Norges Bank Stress Testing of Credit Risks

Report of an External Review Panel

Myron L. Kwast, Chair

Steinar Holden

Demelza Jurcevic

Iman van Lelyveld

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Contents

Summary and recommendations

In the summer of 2010 the Financial Stability wing of the Norges Bank commissioned a panel of external experts (the panel) to review its financial stability stress testing program. The panel was charged with assessing the stress testing program at the Norges Bank relating to credit risk and its implications for the performance and financial resiliency of the major Norwegian banks and the stability of the Norwegian banking system. Special focus was to be placed on the usefulness of the stress testing approach for determining the capital adequacy of the major banks and the implications of capital levels for financial stability in Norway. In addition to evaluating other areas of the stress testing program, the panel was charged with assessing each of the models currently used for stress testing by the Norges Bank. Particular emphasis was to be given to the Norges Bank's Small Macro Model.

This section of the review panel's report (the Report) summarizes the panel's findings with an emphasis on the panel's high priority recommendations for the Norges Bank. Lower priority recommendations and extensive discussions of all the recommendations appear in the text of our report.

In the panel's judgment, the Norge Bank's overall approach to stress testing is highly innovative, economically sound, largely transparent to policymakers and the public and generally should be considered at the top end of best practice at central banks and bank supervisory agencies in developed nations. For example, development of a macro model specifically designed for stress testing is relatively rare, as is the attempt to explicitly include financial accelerator effects. Moreover, the empirical foundation of the model to a large extent ensures that it is consistent with key features of the Norwegian economy, and the model's forecasting properties appear to be quite good. In addition, while the use of a recursive structure with satellite models for specific sectors is quite standard, the combination of traditional macroeconomic models with rich microeconomic data sets for both the household and enterprise sectors is both commendable and much less common. Stress scenarios used in *Financial Stability* Reports appear to meet the widely-advocated criteria of "severe but plausible,"

especially when compared with those used recently by some other European nations. Discussion of the stress tests in the *Financial Stability* Reports is clear and highly informative. There is an explicit effort to design stress scenarios around the key risks to the Norwegian banking system identified in the *Financial Stability* Reports.

While the panel holds the Norges Bank's stress testing approach in high regard, stress testing knowledge and practice continue to evolve and there are few agreed-upon best practices in this difficult and complex area. Indeed, the financial crisis has exposed weaknesses in all approaches to both financial stability and micro (e.g. individual portfolio stress tests using a value at risk model) stress testing.

However, while there is clearly much room for improvement by everyone who conducts stress tests, the panel recognizes that financial stability stress tests tend to be quite resource intensive, and thus can have significant opportunity costs. Indeed, the panel understands that while one may want in theory to integrate new aspects and mechanisms into a model, it is of paramount importance to keep certain practical necessities in mind. In particular, the model must be kept sufficiently straightforward and transparent so that it is both flexible to use and allows for clear communication with policymakers and the public about the model's causal linkages and its results. The panel has attempted to balance sometimes conflicting considerations by endeavouring to provide constructive advice regarding how the Norges Bank might improve its approach and to indicate the priority that the panel attaches to such improvements.

High Priority Recommendations

The review panel recommends that the Norges Bank…

1. … conduct or actively participate in bottom-up financial stability stress tests in conjunction with the major Norwegian banks and, if feasible, with the Finanstilsynet. In addition the Norges Bank should continue to conduct top-down tests. The panel also recommends that for most purposes and in most economic circumstances annual stress tests (and publication) are sufficient.

2.   … develop the individual bank-level data bases necessary to implement both the bottom-up stress tests recommended above, along with other relevant authorities, and improve implementation of the top-down stress tests currently conducted.

3.   … begin to develop ways to allow feedback effects from the satellite models to the **Small Macro Model** (SMM). This is particularly the case with respect to the Bank Model, because the financial crisis has shown that bank credit supply effects can be very important for the real economy. However, the panel is agnostic with respect to which model should be revised, as it may be possible to incorporate explicit credit supply effects in the SMM.

4.   … with respect to the **Bank Model**:

   a. Begin to attempt to explicitly include inter-bank contagion mechanisms in its Bank Model.

   b. Incorporate credit supply effects in the Bank Model and feed back such effects to the SMM if this proves the most efficient way of incorporating credit supply effects (see recommendation (3), above).

   c. Continue and perhaps give increased priority to attempts to better account for the heterogeneity of the Norwegian banking system.

5.   … with respect to the **Enterprise Sector Model**, actively investigate how best to use available, but currently unused, micro databases (both tax files and data that the Finanstilsynet appears to have) to better estimate enterprise-sector credit risk at individual banks. This recommendation should be considered jointly with recommendation (2), above.

6.   The panel has no high priority recommendations with respect to the **Household Sector Model**.

I. Introduction

In the summer of 2010 the Financial Stability wing of the Norges Bank (NB) established a panel of external experts to review its financial stability stress testing program.[1] The panel was charged with assessing the stress testing program at the Norges Bank relating to the performance and financial resiliency of the major Norwegian banks and the stability of the Norwegian banking system. Special focus was to be placed on the usefulness of the stress testing approach for determining the capital adequacy of the major banks and the implications of that capital for financial stability in Norway.

The panel was asked to relate the Norges Bank approach to stress testing best practice, including to similar stress tests conducted by other central banks and supervisory agencies with which panel members were familiar and selected Scandinavian nations (based on published reports). Attention was to be given to the presentation and relevance of the stress tests published previously in the Norges Bank's *Financial Stability* Reports. In addition, the panel was charged with assessing each of the models currently used for stress testing by the NB. Special emphasis was to be given to the Norges Bank's Small Macro Model (SMM). However, the review panel was also asked to evaluate the credit risk models used by the Norges Bank, including related work on financial risk in the household sector.

This Report presents the panel's findings and recommendations. The next section gives a brief overview of the Norges Bank's approach to stress testing. The panel's overall assessment of the Norges Bank's approach is discussed in Section III, followed by four sections evaluating the individual models used in the Norges Bank's stress tests. Section VIII reviews the Norges Bank's approach to publishing the results of its stress tests. Each section begins with a short discussion followed by the panel's specific recommendations. While it will become clear that we have a very high regard for the Norges Bank's approach to stress testing, in each section our primary objectives are to identify both areas where we believe improvements can be made and to indicate

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[1] Biographies of the panel members are provided in the Appendix.

the priority we attach to a given recommendation. In addition, the panel recognizes that separating its recommendations by section is somewhat artificial and thus emphasizes that its recommendations should be viewed as a "whole package." The "Summary and recommendations" section attempts to put our high priority recommendations into such a format.

II.   Structure of stress testing at the Norges Bank

The Norges Bank's stress testing approach is summarized in Figure 1. The system consists of four separate models: (1) the Small Macro Model (SMM), (2) the household sector's Margin Model (Household Sector Model), (3) the enterprise sector's Firm Bankruptcy Probability Model (Enterprise Sector Model) - also called SEBRA - and (4) the financial sector's Bank Model. The structure of the system is recursive, with outputs from the SMM used as inputs to each of the other three "satellite" models. Thus, there are no explicit feedback loops from one model to another. Moreover, the approach is explicitly "top-down" in the sense that the stress test begins with an overall macroeconomic scenario and aggregate equations are then used to "look down" the model's structure at individual banks to construct estimates of, for example, loan losses, profits and capital adequacy. This contrasts with a so-called "bottom-up" approach which, while also building on a macroeconomic scenario, begins with individual bank data (and sometimes individual loan and securities data) to build up to measures such as loan losses, profits and capital adequacy.[2] Norges Bank stress test results focus on credit risk in the Norwegian banking system, although other areas of the NB address, for example, liquidity risk both at individual banks and in the system as a whole.[3]

The SMM was built to facilitate the efficient design and simulation of stress scenarios for the Norwegian economy, and essentially all explicit behavioral relationships are contained in the SMM. For example, the model includes equations for household debt, household problem loans, problem loans of firms, and, of course, GDP.

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[2] A discussion of top-down versus bottom-up stress tests appears in Cihak (2007).

[3] This panel's review does not include assessment of liquidity risk stress tests at the Norges Bank.

A particularly noteworthy aspect of the SMM is its explicit inclusion of so-called financial accelerator effects, whereby household and firm balance sheet changes can feed back to the real economy. While these and other aspects of the SMM are discussed in more detail in Section IV, below, it is worth mentioning here that this is a highly innovative aspect of the SMM and that such explicit modelling is unusual among central banks and supervisory agencies with which the panel is familiar.

Figure 1: Norges Bank Stress Testing System
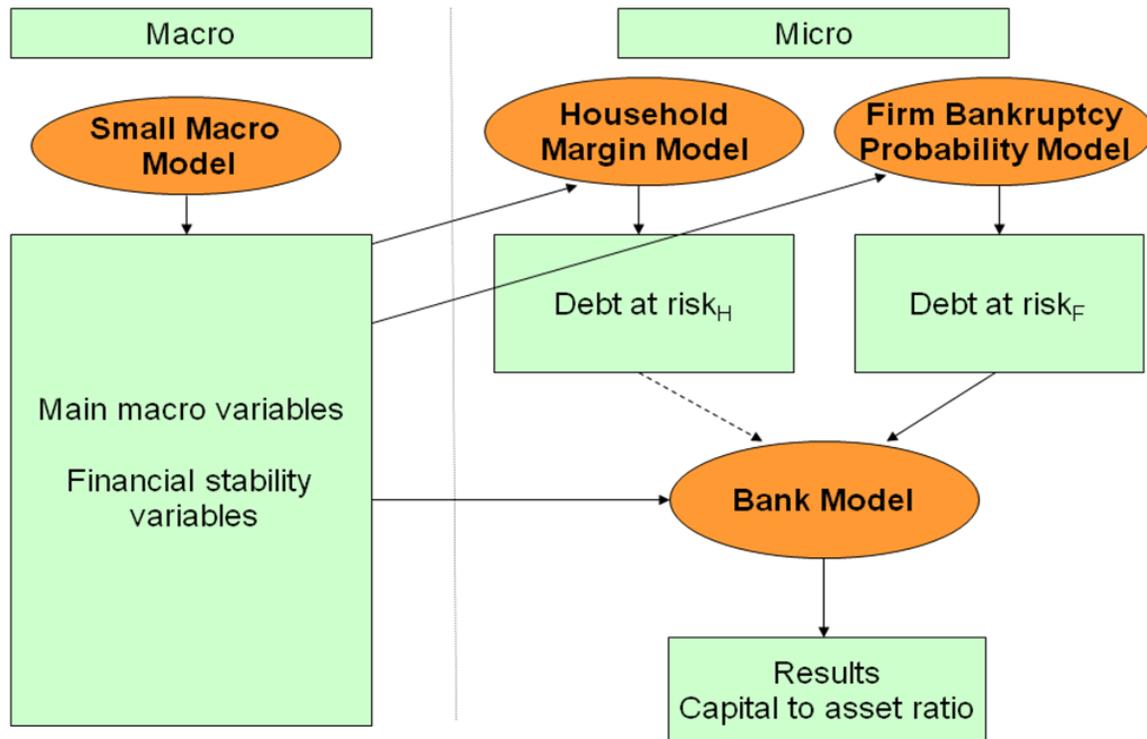
Source: Norges Bank

Key outputs from the SMM to the household sector's Margin Model include income growth, debt growth and interest rates. As discussed in Section V below, the primary function of the Household Sector Model is to predict the probability of households defaulting on their bank loans. Because household defaults are not observed directly, default probabilities are proxied with a measure of household margins, defined as household income less the sum of taxes, interest and principal payments and a measure of standard living costs. Using extensive household level data from tax files that include virtually all Norwegian households, Norges Bank staff is able to compute an estimate of

Norwegian households whose debt is at risk of default. However, it is important to understand that these estimates do not feed directly into the Bank Model (and thus the dashed arrow in Figure 1 from households' debt at risk to the Bank Model). Rather, they are used to judgmentally adjust the estimates of household sector debt growth and problem loans that are transmitted directly from the SMM to the Bank Model.

Primary outputs from the SMM to the Enterprise Sector Model, or Firm Bankruptcy Probability Model, include the growth in borrowing by enterprises, the growth rate in household employment income, the inflation rate, the real exchange rate, the growth in commercial real estate prices, and GDP growth. As discussed in Section VI below, the Enterprise Sector Model is designed to analyze the default and bankruptcy probabilities of all Norwegian limited liability companies. Its estimates are used to assess the credit risk of bank loans to the corporate sector and the model employs an extensive micro data set on thousands of individual companies. The Enterprise Sector Model's projections of firms' debt growth and debt at risk are aggregated at the industry level and used as inputs to the Bank Model (hence the solid arrow in Figure 1).

The Bank Model receives direct inputs from both the SMM and the Enterprise Sector Model, and judgmental inputs from the Household Sector Model. As discussed in Section VII below, the Bank Model is non-behavioral and is essentially composed of disaggregated balance sheet and income statements of the six largest Norwegian banks. Each bank's accounts are projected by linking their main income and cost items to variables determined in the SMM. Problem loans from the household sector flow directly from the SMM and are converted to estimates of loans losses at individual banks by the Bank Model. Total problem loans from the enterprise sector also come from the SMM, and the distribution of those loans across Norwegian industries is received from the Enterprise Sector Model. The quantity projections from both the household and enterprise sector models are converted to estimates of loan losses at individual banks by the Bank Model. These projected losses are used within the Bank Model to compute projections of profits and capital adequacy at the individual banks. These measures are, in turn, used as the key indicators of the health of the Norwegian banking system under the stress scenario.

III. The Norges Bank's overall approach to financial stability stress testing

In the review panel's judgment, the NorgesBank's overall approach to stress testing is highly innovative, economically sound, largely transparent to policymakers and the public and generally should be considered at the top end of best practice at central banks and bank supervisory agencies in developed nations. For example, development of a macro model specifically designed for stress testing is relatively rare, as is the attempt to explicitly include financial accelerator effects. In addition, while the use of a recursive structure with satellite models for specific sectors is quite standard, the combination of traditional macroeconomic models with rich microeconomic data sets for both the household and enterprise sectors is much less common. Stress scenarios used in the *Financial Stability* Reports appear to meet the widely-advocated criteria of "severe but plausible," especially when compared with those used recently by some other European nations. Equally important, there is an explicit effort to design stress scenarios around the key risks to the Norwegian banking system identified in the *Financial Stability* Reports.

The panel's overall judgment is supported by the survey and review of financial stability stress testing practices conducted by the Basel Committee on Banking Supervision's Research Task Force in 2006 and reported in Foglia (2009). Indeed, one of the panel members (Mr. van Lelyveld) chaired the working group that conducted that study and this panel's chairman co-chaired the Research Task Force when the study was conducted. The Norges Bank participated in that survey and review, as did the central banks of twelve other major nations. The review panel's experience with stress testing practices since 2006 in the United States, the Netherlands, the U.K., other European nations through the recent Committee of European Bank Supervisors (CEBS) stress tests and now Norway reinforces the findings of the Basel Committee study.

While the panel holds the Norges Bank's stress testing approach in high regard, it is nevertheless true that stress testing knowledge and practice continue to evolve and there are few agreed-upon best practices in this difficult and complex area. For example, the recent experiences of both the United States and the CEBS with so-called

bottom-up stress tests suggest substantial benefits to such an approach. More generally, the financial crisis has exposed weaknesses in all approaches to both financial stability and micro (e.g. individual portfolio stress tests using a value at risk model) stress testing. However, while there is clearly much room for improvement, the panel recognizes that financial stability stress tests tend to be quite resource intensive, and thus can have significant opportunity costs. The panel has attempted to balance sometimes conflicting considerations by endeavouring to provide constructive advice regarding how the Norges Bank might improve its approach and to indicate the priority that the panel attaches to such improvements.

As indicated by its title, this section of the Report concentrates on discussions and recommendations regarding the NB's overall approach. Recommendations regarding each of the four models and the NB's approach to publishing the results of its stress tests are given in the subsequent five sections.

Recommendations

1   **High Priority.** The Norges Bank should conduct bottom-up financial stability stress tests in conjunction with the major Norwegian banks and, if feasible, with the Finanstilsynet. In addition, the Norges Bank should continue to conduct top-down tests.

This recommendation derives in large part from panel members' and others' positive experiences with the United States' Supervisory Capital Assessment Program (SCAP) stress tests, completed in May 2009, and similar tests conducted by the Committee of European Banking Supervisors (CEBS) and completed in July 2010.[4] In both the SCAP and the CEBS exercises, baseline and adverse macroeconomic scenarios were provided by the relevant central bank which then, along with the relevant micro- prudential authorities worked with participating banks to conduct the stress tests from the bottom-up. For example, in the SCAP exercise bottom-up sometimes meant that analysis was

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[4] See Board of Governors (April and May 2009) and Committee of European Bank Supervisors (2010).

conducted at the individual loan and individual security levels. In the SCAP, the final projections for bank capital adequacy were a combination of results from banks' own models, micro-prudential supervisory models, more aggregate econometric models and expert judgment. In the CEBS exercise it was up to individual countries to choose a top-down or a bottom-up approach. In those countries that chose to conduct a bottom-up approach very similar procedures were used in the CEBS tests as were used in the SCAP.

Both the SCAP and CEBS stress tests involved extensive discussions between supervisors and their banks. According to participants and in the judgment of this review panel, these discussions were one of the most valuable parts of the bottom-up approach. They provided all parties with extensive opportunities to learn from each other and to understand each others' perspectives and objectives. This approach imbued the stress tests with a foundation in "real world" behavior and indeed a degree of credibility that is much more difficult if not impossible to achieve with a top-down approach. Moreover, these lessons and experiences have the potential, indeed the necessity, to ultimately lead not only to improved financial stability stress testing, but also to improved micro-prudential supervision and better risk management at financial institutions.[5]

While the panel **recommends** that the Norges Bank begin to conduct bottom-up stress tests and believes that the SCAP and CEBS experiences provide strong evidence in favor of such an approach, we understand that the SCAP and CEBS approaches cannot and should not be transferred directly to the Norges Bank. Differences in national institutions, laws, culture and economic environments will require the Norges Bank, the Finanstilsynet and the banks to design an approach appropriate for Norway. In addition, both the SCAP and the CEBS stress tests were, at least at the time they were conducted, one-time and

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[5] For a more complete discussion of these and other lessons from the SCAP see Bernanke (2010) and Tarullo (2010).

explicitly supervisory exercises in which banks were required to participate and which was designed to restore confidence in the banking system during a period of intense crisis.[6] Bottom-up stress tests conducted on a regular schedule during more normal times would likely have a very different purpose and be conducted in a very different economic environment, and thus would almost surely require somewhat different procedures than those used in the SCAP and by the CEBS.

The panel would like to make a few final points about bottom-up stress tests. Such tests are clearly resource intensive and can take considerable time. As is also discussed in Section VII, the panel **recommends** that for most purposes and in most economic circumstances an annual stress test is sufficient and would free up staff and other resources that would otherwise be used to conduct more frequent tests. In addition, bottom-up stress tests are probably only needed for the largest or otherwise most important banks. A top-down approach is almost surely sufficient for all other institutions. Both the SCAP and CEBS stress tests only involved relatively large financial institutions. In both cases the banks included in the tests collectively held over half of the assets in the relevant nation's banking system.

2   **High Priority.** The Norges Bank, along with other relevant authorities, should develop the individual bank-level data bases necessary to implement both the bottom-up stress tests recommended above and to improve implementation of the top-down stress tests currently conducted.

Effective bottom-up stress tests clearly require accurate (and in the best case easy to use) data on loans, loan losses, income and other variables at the individual bank level. Ideally, such data should be disaggregated at least for

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[6] It now appears that both the United States and the CEBS/EBA will be conducting stress tests more regularly. For example, the recently-passed financial reform law in the United States requires the Federal Reserve, in coordination with other relevant financial regulatory agencies, to conduct an annual stress test of systemically-important financial institutions. EBA is envisaged, in cooperation with the ESRB, to initiate and coordinate European Union-wide stress tests. In both cases the exact form of such tests has yet to be determined.

each major sector of the economy. In addition, as discussed in some detail in the sections of this Report that discuss specific models, such data would, in the panel's view, help to substantially improve the top-down tests currently conducted by NB staff. Indeed, and as discussed further below, current procedures for converting loan growth and projected problem loans estimated in the SMM and Enterprise Sector Models to loan losses in the Bank Model are, in the panel's view, subject to substantial error and in some cases quite costly and otherwise difficult to implement. Direct data on loans and loan losses that are less costly to manipulate would likely yield substantial net benefits to the NB.

The panel understands that bank-level data could be acquired from two sources, and recommends that the Norges Bank pursue whichever source is most cost efficient. First, the Finanstilsynet may currently have such data, or it could acquire such data from Norwegian banks through its supervisory reporting process. Second, Norges Bank staff has informed panel members of a data set collected by tax authorities on non-financial enterprises that, *inter alia*, for each enterprise includes loans and interest paid on loans identified by bank. The Norges Bank Research Department has recently acquired access to these data and during this fall and winter will be evaluating them for use by the NB.

3   **High Priority.** The Norges Bank should begin to develop ways to allow feedback effects from the satellite models to the SMM. This is particularly the case with respect to the Bank Model, because the financial crisis has shown that bank credit supply effects can be very important for the real economy.

As discussed elsewhere in this Report, the inclusion of some financial accelerator effects in the SMM is highly innovative. This recommendation builds on this innovation in the direction of including effects identified in the financial crises as being of clear importance. Moreover, the panel understands that NB staff sometimes makes judgmental adjustments to stress test projections that attempt to incorporate feedback effects into a scenario's results. The panel understands that modeling feedback effects (and, as discussed in the Bank Model section of this Report, financial contagion effects) is very challenging

and is in fact a challenge faced by financial stability modelers around the world. Thus, our recommendation is primarily meant to encourage Norges Bank staff to continue to give this line of research a high priority.

4 **Medium Priority.** Norges Bank should consider how to better assess judgmentally the importance of the nonbank financial sector and branches of foreign banks operating in Norway for their stress scenarios.

Panel members are unclear how important nonbank financial institutions are for financial stability in Norway, but we believe that a more substantive consideration of them is probably warranted. For example, data on assets in Norwegian financial institutions provided to us by NB staff indicate that, as of the end of 2010:Q2, while Norwegian-chartered banks accounted for 85 percent of the banking sector, they accounted for only 47 percent of total financial sector assets. Put differently, by this measure the NB's financial stability stress tests ignore over half of the Norwegian financial sector.

Foreign branches are the other 15 percent of the banking sector, and eight percent of the financial sector. Certainly foreign branches are part of the credit supply process in Norway, may be a source of contagion risk in the Norwegian banking system, could impose losses of Norwegian creditors if their parent bank failed, and may represent a potential claim on Norwegian taxpayers.

For all of these reasons the panel suggests that the NB consider expanding their evaluation of the nonbank sector and foreign branches in their financial stability stress tests.

5 **Medium Priority.** The Norges Bank should consider doing more sensitivity analysis of its stress test results to uncertainty regarding the size of key parameters in its models.

Norges Bank stress test scenarios are well-designed to focus on the key risks to the Norwegian financial system identified by NB staff. And Norges Bank staff is clearly aware of the high level of uncertainty surrounding their scenario projections. However, the panel saw little explicit discussion of the sensitivity of stress test results to model parameters in either the *Financial Stability* Reports or

the technical papers provided to the panel. Clearly, there is uncertainty about the size of model parameters, and some sensitivity analysis of parameter uncertainly is standard practice in stress testing.

IV. The Small Macro Model

The SMM is a data-based macroeconomic model used for making forecasts, constructing risk scenarios and studying the impact of different transmission channels. The equations are of the error correction type, and the parameters are estimated on quarterly time series going back in some cases to the 1970s and extending into the 2000s. Expectations are generally assumed to be backward-looking. The basis for the model is a model for the real economy, see Bårdsen and Nymoen (2008) and Chapter 9 in Bårdsen, Eitrheim, Jansen and Nymoen (2005). The Bårdsen *et al* model has been extended to include a rather extensive financial block, which consists of estimated equations for household and nonfinancial firm debt, house prices, housing investments, banks' problem loans to households and enterprises, asset prices, money market interest rates, and the bank lending rate. The financial block feeds back to the real economy in part via real credit to households and firms, as well as through real house prices. These effects are meant to capture two financial accelerator mechanisms:

1. In the enterprise sector, an increase in asset prices leads to higher borrowing capacity and thus higher real credit. This will push up GDP via an increase in real investments. Likewise, a decrease in asset prices will push GDP down via the same mechanism

2. In the household sector, there is a pro-cyclical feedback mechanism between credit, house prices and housing investments, where an increase in these three variables will contribute to higher GDP, while a decrease in these variables will lead to lower GDP.

The model incorporates several transmission channels for the effect of a change in the policy interest rate. For example, when the money market interest rate increases, this

leads to higher bank lending rates, as well as to an appreciation of the krone exchange rate. Higher interest rates will also lead to lower house prices, lower credit growth and lower housing investments. The krone appreciation and reductions in house prices and credit will have negative impacts on GDP, which come in addition to the direct negative effect of higher interest rates. Lower GDP will push up the rate of unemployment, which in turn will dampen wage growth. Consumer price inflation will fall due to lower growth in wages and import prices, as well as due to the direct negative effect of the fall in the rate of economic growth.

The SMM has several nice properties. It includes financial accelerator effects that are highly innovative, with explicit modeling which is quite unusual in central bank macro models. Incorporating such effects is especially useful for the purpose of financial stability stress testing. In addition, the empirical foundation of the model to a large extent ensures that it is consistent with key features of the Norwegian economy.

The model's forecasting properties appear to be quite good. A forecast evaluation presented in Hammersland and Træe (2010) shows that the SMM does better than autoregressive (AR) models and EMOD, which is an econometric model developed for use in Norges Bank's system of now-casting models, for most variables and forecast horizons, but less well than a vector autoregressive model (VAR).[7] The SMM's impulse response patterns from various shocks are roughly in line with those that obtain from structural VAR and Dynamic Stochastic General Equilibrium (DSGE) models. However, the existence of the financial accelerators in the SMM implies that the amplitude of shocks is stronger for some variables.

IV.A. Use of the SMM

The SMM is used in conjunction with the other "satellite" models in the Norges Bank's financial stability stress testing (as described in Section II). The baseline scenario is the one published in the *Monetary Policy* Report with the addition of some financial stability variables not published in that Report. For the adverse scenario, the Norges

[7] Now-casting models are designed to forecast current or near-term economic conditions.

Bank adds several negative shocks to the baseline scenario, assumed to capture various negative factors that may come into play, even if they are not necessarily likely to occur. For example, in the stress test in *Financial Stability* Report 1/2010, the Norges Bank considered the combination of zero economic growth among trading partners, an oil price decline to about $40 per barrel, increased premiums in international money markets, and a fall in household expectations (consumer confidence). The Small Macro Model is then used to analyze the possible effects on the Norwegian economy, as captured by the key variables in the model. The output from the SMM is used as input in the Enterprise Sector, Household Sector and Bank Models.

A challenge in designing the stress scenario is that monetary policy has fairly strong equilibrating effects in the SMM. In particular, if adverse shocks occur and the economy deteriorates, a sizeable reduction in the policy rate will dampen the downturn via money market and bank lending rates as well as the exchange rate. The stabilizing effect of monetary policy is clearly a realistic feature. However, it also seems that some other central banks have experienced unusually weak monetary policy effects in the current crisis. Thus, the panel **recommends** that the Norges Bank explores scenarios where monetary works less well. In recent stress scenarios, Norges Bank staff have in fact attempted such experiments by judgmentally imposing interest rate margin and exogenous exchange rate effects, thus to a large extent offsetting the stabilizing effect of lower interest rates and a depreciation of the krone. Panel members are supportive of continuing such efforts.

IV.B. Comparison with other central banks

When designing macro scenarios for stress testing central banks typically use one of two approaches (Foglia, 2009). Many central banks, like the Bundesbank and Sveriges Riksbank, use an existing structural macroeconomic model that is also used for forecasts and policy analysis. Other central banks (e.g. Bank of Japan and Bank of Spain) use more statistical approaches, like vector VAR or vector error-correction models (VECM).

Using the same structural model as is applied for policy analysis has the advantage of ensuring a consistent modeling framework, as well as allowing for policy responses to the shock. However, in many cases the macroeconomic model does not include financial sector variables, so that these must be dealt with in satellite models. Another weakness with the use of structural macro models in this connection is that they generally are local approximations of equilibrium relationships, and for this reason may be less suitable for assessing the effects of large shocks (Foglia, 2009). However, no matter what type of model is used a common concern is whether the model is robust to shocks (scenarios) that are large compared to the shocks actually experienced over the time period in which the model was estimated.

VAR models have the advantage that they are a flexible and fairly simple way of producing a consistent empirically-based macro stress scenario. The absence of economic structure is, however, a disadvantage.

As compared to most structural macroeconomic models, the SMM has the significant benefit of incorporating financial accelerator effects. This is of clear value when designing macro scenarios for stress testing, as the recent financial crisis has shown that such effects are especially important in certain stressful economic environments. The SMM does not impose either the forward-looking expectations or the optimizing behavior that are keys in structural macroeconomic models of the DSGE type. However, this appears to be less of a problem, or perhaps even an advantage, when designing a stress test. One may argue that if unexpected, large shocks occur then uncertainty will also increase, and there is therefore less reason to assume that expectations are model-consistent.

On balance, the panel's recommendations for the SMM reflect the fact that we find that the model generally seems to work quite well for its intended use. Furthermore, while one may want in theory to integrate new aspects and mechanisms in the model, it is of paramount importance to keep certain practical necessities in mind. In particular, the model must be kept sufficiently straightforward and transparent that it is both flexible to use and possible to communicate clearly to policymakers and the public the model's causal linkages and results.

Recommendations

1   **High priority.** The Norges Bank should begin to integrate bank credit supply constraints in the SMM.

    The current version of the SMM captures that households and firms may be credit constrained, and that these constraints are eased when house prices and the price of other assets increase. However, as is also discussed in Section VII below, there is no explicit modeling of constraints on banks' supply of credit. Yet in a stressful period for banks, when they risk considerable losses on their loans and/or other activities, the recent financial crisis has demonstrated that banks themselves can become credit constrained. This will reduce bank lending above the effects that are already in the model, and magnify the contractionary implications for the economy.

2   **Medium priority.** Banks' loan losses usually increase quite markedly with the duration of a downturn of the economy. Thus, when exploring the risks to banks, it seems important to assess to what extent downturns are likely to be persistent. In the SMM, the empirical equations are of the error correction type, reflecting that, whenever a shock takes place, the variables will have a tendency to revert back to their unconditional means. The panel **recommends** that it would be useful to explore how robust such equilibrating mechanisms (including, as discussed above, monetary policy) are. Is there, for example, a potential for persistent deviations from equilibrium after a negative shock unless either decisive and effective policy actions are taken or there is some other positive shock? If so, this would be of vast importance for the consequences of a negative shock, not least for the severity of the losses on bank loans.

3   **Medium priority.** For better evaluation, it would be helpful to also present results from pure "out-of-sample" forecasts. Forecast evaluation is a key part of model development and testing. The evaluation presented in the preliminary study of the SMM includes forecasts that are only partly true "out-of-sample" forecasts.

4   **Medium priority.** In the same vein, it would also be helpful to document a direct comparison of the impulse (shock) response properties of the SMM relative to the impulse response properties of comparable DSGE models.

V. The Household Sector Model

The Household Sector Model (HSM) uses an extremely rich dataset of tax returns of individual households. By themselves these are very useful data for financial stability analysis as they can be used to answer questions about the distributional impact of for instance interest rate changes. They can also be of use in highlighting groups that are especially vulnerable to certain shocks. For example, younger cohorts might have taken on too much debt to buy a first home and would thus be especially sensitive to a house price decline or a change in interest rates. Another valuable use of the data is illustrated in *Financial Stability* Report 1/2010 (page 20), where one considers the effect of the Finanstilsynet's new guidelines for prudent lending on household debt.

Recommendations

1   **Medium priority:** The HSM analysis is now only loosely connected to the other models in the suite: the HSM is used to make judgemental adjustments of loan growth derived from the SMM. Given the sizable resource cost of preparing the household data for analysis, the extensive analysis that is currently done, and the considerable potential for additional analysis, the current limited use in financial stability stress testing seems unfortunate.

In the panel's judgment, the primary area where the HSM could contribute more would be to acquire a better understanding of the effect(s) on consumption of negative macroeconomic developments. Given the comprehensive work-out procedures for personal bankruptcy in Norway, the losses given default are limited in comparison to other countries. When this fact is combined with the fact that household loan default rates are very low in Norway, the effect of, for example, an increased household debt burden on consumption (rather than on credit risk) seems to be the more important research priority.

2   **Medium priority:** The panel was shown some first results from a complementary approach being developed: a Structural Vector Autoregressive Model (SVAR). Such an SVAR model can be a useful tool to analyze the dynamics of a model subject to an unexpected shock. Although the SVAR methodology is not without its criticism, the major advantage is that long macro time series data can be used, data which are generally readily available.[8] On balance, an SVAR model may be a cost-effective alternative to the current approach to using the household data if one were only interested in pass-through effects of macro variables on aggregates such as consumption.

3   **Low priority:** Currently Norges Bank staff undertakes some analysis of the distributional impact of aggregate shocks. Thus, for instance, the change in financial margin due to a change in interest rates is analysed. It seems, however, that such analysis could be linked more closely to the scenario's used in the stress testing exercises. As an enrichment of the stress testing framework one could consider, for example, an analysis of the impact of the interest rate path from the SMM on the distribution of the debt burden.

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[8] Grounds on which the SVAR approach has been criticised include doubts about the interpretation and importance of shocks, about the undisciplined use of informal restrictions, and about whether the assumption that the identified shocks are uncorrelated can be justified.

VI.   The Enterprise Sector Model

The Norges Bank has developed a model to estimate bankruptcy probabilities using enterprises' key annual account data and other related information. The key outputs of the Enterprise Sector Model, or SEBRA, are estimates of the riskiness of sectoral exposures. To this end two related approaches are used. Both methods use micro accounting data on over 100,000 firms. In the first and original approach, a logit model explaining probabilities of default is estimated. Then relationships between macroeconomic variables and accounting variables are estimated. Using the coefficients from this estimation the line items for each individual firm are projected using the benchmark and stress scenario paths of the macroeconomic variables. The individual firm's accounting values and the coefficients of the logit model are used to predict the probability of default for each firm. These default probabilities are then aggregated and multiplied with the nominal exposures resulting in an estimate of the dollar amount of debt at risk.

In the second approach, the analysis is conducted on economic sectors instead of on an individual firm basis. Specific models are estimated for each of five sectors, and a general model is used to estimate parameters for the remaining six sectors. The resulting coefficients are used to predict the future riskiness of sectors and then – combined with banks' sector exposures – the debt at risk for each sector.

Norges Bank staff has expended some effort to establish that the new approach delivers at least equal accuracy compared to the old method. As this seems to be the case, the new method seems to be much more cost-efficient. Because sector loss rates are highly correlated, the panel **recommends** analysing whether the sector classification could be condensed even more.

On balance, however, the methods currently used seem to be rather roundabout ways to establish the credit risk in banks. In our discussions with Norges Bank staff, we became aware of alternative approaches which, in our judgment, merit further consideration. In order of potential these would be:

Recommendations

1. **High priority:** As discussed in Section III, Norges Bank has recently obtained tax return data of nonfinancial firms with information on bank loans and on the bank(s) that provided credit. It appears that with these data firm-specific credit risks could be allocated to individual banks much more precisely than is currently the case. Thus the panel **recommends**, as it did in Section III, that the Norges Bank investigate how to use these data most effectively.

2. **High priority:** As also discussed in Section III, prudential reporting to the Finanstilsynet should include measures of (sector) credit risk. The panel thus **recommends** that Norges Bank endeavour to gain access to such information for stress testing purposes.

3. **Medium priority:** The panel understands that at least in some cases banks publish balance sheet measures of risk (e.g. nonperforming loans) broken down by sector. For those banks, the current roundabout way of inferring the sector exposures seems cumbersome. Thus, the panel **recommends** that this approach also be considered, especially if the approaches recommended in (1) and (2) do not prove feasible.

4. **Medium priority:** The current data only allow for an analysis of loans that are thought to be problem loans. These problem loans are not the actual losses banks experience. They might be a good proxy but if one continues to use the current approach, this is something that needs to be established.

5. **Low priority:** The validation of the models currently focuses on whether the condensed sector model exhibits the same features as the original disaggregated model. These analyses are all within sample and showing that the models also perform adequately out of sample would improve the panel's confidence in these models.

VII. The Bank Model

As described in Section II, the Bank Model receives inputs from the other three models and ultimately computes stress scenario projections of loan losses, profits, and capital ratios at each of the six largest Norwegian banks. These measures are used as the key indicators of the potential health both of the individual banks and of the Norwegian banking system in the stress scenario. There is no explicit feedback from the Bank Model to the other models.

Problem loans in the household and enterprise sectors are obtained from the SMM and from the Enterprise Sector Model. No substantive behavioral reactions are allowed within the Bank Model. Indeed, only one estimated equation appears in the model – an error correction equation for the growth of fee income. All other projections derive from outputs of the other models as applied to balance sheet and income statements of the individual banks. Thus, the Bank Model is essentially a sophisticated set of accounting relationships whose changes are driven by the other models in the stress testing system. Annual projections are reported publicly. In addition, while stress test projections are computed on an individual bank basis, only aggregate results are reported publicly.

From the point of view of financial stability stress testing, the outputs of the Bank Model clearly lie at the heart of any tests' implications for the potential health of the Norwegian banking system. For this reason alone, the panel **recommends** that improvements to the Bank Model be given high priority by the Norges Bank. Several of our high priority recommendations given in Section III's assessment of the Norges Bank's overall approach to financial stability stress testing are also highly relevant for the Bank Model. Indeed, because the Bank Model is so important to the NB's overall approach to stress testing, it is sometime difficult to separate the two sets of recommendations. That said, this section's recommendations attempt to augment those of section III by drilling down a little deeper into the workings of the Bank Model.

Recommendations

1   **High Priority**. The Norges Bank should begin to attempt to explicitly include inter-bank contagion mechanisms in its Bank Model.

A core lesson of the financial crisis is that a shock to one or more segments of the financial sector can cause a contagious loss of confidence, including runs on various liabilities, in other financial institutions and markets, both domestically and internationally. Thus, a highly desirable property of a financial stability stress test is for the test to be capable of simulating the types of interdependencies between banks and possibly other financial institutions that are likely to cause systemic, or contagion, risk within the financial sector. The current Bank Model includes no such interactions, although NB staff informs the panel that judgmental adjustments are sometimes made in this direction.

While not all such interdependencies between banks have currently been identified by practitioners and researchers some key interdependencies, such as interbank loans and highly correlated portfolios, are well-known. Thus, a potentially useful place to begin the inclusion of contagion effects would be to focus on these areas.

Such work would of course require the availability of suitable data at the individual bank level. Importantly such data, some of which the review panel believes could possibly be acquired through the Finanstilsynet, would also be useful for and reinforce the value of the type of bottom-up stress tests recommended in Section III.[9] More generally, the need to include bank contagion effects in realistic financial stability stress tests reinforces the Norges Bank's need for (and the panel's high priority recommendation in Section III that the NB actively seek to acquire) accurate and timely data at the individual bank level.

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[9] The Panel understands that the Finanstilsynet does not have data on interbank lending.

Another approach to modeling contagion effects (and that also requires individual bank data) that has received some attention by both practitioners and researchers is so-called network models.[10] Panel members are agnostic regarding what approach is best for the NB to pursue, and understand that initial attempts to implement contagion effects would inevitably be simplistic and rough. However, panel members believe the crisis has made the need to begin moving in this direction quite clear.

2   **High Priority.** The Norges Bank should consider incorporating credit supply effects in the Bank Model and feed back such effects to the SMM.

As discussed elsewhere in this Report, a highly innovative part of the SMM is its inclusion of certain financial accelerator effects. And, as is also discussed in Section IV, to date, these effects focus on a scenario's implications for the credit worthiness of households and enterprises, and give virtually no attention to the potential for a stress test shock to affect the ability of a bank (or other financial intermediary) to supply credit to households and businesses. For example, losses on assets and takedowns of loan commitments that lower bank capital ratios can also make both regulatory and bank management leverage constraints on credit supply more binding. In addition, lower capital ratios may increase a bank's funding costs through higher risk premiums demanded by investors on uninsured bank liabilities, thereby reducing the supply of funds available for credit creation. Both effects can feed back to the real economy through constraints on consumption and investment.

Panel members understand that Norges Bank staff is well aware of the potential importance of credit supply effects, and that judgmental adjustments to stress test results are sometimes made to attempt to account for them. While

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[10] The earlier, deterministic literature on such models is surveyed in Upper (2007). More elaborate models including feedback effects are Aikman *et al* (2009) and Boss *et al* (2006).

commendable and quite common in applied stress testing, the panel believes a more structured approach could have substantial net benefits.

3   **High Priority.** The Norges Bank should continue and perhaps give increased priority to attempts to better account for the heterogeneity of the Norwegian banking system (this recommendation is meant to complement a similar recommendation regarding nonbank financial institutions and branches of foreign banks given in section III).

The Bank Model currently does not explicitly account for the structure of the Norwegian banking system – a structure where one bank has a very dominant position. While such a structure is not particularly unusual in a relatively small country, the panel believes that the stress tests would likely be more realistic and useful if the structure were acknowledged more explicitly. For example, the one estimated equation in the Bank Model, the equation for fee income, includes no "firm effect" variables that would allow either the regression intercept or slope coefficients to shift depending upon the specific firm.

More generally, stress tests results given to the panel by NB staff suggest considerable variability across the six banks used in the scenarios with respect to such key variables as loss given default, market income, interest rate margins, and correlations between banks' rates of return on market investments. These results strongly suggest that more explicit attention to banking heterogeneity has the potential to yield substantial benefits for stress scenario projections of both (1) individual bank effects and (2) systemic or contagion effects.

VIII. The Norges Bank's approach to publishing stress tests results

The Norges Bank has a long tradition of publishing a *Financial Stability* Report (FSR). This approach has been externally reviewed and the main findings of this evaluation were that the FSR is a comprehensive and highly informative publication (Norges Bank (2006)). That review's recommendations have been taken to heart and the FSR is in the current panel's view one of the more readable such reports around. For example, its consistent format makes it easier for regular users to quickly grasp the most current developments, the reports are written clearly and there is a good use of boxes to explain more complicated, related issues. In short, the overall use of this communication channel, including its discussion of stress test results, is excellent.

A change Norges Bank is considering going forward is publishing individual bank's stress test results twice a year. Because many other countries have recently published similar information, it is an interesting question why the Norges Bank has not yet followed suit? However, in the panel's view this is not an easy decision as both the arguments in favour of and against publishing have some merit. In addition, it would be important to have a clear view of the objectives to be achieved in publishing individual bank's results. For example, in both the SCAP and CEBS stress tests a core objective of the publication of individual bank's results was to help restore confidence in the overall banking system. The following table summarises the arguments which we will discuss briefly below.

Table 1 The pros & cons of individual bank publication

Pros	Cons

* Transparent and informative	* Bias entire stress test towards success:
	  1) Banks might hide losses from the supervisory authorities
	  2) pressure for a more lenient scenario from both the bank as well as from the authorities,
	  3) relationship between supervisor and the bank might deteriorate

* Create an incentive for safety and soundness: if firms know that risky behavior will be revealed by (future) stress tests they will reduce their risks *ex ante*.	* Publishing sensitive stress tests might trigger financial instability

Banks publish a considerable amount of (financial) information about their profitability and risk. The recent crisis has shown that sometimes the market and the authorities find that this information is not adequate for assessing a bank's current risk profile. This was partly caused by inadequate modeling and partly because the models were calibrated /estimated using data from a very benign period. In such circumstances stress tests can reduce (aggregate) uncertainty. Publication can be especially powerful if ex-ante government adjustment plans, including a mechanism for quickly injecting capital into a bank that appears to need more capital, are in place for troubled banks. Note, however, that stress tests are only informative over and above more conventional measures of risk if they have either more relevant data or more applicable models. Conventional credit risk models for instance often assume that the probability of default (PD) is independent of the loss given default (LGD). In a stress test of for example the shipping industry, the analysis could show that if instead the PD and LGD are correlated, then the results can be much more severe.

In addition to the beneficial effect of the revealed information there might also be a publication effect. Banks might, realising that their risky behavior will be revealed in the future, reduce their risk profile pre-emptively.

The two main arguments against publication are that (1) it might trigger financial instability and (2) it will likely affect adversely the cooperative attitude many banks exhibit in a bottom-up stress test. We will discuss each of these in turn. First, publishing in the midst of a crisis (without an adjustment plan) or even in calmer times might be dangerous as it could be the final push towards making a bank illiquid or insolvent. Second, if the stakeholders are aware that the results will be published, the incentive could be quite strong to be very cautious in what information they are willing to share. In particular, both the bank and the supervisor would have an incentive to propose a wrinkle free, easy stress test that would not rock the boat. If such incentives are acted upon, this would reduce the value of the stress test exercise considerably.

The decision whether to publish individual stress test results is therefore not a straightforward one. It requires balancing the value and impact of the additional information taking into consideration the possibly increased noisiness of the signal.

Recommendations

1   **High priority:** The panel recommends that the Norges Bank consider publishing its stress tests only once per year.

As noted several times in this Report, stress testing is a resource intensive activity. Given resource constrains, the frequency of both the tests and their publication should not be too high because otherwise one runs the risk either that the stress test is not conducted in sufficient detail or that only a partial analysis is feasible. In addition, too frequent conduct and publication risk delaying or foregoing other needed research and development activities. Moreover, once a publication schedule is established it is very difficult to change. Thus, any change that the Norges Bank decides to make in its existing publication schedule should be expected to hold for the foreseeable future.

2   **Low priority:** The panel recommends that, as long as the scenarios are sufficiently distinct, to show several stress test scenarios.

In *Financial Stability* Report discussions of stress tests, only one stressed scenario is generally shown. Other scenarios have been computed (e.g. oil price shock, Baltic countries default, incapacitation of monetary policy) but have not been shown. As the (distinct) scenarios have been analysed, discussing them in the *Financial Stability* Reports would provide the public with a richer understanding of the risk profile of the Norwegian banking system.

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Appendix: Panel member biographies

Myron L. Kwast is an independent economic consultant based in Reston, Virginia, USA and a visiting scholar at the Federal Deposit Insurance Corporation in Washington, D.C. In June 2009 Mr. Kwast retired as a senior officer at the Federal Reserve Board in Washington, D.C. with over 30 years experience providing public policy analysis and advice to the Board of Governors of the Federal Reserve System on banks, bank supervision and regulation, financial stability, deposit insurance, antitrust and other financial institutions and markets issues. Mr. Kwast's most recent responsibilities focused on financial stability, including the resolution of troubled large banking institutions, the definition of systemic risk, and the impact of financial instability on the real economy. Mr. Kwast co-chaired the Basel Committee on Banking Supervision's Research Task Force (RTF) for over four years prior to leaving the Federal Reserve. The RTF includes members from the central banks and bank supervisory agencies of over fifteen countries plus international organizations and coordinates research efforts among member institutions.

Mr. Kwast holds a Ph.D. in Economics from the University of Wisconsin, Madison, USA. He has published over 30 papers in professional journals, has spoken frequently at professional meetings, and has been a visiting scholar at the Swiss National Bank and the Dutch National Bank.

Steinar Holden is professor of Macro and Monetary Policy Issues at the Department of Economics, University of Oslo. His main research areas are wage setting, monetary policy, macroeconomics and labor markets. Professor Holden has been the head of three governmental commissions, on Employment and Wealth Creation, on the Traded Sector, and on Shift Work, and he has twice been part of Norges Bank Watch (one time as the head). From 2001 to 2005, he was Editor of the Scandinavian Journal of Economics. Professor Holden holds a Ph.D in Economics from the University of Oslo. He has held a one-year research stay at the London School of Economics (1988/89) and at Harvard University (2000/01). In 1994/95, he worked as an Advisor in the Norwegian Ministry of Finance.

Demelza Jurcevic is a policy advisor at De Nederlandsche Bank (DNB) since early 2008. Ms. Jurcevic works in the Quantitative Risk Management section in the Supervisory Policy Division of DNB. Her main field of expertise is pillar 2 of Basel II. She is active in different working groups that deal with stress testing. She has been intimately involved in developing the CEBS guidelines for stress testing that were published in the summer of 2010. Furthermore, she was involved in the EU-wide stress test exercise of CEBS in both 2009 and 2010. Besides being internationally active in the field of stress testing, she has also been involved at the national level in performing stress test exercises among banks, insurance companies and pension funds. Currently she is participating in the Financial Sector Assessment Programme for the Netherlands which the IMF is organising for the end of 2010. Ms. Jurcevic studied economics at the Erasmus University of Rotterdam and holds a Msc. of Financial Economics. She is also a certified Financial Risk Manager (GARP).

Iman van Lelyveld is senior policy advisor at DNB, active in the development of the Supervisory Review, risk management and banking research. He is a member of the Research Task Force (RTF) and has chaired a RTF working group on stress testing and a group reporting on liquidity research for the Working Group on Liquidity. Mr van Lelyveld held a part-time associate professorship at Radboud University from 2004 to 2008, teaching amongst other topics international financial management and banking. He has worked as an internal and external Research Advisor for the Bank of England. He has published work on financial conglomerates, interbank contagion, payment topology and foreign banking in Central and Eastern Europe. Mr. van Lelyveld studied macroeconomics at the University of Amsterdam and holds a PhD in applied economics from Radboud University.