\infty)}dxdy-PoD_t^x\right]+\lambda_2\left[\int\int p(x,y)\,\chi_{[x_d^y,\infty)}dydx-PoD_t^y\right]+\mu\left[\int\int p(x,y)\,dxdy-1\right]$$

Where $\lambda_1\,\lambda_2$ represent the Lagrange multipliers of the moment-consistency constraints and represents the Lagrange multiplier of the probability additive constraint. By using the calculus of variations, the optimization procedure is performed. The optimal solution is represented by the following posterior multivariate density as:

Error! Objects cannot be created from editing field codes. **Error! Objects cannot be created from editing field codes.** (12)

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