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Four Essays on Financial Stability

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Declaration of Authorship

I hereby declare that this dissertation thesis is my original work and that all sources and literature used are listed. This dissertation thesis has not been used to acquire a different or the same university degree.

Prague, August 10, 2012

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Petr Jakubík

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Abstract

Recent episodes of financial instability have motivated researchers as well as policy makers to intensify research on financial stability. This thesis contributes to current research and policy discussion by elaborating and empirically testing methodologies, which can be used to measure financial sector vulnerabilities and identify potential risks for financial stability. It further focuses on the link between real and the financial sector as well as possible implications of household financial distress on the aggregate economy. Together with the proposed framework we provide the survey of the current literature on these topics as well as the empirical results. We argue in favour of stress testing methodologies covering the key risks on banks' balance sheets. These frameworks can also be used for emerging markets where data availability is typically limited. It is shown that due to high volatility of credit growth in emerging economies, the static approach assuming constant balance sheet items is not very appropriate. Furthermore, the feedback effect between the financial sector and the real economy might play an important role under certain assumptions, and therefore it should be taken into account by policy makers. This effect can also emerge in the real sector itself as potential instability can be related to households' distress and have an impact on the aggregate economy via additional decrease in household consumption.

Keywords: stress testing, systemic risk, macroprudential policy, bank, Russia procyclicality, feedback loop, bank regulation, deleveraging, credit cycle, households' distress, insolvency, household default, aggregate consumption

JEL-Classification: G21, G28, G32, G33, G38, P34

Abstract (in Czech)

Nedávné období finanční nestability motivovalo výzkumníky i tvůrce hospodářských politik ke zintenzivnění výzkumu v oblasti finanční stability. Tato disertační práce rozšiřuje současné poznání a diskuze rozpracováním a empirickým testováním metodologií, které mohou být využity pro měření zranitelnosti finančního sektoru a identifikaci potenciálních rizik pro finanční stabilitu. Dále se zaměřuje na vztah mezi reálným a finančním sektorem a možné dopady finančních obtíží domácností na agregátní ekonomiku. Společně s navrhovanou metodologií poskytujeme přehled současné literatury na tato témata i empirické výsledky. Argumentujeme ve prospěch stresového testování zahrnujícího klíčová rizika v bilancích bank, které je možno použít i pro nově se rozvíjející trhy s omezenou dostupností dat. Pro tyto ekonomiky je statický přístup předpokládající konstantní rovahovové položky zcela nevhodný díky vysoké volatilitě růstu úvěrů. Dále práce ukazuje, že tzv. efekt zpětného dopadu mezi finančním sektorem a reálnou ekonomikou může hrát za určitých předpokladů důležitou roli, a proto by měl být brán v úvahu tvůrci hospodářských politik. Tento efekt se objevuje také v samotném reálném sektoru, protože potenciální nestabilita může pramenit z bilancí domácností a promítat se do agregátní ekonomiky prostřednictvím dodatečného poklesu jejich spotřeby.

Klíčová slova: stresové testování, systémové riziko, makroprudenční politika, Rusko, banka, procykličnost, efekt zpětného dopadu, bankovní regulace, pokles úvěrování, kreditní cyklus, finanční obtíže domácností, insolvence, selhání domácností, agregátní spotřeba

JEL kód: G21, G28, G32, G33, G38, P34

Contents

Introduction

The recent global financial crisis has revealed the importance of macro-prudential analysis to achieve financial stability and sustainable growth. Researchers and policy-makers have intensified their efforts in designing the new framework helping to assess and monitor systemic risk within the financial system as well as the links between the financial and the real sector, their mutual interactions and implications. This effort has been already reflected in the new banking regulation known as Basel III or the changes in the EU supervisory architecture, establishing the European Systemic Risk Board (ESRB) responsible for macroprudential oversight. The important tool which has been massively used for macroprudential analyses is, in particularly, a macro stress test of the banking sector. It has been employed on a national as well as regional or international level.

This thesis argues in favour of conducting macro stress test as a tool able to reveal vulnerabilities on banks' balance sheets and to detect systemic risk in the banking sector. However, it is important to design stress tests in the way to correctly reflect the reality and banks' practices. The proper stress test needs to be based on large, yet plausible, shocks. Stress tests which employ too mild scenarios can rather provide puzzling information and increase further uncertainty among market participants. Moreover, macro stress tests would seem to need to be based on multivariable macroeconomic shocks which would result in losses for the banks' trading portfolios as well as loan books (Schmieder, Puhr and Hasan, 2011). Furthermore, we believe that successful macro stress testing requires the careful use of macroeconomic models which would underpin the exercise, making it more plausible reflecting the current risks in the economy. As macroeconomic models are typically linear, they might have difficulty capturing nonlinear aspects of the behavior of key variables. Hence, alternative nonlinear models might be considered in case that available data allows their estimation (Jakubik and Schimeder, 2008).

One of the key aspects of successfulness of conducted stress tests is the communication strategy of their results. Different communication policies might affect response of market participants. For example, while the stress test conducted during the recent financial crisis by the Federal Reserve System (Board of Governors of the Federal Reserve System, 2009a, 2009b) contributed to restore confidence in the US banking system, the stress test conducted by the European Banking Authority (2011) was rather unsuccessful in delivering more stability in European markets. More transparency in the conducting of the US compare to the European stress test might play the crucial role. Moreover, the recent EU wide stress test conducted by the European Banking Authority was criticized by markets participants not only for a lack of transparency and information revealed, but also for a relatively mild scenario. It was interpreted as a tendency to hide negative information and resulted in the expectation that European banks have severe difficulties to deal with their risks. Of course, revealing complete

results might destabilize markets in case of less favourable results. Hence, such results would need to be revealed together with a credible strategy for a recapitalization program of problematic banks. A successful example of the communication strategy can be seen in the case of The Sveriges Riksbank which regularly publishes individual data on banks' stress tests within the financial stability reports e.g. (Sveriges Riksbank, 2012). The decision to move into this direction was driven by the relatively small number of systemically important banks and the potential harmful effects of negative aggregate results on sound institutions.[1] Despite the fact that the Swedish banking sector has a lot of specifics, this experience points out that higher levels of transparency might be beneficial. However, the important aspect of the success of such strategy is a long credible history in transparency which might be building up during the good time rather than crisis time when introduction of such policy can be quite challenging.

This thesis is primarily focused on financial stability assessment using stress testing methodology for the banking sector. However, part of this thesis is also focused on the link between the banking sector and the real economy. Finally, the special part is devoted to stress testing of the household sector and implication for the real economy. The study consists of four essays which are tied together by the common themes of financial stability, stress testing, and macroprudential analysis. The first three essays are co-authored by three different co-authors with 50% split of the work. It should be noted that all four essays presented in this dissertation thesis were previously published as working papers or a journal article.

The first chapter "Thoughts on the Proper Design of Macro Stress Tests" provides the survey of the stress testing literature discussing the main features of the currently employed methodologies. We argue for the importance of such exercise focusing on the key features, which need to be carefully taken into consideration by regulators. Despite the fact that these methodologies already appeared before the recent financial crisis, it did not help regulators to avoid banking system failures and subsequently substantial losses on banks' balance sheets have been seen. We discuss some reasons and features of the financial systems which need to be included into the current methodologies. Special attention is also devoted to macroeconomic scenario.

The second chapter "Bank Stress Tests as an Information Device for Emerging Markets: The Case of Russia" is focused on designing stress testing methodology for emerging markets. Typical obstacles for these economies are limited data availability, short time series and structural breaks making macro stress test more challenging. We show how to overcome these data problems by proposing top-down stress test methodology that employs relatively limited information. Furthermore, we use that framework to assess Russia's banking sector vulnerabilities. Our results revealed high sensitivity of the capital adequacy ratio to an economic cycle. Furthermore, given that Russia's banking sector is small and fragmented compared to that of advanced economies, the loss of external financing can engender profound economic stress, especially for medium-sized

[1] The Sveriges Riksbank regularly conducts macro top-down stress tests for four largest banks – Handelsbanken, Nordea, SEB and, Swedbank.

and small enterprises. However, the Russian state has a comparatively low public debt-to-GDP ratio and directly or indirectly controls domestic banks. Hence, there is sufficient fiscal space for potential recapitalisation of problematic banks.

The third chapter "How Important Is the Adverse Feedback Loop for the Banking Sector?" deals with banking system cyclicality and an adverse feedback loop related to banks' response to deterioration of a macroeconomic environment. We discuss potential sources of banking sector cyclicality and reflect the main streams of numerous international initiatives examining how regulatory, macro-prudential and accounting principles can mitigate procyclicality of the financial system. We further use the stress test methodology employed by the Czech National Bank to simulate the feedback loop for the Czech economy. We assume that banks respond to an economic downswing by de-leveraging and reducing their lending to the economy in order to maintain the required capital adequacy ratio. This then further negatively affects economic growth and impacts back on banks in the form of higher loan losses. The simulation results point out that under certain assumptions the feedback loop may play an important role.

The fourth and last chapter "Household Balance Sheets and Economic Crisis" elaborates the aspect of financial instability which could emerge on households' balance sheets. This study focuses on determinants of household financial distress and its impact on the aggregate economy. This feedback effect of household financial difficulties is empirically assessed for the Czech economy using simple Keynesian framework. The analysis clearly shows that there is a significant additional decline in consumption related to an increase in household default rates and unemployment. Our results suggest that potential household insolvencies can have important implications both macroeconomic and for the financial system.

All four chapters focus on aspects of financial stability, macro-prudential analysis and negative impact of adverse macroeconomic scenarios on the financial system or the economy as a whole. The thesis deals with these highly relevant issues, in particular stress testing techniques.

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Thoughts on the Proper Design of Macro Stress Tests

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Abstract

This paper argues that properly designed macro stress tests could be an important part of enhanced macroprudential policies, because they can help measure, monitor and control systemic risk. This basic idea is not new, but the reasons we give why macro stress tests can help in the achievement of these objectives are new. One of these is the observation that most common systemic risk indicators based on asset prices did not signal heightened risk prior to mid-2007. This strongly argues in favour of the regular execution of macro stress tests that have the potential to yield important information concerning a build-up of systemic risk. We also believe that macro stress tests can overcome potential flaws in the stress testing practices of financial institutions. One of these is the tendency for stress tests to be based on shocks that are too mild. Another is that some banks assume diversification benefits when combining stress losses across their trading portfolio and loan book, diversification benefits that might not materialize during periods of severe macroeconomic stress. The paper makes a few recommendations for the design of macro stress tests that would enable them to overcome these questionable stress testing practices. It also discusses some elementary sources of systemic risk including a number of self-reinforcing feedback loops that, while not operational during normal times, can amplify systemic risk during times of significant macroeconomic stress. The paper also discusses systemic risk arising from house price bubbles and issues related to the deleveraging and releveraging of banks' loan books.

Keywords: stress testing, systemic risk, macroprudential policy

JEL-Classification: G21, G28, G32

1. Introduction

The recent international financial crisis and associated economic crises in some countries can be viewed as the collateral damage resulting from the failure, or near failure, of a number of large financial institutions. Sadly these events appear to have been to some extent avoidable, because risk management failures were a major source of the problems encountered by financial firms. These included insufficient holdings of high-quality capital and an over-reliance on short-term funding.[2] Unsurprisingly, therefore, significant changes in the regulations governing the behaviour of financial institutions aimed at correcting these and other flaws in risk management practices have been adopted or are under consideration. These include much more stringent minimum regulatory standards for internationally active banks (Basel Committee on Banking Supervision (2011a, 2011b, 2011c)) that incorporate new liquidity rules, increases in capital requirements, measures aimed at preventing a build-up of excessive leverage in banking systems and ways to deal with banks that are perceived to be "too big to fail". A number of countries that have experienced especially severe economic downturns and/or have large financial sectors relative to the size of their economies have adopted or proposed additional standards that will have to be met by some banks and nonbank financial institutions.[3]

There have also been calls for, and new rules requiring, an enhanced macroprudential approach to financial sector regulation and supervision. For example, the revised *Core Principles* of the Basel Committee on Banking Supervision (2011d) specifically indicate that bank-specific supervision, so-called microprudential supervision, should be complemented with a macro perspective.[4] Such a macroprudential approach to supervision (and regulation) focuses on risks to the financial system as a whole. In particular, it aims to measure, monitor and control systemic risk. However, before systemic risk can be measured accurately, and thus also accurately monitored and controlled, it must first be defined precisely in a way that permits its measurement. Yet a precise definition of systemic risk that would permit its accurate measurement has yet to be widely adopted. Therefore, for the foreseeable future, "measuring" systemic risk is likely to be more art than science. Nevertheless, one could define systemic risk as the risk that failure of part of the financial system would morph into wide-spread financial sector difficulties with large adverse effects on the real economy.

[2] See Bernanke (2012) for a discussion of these and other risk management failures of financial firms in the run-up to the crisis.

[3] See, for example, Jordan (2011), Bernanke (2011a), Tarullo (2011, 2012a), Kiang (2011), Sveriges Riksbank (2011a), Goodhart (2011) and Austrian National Bank (2011).

[4] See also Bean (2009), Geneva Association (2010), Basel Committee on Banking Supervision (2010b), Tucker (2010, 2011), Weber (2011), Hoshi (2011), Bernanke (2011b, 2011c), Ingves (2011), Praet (2011) and Tarullo (2012b), among others.

Recent work has discussed macroprudential policies for financial sector regulation and/or supervision and the control of systemic risk.[5] In this paper we argue, as do Greenlaw et al. (2011), that properly designed macro stress tests could be an important part of enhanced macroprudential policies. Macro stress tests are conducted by financial sector regulators (or supervisors), central banks and international financial organizations, usually with the aid of key financial institutions, and have different objectives than stress tests financial firms run for internal risk management purposes. For example, macro stress tests were undertaken during and after the recent international financial crisis with the main goal of restoring confidence in financial systems (Bank of England (2008); Board of Governors of the Federal Reserve System (2009a, 2009b); Committee of European Banking Supervisors (2010); Central Bank of Ireland (2011); European Banking Authority (2011)). Of course, macro stress tests are also conducted during "good times". No matter when they are conducted, macro stress tests will try to identify potential sources of systemic risk and, to the extent possible, measure their importance. This usually entails estimating the losses that a group of financial institutions considered key to the proper functioning of the financial system and economy, usually a group of large banks, could suffer under adverse macroeconomic developments or other shocks.

The idea that effective macroprudential policies would include an important role for macro stress tests is not new. Fisher (2011), Constâncio (2011), Sveriges Riksbank (2011b) and Bank of England (2011) have recently suggested their usefulness for assessing systemic risk, perhaps supplemented with additional tools; however, the idea has earlier roots. It can be traced back at least to Worrell (2004) who suggests an important role for macro stress tests in an approach to financial stability analysis that also incorporates early warning systems and financial soundness indicators. For a couple of reasons, however, the recent financial crisis lends support to the view that macro stress tests could play an especially important role in enhanced macroprudential policies. One concerns the usefulness of a number of systemic risk measures derived from the prices of financial instruments. Rodríguez-Moreno and Peña (2010) show that none of the most widely used of these measures signalled heightened risk prior to mid-2007. Yet with the aid of hindsight it is clear that the housing price boom in the United States that had started a number of years before was, against the backdrop of excessive risk taking by financial institutions, a source of significant systemic risk. It is clear, however, that financial markets can only reveal known information on a build-up of financial sector risks, and some risks can go undetected for a prolonged period of time. It thus seems that accurately measuring and monitoring systemic risk, a basic requirement for the successful implementation of macroprudential policies, requires the regular execution of macro stress tests which exploit information obtained from the

[5] See, for example, Kashyap et al. (2008), Bank of England (2009, 2011), Committee on the Global Financial System (2009, 2010a, 2010b), Financial Stability Board (2011a), IMF (2011), Moreno (2011), Sinha (2011), Galati and Moessner (2011), Fischer (2011), Hanson et al. (2011), Hong Kong Monetary Authority (2011), Monetary Authority of Singapore (2011), Nier et al. (2011), Bank for International Settlements (2011), Gerlach (2012), Ekhom (2012) and Spencer (2012).

balance sheets of key financial institutions, information that may not be in its entirety available to the general public.

An important role for properly designed macro stress tests in enhanced macroprudential policies is also suggested by the demonstrated failure of the stress tests run by a number of large financial institutions to mitigate the risks that led to the financial crisis. There have been many suggestions for ways financial sector regulators could improve upon the stress tests these firms run for internal risk management purposes, including those put forward by Greenlaw et al. (2011). Our argument is more basic and focuses on two potentially key flaws in stress testing practices. One of these is the tendency for stress tests to be based on shocks that are too mild. This was pointed out by the UK Financial Services Authority (2006) prior to the financial crisis, and the agency even speculated that financial institutions might underestimate the likelihood of severe events. This might be considered a logical consequence of the prolonged period of favourable economic conditions prior to the crisis and short human memories. This possibility is consistent with the findings of Kates (1962) concerning the behaviour of a number of managers of businesses located in a particular flood plain in the United States. For example, he writes "Another obstacle to more refined emergency actions lies in the progressive atrophy of any disaster preparations with time."[6] Bankers also seem to be afflicted by short memories. Jiménez and Saurina (2006) report that in Spain loans granted in "good times" have a greater likelihood of ending up in default than loans made during recessions. Their interpretation of this finding is that in "good times" lenders are overconfident in borrowers' ability to service loans in part because they have forgotten the difficulties many borrowers faced in the last recession.

Haldane (2009) also argues that "short memories" likely played an important role in the weakening of risk management practices in the run-up to the crisis; however, he suggests in addition a more alarming possibility. This is that moral hazard may be adversely influencing financial firms' stress testing programs. In particular, financial institutions might believe that government assistance would be forthcoming in response to large shocks that would lead to difficulties for a number of key institutions, thereby raising systemic risk to unacceptable levels. Financial institutions that believe that they are "too big to fail", because their failure alone would raise systemic risk to unacceptable levels, would probably also expect government assistance in response to large shocks. These expectations would likely lead to an inadequate consideration of large shocks in these firms' internal risk management practices.

Another potential flaw in stress testing practices with possibly significant consequences is related to the fact that the firm-wide stress tests run by large banks with sizable trading portfolios tend to focus on either the trading portfolio or loan book but not combined losses. This is arguably a consequence of the fact that banks often employ separate quantitative risk management models (QRMMs) to measure market risk in their trading portfolio and credit risk in their loan book. To the extent that financial institutions perform stress tests to supplement the output of QRMMs, then it is easy to

[6] See page 111.

see how the practice of running separate stress tests could emerge. Yet large macroeconomic shocks have the potential to generate significant losses in both a bank's trading and lending activities, and the correlation between these losses could increase significantly during times of severe macroeconomic stress. This is because large swings in financial market prices and rates, such as steep increases in interest rates and exchange rate depreciations, have the potential to negatively impact the creditworthiness of households and firms, in addition to being the source of significant trading losses. It is also because severe economic downturns, that would be expected to lead to substantial losses in loan books, are usually associated with sharp declines in equity prices, sharp increases in credit spreads and other changes in financial markets. If a bank allocates sufficient capital to cover the sum of trading portfolio and loan book stress losses, then the running if separate stress tests for the trading portfolio and loan book is not necessarily a risk management flaw.[7] However, some banks assume diversification benefits when combining the two stress losses. Yet substantial diversification benefits may not materialize during periods of severe macroeconomic stress, so this approach has the potential to underestimate the capital needed to survive adverse macroeconomic developments.

Macro stress tests that are based on large macroeconomic shocks and, in the case of banks with sizable trading portfolios, take an integrated view of trading portfolio and loan book risks, could therefore play an important role in enhanced macroprudential policies. This is also the case because QRMMs, the other main tool banks employ to measure and monitor their market and credit risks, do not measure well risks associated with extreme events.[8] Of course, these are the risks that can lead to the insolvency of financial institutions and financial sector problems more broadly. Their proper management is thus very important and, with potential flaws in financial institutions' stress testing practices with possibly significant consequences, it would seem to require effective macro stress testing. Macro stress tests also have an advantage over a number of other macroprudential tools, because the legal authority for their use already exists. Indeed, they have been performed for a number of years under the Financial Sector Assessment Programs (FSAPs) of the IMF and World Bank. Financial sector regulators, supervisors and central banks also conduct macro stress tests outside of FSAPs. Presumably the outcomes of macro stress tests can lead to regulatory actions to help control systemic risk, such as heightened capital requirements.[9] The laws needed to

[7] Yet Breuer et al. (2005) point out that there can be inter-linkages between market and credit risk. For example, a counterparty default can expose a financial institution to market risk if it opens up a previously closed position. In the case of a bank for which inter-linkages across its trading portfolio and loan book are important, the determination of total stress losses would seem to require the simultaneous estimation of stress losses for both portfolios.

[8] Sutton (2012) discusses a number of reasons why this is the case.

[9] This would be the case, for example, in countries that comply with the Basel Committee's *Core Principles for Effective Banking Supervision* (Basel Committee on Banking Supervision (2011d)). The essential criteria for satisfying the first Core Principle related to supervisory responsibilities, objectives and powers include "the supervisor has the power to increase the prudential requirements for individual banks and banking groups based on their risk profile

implement other macroprudential tools are currently not in place in a large number of countries.

The remainder of the paper is organized as follows. Section 2 explains basic macro stress testing methodology and identifies features a macro stress test would need to have in order to overcome the potential flaws in stress testing practices that we highlight. Section 3 discusses some elementary sources of systemic risk including credit risk, house price bubbles and a number of self-reinforcing feedback loops that, while not operational during normal times, can amplify systemic risk during times of significant macroeconomic stress. Section 4 discusses some additional issues concerning the measurement of credit risk and the deleveraging and releveraging of banks' loan books. Some conclusions are offered in Section 5.

2. Basic Macro Stress Testing Methodology

A macro stress test can be bottom up, top down or a combination of the two approaches. A bottom-up macro stress test is based on loss calculations performed by the financial institutions involved in the exercise derived from a set of common assumptions about future developments. These are usually produced by the country's central bank (or financial sector supervisors), perhaps with the aid of international financial organizations. Although individual firms calculate the losses they would suffer under the assumed future developments, official authorities nevertheless exercise some control over the many assumptions made and models used. They also aggregate the results. In contrast, a top-down macro stress test is completely designed and performed by some combination of the above-mentioned official authorities. It should arguably compute losses for individual financial institutions, when sufficient data are available, consistently applying the same models across all firms' balance sheets. Aggregate data can also be employed in top-down macro stress tests. The mix of aggregate and firms' balance-sheet data used in a top-down macro stress test is likely to be primarily determined by what data are available to the official authorities undertaking the exercise.

There are perceived advantages to both the bottom-up and top-down approaches. Clearly, loss estimates generated under the top-down approach are to a greater extent under the control of the official authorities responsible for the macro stress test. When the top-down approach is applied to the balance sheets of individual financial firms, loss estimates are likely to be more consistently calculated across firms and thus more comparable; however, they might not be the most meaningful. Financial institutions might understand their risk profiles better than official authorities, suggesting that there could be an advantage to bottom-up macro stress testing exercises that incorporate more

and systemic importance". In addition, the essential criteria for satisfying the ninth Core Principle include the power to undertake supervisory stress tests and the ability to force banks to take mitigating action in response to vulnerabilities revealed by the exercise that have the potential to affect the stability of the banking system.

"firm knowledge" in loss estimates. That both approaches can be recommended suggests that a combination of the two might be the best template for a macro stress test, with the official authorities and financial firms involved in the exercise challenging one another's results.[10] A combined approach would also permit the computation of average loss estimates obtained by averaging across the models used by both groups when computing expected losses. The intuition that averaging across a number of models may yield better loss forecasts follows from the observation that all models are wrong in some dimensions, and it is hard to know in advance which models will perform better in a particular situation.[11]

Regardless of the approach adopted, there would seem to be advantages to studying individual firms' balance sheets (instead of aggregate data for groups of institutions). It is more likely that a build-up of systemic risk would be identified this way. Moreover, the computation of separate losses for individual financial institutions, and thus a study of their individual balance sheets, is necessary if one of the objectives of the exercise is to determine which firms need additional capital. A study of individual balance sheets is also necessary if one of the goals of the exercise is to determine whether significant diversification benefits between stress losses for a bank's trading portfolio and loan book would likely materialize during periods of severe macroeconomic stress.

A number of these issues, and others, are discussed in greater detail in work published by the IMF and World Bank that draws on their experience with FSAPs[12] and also by financial stability reviews that report the key assumptions underpinning macro stress tests, conducted both within and outside of FSAPs, and their results.[13] While insurance companies and other nonbank financial institutions can be included in the analysis, macro stress tests usually focus on a country's banking sector. This is because of the important role banks play in the provision of credit and also because their business model leads them to be a potentially significant source of systemic risk. Perhaps not surprisingly, therefore, an analysis of credit risk is usually an important part of a macro stress test. Because macroeconomic risk is arguably the main common

[10] Supervisors would also have the opportunity, under a combined approach, to evaluate how good financial institutions are at assessing their risks. Dudley (2011) argues that this was an important component of a recent US macro stress test.

[11] This same reasoning has led the Norwegian Central Bank to base some forecasts of key macroeconomic variables on the weighted-average output of a large number of forecasting models. See Olsen (2011).

[12] See, among others, Blaschke et al. (2001), Jones et al. (2004), IMF and World Bank (2005), Čihák (2007) and Schmieder et al. (2011). Foglia (2009) discusses some of the models official authorities have used in the execution of macro stress tests, and the origins of many of them were FSAP exercises.

[13] See, for example, Hoggarth and Whitley (2003), De Bandt and Oung (2004), Bunn et al. (2005), Bank of Canada (2008), Boss et al. (2008), Czech National Bank (2009), European Central Bank (2009), Hong Kong Monetary Authority (2009), Banco Central de Chile (2010), Norges Bank (2010), Reserve Bank of India (2010), Bank of Mauritius (2011), Central Bank of Malta (2011), Deutsche Bundesbank (2011) and State Bank of Pakistan (2011).

source of loss for many credit exposures, macro stress tests almost always estimate (at least) the impact an economic downturn (or slowdown) would have on banks' credit losses.

2.1. Sensitivity Tests and Scenario Analysis

Macro stress tests can be based on single-variable shocks, so-called sensitivity tests. In the case of an assessment of market risk, the single variable shocked could be an interest or exchange rate. In the case of an assessment of credit risk, the assumed shock could be an increase in nonperforming loans (NPL), a default by the largest nonfinancial corporate borrower in the financial system or a fall in the price of a key export. Historical data are often used to help determine shock sizes, but expert judgement should also be employed. While relatively easy to formulate, unfortunately sensitivity tests usually lack plausibility, because in a stress event it is unlikely that only one important risk factor will be significantly affected. Nevertheless, many macro stress tests have relied extensively on single-variable shocks.

A more plausible approach to stress testing is scenario analysis which examines the impact of simultaneous changes in a number of risk factors. In the case of banks with large trading portfolios, it is probably not controversial to argue that an accurate assessment of total stress losses for these firms requires basing stress tests on multi-variable shocks. However, this is probably also the case for a bank with a small trading portfolio. Loan-book losses arguably depend during times of macroeconomic stress on the evolution of a number of variables such as GDP and residential and commercial real estate prices. Other variables, such as interest and exchange rates, may also be important. Therefore, we believe that macro stress tests should be based on multi-variable shocks.

Macro stress tests usually rely extensively on macroeconomic models, especially in the construction and implementation of multi-variable shock scenarios. However, we believe that macroeconomic models need to be used cautiously. There is of course the potential for a positive contribution of macroeconomic models in macro stress testing. For example, when constructing scenarios for key variables, the models can shed light on their possible co-movements. Yet standard macroeconomic models, which are typically linear models, reflect the "normal" co-movements of macroeconomic variables, not their co-movements during times of severe macroeconomic stress when many economists believe nonlinear aspects of the behaviour of key variables become important. Also, large movements in key macroeconomic variables are probably more likely to occur in reality than linear macroeconomic models would suggest.[14] An

[14] Alfaro and Drehmann (2009) present supporting evidence. They show that, starting from a situation of strong economic growth, simple autoregressive models have difficulty generating the significant falls in economic growth associated with crises. Misina and Tessier (2008) discuss a number of reasons why standard macroeconomic models are ill-suited to capture the large shocks associated with crises, including their linear structure. They also show that

implication of this is that model-derived probabilities for large shocks are likely to be too low.[15] Scenario formulation should therefore not depend mechanically on the output of macroeconomic models. Expert judgment should be used when specifying how the variables in multi-variable shock scenarios will evolve, including of course their co-movements. Expert judgment should also be employed to ensure that the shocks underpinning stress test scenarios are the large shocks associated with times of significant macroeconomic stress.[16]

2.2. Assessing the Impact of a Shock

Whether a single- or multi-variable shock underpins a macro stress test, it is important to specify an appropriate time horizon over which the effects of the disturbance will be traced. An appropriate time horizon will balance competing forces. On the one hand, a relatively long time would likely be required for most of the credit losses associated with an adverse shock, such as a significant decline in domestic economic activity, to be realized. This is especially the case if credit losses are associated only with defaults and not general declines in creditworthiness (mark-to-market credit losses).[17] Given that most macro stress tests aim to estimate losses from credit exposures, this argues for a relatively long time horizon. On the other hand, a shorter time horizon makes it less important to model changes in financial institutions' portfolios. Shifts in the compositions of a bank's trading portfolio and loan book of course occur, and in the case of the former they can occur very quickly. This can pose challenges for the joint assessment of losses across a bank's trading portfolio and loan book, because the time horizon of a macro stress test is usually between one and three years.

Another issue is the metric used to assess the post-shock health of financial institutions. The metric could be losses measured relative to capital, or post-shock capital measured relative to assets or risk-weighted assets (RWA). The latter metrics would usually take estimates of current and future net income of the institution(s) into

nonlinearities are important when relating default rates in Canada to macroeconomic variables.

[15] Model-derived probabilities are sometimes used to help determine the plausibility of a particular scenario. Yet, it is not necessary to assign probabilities to the scenarios that underpin stress tests.

[16] As previously discussed, the potential for large shocks does not seem to be adequately reflected in financial institutions' internal stress testing practices. If this mostly reflects moral hazard, then the official authorities responsible for a macro stress test might find it relatively easy to overcome this risk management flaw. Counteracting the influence of "short memories", which presumably affect both the public and private sectors, may be a greater challenge for official authorities. Yet it may be possible for them to do so, in part because official authorities may be less influenced by arguments such as "it is different this time".

[17] As noted by the Basel Committee on Banking Supervision (2012), ignoring credit migration effects likely results in an underestimation of credit losses in the stress scenario.

consideration. Because it is difficult to model how a large number of components of income would evolve under stress scenarios, forecasts of income are commonly based only on past average income.[18] The uncertainty about the income that will be realized over the horizon of the exercise adds to the uncertainty surrounding post-shock capital.[19] There is a potential advantage to measuring the outcome of a macro stress test in terms of capital only and not capital measured relative to assets, risk weighted or not. If financial institutions are required to raise capital measured relative to assets or RWA, then they may shrink their balance sheets. Such deleveraging, if undertaken by a number of financial institutions simultaneously, can have adverse effects on the real economy that can feed back negatively on the profitability of financial institutions. This can adversely influence capitalization ratios and generate additional deleveraging. This self-reinforcing feedback loop, a potentially important source of systemic risk, does not arise if financial institutions must maintain an absolute amount of capital, because capital levels cannot be raised by deleveraging only.

2.3. Issues Concerning Public Disclosure

The official authorities responsible for a macro stress test must decide what to disclose to the general public concerning the outcome of the exercise. While there will undoubtedly be laws prohibiting the release of certain information, official authorities will nevertheless most likely possess considerable freedom over the extent of public disclosure. This decision is likely to be a difficult one. On the one hand, it can be argued that minimal disclosure reduces the risk of misinterpretations. Because the full picture of the health of financial institutions can never be provided, the potential for misinterpretations that can have unfavourable consequences such as runs on financial institutions should not be underestimated. This risk of runs may be especially present when institution-specific results of a macro stress test are made public. The extent of deposit insurance would seem to be an important factor determining the extent of this risk. On the other hand, it is not only stress test results that can be misinterpreted. The decision to conduct a macro stress test and not make public many of the results can also be misinterpreted. It can be mistakenly viewed as a signal of weakness of the financial institutions involved.

Whether or not there is a credible plan to recapitalize financial institutions that fail to pass the test would also seem to be an important consideration when deciding upon the extent of disclosure. Institutions that are named as needing additional capital may have difficulty obtaining it solely from private sources, especially if market conditions are unfavourable. Market participants of course share this knowledge. Therefore, without a backup plan to recapitalize these institutions with public funds, there might be unintended consequences of indicating which institutions failed the test. Moreover, even

[18] When available, the interest sensitivity gap between assets and liabilities can be used to project at least net-interest income.

[19] Another assumption of most macro stress tests is that additional capital is not raised.

if sufficient private capital is available, financial institutions might be reluctant to tap it because of a belief that market participants would perceive such actions as indicative of further financial weakness. A forced alternative of ending up partly government owned could be a strong incentive for financial institutions to raise as much capital as they can via private sources. However, getting this backup in place may be a challenge for international macro stress tests. The terms of any recapitalizations at public expense are currently a national decision, and reaching agreement between the relevant national authorities for a large group of countries is likely to be a difficult task. Unfortunately, the absence of such an agreement can work to undermine the credibility of a macro stress test. This is because the general public will probably correctly assume that, absent a credible plan for dealing with financial institutions deemed to have capital shortfalls, the official authorities responsible for a macro stress test will be reluctant to name any firms as such in the first place. This could generate the suspicion that the parameters of the macro stress test in general, and the severity of the underlying scenario in particular, have been manufactured to keep the test from identifying any significant capital shortfalls.

One situation where the balance of risks might weigh more heavily towards extensive public disclosure of firm-specific results of a macro stress test is when an economy's financial system is gripped with substantial fear of the "unknown unknowns". In this situation of elevated Knightian uncertainty, information disclosures have the potential to shift attention towards the "known unknowns" related to individual financial institutions. This can lead to a greater willingness of the public to engage in financial transactions with the relatively healthy institutions once the Knightian uncertainty premium is reduced. Of course, there is no guarantee that extensive public disclosure of firm-specific results will have this effect.

3. Sources of Systemic Risk

There are many sources of systemic risk, and a large number of these derive from banks.[20] This is because banks are leveraged institutions, so that modest declines in the values of their assets can lead to their insolvency. They also fund long-term, illiquid assets short term, so they are vulnerable to runs. This vulnerability raises the possibility of self-fulfilling crises via runs which can spread across a banking system when doubts emerge about the solvency of banks, so-called contagion. This can lead to troubles for banks whether or not initial fears were justified. Contagion risk also materializes when

[20] For more information concerning various sources of systemic risk, see Financial Stability Board (2009, 2011b), International Association of Insurance Supervisors (2009, 2011, 2012a, 2012b), Joint Forum (2010), Geneva Association (2010), Sveriges Riksbank (2010), International Organization of Securities Commissions (2011), Bank of England (2011) and European Commission (2012).

defaults on interbank loans propagate losses across a banking system.[21] These possibilities are a major concern of policymakers, because banking crises are typically associated with significant lost output, reflecting the important role banks play channelling funds from savers to ultimate investors in an economy. Indeed, the Basel Committee on Banking Supervision (2010a) reports, after surveying a large number of academic studies that estimate the output losses associated with banking crises, a median loss of 63% of pre-crisis output. Historically, significant fractions of the output losses were likely the direct result of the shocks that led to the banking crises, shocks that may have originated from outside of the financial system. Yet banking crises undoubtedly worsen the impact of outside shocks on the real economy.

Another form of financial contagion is elevated uncertainty about which institutions are exposed to bad credits or have exposures similar to those of financial institutions with bad credits.[22] This type of contagion was associated with the collapse of the investment bank Lehman Brothers and is considered to have been an important cause of the recent crisis. Lehman had operations across the world and was counterparty to a large number of financial institutions in and outside of the United States. When it entered bankruptcy, what can be a lengthy legal process, the financial positions it had with many of its counterparties were frozen. This had direct impacts on other financial institutions in a number of countries. In addition, because the risks that led to the demise of Lehman were also borne by other financial institutions, uncertainty concerning the ultimate profitability of financial transactions with numerous financial firms became elevated. This led to a general reluctance of many to enter into financial transactions, a key cause of the recent crisis.

The consequences of the Lehman bankruptcy have shown that securities firms can be a significant source of systemic risk. A question that naturally arises is whether this is also the case for insurance companies which traditionally have not been considered to be a significant source of systemic risk. The reason is that insurance companies do not typically engage in maturity transformation; therefore, they are not prone to runs as banks are. This implies that supervisors usually have plenty of time to deal with an insurance company that gets into trouble. It can be wound down slowly over time. However, insurance companies that insure financial products, as was true of the US monoline insurers or the firm American International Group (AIG), can obviously be a significant source of systemic risk. Concerns about the solvency of such insurers can be an important source of contagion, and their failure to make good on financial guarantees can be a significant source of losses for other financial institutions, including of course banks. Another way an insurance company, or any other nonbank financial institution, can be a source of contagion is if the firm belongs to a financial group that owns a bank. In this case, losses by the nonbank firm can cause the financial group's banking-unit

[21] Boss et al. (2006), Sveriges Riksbank (2006) and Reserve Bank of India (2011) give examples of macro stress tests that take this form of contagion risk into consideration. The modeling strategy of Sheldon and Maurer (1998) is usually followed in exercises of this type.

[22] See Allen and Gale (2002) for a discussion of theoretical models of systemic risk arising from financial contagion.

depositors not fully protected by deposit insurance to doubt the unit's solvency and run. The systemic risk posed by this possibility is greater when the nonbank entity suffering losses has risk exposures similar to those of banks.

In some economies, it may also be important to consider the direct impact a loss of insurance capacity could have on economic activity. For example, the inability of certain specialized businesses to obtain needed insurance cover from foreign insurers that might have limited experience providing the needed coverage could be a source of systemic risk, assuming lack of a competitive industry domestically or a large loss of capacity. This is because the specialized activities might not be undertaken without the insurance coverage. The extent to which domestic economic activity would be affected, and thus the extent of systemic risk, is of course directly related to the importance of the specialized activity in the economy.

3.1. Common Exposures

While financial contagion can be an important source of systemic risk, because of data limitations it is typically not the main focus of macro stress tests. Instead, macro stress tests usually try to identify systemic risk arising from common exposures across banks and sometimes also other financial institutions. Common exposures make bank runs more likely, because in this case depositors are more likely to take difficulties at one bank (or nonbank financial institution) as a reliable signal that other banks are also likely to be in trouble. Another way common exposures can lead to elevated systemic risk is by increasing the likelihood that a number of financial institutions get into trouble simultaneously. Of course, the intermediation capability of the financial sector is likely to be more greatly impaired if the common exposures leading to losses are across large, as opposed to small, financial institutions. "Short memories" could play a role in a build-up of large exposures, especially after a prolonged period of favourable economic conditions, because in this case bankers and others would likely underestimate the associated risks. This could turn hard position limits into soft limits, allowing a build-up of large exposures.

3.2. Interest and Exchange Rate Risk

Interest rate risk, and also sometimes exchange rate risk, can be very important for financial institutions. Unexpected increases in interest rates can adversely affect the economic values of fixed income securities held in trading portfolios and, for banks, the economic value of their loan books funded with short-term borrowing. The impact of parallel upward (and downward) shifts of government yield curves (base rates) on the economic values of financial instruments held by financial institutions can be approximated, following Macaulay, as the product of the interest rate change, duration and total notional amount. The impact of changes in credit spreads should also be investigated. During "good times" this would arguably call for an investigation of a sudden, sharp widening of credit spreads, which might be considered a more probable

event than their sudden, sharp fall. It may be possible in the case of some relatively homogenous pools of securities to compute exact present values when their average characteristics are available. A macro stress test may also wish to assess exchange rate risk, and a simple measure can be obtained by multiplying the net open foreign exchange positions of financial institutions, both on and off balance sheets, by assumed changes in key exchange rates. There is also an element of interest and exchange rate risk that shows up as credit risk for financial institutions, as will be discussed below.[23]

3.3. Credit Risk

Credit risk is the most important risk for many financial institutions and macro stress tests almost always attempt to measure it. In the case of banks, this would typically include assessing the credit risk in their loan books, typically the main risk for a bank. The most important influence on credit risk, whether in banks' loan books or elsewhere in the financial system, is often thought to be the general state of the macro economy, reflected in large part by the growth of domestic national income, with greater income growth making it easier for households and corporate borrowers to service their debts. Of course, by way of demand for a country's exports, income growth abroad can be an important determinant of domestic income. Concerning other macroeconomic variables, increases in interest rates might be expected to decrease the creditworthiness of households and firms, especially if a significant amount of their debt is in floating rate agreements.[24] Changes in exchange rates can also damage borrowers' creditworthiness, although in this case it is less clear what moves would do the most damage. In the absence of complete currency hedging, exporters with negligible foreign currency debts would likely become greater credit risks when the domestic currency appreciates. A depreciation of the domestic currency can also damage the creditworthiness of companies, and households too, if they have significant foreign currency debts but insignificant foreign currency income.[25]

One way of measuring credit risk in banks' loan books is to project losses under an adverse macroeconomic scenario.[26] Often the ratio of NPL to total loans is the measure of credit losses in top-down macro stress tests which employ aggregate data; however,

[23] Exchange rate risk can also emerge as funding liquidity risk, a risk that we do not cover. Čihák (2007), Aikman et al. (2009) and Sveriges Riksbank (2010) discuss approaches to incorporate funding liquidity risk into macro stress tests.

[24] Even if this is not the case, the fact that interest rate increases mean that new borrowing would have to take place at higher rates reduces creditworthiness, because it reduces an entity's ability to survive adverse shocks.

[25] Of course, importers with insignificant foreign currency debts and insignificant foreign currency income could also see their creditworthiness decline in response to a depreciation of the domestic currency.

[26] Pesola (2001), Shu (2002), Pain (2003), Jakubík (2007) and Jakubík and Schmieder (2008) provide examples of statistical models relating measures of loan-book losses to macroeconomic variables.

this indicator can significantly underestimate credit risk in the case of rapid credit growth. To illustrate this problem, let $npl_t \equiv NPL_t / Loans_t$ and $gnpl_t \equiv (npl_t - npl_{t-1}) / npl_{t-1}$. It is then easily shown that

$$gnpl_t = \frac{gNPL_t + 1}{gLoans_t + 1} - 1 \qquad (1.1)$$

where $gNPL_t = \frac{NPL_t - NPL_{t-1}}{NPL_{t-1}}$ and $gLoans_t = \frac{Loans_t - Loans_{t-1}}{Loans_{t-1}}$. If credit is growing

rapidly, the fact that it usually takes time for bad loans to reveal themselves implies that the variable *gnpl* may be low even if credit risk is building up in the sense that many loans are likely to turn sour in the near future. Therefore, this ratio is not our preferred measure of credit risk in loan books, although we realize that data limitations may require its use.

Another approach to measuring credit risk in loan books is macroeconomic credit risk modelling. This approach, pioneered by Wilson (1997), relates credit risk to the "health" of the domestic economy as reflected by a number of macroeconomic variables.[27] In the default mode application of the model, average default probabilities for borrowers in different sectors of the economy are related to macroeconomic variables, and the time series dynamics of the macroeconomic variables are also modelled. The approach is thus capable of predicting how default probabilities will evolve in the future under alternative macroeconomic scenarios, given initial macroeconomic conditions. These initial conditions could be the actual values of macroeconomic variables or those that would be associated with a particular stress scenario. Using further simulations, the conditional loss distribution associated with a bank's loan book can be derived. The generated default probabilities can also be used to compute expected credit losses per sector.

In the case of corporate exposures, it may be possible to perform a more refined analysis of expected credit losses under a stress scenario with the use of statistical credit rating models. These models associate with each exposure a score which is then related to the exposure's probability of default (PD). An expected loss for the exposure can be calculated as the product of the PD, the exposure at default (EAD) and the loss given default (LGD). Statistical credit rating models include obligor specific data when generating scores. When these models also incorporate macroeconomic variables, they can be used to compute "stressed" scores and default probabilities for obligors that would be associated with adverse macroeconomic developments.[28] These stressed

[27] Sensible modifications to the Wilson (1997) approach have been suggested by Wong et al. (2006).

[28] See, for example, Vallés (2006).

default probabilities can be used to compute expected stress losses for individual exposures that can be aggregated to obtain total stress losses for the corporate loan book.

3.4. Real Estate Price Risk and Asset Price Bubbles

A particularly important source of credit risk for banks and other financial institutions is real estate. In addition to the traditional form of this exposure, mortgages backed by residential or commercial properties, financial institutions today can build up large exposures to real estate price risk through purchases of mortgage-backed securities and related structured finance products such as collateralized debt obligations (CDOs). As discussed by the Committee on the Global Financial System (2009), structured credit products can, by pooling and tranching, substantially increase the exposure of an investor to the price risk of the underlying asset. While systemic risk usually materializes when real estate prices fall, it can be increasing during a period of rising real estate prices. This is especially the case if a bubble pushes real estate prices too high, as prices would likely experience marked falls when the bubble eventually bursts. Indeed, a bursting house price bubble in the United States is considered by some to be the underlying cause of the US subprime crisis that grew into an international financial crisis. As the bubble began to deflate after 2006, falling home prices led a large number of homeowners into a situation of negative equity, raising default rates.[29] Given the high loan-to-value ratios of many subprime home loans at origination, the US subprime sector was where problems first emerged. However, as house prices continued to fall in the United States, defaults also rose significantly for homes purchased with traditional mortgages.

Falling real estate prices can also generate indirect losses for financial institutions. For example, falling house prices can reduce the wealth of a large part of the population in countries with high rates of home ownership. This can lead to declines in consumption expenditures. Falling real estate prices can also lead to low rates of construction activity and thus low rates of investment. Lower output and reduced profits of banks and other financial institutions would accompany lower aggregate demand. This situation can also persist for a prolonged period of time, because housing markets are not efficient asset markets. The high costs associated with managing portfolios of homes makes it very unlikely that substantial “hot money” can be relied upon to keep housing prices near fundamental values. This not only implies that housing markets might be especially prone to price bubbles but also that there is the potential for significant overshooting on the downside by house prices when a bubble bursts. Thus, the adverse effects on consumption and investment associated with a bursting house price bubble could be large and persistent. This might help to explain the finding by Claessens et al. (2011) that recessions accompanied by house price busts tend to be longer and deeper than other recessions and the recoveries that follow weaker. The

[29] As noted by Dudley (2012), negative equity is one of the most significant predictors of default.

potential for house prices to deviate significantly from their fundamental value suggests that drivers of fundamental values, such as interest rates, cannot be relied upon to have a quick impact on house prices. Thus, a monetary authority might find it difficult to quickly arrest significant house price declines by reducing policy interest rates.[30]

A question that naturally arises is whether asset price bubbles are a source of systemic risk generally. Mishkin (2008) argues that bubbles in the prices of assets purchased with loans from financial institutions are a potential source of systemic risk, because in this case the eventual bursting of the bubble would likely generate loan losses that could damage the health of financial institutions. Because of their high leverage, banks and other financial institutions may be particularly vulnerable to losses arising from the collapse of asset price bubbles. A bursting asset price bubble could also harm financial institutions through indirect channels such as wealth effects and by influencing investment demand. The extent to which the particular asset price could overshoot on the downside following the bursting of the bubble would seem to be an important factor determining potential systemic risk. Concern about asset price bubbles can lead to concern over international capital flows which can fuel bubbles.[31] This is a major concern for emerging economies that usually do not have deep financial markets, so that capital inflows and outflows can have large impacts on domestic asset prices. Of course, capital flows can also be a source of concern for advanced economies. Indeed, large capital inflows were arguably at least part of the cause of the recent bubble in US house prices.

3.5. Self-Reinforcing Feedback Loops

As noted by Greenspan (2005), successful macroeconomic stabilization policies can be a cause of asset price bubbles, especially when investors have “short memories”. For example, a monetary policy that has a history of effectively counteracting shocks to an economy can lead investors to expect low economic volatility in the future, especially if they place too much weight on data from the recent, relative to the more distant, past.[32] In this situation, investors are likely to underestimate the riskiness of various assets. This “infectious euphoria” can lead to asset price gains that overshoot what economic fundamentals alone would indicate are appropriate valuations. The growing asset price bubble would likely be associated with greater spending by households and firms. A

[30] This same reasoning suggests that a monetary authority might find it difficult to prevent a significant house price bubble from forming solely by raising interest rates. Of course, a large increase in rates that significantly reduces the rate of economic activity would probably eventually burst the bubble.

[31] Of course, large capital inflows that are invested poorly can be a significant source of systemic risk even if they are not associated with asset price bubbles.

[32] The flip-side of placing too little weight on data from the distant past when forming expectations is to place too little weight on payments in the distant future when evaluating (risky) income streams. Haldane (2011) has recently argued that such “short-termism” helps explain stock prices.

self-reinforcing feedback loop in which asset price gains stimulate economic activity which in turn puts upward pressure on asset prices would likely develop. Asset price bubbles generated in this way can of course be a source of systemic risk.

Short memories can lead to another self-reinforcing feedback loop that works through assessments of credit risk. If an exogenous shock reduces the number of defaults in an economy and bankers and others extrapolate the short-term performance of loans and other credits into the future, this is likely to lead to an easing of credit conditions. The easing of credit conditions is in turn likely to make defaults less likely, because marginal firms will find it easier to obtain financing at reasonable rates. A related situation would be a time a rising home prices, which is also likely to be a time of low delinquencies and defaults on residential mortgages. This could fuel lending, and further house price appreciation, if the risk of new home mortgages is assessed in large part by recent repayment behaviour. These situations can be associated with greater credit risk on the associated credits than is appreciated.

There are other self-reinforcing feedback loops that can generate systemic risk. As pointed out by Credit Suisse (2012), one of these can arise from declines in house prices that lead a significant number of home owners into a situation of zero or negative equity. This would likely be associated with elevated default rates, generating foreclosures and associated distressed sales. This would arguably lead to further falls in home prices and more mortgages ending up underwater. In addition, falling house prices are likely to lead to a reduced demand for homes when potential buyers extrapolate price declines into the future and banks and other financial institutions tighten lending standards for home loans, in part because of concerns that collateral values may fall further. Of course, weakened demand for homes, brought about in part by tighter lending standards, would be expected to lead to further declines in house prices.

Another such loop can arise when banks and other financial institutions experience large, unexpected losses. It is natural to expect that lending standards would be tightened in response, in part to rebuild capital buffers but also as a consequence of the increase in perceived risk, and probably also elevated risk aversion, that would likely follow such losses. This could lead to a further deterioration in the real economy, additional financial sector losses and further cuts in credit availability.[33]

Yet another self-reinforcing feedback loop can arise from efforts to improve public sector finances. Cuts in public sector spending and tax increases can lead to slower economic growth if not an outright contraction in the economy. This would most likely be associated with lower tax revenues and thus a greater need for fiscal consolidation. A related self-reinforcing feedback loop can arise if the perceived PD of the sovereign

[33] As discussed by Borio, Furfine and Lowe (2001), risk-sensitive regulatory capital requirements and the dependence of collateral values on the state of the macro economy may also play an important role in this self-reinforcing feedback loop. Aikman et al. (2010) also discuss the importance of collateral values for lending decisions in addition to “herding” mechanisms that can also generate credit cycles that can amplify cycles in the real economy.

rises, perhaps because of greater public sector debt. In this case, domestic financial institutions will typically experience an increase in funding costs. This is because implicit and explicit support for them by the sovereign becomes more difficult, because the sovereign will likely be concerned about additional declines in its perceived creditworthiness. Funding costs are also likely to rise, because financial firms that lent to the sovereign will be subject to greater expected losses on these credits.[34] Higher funding costs for financial institutions in turn raise the likelihood that the sovereign will need to offer additional financial support to them, to the extent that it can, increasing the potential claims on the sovereign. If the country's financial sector is large in relation to the borrowing capacity of the sovereign, this can further increase its perceived PD.[35]

A self-reinforcing feedback loop can also result from asset fire sales. When a financial institution sells assets in less-than-perfectly-liquid markets, the sales can depress prices and, in mark-to-market accounting environments, generate losses for other financial institutions with similar exposures. These institutions may in response reduce their exposure to the same assets, further depressing prices. This possibility relates mainly to large banks and securities firms; however, insurance companies are also considered to be a potentially important source of asset fire sales. This is because they can be large holders of specific assets, such as corporate and government bonds. This feedback loop, whether caused mainly by banks or nonbank financial institutions, can lead to the overshooting of asset prices on the downside. This appears to have been an important factor behind the very large losses experienced by some financial institutions during the recent international financial crisis. On a positive note, the overshooting of prices will eventually correct itself, and this will support the profits of financial institutions hurt by the original asset price declines, assuming that they are still in operation when markets recover (with a net positive exposure to the particular asset class). How a financial institution funds itself can affect the probability that it will start an asset fire sale. Financial institutions that rely heavily on short-term wholesale funding, including of course a number of large banks and securities firms and possibly also some large insurers, are vulnerable to a rapid loss of funding that, if it were to occur, might force them to sell large quantities of financial assets.

While not operational during "normal" times, these self-reinforcing feedback loops can amplify systemic risk during times of significant macroeconomic stress. This poses challenges for macroeconomic models used in stress testing exercises. These models typically do not take into formal consideration the self-reinforcing feedback loops discussed above.[36] Moreover, macroeconomic models are estimated on data sets that

[34] Of course, greater sovereign risk will tend to be associated with higher default probabilities for credits extended to the country's households and firms.

[35] See Committee on the Global Financial System (2011) for a discussion of additional ways that perceived sovereign risk can influence the funding conditions of financial institutions.

[36] However, Aikman et al. (2009) and Chan-Lau (2010) present models useful for macro stress testing that incorporate the potential for financial sector losses arising from asset fire sales and a recent macro stress test by the Bank of Japan (2011) assesses the impact of bank profitability on the rate of economic activity via bank lending decisions.

primarily reflect the behaviour of key variables during "normal" times when such loops will not be in operation. This suggests that macroeconomic models have the potential to underestimate systemic risk.

Concern about the systemic risk arising from self-reinforcing feedback loops can nevertheless be a motivation for macro stress tests. As noted by Bernanke (2010a), one of the objectives of a macro stress test recently carried out in the United States (SCAP) was to ensure that large US banks would continue to lend to creditworthy households and firms even if economic conditions turned out worse than expected. To the extent that the SCAP was credible in this respect, expectations were likely focused on a more favourable future macroeconomic trajectory with lower financial sector losses. In this way, the SCAP helped to restore confidence in the US financial system.

3.6. New Financial Instruments

New financial instruments, especially sophisticated and complex ones, can be a source of significant systemic risk if their use is widespread or concentrated across key financial institutions. As argued by Sutton and Tošovský (2005), limited knowledge of the risk characteristics of new financial instruments can be associated with inadequate risk management practices, especially after a prolonged period of tranquil macroeconomic and financial market conditions.[37] In this situation, there might be limited possibilities to counter the influence of "short memories" with data reflecting the true riskiness of the instruments. The recent international financial crisis arguably provides supporting evidence. Bernanke (2010b) notes that in the run-up to the crisis risk management techniques failed to keep up with financial innovations related to complex financial products backed by US residential subprime mortgages. These financial products were the source of the first wave of unexpected losses that hit a number of financial institutions. In addition, excessive risk taking by the large insurer AIG was associated with a failure to properly manage risks associated with positions in credit default swaps on complex securitized mortgage products. The problems at AIG were of course considered to be a source of significant systemic risk, leading to a government bailout of the company. The potential for new financial instruments to be a significant source of systemic risk is arguably greater today than in the past, because the financial sectors of many countries are much larger today. Thus, shocks originating in a country's financial sector are likely to do more damage to its real economy today than would have been the case a decade or so ago.

[37] Geithner (2006) argues that processing and settlement infrastructure, in addition to risk management practices, can fall behind during times of significant financial innovation, and this is of course a potential source of systemic risk.

3.7. The Shadow Banking System

Systemic risk can also arise from so-called shadow banks that are institutions, instruments and markets that perform credit intermediation involving maturity and liquidity transformation outside of the regulated banking system. The shadow banking system includes investment banks, money market mutual funds and the off-balance-sheet activities of commercial banks such as structured investment vehicles (SIVs). Being mostly outside the perimeter of regulation, shadow banks can take on more risk than traditional (regulated) commercial banks. In the run-up to the recent crisis, this included the taking on of too much leverage and liquidity risk by investment banks and a number of SIVs. One problem with shadow banks performing maturity and liquidity transformation is that in contrast to traditional, deposit-taking banks their liabilities may not be covered by deposit insurance and they may not have access to central bank liquidity support. Shadow banks may therefore be especially susceptible to runs and downward spirals of investor confidence.

An important part of the shadow banking system in some countries is securities financing transactions. This became an important source of borrowed funds for some US securities firms in the run-up to the financial crisis. The growth of securities financing transactions can be partly attributed to "short memories" by lending firms, because the low realized financial market volatility in the years leading up to the crisis was arguably a key cause, in some cases, of the low haircuts on pledged collateral demanded by them.[38] The increase in financial market volatility led to larger haircuts which in turn led in some cases to forced sales of collateral. The greater volatility in asset prices brought about in part by forced sales led in turn to lending firms demanding still higher haircuts, another self-reinforcing feedback loop.

Shadow banking activities naturally evolve over time. It is therefore important to constantly reassess potential systemic risks arising from this sector. This is especially the case after a significant tightening of banking regulations, because this creates incentives for financial activities to be shifted to the shadow banking system. It therefore seems likely that, as part of enhanced macroprudential policies, macro stress tests will in the future need to assess risks associated with shadow banks, at least in economies with important shadow banking activities. An advantage of assessing the risks of these activities by way of macro stress tests, exercises that have traditionally focussed primarily on commercial banks, is that the shadow banking system and the commercial banking system can be highly interconnected and risks arising from the former can get magnified by the latter.

[38] This was the case, for example, for firms that based haircuts on the riskiness of the position as indicated by their QRMM for market risk estimated on data from the recent past. Of course, short memories on the part of borrowing firms may have also played a role by leading them to increase their reliance on short-term funding.

3.8. The International Dimension of Systemic Risk

The previous discussion concerning the financial contagion associated with the failure of the investment bank Lehman Brothers touched upon the international dimension of systemic risk. It arises, because the world financial system is highly interconnected in a number of ways. One is through global financial institutions, like Lehman was, with operations in many countries. Another is a consequence of the large capital flows between today's much more open economies. In addition to the Lehman bankruptcy example, the recent crisis revealed that a number of European financial institutions were exposed to developments in the United States via their holdings of complex securitized mortgage products backed by US subprime residential mortgages. Losses on these positions helped spread the US subprime crisis internationally. Both the importance of global financial institutions on the financial landscape and the size of international capital flows are unlikely to diminish in the future. In fact, it is likely that they will become even more important. This implies that accurately measuring systemic risk via macro stress tests will increasingly require an international, if not global, perspective. This suggests that it will become even more important in the future to overcome the challenges facing international macro stress testing exercises.

4. Credit Risk Parameters, Deleveraging and Releveraging

Short time series and structural breaks can prevent the use of the methods for evaluating credit risk in banks' loan books discussed in Section 3. In this section, we discuss an alternative approach. The framework developed also sheds light on issues related to declines (increases) in the amount of credit extended by banks, that is deleveraging (releveraging), on their loan books and capital adequacy ratio (CAR).

When data limitations prevent the use of the methods for evaluating credit risk in loan books discussed in the previous section, expected losses for a loan portfolio can be calculated as the product of the portfolio-average PD and LGD and the total portfolio EAD. Perhaps the biggest challenge with this approach is determining an appropriate portfolio-average LGD, and this parameter is often determined mainly by expert judgment.[39] Total loan-book EAD equals the difference between total outstanding loans (performing and nonperforming) and current NPL. Expected future NPL depend on the expected inflow to NPL (determined by PD estimates and the amount of performing loans), expected outflows from written-off loans and the current stock of NPL. Formally,

$$NPL_{t+1} = NPL_t + PD_t \cdot (Loans_t - NPL_t) - r \cdot NPL_t \qquad (1.2)$$

[39] However, because of real estate's important role as collateral, real estate prices can often inform this judgment.

where r represents the write-off rate of NPL. A simplifying assumption is to set the value of this parameter to its average value over a previous period, perhaps of several years' length, although this would of course be only a rough approximation to actual write-offs. Future NPL are therefore not known with certainty one period in advance as equation (1.2) suggests, but we abstract from the uncertainty related to the period t write-off rate.

One use of equation (2) is to provide a simple framework to discuss issues related to deleveraging and releveraging. From the equation it is seen that a high default rate on outstanding performing loans raises future NPL, all else equal. Absent a sufficient quantity of new loans, which may be expected to characterize times of elevated default rates and their immediate aftermath, greater future NPL implies a lower amount of performing loans and a fall in the future EAD of the portfolio. Yet EAD parameters are usually assumed to remain constant in macro stress tests, so deleveraging and releveraging effects are typically not taken into account in the computation of RWA.[40] This would lead to an overestimate (underestimate) of RWA under deleveraging (releveraging) and, consequently, an underestimate (overestimate) of the CAR of a bank. Thus, ignoring changes in EAD can lead to an incorrect view of the health of a bank when total EAD is changing.[41] Although macro stress tests do not normally take into consideration changes in RWA arising from changes in EAD, RWA are sometimes adjusted for changes in PD and LGD parameters or simply adjusted by subtracting new NPL from RWA.

Equation (2) also delivers a simple expression for the portfolio-average PD. This can be very helpful in the case of emerging economies where aggregate data on defaults are very often not available, but aggregate data on NPL are available. To see this, assume that the stock of NPL is relatively small compared to the stock of loans, so that equation (1.2) can be approximated by:

$$NPL_{t+1} \approx NPL_t + PD_t \cdot Loans_t - r \cdot NPL_t \tag{1.3}$$

Rearranging (3) gives:

$$PD_t \approx \left(\frac{\Delta NPL_{t+1}}{NPL_t} + r\right) \cdot \frac{NPL_t}{Loans_t} \tag{1.4}$$

[40] This was the case, for example, in the 2011 EU-wide macro stress test. The exercise assumed zero growth for nominal assets. See European Banking Authority (2011).

[41] Deleveraging, including a fall in EAD to the corporate sector, recently had a large impact on Belgian banks' capital adequacy ratios, for example. See National Bank of Belgium (2011).

The approximation (1.4) demonstrates that the portfolio-average PD depends on the growth rate of NPL, the write-off rate and the initial level of NPL relative to outstanding loans.

4.1. Deleveraging and Releveraging in Emerging Economies

In the case of macro stress tests for emerging economies, where credit growth tends to be relatively volatile, it may be especially important to take into consideration the impact of loan growth on banks' capital adequacy ratios. For example in many EU neighbouring countries, as well as in EU member states in Central and Eastern Europe, nominal credit expansion rates were ranging from 20% to 100% p.a. prior to the recent financial crisis. They then fell in the -10% to 0% range during the crisis and are currently growing rapidly again in some countries.

Table 1.1: Impact of credit growth on a bank's CAR

Capital adequacy ratios for various growth rates of credit and NPL for a hypothetical corporate loan portfolio

CAR (%)		Credit growth rate (in %)							
		-15%	-10%	0%	10%	20%	30%	40%	50%
NPL growth rate (in %)	5%	13.29%	12.69%	11.67%	10.83%	10.12%	9.52%	9.01%	8.56%
	10%	12.94%	12.37%	11.38%	10.55%	9.85%	9.26%	8.74%	8.29%
	20%	12.21%	11.70%	10.80%	10.04%	9.39%	8.83%	8.33%	7.90%
	30%	11.50%	11.04%	10.23%	9.55%	8.96%	8.44%	7.99%	7.58%
	40%	10.89%	10.45%	9.70%	9.08%	8.54%	8.07%	7.65%	7.28%
	50%	10.43%	9.99%	9.26%	8.66%	8.15%	7.71%	7.33%	6.98%

De-leveraging in 2009 Re-leveraging in 2011

Note: Using the Basel II formula, the simulations assess capital adequacy after one year for various growth rates of credit and NPL assuming that credit risk is the main risk in the loan portfolio. Loan portfolio losses are deducted from capital. Profits are thus not taken into account, nor are capital raising actions. RWA depend on default probabilities, which can be computed from NPL, credit growth and LGD and EAD parameters. The initial NPL ratio and CAR are assumed to be 8% and 12%, respectively. The LGD parameter is set at 55%, the minimum capital requirement at 10% and the write-off rate at 20%. The average maturity of loans is assumed to be 2.5 years. Similar results were also obtained for a hypothetical household loan portfolio.

The impact of credit growth on the capitalization needs of the banking sector in emerging economies can be illustrated by simulations of capital adequacy ratios for a hypothetical corporate loan portfolio for various assumptions for the growth of NPL.[42] The results of such simulations, reported in Table 1, suggest that the effect of credit growth on capital adequacy ratios can be substantial. In practice, losses associated with

[42] Regulatory capital requirements for credit risk are calculated using Basel II formulas for banks under the IRB framework (see, for example, Basel Committee on Banking Supervision (2006)).

greater NPL could be mitigated to some extent by banks' profits which typically increase during a boom period. However, rising RWA usually outweigh this effect as capital adequacy ratios decrease as a consequence of rapid credit growth. This analysis suggests that improving capital adequacy ratios in some countries during 2009-10 were to a large extent driven by deleveraging. At the same time, the current rapid recovery of credit growth suggests that banks in emerging economies may have to raise additional capital to remain adequately capitalized. This might lead to pressures in local funding markets, in particular in countries with underdeveloped financial systems. Cross-border financing via external deficits, on the other hand, might lead to returning external vulnerabilities in the region. In the extreme, government recapitalizations or bank failures in some countries are also conceivable.

5. Conclusions

This paper argues that properly designed macro stress tests could be an important part of enhanced macroprudential policies, because they can help measure, monitor and control systemic risk. This basic idea is not new, but the reasons we give why macro stress tests can help achieve these objectives are new. One of these is scepticism concerning the usefulness of systemic risk measures derived from the prices of financial instruments. We believe that macro stress tests which exploit information obtained from the balance sheets of key financial institutions, information that may not be in its entirety available to the general public, are more likely to yield important information concerning a build-up of systemic risk.

Reasons we give why macro stress tests could help control systemic risk are related to the demonstrated failure of the stress tests run by a number of large financial institutions to mitigate the risks that led to the financial crisis. One of these is the tendency for stress tests to be based on shocks that are too mild. Some banks with large trading portfolios engage in another questionable stress testing practice. This is the running of separate stress tests for their trading portfolio and loan book and the assumption of significant diversification benefits when the two stress losses are combined. Yet it is not clear that significant diversification benefits would actually materialize during periods of severe macroeconomic stress, so this practice has the potential to underestimate capital needs.

To overcome these apparent flaws in stress testing, macro stress tests would seem to need to be (1) based on large, yet plausible, shocks and (2) in the case of banks with sizable trading portfolios, estimate simultaneously stress losses for their trading portfolio and loan book. To be plausible, the disturbance underpinning the exercise should be a multi-variable shock. The shock should also arguably be macroeconomic in nature. Although macroeconomic models have been extensively used in the construction and implementation of multi-variable shock scenarios, we believe that successful macro stress testing requires the cautious use of macroeconomic models. This is in part because macroeconomic models are usually linear models; therefore, they will not be

able to capture fully nonlinear aspects of the behaviour of key variables that many economists believe appear during crises.

A potentially important source of nonlinear behaviour of key variables is a number of self-reinforcing feedback loops discussed in the paper. While not in operation during "normal" times, these loops can amplify systemic risk during times of significant macroeconomic stress. Macroeconomic models used for stress testing purposes usually do not take into consideration these feedback loops. Moreover, macroeconomic models are estimated on data sets that primarily reflect the behaviour of variables during "normal" times when such loops are not in operation. This suggests that macroeconomic models have the potential to underestimate systemic risk. It would also seem that shocks derived solely from macroeconomic models are likely to be too small for stress testing purposes. This suggests that expert judgment should be employed to ensure that the shocks underpinning stress test scenarios are the large shocks associated with times of significant macroeconomic stress.

The paper also discusses other elementary sources of systemic risk. For example, we argue that the high costs associated with managing portfolios of homes makes it very unlikely that substantial "hot money" can be relied upon to keep housing prices near fundamental values. This not only implies that housing markets might be especially prone to price bubbles but also that there is the potential for significant overshooting on the downside by home prices when a bubble bursts. This can lead to a significant erosion of household wealth and low rates of construction activity that persist for a prolonged period of time. These observations have the potential to explain why recessions accompanied by house price busts tend to be longer and deeper than other recessions and the recoveries that follow weaker. We argue in addition that there is an important international dimension to systemic risk, arising in part from globally active financial institutions and large international capital flows. Lo Duca and Peltonen (2012) develop an early warning system (EWS) that exploits this idea by incorporating global factors. Their EWS would have predicted the start of the US subprime crisis with a significant lead time. These results indicate a potentially important role for early warning systems in enhanced macroprudential policies. We believe that financial soundness indicators also should be considered for inclusion. Whatever tools are employed in enhanced macroprudential policies, the growing importance of globally active financial institutions and international capital flows suggests that these policies will need to take an even greater international perspective in the future. To the extent that enhanced macroprudential policies include an important role for macro stress tests, and we of course think that they should, it will become even more important in the future to overcome the challenges facing international macro stress testing exercises.

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Bank Stress Tests as an Information Device for Emerging Markets: The Case of Russia

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Abstract

The recent financial crisis emphasised the need for effective financial stability analyses and tools for detecting systemic risk. This paper looks at assessment of banking sector resilience through stress testing. We argue such analyses are valuable even in emerging economies that suffer from limited data availability, short time series and structural breaks. We propose a top-down stress test methodology that employs relatively limited information to overcome this data problem. Moreover, as credit growth in emerging economies tends to be rather volatile, we rely on dynamic approach projecting key balance sheet items. Application of our proposed stress test framework to the Russian banking sector reveals a high sensitivity of the capital adequacy ratio to the economic cycle that shows up in both of the two-year macroeconomic scenarios considered: a baseline and an adverse one. Both scenarios indicate the need for capital increase in the Russian banking sector. Furthermore, given that Russia's banking sector is small and fragmented relative to advanced economies, the loss of external financing can cause profound economic stress, especially for medium-sized and small enterprises. The Russian state has a low public debt-to-GDP ratio and plays decisive role in the banking sector. These factors allow sufficient fiscal space for recapitalisation of problematic banks under both of our proposed baseline and adverse scenarios.

Keywords: stress testing, bank, Russia
JEL Classification: G28, P34, G21

1. Introduction

The recent global financial turmoil emphasised the importance of stress tests in evaluating financial sector resilience to adverse macroeconomic shocks.[43] Typically, financial sector supervisors and central banks have carried out macro stress tests in cooperation with key financial institutions. Unlike the stress tests financial firms perform for their own internal risk management purposes, however, the objective of macro stress testing is to identify potential sources of systemic risk and estimate the losses key financial institutions in a given country might suffer under adverse macroeconomic developments or various shocks. The recent crisis also demonstrated that stress testing can serve as an important macroprudential tool for restoring confidence in financial systems, increasing transparency and reducing market uncertainty.[44]

Even if the adverse macroeconomic shocks of the recent global economic recession were largely generated in advanced economies, they strongly impacted emerging markets. The decaying macroeconomic environment was felt strongest in banking sectors of emerging economies with strong linkages to the international financial system. The fact, that emerging markets can be highly vulnerable to this kind of adverse macroeconomic development stems from the much higher volatility of credit growth than in advanced economies. Thus, to properly assess potential banking sector vulnerabilities, stress tests should reflect the actual conditions of emerging markets if they are to serve as an effective information device. Moreover, an adverse scenario needs to be sufficiently severe to expose systemic fragility, yet remain plausible. The formulation of an appropriate scenario for stress testing is discussed in Berkowitz (2000), who argues for a probabilistic scenario structure and backtesting.

Stress testing has been employed widely by regulators and private financial institutions, yet no clear consensus on the applied methodology has arisen. Most currently applied techniques are based either on academic research (Blaschke et al., 2001; Jones et al., 2004) or developed from practice-based guides published by central banks and international organisations (IMF and World Bank, 2005; Čihák, 2007).

Here, we employ a top-down approach to assess the resilience of the Russian banking sector to negative macroeconomic shocks. Our baseline and adverse macroeconomic scenarios are projected on individual bank balance sheets via simple econometric models that link non-performing loans and credit growth with selected macroeconomic indicators. We calculate credit, interest and contagion risks for both the baseline and

[43] Well before the current crisis, Borio, Furne and Lowe (2001) point out the importance of stress tests in understanding risk and how risk relates to the economic cycle.

[44] See e.g. Bank of England (2008), Board of Governors of the Federal Reserve System (2009a, 2009b), Committee of European Banking Supervisors (2010) and European Banking Authority (2011).

adverse scenarios. Using this information, we calculate the impact on bank capital for each bank, the sector as a whole, and groupings of banks broken down in terms of their size and ownership.

Our study contributes to the current literature in two ways. First, we use a unique data sample based on the balance sheets of banks that hold a total of about 94% of banking sector assets. This is important because the stability of Russia's bank-based financial system remains highly dependent on bank health and the fact that the Russian economy is so big that its stability might affect financial stability in other countries. Second, our applied methodology reflects the recent trend towards dynamic approaches. We employ a two-year time horizon to capture the deleveraging/releveraging process driven by swings in lending (Jakubík and Schmieder, 2008; Schmieder, Puhr and Hasan, 2011). The impact of the deleveraging/releveraging process on the capital adequacy ratios of banks, although commonly omitted in the literature, is crucial in assessing Russia as credit growth in emerging markets tends to be more volatile than in advanced economies. This is also reflected in the higher volatility of capital needs due to higher volatility of credit exposures. Admittedly, this emerging economy phenomenon to some extent reflects lower levels of financial intermediation and catching-up needs, but it can also stem from the aggravated boom/bust cycles typical of these economies.

Our paper is structured as follows. Section 2 describes the main features of the Russian banking sector. Section 3 provides description of data sources and stress test methodology. Section 4 presents and discusses our results. Conclusions are provided in Section 5.

2. Main features of the Russian banking sector

Despite the large number of banks operating in Russia (955 at the end of 2010) and significant growth during the past decade (see Table 2.1), Russia's banking sector remains small and underdeveloped compared to economies of similar size. Indeed, banking sector assets only correspond to about 75% of GDP and only 40% of Russians have a bank account. Moreover, banking sector assets are concentrated in the major banks; the five largest banks hold almost half of the sector's total assets, and the 200 largest banks some 94%. Other banks are typically quite small, even if they might have regional significance. Growth in credit to companies and households contributed to increasing financial intermediation by banks in Russia during the past decade, but the ratio of domestic credit to GDP in Russia is still below 50% (over 100% in the Eurozone and China).

Table 2.1: Development of the main banking sector indicators (annual growth rates, %)

	2004	2005	2006	2007	2008	2009	2010
Total assets	27.3	36.6	44	44.1	39.2	5	14.9
Capital (own funds)	16.2	31.2	36.3	57.8	42.7	21.2	2.4
Corporate loans	38	31.3	39.8	51.5	34.3	0.3	12.1
Household loans	116.4	96.2	78.3	57.8	35.2	-11	14.3
Individual deposits	30.4	39.4	38	35.4	14.5	26.7	31.2
Corporate deposits	36.9	43.7	52.6	47.2	24.4	8.9	16.4

Source: Central Bank of Russia

Unlike most countries in Central and Eastern Europe, no major bank privatisation occurred in Russia. Its banking sector remains predominantly state-controlled to this day.[45] Sberbank and VTB, Russia's two largest banks, held IPOs in 2007 that lifted the private shareholdings in these banks to 40% and 23%, respectively. In October 2010, the Russian government approved a programme to sell shares in numerous large state enterprises including banks over the next five years. In February 2011, VTB conducted a second public offering that resulting in the sale of a further 10% stake. Even so, the Russian state still owns about 75% of VTB. Similarly, the Central Bank of Russia (CBR), which currently holds a 57.6 % stake in Sberbank, plans to retain a 50%-plus-one-share majority in the giant bank even after selling 7.6% of its shares in the near future. Although referred to as a "privatisation programme," the state will retain controlling voting shares in major banks and other "strategic" enterprises.

Like in other economies, Russia saw state control increase during the recent financial crisis. However, at the start of the crisis, state-controlled banks already accounted for over half of the Russian banking sector and all of the country's five largest banks were state-controlled. These big banks acquired other banks during the crisis, further strengthening their market positions. Foreign participation in the Russian banking sector remains low, but has been increasing over the years. The number of banks with foreign ownership rose from 174 in 2000 to 220 at the end of 2010. About half of these banks

[45] High participation of the Russian state in the banking sector is not related to the Russian debt crisis in 1998. Despite a lot of banks bankrupted as a consequence of this crisis, they were rather smaller with a short history in the market and low market share. Moreover, the most deposits from households were still concentrated in Sberbank as the biggest bank controlled by the state.

are majority foreign-owned. Three of Russia's "Top 10" banks are foreign-owned (see Table 2.2).[46]

Table 2.2: "Top 10" banks based on total assets and their market share (end of August 2011)

Bank	**% of total banking sector assets**	**Ownership**
Sberbank	27 %	State (CBR)
Bank VTB	9.7 %	State
Gazprombank	5.4 %	State (Gazprom)
Rosselhozbank	3.7 %	State
VTB-24	3 %	State
Alfa-bank	2.5 %	Domestic Private
Bank of Moscow	2.3 %	State*
UniCredit Bank	2.3 %	Foreign
Rosbank	1.7 %	Foreign
Raiffeisenbank	1.6 %	Foreign

Source: www.banki.ru
*Note: * through VTB*

Russia's banking sector succumbed to the financial crisis in the second half of 2008. While banks were not directly exposed to the financial instruments that triggered the crisis, they and the rest of the Russian economy were hit with the double-whammy of reduced access to foreign financing and a severe drop in oil prices.

The Russian government and CBR swiftly responded by implementing measures aimed at maintaining stability of the financial system. The emphasis was on liquidity support to the banks and maintaining stability of the ruble. The implemented measures included a temporary decrease in bank reserve requirements, CBR guarantees for interbank lending to qualified banks, non-collateralised central bank loans, widening the range of acceptable collateral for Lombard and repurchase operations, as well as auctions allocating free budgetary funds to the banks.

The deposit insurance framework was enhanced by increasing the deposit insurance limit, and Russia's deposit insurance agency assumed responsibility for restructuring individual troubled banks. Recapitalisation of banks was accomplished directly by the government in the form of capital support to state-controlled banks, or indirectly in the form of unsecured subordinated loans from the CBR and development bank

[46] Several foreign banks have recently decided to abandon their retail operations in Russia (Barclays, Banco Santander, HSBC). Moreover KBC is selling its stake in Absolut Bank and Rabobank plans to concentrate on other countries. Last year Morgan Stanley sold its local mortgage unit and Swedbank decided to curtail its operations as well. On the other hand, China Construction Bank has decided to enter the Russian market.

Vneshekonombank (VEB). In theory, both state-controlled and private banks had access to these subordinated loans, but the level of reliance on these loans depended on bank ownership. Private banks were recapitalised largely from other sources, while most of the capital increase of state-controlled banks was supplied in the form of subordinated loans. VEB was also given resources to help refinance foreign debt of Russian firms. These measures helped stabilise Russia's banking system and boosted the state's presence in banking as the government took over troubled banks via state-controlled firms or banks to preserve trust in the banking sector and avert bank runs.

3. Data and methodology

The state's extensive participation in the Russian banking sector has strong implications for the risk assessment for the sector. As borne out by the recent financial crisis, the Russian state has the will and resources to bail out troubled banks. Russia's interbank market, on the other hand, remains underdeveloped and dominated by the biggest banks. Most banks were shut out of the interbank market during the crisis, highlighting the lack of mutual trust in the banking community. Moreover, as most transactions are overnight, liquidity risk can be quite significant in Russian conditions, especially for smaller banks.

3.1 Data

To assess risks in the Russian banking sector more rigorously, we conduct a top-down macro stress test analysis. Unlike the bottom-up approach, the same models and assumptions are applied to all banks in our estimations.[47] Analysis is based on the balance sheet data of Russian banks as of end-2009. The 200 largest banks, which together hold about 94% of the Russian banking sector assets, are included in the analysis to assess banking sector vulnerabilities over a two-year horizon, i.e. we provide projections for 2010 and 2011. Our data come from the financial information agency Interfax, which collects and organises bank data from the CBR. Aggregate indicators covering the development of the Russian banking sector originate from the CBR and at the time of writing were available for 2010. Data describing the macroeconomic environment are taken from Rosstat.

3.2 Methodology

Our methodology links bank balance sheet data and the macroeconomic environment under different scenarios. Adverse macroeconomic shocks are translated into capital adequacy ratios to assess financial sector resilience. Risks on bank balance sheets (credit, market, contagion and income risks) are consistently covered within a single framework. Drehmann, Sorensen and Stringa (2008), who point out the importance of off-balance sheet items as a potential source of risk, saw their assertion recently

[47] Some central banks use a combined top-down/bottom-up approach, e.g. the Dutch central bank (see Van den End, Hoeberichts and Tabbae, 2006).

confirmed by the global financial crisis. Since these items are insignificant in the case of Russian bank balance sheets, however, we do not include them in our analysis.

We conduct the investigation in a dynamic framework in line with recent literature (Schmieder, Puhr and Hasan, 2011). For each item of assets, liabilities, income and expenditure, there is an initial (i.e. last actually known) stock to which the impact of the shock in one year is added. This final stock is then used as the initial stock for the following year. The changes in flow and stock variables are modelled in a consistent manner. Thus, losses reflected in a fall of profit (a flow indicator) will also be reflected in the same amount in total assets (a stock indicator). The dynamic nature of the analysis provides more realistic insights into banking sector vulnerabilities than sensitivity analyses or the commonly used static stress tests (Čihák, 2007). We cover credit, interest rate, exchange rate and contagion risk. However, liquidity risk is not part of our analysis. Liquidity stress test is typically conducted as a separate exercise from the conventional top-down macro stress test. The reason is a different time horizon under which the considered shocks are materialised. While the conventional macro stress tests employ from one to three years horizon, liquidity stress tests consider usually a few days or months. Hence, the liquidity stress test is difficult to integrate into the conventional stress test. Nevertheless, liquidity channels and fire sales increasing market risks should be carefully investigated as an integral part of the new macroprudential framework. More details on these issues could be found in e.g. Ong and Čihák (2010) and Schmieder at al (2012).

Our stress test analysis is performed in five steps:

(i) Creation of macroeconomic scenarios
(ii) Forecasting stress parameters by “satellite” models
(iii) Deduction of losses from bank capital
(iv) Iterative interbank contagion
(v) Computation of post-shock and post-contagion capital adequacy ratios.

In step one, we create two macroeconomic scenarios for 2010-11. These are generated on the basis of publicly available professional consensus forecasts (baseline scenario) and expert judgement (adverse scenario). The scenarios include real GDP, inflation, the exchange rate between the Russian ruble and the US dollar and short-term interest rate.[48] These variables are then used to project housing prices and the development of key credit variables, including nonperforming loans (NPLs) and total loans.

In the next step, econometric models for aggregate data linking NPL ratio growth, total banking loans growth and housing prices to past GDP growth and other lagged economic and financial variables are employed to forecast credit growth, nonperforming loan ratio growth and growth rate of housing prices for the baseline and the adverse scenario. These are estimated independently as follows:

[48] The parallel shift of the yield curve is assumed for simplification in further calculations.

$$gnpl_{t_{c,h}} = \alpha + \beta_{1_{c,h}} realGDP_{t-1} + \beta_{2_{c,h}} realGDP_{t-2} + ... + \beta_{k_{c,h}} realGDP_{t-k} + \lambda_{c,h} X + \varepsilon_{1t_{c,h}} \quad (2.1)$$

$$gLoans_{t_{c,h}} = \theta + \gamma_{1_{c,h}} realGDP_{t-1} + \gamma_{2_{c,h}} realGDP_{t-2} + ... + \gamma_{k_{c,h}} realGDP_{t-k} + \chi_{c,h} Y + \varepsilon_{2t_{c,h}} \quad (2.2)$$

$$gHousep_t = \mu + \delta_1 realGDP_{t-1} + \delta_2 realGDP_{t-2} + ... + \delta_k realGDP_{t-k} + \tau Z + \varepsilon_{3t} \quad (2.3)$$

where the lag structure is determined by statistical significance and X,Y and Z are vectors of other control variables such as nominal GDP, the NPL ratio, housing prices and household credit growth. These “satellite” models help us project credit growth and the NPL ratios for both the household (index h) and corporate (index c) sector consistently with the considered macroeconomic scenarios. The same growth rates are applied to all banks in the analysis. We apply univariate modelling approach due to limited data availability. Short time series and their different length for the modelled dependent variables do not allow for joint estimate in vector autoregressive framework. However, longer time series allowing joint estimate could better capture mutual interaction of the modelled variables and improve the overall stress testing framework in the future. Moreover, it would also allow non-linear modelling of the financial variables projected by the mentioned satellite models. This could better capture some more extreme scenarios (see discussion in the first chapter “Thought on the Proper Design of Macro Stress Tests”).

Satellite models are the crucial part of stress testing frameworks. However, all estimates are based on historical relationships and observations. Hence, the sample used in the estimation should include at least one crisis period in order to allow the parameters to be correctly calibrated. The satellite models employed within the applied framework is based on data sample which covers the recent financial and economic crisis. However, due to short time series and emerging nature of the Russian economy the estimated coefficients might change over time. Hence, regular stress testing of emerging markets economies require for regular satellite models re-estimation.

In the third step, we use our projected values and balance sheet data to calculate credit and market risks (including both foreign-exchange and interest-rate risks) for each bank over the two-year horizon. The value of risks is then deducted from total bank capital.

Market risk is evaluated based on the changes in interest rates and exchange rates. With respect to interest-rate risk, we consider changes in present values of investment securities available for sale (trading book), in particular corporate, foreign government, federal and municipal bonds. Their present value is influenced by changes in short-term interest rates that originate from the macroeconomic scenario under consideration. Again, the parallel move in the yield curve is assumed. As data on duration are not available at the level of individual banks, we estimate average duration for available securities on the Russian market. We split securities into corporate bonds, federal loans, municipal bonds and foreign government bonds. Based on CBR (2010) data for the sector, the same durations are assumed for all banks (1.7 for corporate bonds, 4.3 for federal loan and municipal bonds and 1 for foreign government bonds). Finally, the sum of the changes in values for all mentioned segments based on standard Macaulay duration is calculated for the interest-rate risk of every bank. Exchange-rate risk for

each bank is calculated as the product of the net-open foreign exchange position and the change in the exchange rate resulting from the macroeconomic scenario under consideration. Hedging against foreign exchange risk is not taken into account (as this information is not available) so that foreign exchange risk might be overestimated in some cases. The same caveats also apply to the interest-rate risk calculation.

Credit risk is traditionally the key risk for banks. This is particularly true for the Russian banking sector, which is mainly involved in commercial banking. The Russian economy was strongly affected by the crisis and experienced a sharp fall in economic output in 2009. As a result, NPLs in the local banking sector rose considerably. This increase in credit risk took place against the backdrop of a pronounced local boom-bust cycle. Annual credit expansion rates exceeded 40% before the crisis, collapsed to -2.5% during the crisis in 2009, and then rebounded to over 12% growth in 2010. Credit risk built up during the boom period in which lending standards were lowered materialised during the bust period when credit growth collapsed, leading with some time lag to a sharp rise in nonperforming loans. This is in line with the evidence from other countries. For example, Jiménez and Saurina (2006) look at the Spanish data and show that credit granted during "good times" has a greater likelihood of ending up in default than loans made during recessions.

Due to the crucial impact of credit risk on bank balance sheets, macroeconomic credit-risk modelling often links credit risk and macroeconomic environment. Some researchers highlight the nonlinear relationship between macroeconomic shocks and credit risk (e.g. Čihák, 2007; Jakubík, 2007). Moreover, the non-linear logistic function originally introduced in credit-risk modelling by Wilson (1997a, 1997b) is often employed in credit-risk modelling.[49] If appropriate data is available, probability of default can be modelled directly (Hamerle, Liebig and Scheule, 2004). However, this information is rarely available, so NPL data are employed in credit-risk modelling. This is also the case here.

For the analysis, we calculate credit risk for each bank, distinguishing between corporate and household loan portfolios. Expected credit losses are calculated as the product of the average probability of default (PD) for the loan portfolio, the exposure at default (EAD) and the loss given default (LGD). Due to the lack of LGD data for individual banks, we use the sector averages for corporate, household and other exposures (59% for corporate exposures, 55% for households and 58% for others) based on estimation performed by rating agencies as initial values for 2009.[50] The LGD projection uses a simple econometric model for housing prices. The exposure at default can be expressed as the difference between outstanding loans and NPLs. Projected NPLs depend on new NPLs (determined by PD estimates), outflows (as write-offs or selling-out of existing NPLs) and the current stock of NPLs. This is expressed formally as:

[49] See Boss et al. (2006), Boss et al. (2009), Virolainen (2004) and Jokivuolle, Virolainen and Vahamaa (2008) among others.

[50] Moody's Global Banking report for Russia was used for calibration - see Moody's (2010).

$$NPL_{t+1} = NPL_t + PD_t \cdot (Loans_t - NPL_t) - r \cdot NPL_t, \qquad (2.4)$$

where r represents the average write-off (or sell-out) rate of existing NPLs. In practice, this parameter can be unstable over time. For instance, in times of crisis, banks may increase the pace of write-offs to clean up their portfolios. This parameter is hard to model, so we set a constant value based on common practices in the Russian banking sector and anecdotal evidence. We employ the value 10% for corporate and other exposures, and 20% for household exposures.[51]

The estimated regression models for growth in the NPL ratio (gnpl) and credit growth (gLoans) are then used to indirectly derive the probability of default for loans to corporations and households separately. The growth of the NPL ratio can be expressed by the growth rate of NPLs' stock and credit growth, i.e.:

$$gnpl_t = \frac{gNPL_t + 1}{gLoans_t + 1} - 1 \approx gNPL_t - gLoans_t \qquad (2.5)$$

where

$$gNPL_t = \frac{NPL_t - NPL_{t-1}}{NPL_{t-1}} \qquad gLoans_t = \frac{Loans_t - Loans_{t-1}}{Loans_{t-1}}$$

The expected probability of default (PD) is derived from the NPL ratio and credit growth projections. Probability of default is calculated as:

$$PD_t = (gNPL_{t+1} + r)npl_t. \qquad (2.6)$$

Equation (2.6) suggests that the portfolio-average PD depends on the average write-off rate (r), the initial level of the NPL ratio and the growth rate of NPLs, calculated as:

$$gNPL_t = (gnpl_t + 1)(gLoans_t + 1) - 1. \qquad (2.7)$$

[51] These numbers imply that banks on average keep bad loans on their balance sheets for ten years in the case of corporate and other exposures, and five years in case of household exposures, before they write off or sell them.

To account for unexpected losses, we use the Basel II formula as it considers changes in risk-weighted assets (RWA). This allows us to project RWA so that the deleveraging/releveraging effects that characterise the high volatility of Russian credit growth can be taken into account by satellite models for credit growth.[52] RWA change also affects bank risk profile.

For the calculation of credit risk, we assume all banks behave as if they were complying with the Basel II framework, even if it is not fully implemented in Russia. Hence, the loan portfolio is split into corporate loans, retail loans and other loans. Credit risk is computed using separate formulas as indicated in the Basel II framework. For the capital requirement for corporate loans, we proceed as follows:

$$\text{Correlation (R)} = 0.12 \times (1 - EXP(-50 \times PD)) / (1 - EXP(-50)) + 0.24 \times [1 - (1 - EXP(-50 \times PD))/(1 - EXP(-50))] \quad (2.8)$$

$$\text{Maturity adjustment (b)} = (0.11852 - 0.05478 \times \ln (PD))^2 \quad (2.9)$$

$$\text{Capital requirement (K)} = [LGD \times N [(1 - R)^{-0.5} \times G (PD) + (R / (1 - R))^{0.5} \times G (0.999)] - PD \times LGD] \times (1 - 1.5 \times b)^{(-1)} \times (1 + (M - 2.5) \times b) \quad (2.10)$$

In the case of capital requirement for retail loans, we use the following:

$$\text{Correlation (R)} = 0.03 \times (1 - EXP (-35 \times PD)) / (1 - EXP (-35)) + 0.16 \times [1 - (1 - EXP(-35 \times PD))/(1 - EXP(-35))] \quad (2.11)$$

$$\text{Capital requirement (K)} = LGD \times N[(1 - R)^{-0.5} \times G(PD) + (R / (1 - R))^{0.5} \times G (0.999)] - PD \times LGD , \quad (2.12)$$

where N denotes normal distribution function and G inverse normal distribution function. For “other loans,” the same formula as for corporate loans is applied. The capital requirement for market and operational risk are assumed to grow at the same rate as the capital requirement for credit risk.

Expected losses are calculated separately for credit and market risk, and then deducted from total capital. Unexpected losses are covered by the Basel II formula so as to take into account the change in risk-weighted assets:

[52] This approach is in line with Schmieder et al. (2011). It was previously also applied by Jakubík, Schmieder (2008).

Expected losses (EL) = EAD * PD * LGD (2.13)

Risk-weighted assets (RWA) = K x (1/MCAR) x EAD, (2.14)

where EAD denotes exposure at default and MCAR is the minimum capital adequacy ratio (10% for Russia).

Losses stemming from the described credit and market risk calculations can to some extent be covered by available net income. Therefore, bank income is taken into account as the first line of defence against the losses. In particular, it is assumed that banks will use all available income to sustain their capital adequacy ratio at the same level when hit by a financial shock. If income is insufficient to fully absorb the losses emerging in the macroeconomic scenario under consideration, the losses are deducted from bank capital. Net income is computed as a sum of net interest income and non-interest income. The change in interest rate based on considered scenario and average net-interest income over last three years is considered to project the total net-interest income. Non-interest income is projected as an average over last three years.

In the fourth step of our analysis, we take into account possible interbank contagion. After losses are deducted from bank capital, a mapping of capital ratios into the probability of default of the respective bank (bank-specific PD) is used to determine the likelihood of the bank under consideration defaulting on its interbank liabilities to other banks. To consider interactive rounds of interbank contagion, we approximate bilateral interbank exposures, which are unavailable, using the maximum entropy principle proposed by Upper and Worms (2002).[53] Losses are computed using the default on interbank liabilities. Approximated bilateral interbank exposures are then multiplied by a bank-specific PD derived from an expert-based mapping (see Table 2.3 below) of post-shock capital adequacy ratios into PDs. The LGD on a bank default is assumed to be 10%.

[53] Off course it would be better to employ actual exposures rather than approximate them via maximum entropy algorithm. Unfortunately, only the total exposures are available for the considered banks. Hence, the applied algorithm generates bilateral interbank exposures, assuming spreading the total exposures among all banks. However, in practice only some bank might be interconnected.

Table 2.3: Mapping of bank CAR into PD

CAR >=	PD
14.00%	0.00%
12.00%	0.01%
10.00%	0.05%
8.00%	5.00%
7.00%	15.00%
5.00%	50.00%
3.00%	80.00%
<3.00%	100.00%

The resulting losses are deducted from the capital of the affected banks. Ten iterations of such interbank contagion rounds are taken into account.

In the last step of our analysis, post-shock and post-contagion CARs that take into account the shock and interbank contagion are computed as average of the banking sector and bank-by-bank capital adequacy ratios. Possible recapitalisation costs that would arise if the capital adequacy ratio of a bank falls below the minimum regulatory requirement (10%) are computed as a proportion of GDP. Recapitalisation for the top 200 banks is scaled up to reflect their share of total banking sector assets.

The applied methodological approach does not allow feedback between the macro and financial variables and therefore can underestimate the impact of the shocks. This issues is further elaborated in the next chapter “How Important Is the Adverse Feedback Loop for the Banking Sector?”.

4. Empirical analyses

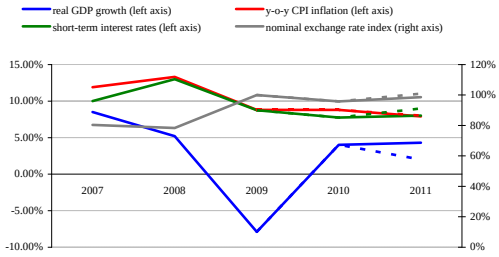
In this section, we present the results for the banking sector as a whole and the results for banks categorised on the basis of ownership and size.

4.1 Results for the banking sector overall

The results of stress test analysis suggest that the Russian banking sector is quite sensitive to changes in the macroeconomic environment. High credit risk and cyclicality typical of emerging markets combined with the low level of financial intermediation appear to dampen economic development under our baseline scenario. While this likely reflects the low level of financial intermediation and catching-up needs of Russia, it also is an indication of aggravated boom/bust cycles. The CAR improvements in the Russian banking sector seen during 2009 and 2010 seem to be largely driven by deleveraging.

Results of the macro stress test

Chart 2.1
Macroeconomic scenarios
(%)



Note: An increase in the nominal exchange rate index means depreciation.
Solid line referes to "Baseline", dashed line to "Adverse" sceanrio.

Chart 2.2
Credit growth for both scenarios
(%, year-on-year)

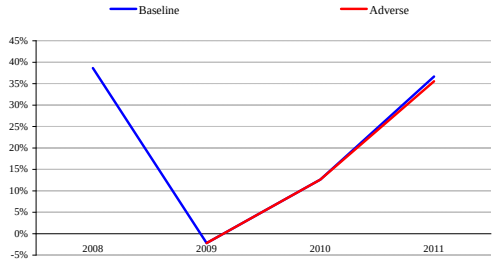


Chart 2.3
NPL ratios for the scenarios
(% of total loans)

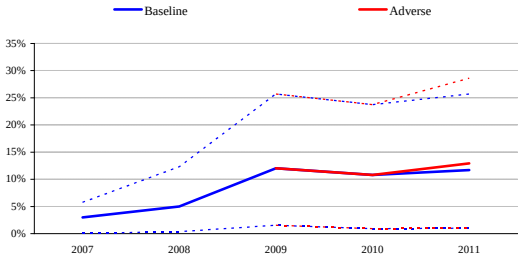
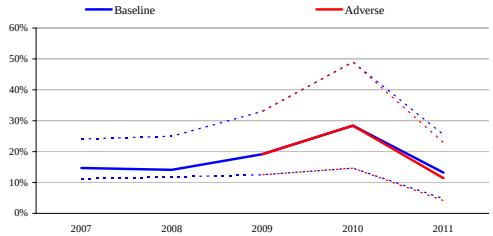


Chart 2.4
CARs after interbank contagion
(%)



Source: Bank of Finland Institute for Economies in Transition and ECB calculations.
Note: Capital adequacy and non-performing loan ratios refer to the average (solid lines) and the 10th and 90th quantile (dashed lines) for the 200 largest banks by total assets.

Banks on average appeared to be adequately capitalised at the end of 2010. The macroeconomic recovery that started in 2010 continues in 2011 under the baseline scenario. This is reflected in an acceleration of credit growth that, after the decline during the crisis, turns positive in 2010. The rate of credit growth is predicted to more than double in 2011, which might constitute a threat for certain banks. Even if the NPL stock stabilises, certain banks might not be able to bear acceleration in credit growth that puts downward pressure on their capital adequacy ratios. Based on our calculations and provided that banks are unable to raise additional capital from other sources, the CAR for 67 banks out of 200 included in our sample would fall below the regulatory minimum of 10% in 2011 and the total recapitalisation costs would reach 0.6% GDP in 2011. On the other hand, profitability of the banking sector in 2010 outpaced even pre-crisis levels, which would help improve the situation of some banks in 2011. Moreover, state-controlled banks could be recapitalised easily by the government and state support for domestic private banks could also be provided via state-controlled companies as in 2008 and 2009. In addition, some banks will have to increase their registered capital

anyway when new minimum capital requirements of RUB 180 million (about €4.6 million) enter into force at the beginning of 2012.[54]

Under our adverse scenario, which assumes only sluggish growth in 2011, the situation deteriorates further. As the macro data for 2010 and much of 2011 are already known, it is clear that this scenario is only hypothetical. The NPL ratio increases under the scenario to about 13%, while the average CAR for all banks included in our analysis remains above the regulatory minimum.[55] Some 80 banks out of the 200 in our sample would need recapitalisation in 2011.[56] Total recapitalisation costs during 2011 would reach as high as 0.8% of GDP.

Taking into consideration Russia's low public debt-to-GDP ratio (just below 10% at the end of 2010), the government is fully able to recapitalise banks under each scenario without facing significant fiscal strains. Despite this, our analysis highlights some weaknesses in the Russian banking sector. The currently large average capital buffer (18.1% at the end of 2010) was partly the result of a substantial slowdown in credit growth (from over 40% of annual nominal credit growth in pre-crisis period to decrease of about 2.5% in 2009). As the economy recovers, high credit growth can put downward pressure on the CAR from the increase in risk-weighted assets and banks tightening credit conditions. Thus, economic recovery could be dampened as access to external financing worsens, especially for medium-sized and small firms. Here, the capacity of the Russian banking sector to maintain pre-crisis credit growth without generating additional risk would be limited. This reinforces the views that Russia's banking sector is under-dimensioned for the size of the economy and that private sector actors still face serious constraints in access to bank financing. Even today, Russian corporations tend to rely on financing obtained from global markets if they can get it.

[54] Minimum capital requirements at the time of writing were RUB 90 million. In December 2011, however, the president signed a new law that incrementally raises the minimum capital requirements for existing banks to RUB 300 million (about €7.4 million) by 2015.

[55] This number has been adjusted to obtain the value comparable with the commonly used practices and does not correspond to officially reported numbers provided in section 2.

[56] These results are in line with the stress test results conducted by the Central Bank of Russia (CBR, 2011), whereby about a third of all Russian banks would need to be recapitalised under our adverse scenario. The CBR results are based on bank-level data as of end-2010.

Individual results of macro stress tests

Chart 2.5

CAR, baseline and adverse scenario in 2011 (%)

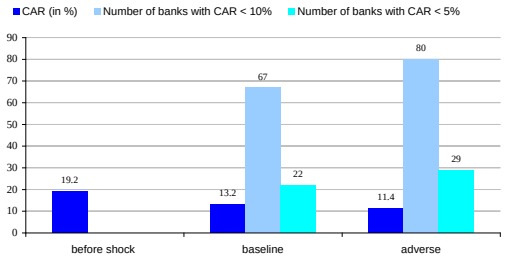


Chart 2.6

CAR and NPL ratios for baseline scenario in 2011 Note: CAR (%) is on the horizontal axis and NPLs (% of total loans) are on the vertical axis.

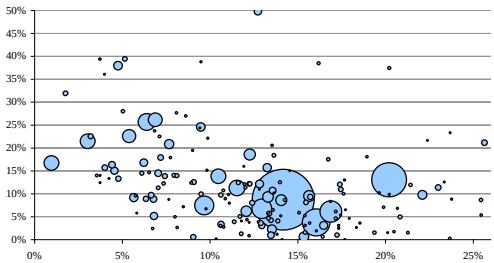
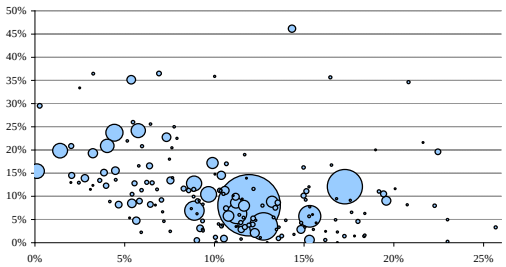


Chart 2.7

CAR and NPL ratios for adverse scenario in 2011

Note: CAR (%) is on the horizontal axis and NPLs (% of total loans) are on the vertical axis.



Source: Bank of Finland Institute for Economies in Transition and ECB calculations.

4.2 Results by ownership

One of the distinctive features of the Russian banking sector is the substantial role of the state. While state-controlled banks are tacitly assured of being bailed out in case of financial distress, this tells us nothing about how vulnerable these banks actually are to macroeconomic downturns. To investigate this question, we divide banks in our sample into three categories according to ownership. Foreign-owned banks are those where foreign ownership share exceeds 50%. State-controlled banks are identified based on the data from Vernikov (2009) updated at BOFIT. The last group consists of private domestic banks.

Our analysis reveals that all types of banks are highly sensitive to macroeconomic development in the country. In line with the above-described results for the entire banking sector, the CAR of banks in all subgroups drops significantly in 2011 (even under the baseline scenario). The average CAR of foreign-owned and domestic private

banks drop to near the regulatory minimum. The situation of state-controlled banks seems a bit better as the starting level of CAR was higher for these banks; their average CAR does not fall below 15% under baseline scenario in 2011. Moreover, state-controlled banks can rely on relatively stable household deposits and access to CBR financing as necessary.

Foreign-owned banks seem most vulnerable. Almost half of foreign-owned banks under the baseline scenario and over half under the adverse scenario see their CARs fall below the regulatory minimum without infusions of fresh capital. The recapitalisation costs here amount to almost 0.3% of GDP under the baseline scenario, and even higher under the adverse scenario for 2011. Prior to the European debt crisis, at least, the working assumption was that these banks have strong parent companies that would have little trouble providing additional capital infusions under normal circumstances.

Similar recapitalisation costs as in the case of foreign-owned banks would be necessary for domestic private banks. Some 30% of these banks under the baseline scenario and 40% in the adverse scenario would have CARs lower than the regulatory minimum required by Russian regulator (10%). For some of these banks, it could be challenging to increase their capital. Nevertheless, they can become interesting targets for acquisition by other banks. Russia's state-controlled banks have grown recently by acquiring other banks, a trend that undoubtedly strengthens the role of state-controlled banks in all segments of the market.

Under our adverse scenario, the situation worsens for foreign-owned and domestic private banks. The average CAR falls below the regulatory minimum for these subgroups of banks in 2011.

Results of macro stress test for ownership subgroups

Chart 2.8
STATE-CONTROLLED BANKS
CAR after interbank contagion
(in %)

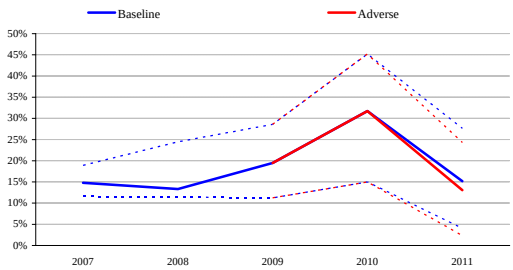


Chart 2.9
FOREIGN-OWNED BANKS
CAR after interbank contagion
(in %)

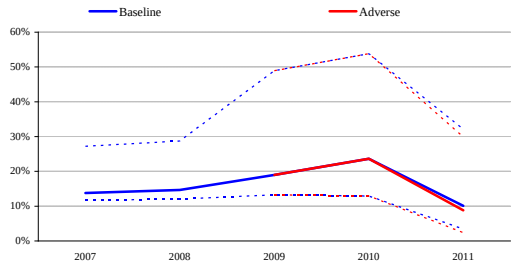
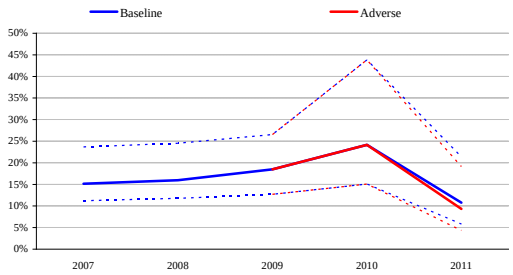


Chart 2.10
DOMESTIC-PRIVATE BANKS
CAR after interbank contagion
(in %)



Source: Bank of Finland Institute for Economies in Transition and ECB calculations.
Note: Capital adequacy and non-performing loan ratios refer to the average (solid lines) and the 10th and 90th quantile (dashed lines) for the 200 largest banks by total assets.

4.3 Results by size

The fact that the Russian banking sector is so concentrated increases the relative importance of its largest banks. It is therefore prudent to analyse the results of our stress tests for different sized banks. We divide the banks in our sample into three categories (large, medium and small) based on total assets. We apply two different sets of criteria

to divide the banks into these subgroups,[57] but both produce the results we now describe.

Our analysis suggests medium-sized banks are the most vulnerable. Even under the baseline scenario, about half of medium-sized banks end up with CARs lower than the regulatory minimum and the average CAR for all medium-sized banks drops below the minimal level. On the other hand, the average CAR of both large and small banks does not fall below the 10% minimum even under the adverse scenario. Large and small banks tend to be a bit better capitalised than medium-sized banks, but their CAR declines are also not as sharp. Medium-sized banks are systemically important, since they are large enough to precipitate major bank runs.[58] The recapitalisation costs that would be necessary for medium-sized banks under adverse scenario provided that they were not able to raise new capital otherwise, would reach approximately 0.3% of GDP.

Unlike medium-sized banks, small banks seem largely resilient to deterioration in the macroeconomic environment. A possible explanation for this phenomenon might be that they typically operate within a small region and focus on some specific businesses they know well. Such a strategy likely makes it easier to manage risk. Moreover, small banks on average hold substantial capital buffers. On the other hand, in comparison to large banks it is more difficult and more costly for medium-sized banks to acquire capital which makes them more vulnerable than large banks.

[57] The large banks are Russia's ten largest banks by assets. Medium-sized banks are defined as either the eleventh to thirtieth largest banks, or alternatively, as the eleventh to fiftieth largest banks. The remaining banks in the Top 200 are considered as small banks.

[58] Despite medium-sized banks can be important for the overall Russian banking sector stability, they still shall not be treated as Globally Systemically Important Financial Institutions.

Results of macro stress test for size subgroups

Chart 2.11
LARGE BANKS
CAR after interbank contagion
(in %)

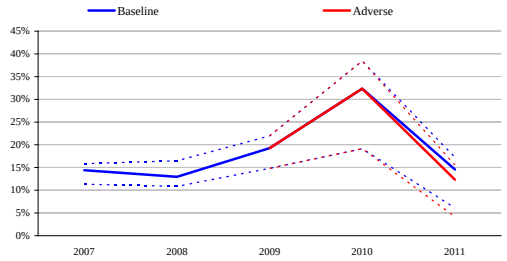


Chart 2.12
MEDIUM-SIZED BANKS
CAR after interbank contagion
(in %)

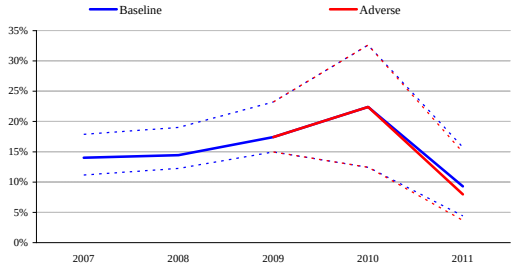
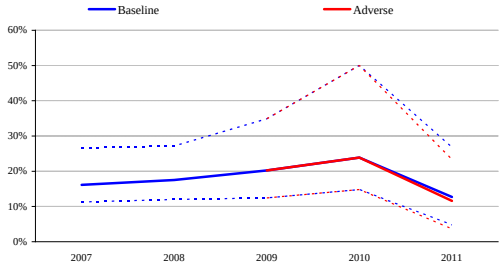


Chart 2.13
SMALL BANKS
CAR after interbank contagion
(in %)



Source: Bank of Finland Institute for Economies in Transition and ECB calculations.
Note: Large banks are defined as the ten largest banks by assets, medium-sized as the eleventh to thirtieth largest banks and the rest are considered to be small. Capital adequacy and non-performing loan ratios refer to the average (solid lines) and the 10th and 90th quantile (dashed lines) for the 200 largest banks by total assets.

4. Conclusions

A healthy financial sector is necessary for sustainable economic growth. Hence, it is crucial to assess risks and potential vulnerabilities of the banking sector. Our paper proposes a top-down stress test methodology that employs relatively limited information. This is especially important in emerging markets where short time series, structural breaks and limited data availability with absence of reliable market data can make banking sector analyses quite challenging. Moreover, credit growth in emerging economies tends to be rather volatile, especially when compared to advanced economies. This aspect of emerging economies has an important implication for choice of stress testing methodology as such volatility influences risk-weighted assets (RWA) in bank portfolios. While a commonly used static framework assuming constant balance sheet items over the projected horizon can be sufficient for an advanced economy, it can substantially bias the results for emerging economies where the amount of total loans can as much as double over a short period of time. Thus, a dynamic approach projecting key balance sheet items may better capture the high volatility of credit growth typical of emerging economies. Despite the proposed methodology is used to assess the Russian banking sector, it can be also applied to other emerging bank-based markets. The above described methodology with some adjustment was also applied to the banking sectors of Ukraine, Turkey, Croatia and Serbia for financial stability assessments. Moreover, similar methodology was recently implemented in Turkey and Serbia within the technical cooperation projects of The Central Bank of the Republic of Turkey and National Bank of Serbia with the European Central Bank (Central Bank of the Republic of Turkey, 2011).

Moreover, proper analysis of banking sector vulnerabilities is essential to address potential financial instability in an adequate and timely manner. Stress tests constitute an important part of financial stability assessment that helps regulators and policymakers respond appropriately to changing macroeconomic conditions.

Russia's financial system is bank-based. Important sources of risk in the sector can be easily overlooked in aggregate banking sector numbers. Hence, we employ individual bank level data to detect possible banking sector vulnerabilities. A top-down macro stress test approach is applied here to assess stability of the Russian banking sector. We consider the 200 largest banks which constitute 94% of the banking sector's assets. Using stress test framework we consistently evaluate risks on bank balance sheets (credit, market, contagion and income risks). Moreover, the employed dynamic approach allows us to capture impact of re/de-leveraging effect on banks' balance sheets which is especially important for emerging markets like Russia. We analyse the banking sector as a whole, as well as the resilience of subgroups based on bank size and ownership. The applied two-year horizon is shown to better explicate the long-term nature of credit risk that the commonly used one-year horizon.

Our analysis backs up the view that the Russian banking sector is under-dimensioned for the size of the economy and that the private sector is likely to face difficulties in obtaining external financing when macroeconomic conditions deteriorate. The Russian banking sector remains dominated by state-controlled banks that are less vulnerable to global financial problems than foreign-owned banks. In any case, the government still has sufficient fiscal space to recapitalise the banks in a downturn. This was illustrated in summer 2011 with the massive public rescue of Bank of Moscow with a $14 billion bailout package. Our analysis further shows that medium-sized banks are on average more vulnerable than large and small banks.

As a policy note, Russian banks in general should be expected to bolster their capital as economic growth recovers. Here, it is important to keep in mind that we assume no increase in bank capital in our calculations. In general, when considering the situation in pre-crisis years, bank capital was growing at about 38% on average in the period 2001−2007. If the banking sector returns to growth, only some banks for which we have identified CARs below the minimum requirement would actually face this situation. Nevertheless, the limited ability of the banking sector to finance the real sector could curtail Russian economic growth over the medium and long term.

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How Important Is the Adverse Feedback Loop for the Banking Sector?

Published as

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Abstract

Current regulatory framework for EU banks can have potential procyclical effects. Under certain conditions, procyclical behaviour of the banking sector can lead to an adverse feedback loop whereby banks, in response to an economic downswing, engage in deleveraging and reduce their lending to the economy in order to maintain the required capital adequacy ratio. This then further negatively affects economic output and impacts back on banks in the form of, for example, increased loan losses. This effect was simulated on the example of the banking sector of a selected EU country, namely the Czech Republic. The simulation results point out that under certain assumptions the feedback loop may play an important role.

Keywords: *procyclicality; feedback loop; bank regulation; deleveraging*

JEL Classification: G21, E44, E47

1. Introduction

One of the issues that have taken centre stage in the international debate on the lessons of the global financial crisis is that of procyclicality of the financial system. Procyclical behaviour of the financial system, and especially of banks, means that financial intermediaries amplify swings in economic activity. This might be of higher relevance especially for the EU countries with traditionally bank-based financial system. Procyclical behaviour can have particularly serious implications in an economic downturn, as under certain assumptions it can considerably prolong and deepen the recession via a feedback effect on the economy.

This paper sets out to describe the main arguments of the current debate on financial system procyclicality and to give an overview of the current regulatory proposals for reducing procyclicality. To illustrate the seriousness of the effects of the potential strongly procyclical behaviour of the financial sector on a selected EU economy, the adverse feedback loop was simulated for the case of an adverse scenario for the Czech Republic. This is a useful case study as the banking system in this particular EU country is a typical example of an integrated financial system with the rest of the EU, as majority of banks in the Czech Republic are foreign-owned mostly by other EU institutions. Ideally, one would like to provide an empirical analysis of this phenomenon for the EU as a whole, but the data limitations are preventing us to do so.

The paper is structured as follows. Section 2 examines the sources of procyclicality of the financial system and summarises the debate on three related areas of regulation: provisioning, accounting rules for revaluation of financial assets and the procyclical effect of the current Basel II bank capital regulatory framework. This section also provides a brief overview of the tools that can be used to reduce procyclicality of the financial system. Section 3 describes the methodology of the simulation of the feedback effect that relies on the stress testing framework used by the central bank of the Czech Republic. Section 4 shows the results of an empirical simulation of the adverse feedback loop for the case of the Czech economy, using bank-by-bank data as well as projections of macroeconomic and financial variables. Section 5 compares the adverse scenario with real developments in 2010 and draws some policy implications. In the conclusion, the main findings from the synoptic and empirical sections are summarized.

2. Procyclicality of the Financial System

Procyclicality is usually defined as the magnification of swings in the economic cycle by financial sector activities, most notably bank lending. It is caused by a whole range of interconnected factors, such as information asymmetry, fluctuations in balance-sheet quality, over-optimistic (or over-pessimistic) expectations, herd behaviour by market participants and financial innovation. Besides the natural sources of

procyclicality, financial regulation and the accounting rules for revaluation of financial assets in financial institutions' balance sheets can play an important role.

The main determinants of the credit cycle are discussed in the literature connected with the cyclical nature of bank lending. Numerous studies have shown a positive correlation between GDP and the credit cycle (e.g. Calza, Gartner and Sousa, 2001). The profitability of corporate projects and credit demand rise in line with economic activity and productivity. Conversely, banks react to rising macroeconomic uncertainty by reducing the supply of credit (Quagliariello, 2007). Koopman, Kraussl, Lucas and Monteiro (2009) demonstrate empirically that GDP is the most significant indicator affecting bank lending.[59] Macroeconomic fluctuations affect not only the volume of loans in the economy, but also credit standards. De Bondt et al (2010) demonstrated on data for the euro area countries that credit standards are tightened at times of economic contraction and softened at times of economic growth. Moreover, low interest rates cause credit standards to be softened (Bernanke et al., 1999; Maddaloni and Peydró, 2010).

Another natural source of procyclicality is the way in which risks are measured and managed. Problems distinguishing between short-term swings and longer-term trends and estimating robust correlations between market and economic variables, together with the use of risk management techniques that take into account relatively short periods of past observations, can cause risks to build up in an expansion phase (Borio, Furfine and Lowe, 2001). This phase usually results in growth in optimistic expectations, leading to rising leverage of financial and non-financial institutions at times of growth.

Simultaneously, the need to create a buffer of reserves for the adverse phase of the cycle is underestimated during the growth phase. During the subsequent economic slowdown, measured risk rises sharply and leverage falls, with mutually reinforcing effects on the financial and non-financial sectors in a situation where financial institutions have inadequate capital and other buffers. This is indirectly supported by the current regulatory and accounting system. The prevailing system of provisioning for bad assets which is based on incurred (i.e. observed) losses leads to low provisions in good times and a rapid increase in provisions in bad times that can drag on capital and push banks to behave procyclically. Additional role is played by the accounting rules for revaluing financial assets using market prices. The application of "mark-to-market" techniques for valuing financial assets (fair value accounting) can foster procyclicality of the financial system, particularly given the assumption that market prices are themselves procyclical because of over-optimism or imperfections in risk measurement and management (Novoa, Scarlata and Sole, 2009).

[59] Eickmeier, Hofmann and Worms (2006) show that the fall in lending in Germany in 2000 – 2005 was driven by an adverse supply shock.

Finally, one source of procyclicality of the financial system is the current Basel II regulatory framework (BCBS, 2006; Gordy and Howells, 2006). Basel II requires banks to hold higher capital if the risks associated with holding financial assets (loans and securities) rise. This is because the capital requirement for credit risk, at least in the more advanced Internal Ratings Based approach on (IRB), is a function of the probability of default (PD), the loss given default (LGD) and the exposure at default (EAD), whose values and correlations can change according to the phase of the economic cycle.[60] An economic contraction will thus generate, via growth in PD and LGD, a need for higher capital requirements, which, given certain assumptions, can lead to a decrease in lending to the real economy ("deleveraging"). Such a decrease, however, can produce a further negative effect on the real economy and a further increase in PD and LGD with a subsequent further increase in the capital requirements (Benford and Nier, 2007). The assumptions for strongly procyclical bank behaviour are discussed in detail in section 3.

At least since the global financial crisis erupted, numerous international initiatives have been examining how regulatory, macro-prudential and accounting principles can mitigate procyclicality of the financial system. First, as to the provisioning rules, efforts are being made to find a provisioning mechanism that will ensure timely recognition of loan losses and reduce the sensitivity of financial institutions to cyclical fluctuations in the economy (EC, 2009; 2010). However, this is generating a conflict between macro-prudential regulation and current accounting principles. Advocates of the macro-prudential concept are pushing for the introduction of a provisioning system that would ideally cover expected losses over the entire economic cycle. This concept, implemented, for example, under the name "dynamic provisioning" in Spain in 2000, is aimed at enabling banks to build up a capital buffer in good times that can be used in bad times (De Lis, Pages and Saurina, 2000).[61] By contrast, the accounting authorities prefer information provided to investors to be verifiable and object that dynamic provisioning allows profit to be manipulated and artificially smoothed on the basis of "excessive" provisioning in times of boom. The conflict between the regulatory and accounting views of loan loss provisioning is examined in, for example, Borio and Lowe (2001) and Frait and Komárková (2009). In January 2011, both relevant bodies in this area (i.e. International Accounting Standards Board, IASB, and US Financial Accounting Standards Board, FASB) issued a joint proposal on provisioning favouring better accounting for future credit losses. However, the proposal will have to go through

[60] The risk of procyclicality was taken into account when Basel II was being prepared and some countercyclical elements, such as a requirement for conservative PD and LGD estimates (ideally covering the entire business cycle and containing a conservative buffer) were incorporated into the overall framework. In addition, under Basel II the time series used to estimate the models should cover essentially the entire economic cycle, bank portfolios should be tested for resilience to extreme shocks, and the models used should be validated and backtested.

[61] Saurina (2009) suggests that the dynamic provisioning system played a positive role in maintaining the stability of the Spanish banking sector during the global financial crisis.

a number of commenting rounds and discussions before it will be ready for implementation.

Second, as to the mark-to-market valuation, an IASB (2009) is proposing reduction of categories of financial assets from four to two – those measured at amortised cost and those measured at fair value. Third, the tools further include a BCBS proposal within its Basel III package to introduce leverage limits on banks. This leverage ratio would be used as a safeguard against excessive growth in banking transactions and underestimation of risks undertaken at times of economic growth. The leverage ratio should be introduced fully only in 2018, but since 2013 it could be applied by supervisors for selected banks.

Finally, as to the procyclicality of capital requirements, options are discussed to smooth the capital requirements over time without losing the ability to differentiate between risks. This can be achieved by, for example, reducing the cyclicality of the parameters inputted into the capital adequacy calculation or by smoothing the already calculated capital requirements, i.e. to create countercyclical capital reserves on top of the minimum capital requirements. The Basel III package opted for the latter solution via introduction of the so-called countercyclical capital buffer which should be created in good times and released (i.e. serve to cover losses) in bad times (Geršl and Seidler, 2011). The size of the buffer should be based on the judgment of the national regulatory authority as to the accumulation of systemic risk and as a first guide, the departure of amount of credit in the economy from its long-term trend should be used.

3. Description of the Methodology and Data for Simulation of the Feedback Loop

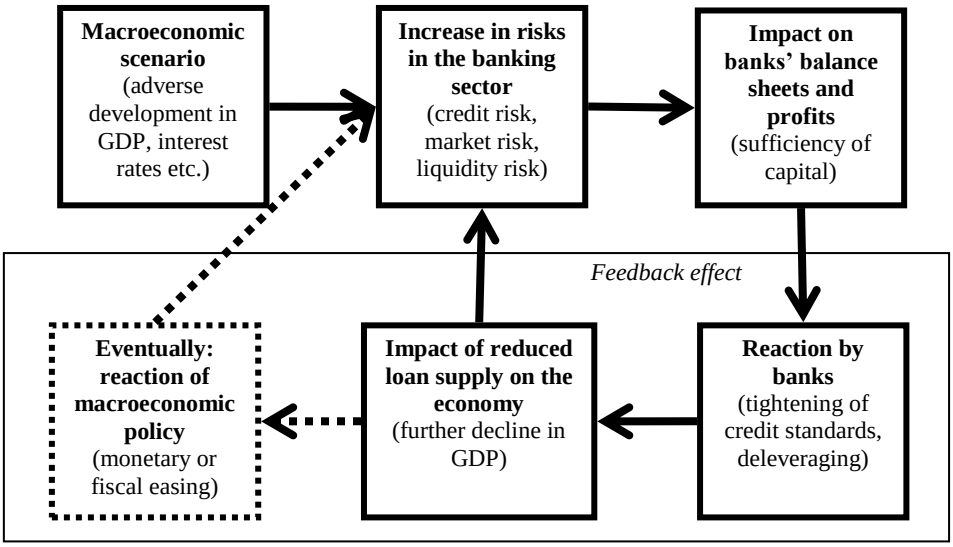
In our simulation, we were inspired by the developments at the outset of the 2007 – 2009 global financial crisis. In its initial phase, banks worldwide incurred substantial losses on assets linked to the sub-prime segment of the US mortgage market. When falling economic output in most economies started to lead to growth in credit risk in the traditional segments of households and corporations, concerns arose about the impact of the potential stronger procyclicality of the then newly implemented Basel II.[62] This uncertainty was exacerbated by the fact that the new regulatory framework was untested by crisis and contained certain procyclical elements.

The main source of concern was the fact that rising credit risk was leading, via growth in PD (and possibly also LGD), to growth in risk-weighted assets (or capital requirements) in a situation where bank capitalisation had already been significantly weakened by losses from toxic assets. Growth in risk aversion and the globally synchronised recession, moreover, effectively eliminated any privately funded capital increases. To stop their capital adequacy ratios falling below a certain threshold, banks had to radically reduce their exposures to the real sector (and tighten their credit

[62] Basel II was implemented in most European economies in 2007.

standards) and thus reduce their risk-weighted assets. This deleveraging process, however, could have adverse consequences for the economy and feed back to the banking sector, as a fall in lending to the real sector would inevitably lead to a further decline in economic output and thus to further growth in credit risk (the feedback effect). This growth could lead to a further decrease in exposure to the real sector, which, in turn, would cause a deeper decline in economic output, and so on. Figure 3.1 illustrates this mutually reinforcing feedback loop. The figure also shows that eventually macroeconomic policy would react to such a feedback loop (for example monetary policy) so that the effect of deleveraging on the economy and further increase in risks in banks' balance sheets could be partially muted. However, to stay on the conservative side, in the simulations described in this article we did not take the countercyclical stance of policymakers into account.

Figure 3.1: Feedback Loop



Source: Authors.

However, the high degree of procyclicality that would lead to such a feedback loop has numerous strong assumptions. We applied the following five assumptions for our empirical analysis.

1. The volume of risk-weighted assets of most banks would have to be a direct function of PD and LGD, i.e. the majority of banks would have to apply the IRB approach[63] to the calculation of capital requirements for credit risk.

2. When calculating capital requirements most banks would have to use PD and LGD estimates responding directly to the phase of the economic cycle ("point-in-time"

[63] The Internal Rating Based Approach, a technique allowing banks to use internal rating models to manage credit risk.

estimates). Only in this case would an economic downturn be reflected immediately in changes in PD and LGD.

3. Higher capital requirements would have to force the bank to change its behaviour, in the sense of reducing the supply of loans. This is possible if the bank is operating at the threshold of its targeted capital adequacy ratio, for example because of a fall in regulatory capital due to accumulated accounting losses. However, we would have to assume simultaneously that the bank does not have the option of strengthening its regulatory capital from external sources or accumulated retained earnings. The capital adequacy ratio targeted by banks would moreover have to be higher than the regulatory minimum of 8%. Many banks maintain a capital buffer above the regulatory minimum (for example to maintain their ratings) which they do not want to fall to zero.

4. The reduction in the supply of loans would have to exceed the decline in demand for loans due to the contraction in economic activity. Otherwise, banks would not have to actively reduce their risk-weighted assets by reducing their exposures, but would merely wait for demand for loans to fall spontaneously. This simultaneously implies that banks are able in reality to reduce the supply of loans (or reduce their portfolios).

5. The reduced supply of loans would have to have a strong effect on economic output. This implies, for example, that private entities would have no other ways of raising funding (for example by issuing securities in the financial markets, retaining profits or obtaining funding from non-banking institutions). The propagation mechanism and transmission channels of this impact are discussed in more detail in, for example, Aikman et al. (2009).

Using data on the Czech banking sector we tried to simulate the feedback loop for a selected adverse macroeconomic scenario. To get as close as possible to a potential real situation, the simulation was conducted using disaggregated data on individual banks within the Czech National Bank's (CNB) existing macro-stress-testing system. This system offers a suitable framework thanks to its orientation towards adverse macroeconomic scenarios, its dynamic nature (capturing the situation in banks over the eight subsequent quarters), satellite models mapping macroeconomic developments into financial variables and the use of disaggregated data on the portfolios of individual banks in the Czech Republic (see Jakubík and Schmieder, 2009). The stress testing framework is described in detail in Geršl and Seidler (2010). In this section, we focus on its most relevant features that enable us to simulate the feedback loop.

First, the stress testing framework has a horizon of 8 quarters and the prediction for macroeconomic and financial variables for individual quarters is reflected directly in the prediction for the main balance-sheet and profit and loss account items of banks.

Second, the predictions for macroeconmic variables enter the so-called satellite credit risk and credit growth models. The credit risk models are used to predict the probability of default (PD) for the four main credit segments (non-financial corporations, loans to households for house purchase, consumer credit and other loans). Credit growth models

are used to estimate the growth in bank portfolios and are used (after certain adjustments) to estimate the evolution of risk-weighted assets (RWA).

Two econometric models based on one-factor model (Jakubík, 2007; Jakubík and Schmieder, 2009) are employed to calibrate PD for all considered segments. Both models were estimated using quarterly data obtaining from bank credit registries in the Czech Republic. This data covers newly past due loans which were used to calculate proxy for default rates.

Credit risk model for corporations suggests that lagged increases in short-term interest rates, lagged decreases in real investment growth, lagged decreases in real foreign demand growth, lagged decreases in real gross domestic product growth and lagged decreases in real consumption growth all positively affect the corporate default rate. The model captures domestic demand (real consumption) as well as foreign demand for firms' product (real foreign demand). The real investment can serve as an indicator for firms' financial health as corporates will probably reduce their investment during times of financial distress. Finally, the real GDP is used as a proxy for firms' revenues and the interest rate represents financial costs for corporate sector funding.

Credit risk model for households suggests that the lagged real GDP growth negatively affects default rates. However, a decrease in lagged nominal wage growth, an increase in the unemployment rate and an increase in lagged interest rates has a positive effect on the household credit default rate. The model captures both the asset and liabilities side of households' balance sheets. While unemployment and nominal wages have an impact on household income, interest rates have an influence on household financial costs. Real GDP is used as a proxy for the factors affecting disposable income not covered by the previously mentioned indicators. Household financial distress or default can be defined as a situation when a debtor is not able to service its outstanding debt. Under these circumstances, the disposable income of such a household is negative. The predicted household default rates are used to calculate PDs for both mortgage and consumer lending portfolios.[64]

Third, assuming certain levels of loss given default (LGD) determined by expert judgement for different credit segments in line with the projected economic development, especially the house prices, the loan losses are computed as a product of PD and LGD. However, the equally important impact of increased PDs comes as the increased capital requirements for credit risk. For banks applying the advanced approach to the calculation of capital requirements for credit risk under Basel II, the capital requirements for credit risk are a function of PD and LGD. Given that the largest banks in the Czech Republic apply the advanced approach, this relation is applied to all banks for the sake of simplicity. An increase in PD and LGD results in an increase in RWA providing a constant portfolio volume.

[64] For evidence on drivers of default in retail segment in the Czech Republic see Kočenda and Vojtek (2011).

Fourth, next to credit losses, the framework also contains modules for calculating the impact other risks, namely market risk and interbank contagion. The prediction for long-term interest rates is used to estimate profits/losses from the revaluation of bond holdings (except for bonds held to maturity and bonds with a variable coupon linked to certain reference interest rate). The quarter-on-quarter change in the CZK/EUR exchange rate is applied to the net open foreign currency position, generating either a loss (in the case of a positive open position and appreciation of the koruna) or a profit due to the change in the exchange rate (in the opposite case). Interbank contagion risk is modelled on the basis of data on interbank exposures and uses iterations for modelling a possible domino effect of a fall of one banks on the system as whole.

Fifth, the framework assumes a decline in operating profit in adverse macroeconomic scenario. This, together with the incurred credit and market losses, may lead to accounting loss which is directly subtracted from the regulatory capital.[65]

Finally, the stress testing framework was adjusted to allow reaction of banks in the supply of credit (the feedback effect). The above mentioned credit growth models are interpreted as models of credit demand and the banks have a possibility to cut lending in order to reach such a level of risk-weighted assets for which the regulatory capital at disposal is sufficient to achieve a pre-determined targeted capital adequacy ratio.

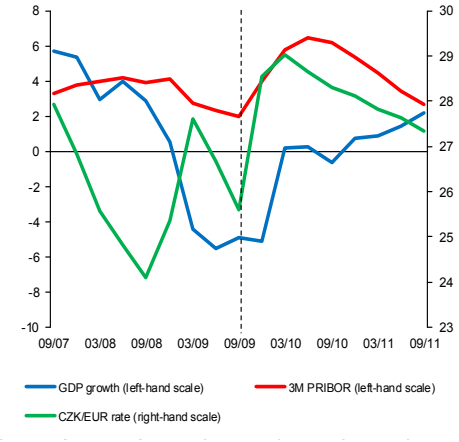
As to the data, the bank-level data used in the simulation come from the internal databases of the Czech National Bank. Default rates are based on data from the CNB Credit Register (corporations) and the private Banking Register run by Czech Credit Bureau (households). Macroeconomic and financial market variables are taken from publicly available sources such as Czech Statistical Office, Datastream and Bloomberg. Projections of macroeconomic variables for the adverse economic scenarios are produced by the official CNB forecasting model *g*3.

4. Empirical Simulation for the Czech Economy

The simulation was conducted on the data for the Czech banking sector as of end-September 2009 using a highly adverse macroeconomic scenario describing a typical crisis in developing markets (e.g. the 1997 crisis in the Asian economies) for the next eight quarters, i.e. for 2010 and three quarters of 2011. This unlikely yet plausible scenario assumes very low Czech economic output in 2010 and a significant rise in risk aversion towards the Czech economy, manifesting itself in strong depreciation of the exchange rate and an immense rise in short-term interest rates (see Chart 3.1). A variation of this scenario can be found in the CNB Financial Stability Reports (CNB, 2010; 2011).

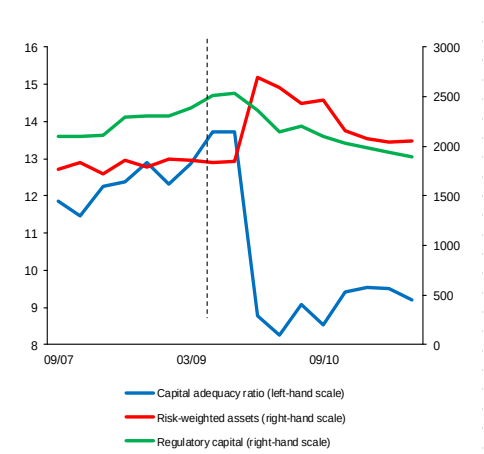
[65] If a bank generates profit (i.e. its operating profit is higher than its credit and market losses), its regulatory capital remains at the same level and once per year there is decision modelled about distribution and/or (partial) retention of the profit.

Chart 3.1
Evolution of Key Macro-indicators in Adverse Scenario
(in %; in CZK/EUR)



Source: CNB; authors´ calculations.

Chart 3.2
Evolution of Capital Adequacy Ratio in Adverse Scenario
(in %; RWA in CZK billions, regulatory capital in CZK hundreds of millions)



Source: CNB; authors´ calculations.

Additionally to adverse macroeconomic developments, we also assumed that banks will generate very low operating profit over the entire simulation period to serve as a first line of defence against loan losses and losses due to market risks.[66] This leads immediately to accounting losses in many banks due to a fall in the value of bond holdings, exchange rate changes and loan loss provisioning, which together exceed the assumed operating income. The final losses are reflected immediately in a fall in regulatory capital.

The downturn in economic output, however, is reflected simultaneously in growth in risk weights via growth in PD (via credit risk models) and LGD (expertly set) [67] and leads to higher risk-weighted assets. In some banks, this can give rise to pressure to maintain sufficient capital adequacy. Compared to the initial position as of September 30, 2009, the aggregate capital adequacy ratio is lower owing to a fall in capital (due to

[66] The scenario assumes that banks' operating profit adjusted for market gains/losses (i.e. net interest and fees income minus administrative costs) in the period 2009 Q4 – 2011 Q3 will reach just 50% of the average for the previous two years. This is an extreme assumption used to create a truly bad but still possible alternative scenario that is consistent with the aforementioned assumptions for realisation of the feedback effect.

[67] In the corporate exposure segment, for example, a rise in LGD from the regulatory 45% to 70% is assumed. In other loan segments, the increase amounts to some 20 – 30 percentage points.

realisation of accounting losses) and to the rise in risk-weighted assets (see Chart 3.2), and is bordering on the regulatory minimum of 8%.

For the analysis, we assume that all banks want to maintain a capital adequacy ratio above regulatory minimum and set the targeted ratio to 10%. Moreover, we assume that there is no way of raising capital externally,[68] thus the logical response of banks is to lower their risk-weighted assets by reducing their credit exposures. The aforementioned results of the adverse scenario already contain a decrease in the credit portfolio projected by the credit growth model reflecting reduced demand in an environment of weak economic output. To maintain a sufficient capital buffer, banks would therefore have to resort to a further decrease in loans in excess of the decline in credit demand.

In the following analysis of the feedback effect we proceed in a sequential manner. This approach is permitted by the dynamic nature of the banking sector stress-testing system. In the first quarter of the simulation (in this case 2009 Q4) banks are exposed to the effect of the worse economic situation and observe growth in PD and estimated LGD, a fall in the value of bonds, very low yields and also a decline in demand for loans. On the basis of these observed developments, banks for the first time calculate for themselves what their capital adequacy ratio would be at the end of the quarter if they failed to react in a significant way. If this calculated capital adequacy ratio is lower than required (the 10% assumed above), they will reduce their exposures during this quarter such that the resulting capital adequacy ratio is at least 10%. This is, of course, a very simplifying assumption, as the reduction in exposures would in reality probably last more than one quarter.

In the adverse scenario given here, 15 of the 21 banks tested are forced to react in the first quarter of the simulation.[69] The reduction in the supply of loans (for example through the sale of claims out of the banking sector or through the non-renewal of short-term revolving and overdraft financing, or even – which is more costly for banks, although not an entirely impossible strategy – through the cancellation of standby credit or the reduction of credit limits) in excess of the decline in credit demand will have a major impact on the economy, especially if economic agents have significantly limited access to funding from alternative sources. The existing evidence on bank financing in the Czech Republic suggests that the overwhelming majority of non-financial corporations have just one financing bank. This effectively prevents firms from switching to other banks with which they have no credit history (Geršl and Jakubík, 2011). Market financing is also not very widespread. On the other hand, we should add that large firms (which very often have foreign owners) can theoretically have other sources of funding either directly from their parent companies or from foreign banks in

[68] The option of increasing capital internally from retained earnings is kept, but this is more of a theoretical option given the assumed accumulated losses.

[69] As capital regulation is responsible for the procyclical behaviour of banks in this simulation, the simulation is performed only for capitalised banks, i.e. branches of foreign banks are excluded.

the form of cross-border loans. For the sake of simplicity, the simulation assumes very strong financial constraints on firms, which are forced to cut output if they lose bank financing, which in turn leads to a further decline in economic output.

We assume that the reduced bank financing has a slightly lagged effect on the economy such that the decline in the loan supply in the first quarter of the simulation is reflected in real GDP in the following quarter, i.e. in 2010 Q1. The key issue is the estimation of the feedback effect itself. In this paper we use a simple approach based on an estimate of the elasticity of GDP to changes in lending. Most of the studies applying this idea are based on the methodology presented in Driscoll (2004). This technique was also used by Čihák and Brooks (2009), who in cooperation with the European Central Bank for a panel of European countries estimated the elasticity between a decline in the year-on-year growth rate of loans (in excess of the decline caused by reduced loan demand) and year-on-year real GDP growth at around 0.1. This means that, for instance, a decline in the year-on-year growth rate of loans of 10 percentage points in excess of the decline due to lower demand is reflected in a decline in year-on- -year GDP growth in the following quarter of 1 percentage point. This elasticity estimate was used to simulate the feedback effect for the Czech economy.

The contraction of the economy in the second quarter of the simulation (2010 Q1) caused by the feedback effect is reflected in bank portfolios in further growth of PD in the following quarters (LGD is assumed to be at a higher, but constant level). This leads to increased growth in loan losses, a decrease in regulatory capital and a rise in risk-weighted assets. At the same time, however, the feedback effect also generates a further decline in demand for credit in the given quarter.[70] The overall effects on profit/loss, regulatory capital and risk-weighted assets in 2010 Q1 and hence the resultant capital adequacy ratio depends on the calibration of the scenario and the size of the portfolios relative to banks' income. In 2010 Q1, banks will evaluate the expected impact of the economic environment on the resultant capital adequacy ratio and, if necessary, will further decrease the credit supply during the quarter. This will negatively affect GDP in the next quarter. The simulation performed here reveals, for example, that the same number of banks as in 2009 Q4 must further reduce their loan portfolios.[71] The same logic is then applied to all eight quarters for which the simulation is performed. Hence, if the feedback effect materialises, the original scenario (see Chart 3.1) and the original path of the effect on the banking sector (see Chart 3.2) do not apply and the economy and the key banking sector variables develop differently (see Chart 3.3 and Chart 3.4).

For the sake of simplicity, the simulation of the effect of procyclical bank behaviour on the economy is performed only for GDP; the other macroeconomic variables

[70] Another highly likely impact would be a decline in operating profit; this is fixed in the simulation for the time being and does not change as GDP declines further.

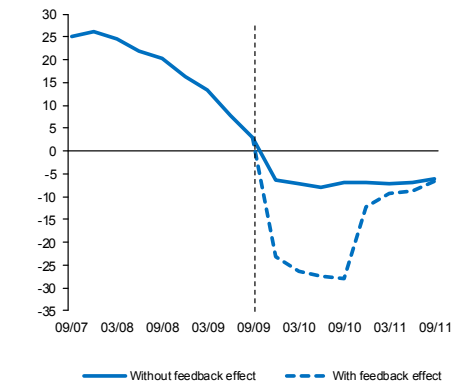
[71] Only in the third quarter of the simulation, i.e. in 2010 Q2, does the number of reacting banks start to fall slightly.

maintain their original paths. This is, of course, a very significant simplification. It can be expected, for example, that monetary policy-makers would in all probability react to the sharper decline in GDP by easing the interest-rate conditions.

Chart 3.3 shows the evolution of year-on-year loan portfolio growth for the scenario without the feedback effect (i.e. with a demand-driven decline in loans only) and for the scenario with the feedback effect. The difference in the paths is directly correlated with the impact on GDP growth, as illustrated in Chart 3.4.

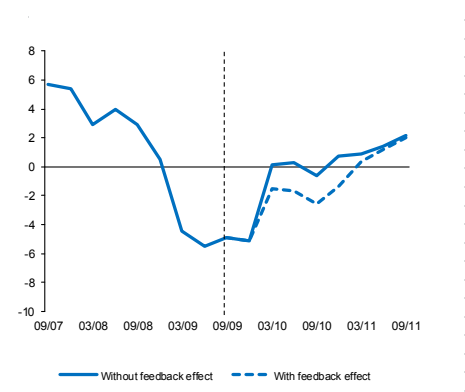
The decline in credit exposure reduces risk-weighted assets such that all the banks maintain the targeted capital adequacy ratio of 10% (see Chart 3.5). The path of the capital adequacy ratio in the presence of the feedback effect is thus better, since RWA declines. However, the worse evolution of the economy is reflected, with a lag, in growth of the risk parameter PD for the principal sectors of the economy (see Chart 3.6).

Chart 3.3
Evolution of Total Loans in Adverse Scenario
(year-on-year growth in %)



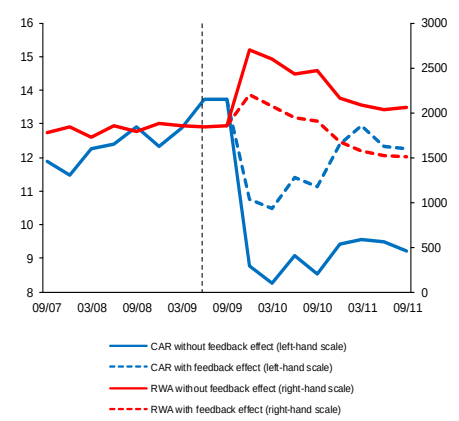
Source: CNB; authors´ calculations.

Chart 3.4
Evolution of Real GDP in Adverse Scenario
(year-on-year growth in %)



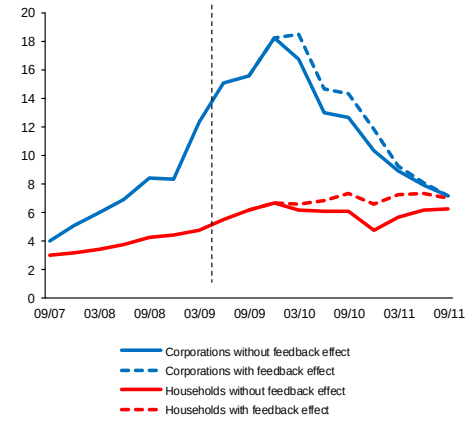
Source: CNB; authors´ calculations.

Chart 3.5
Evolution of Capital Adequacy Ratio (CAR) and RWA in Adverse Scenario
(in %; in CZK billions)



Source: CNB; authors´ calculations.

Chart 3.6
Evolution of PD Predictions for Corporations and Households in Adverse Scenario
(in %)

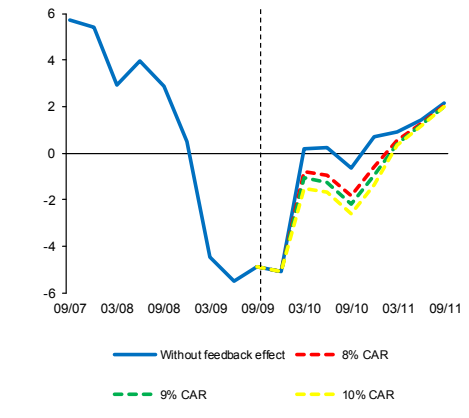


Source: CNB; authors´ calculations.

The simulation results depend on many of the parameters discussed above. Besides the elasticity between the supply of loans and GDP growth, the key parameters include above all the capital adequacy ratio targeted by banks. For this reason, we conducted several alternative simulations with different targeted capital adequacy ratios of 8% and 9% and the original 10%. As the simulation results show (see Chart 3.7), the impact on the GDP growth path ranges from one percentage point (for a targeted capital adequacy

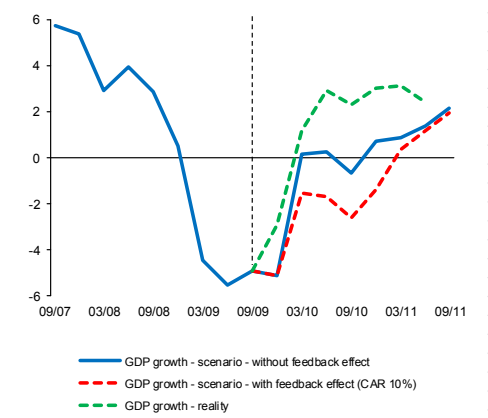
ratio of 8%) to two percentage points (for a targeted capital adequacy ratio of 10%) of year-on-year GDP growth over a period of at least one year.

Chart 3.7
Evolution of Real GDP in Adverse Scenario Given Alternative Assumptions about Targeted Capital Adequacy Ratio
(year-on-year growth in %)



Source: CNB; authors´ calculations.

Chart 3.8
Comparison of GDP Growth in Adverse Scenario and Reality
(in %)



Source: CNB; authors´ calculations.

5. Economic Developments in 2009 – 2011 and Policy Implications

Due to the fact that data for end-2009, 2010 and partially also for 2011 are already available, one can ex-post discuss to what extent the macroeconomic scenario employed in the simulation exercise was materialized. Comparing macroeconomic data for the simulated horizon with the employed adverse scenario, we can find out that actually the assumed adverse scenario was relatively close to the real developments in terms of GDP growth path (see Chart 3.8). However, even a relatively bad situation in the real economy in 2009 – 2010 did not lead to the materialization of the feedback effect in the Czech Republic, as simulated in our analysis.

There are several reasons why the feedback effect did not materialize. First, the real GDP path was slightly more favourable than the one in our adverse scenario, mainly due to a revival in external demand. Second, the risk aversion to the Czech Republic did not increase and the banks did not suffer market losses from revaluating bond portfolios. On the contrary – the Czech koruna appreciated and interest rates stayed at very low levels, as the central bank responded to the economic recession and low inflation pressures by accommodative monetary policy. This was probably the crucial factor which mitigates negative impact of the crisis on economic growth and also prevented the feedback effect to be fully materialized. Stronger external demand also helped to mitigate the effect of appreciation of the Czech koruna on the Czech corporate sector.

Third, the banks did not experience declines in operating profits – on the contrary, some part of banks' income even increased (such as net interest income). The banking sector increased its overall profits (net, i.e. after tax) from some 45 CZK billion to levels close to 60 CZK billion both in 2009 and 2010, a good base from which the regulatory capital was strengthened. The capital adequacy increased from levels around 14% in 2009 to close to 16% in mid-2011. Overall, despite similar GDP growth path, the situation was more favourable compared to the simulation exercise.

Despite the feedback effect was not fully materialized during 2010, our analysis suggests that it could be an important factor which needs to be taken into account by policymakers, especially if some of the conditions listed in section 3 should become binding. Our experience suggests an important role for monetary policy which could ease the pressures on real economy via accommodative stance. Moreover, over time, macroprudential tools such as countercyclical capital buffers and regular stress testing should be utilized to encourage banks to create capital buffers in good times to be drawn down in bad times. Finally, the negative impact of de-leveraging on the corporate sector could be minimized trough supporting the financial developments in funding markets, such as the domestic corporate bond market.

6. Conclusion

This paper set out to present an overview of the debate on the sources and effects of procyclical behaviour of the bank-based financial system that prevails in most EU countries. The main natural and regulatory sources of procyclicality were discussed, as were the current regulatory proposals for mitigating procyclicality.

In the event of a very strong decline in economic activity, and given some assumptions, procyclical behaviour by financial intermediaries can lead to a feedback loop, i.e. a mutually reinforcing effect between growing risks in the financial sector and in the real economy. The main objective of the paper was to try to simulate the potential magnitude of this feedback loop on the example of a selected EU country, namely the Czech Republic. A single highly adverse scenario was chosen for the simulation and the entire simulation was performed on disaggregated data for the Czech banking sector using the CNB's stress-testing system. The results of the simulation showed that under certain – relatively restrictive – assumptions the feedback effect on the real economy can be 1 – 2 percentage points of year-on-year GDP growth over a period of at least one year.

Ex-post comparison of the conducted simulation exercise with the real developments suggest that adequate monetary and ex-ante macroprudential policy can help to mitigate the feedback effect on the economy. All in all, the empirical analyses point out that procyclicality of the financial system should thus be taken into account in economic and macro-prudential policy-making.

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Household Balance Sheets and Economic Crisis

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Abstract

This paper studies the economic impact of the recent global economic downturn on the household sector. Household budgets can be negatively affected by declines in nominal wages and increases in unemployment. We empirically test this effect for the small open emerging economy. As a result of a lack of individual data on household finances, micro data are simulated. Our analysis clearly shows that there is a significant additional decline in consumption related to an increase in household default rates and unemployment. We find that potential household insolvencies have important implications for the financial system as well as for the macroeconomy.

***JEL**: G28, G32, G33, G38*
***Key words:** credit cycle, households' distress, insolvency, household default, aggregate consumption*

1. Introduction

There are numerous studies that address household financial distress. Some investigate the main drivers of the insolvency risk and try to link them to the macroeconomic environment while others focus on the effects of adverse macroeconomic scenarios on household consumption. Of note is that only a few studies discuss the household credit cycle as a whole. The lack of research on this issue is largely related to insufficient household statistics on structured balance sheets and consumption.

A severe economic downturn has a negative effect on household balance sheets and can cause financial distress. This study aims to assess the impact of the economic recession on a household's finances by taking their debt burden into account and evaluating the negative feedback on the aggregate economy via reduced consumption. This is of particular importance from the government's perspective, as household insolvencies can significantly reduce government revenue and increase the need for social spending.

The next section contains a literature review on household distress, insolvency triggers and the impact of adverse macroeconomic scenarios on a household's balance sheet. Section 3 discusses the theoretical framework, focusing on the impact of an adverse macroeconomic scenario on aggregate consumption. Section 4 contains a description of the data employed in the paper. The empirical results are presented in section 5, and the final section summarises and concludes.

2. Related Literature

A number of studies address the issue of household insolvency and focus specifically on the main drivers. The recent financial turmoil and subsequent economic recession provide additional incentive for creditors as well as regulators to deal with the issue. Four main streams of research can be identified. The first looks at household default prediction, using a traditional insolvency framework. The second focuses on the impact of household defaults on the financial sector within a stress test framework for evaluating the potential negative effects of adverse macroeconomic scenarios. The third focuses on the optimal legal framework to deal with individual insolvencies. The fourth addresses the credit cycle and consumption.

The first group of studies focus on household default prediction. Peter and Peter (2006) investigate the main drivers of household default. To this end they developed a risk management model for the Australian economy, using micro data from the Australian Bureau of Statistics. DeVaney and Lytton (1995) chose to focus on household insolvency by applying a predictive model and using financial ratios to identify insolvent households. They discuss the implications for monitoring household solvencies and present a response to insolvencies. Herrala and Kauko (2007) present a micro simulation model of household distress. They use a logit analysis to estimate the extent to which a household's risk of being financially distressed depends on net income after tax and loan servicing costs. The impact of the assumed macroeconomic shocks on

the net income is calculated at the household level. Their micro simulation model is used to simulate both the number of distressed households and their aggregate debt in various macroeconomic scenarios. Del-Rio and Young (2005) examine how attitudes towards unsecured debt are related to household finances and other characteristics, using a British Household Panel Survey. This analysis suggests that the main causal factors for problems relating to debt are the unsecured debt-income ratio, the level of mortgage income gearing, the level of households' financial wealth, and their health, ethnicity and marital status. They also concluded that the increase in levels of indebtedness of young people was the main factor driving the greater tendency to report debt related problems.

The second research stream tries to evaluate the impact of household defaults on the financial sector under adverse macroeconomic scenarios. Kadeřábek, Slabý and Vodička (2008) modelled household default probability as a function of macroeconomic variables, such as wages, unemployment and interest rates. They further employed an estimated model within the stress test framework by applying exogenous stress scenarios for the development of these indicators. The authors pointed out that stress-sensitivity of default probability is mainly driven by the instalment-to-income ratio and loan maturity. Jakubík, Schmieder (2008) estimated macroeconomic models for forecasting household default for the Czech and German economies. They employed these models to stress test banking portfolios and pointed out that macroeconomic indicators alone have limited use in explaining household defaults. Moreover Jiménez, Saurina (2006) found strong empirical support for a positive lagged relationship between rapid credit growth and loan losses. Their study contains empirical evidence of lax credit standards during boom periods, in terms of screening of borrowers as well as collateral requirements and loan losses. They advocate a regulatory prudential tool based on a countercyclical, or forward-looking, loan loss provision that takes into account the credit risk profile of a bank's loan portfolios across the business cycle.

The third group of studies focuses on the optimal legal framework. Li and Sarte (2006) study the implications of US personal bankruptcy rules for resource allocation and welfare. They found that the complete elimination of bankruptcy provisions can cause a significant decline in output and welfare as it reduces capital formation and labour input. Feibelman (2009) pointed out that the deepening of consumer finances promotes growth and development in emerging markets. His research stressed the importance of consumer bankruptcy law as an effective form of regulation to address the problem of over-indebtedness. He calls for emerging economies to consider adopting a consumer bankruptcy system or modernizing their existing regimes.

The fourth research group focuses on consumption and economic growth, employing credit cycle models. Chang, Hanna, Fan (1997) presented and empirically tested a three-period model for optimal consumption. The latter suggests that many US consumers without sufficient levels of liquid assets may be acting rationally. Elmer and Seeling (1998) combine the issue of consumption and solvency. They proposed a theoretical model for a single family mortgage default and investigated events that could trigger defaults within this framework. McCallum (1988) applies an evaluation of strengths and

weaknesses of the real business cycle approach to the analysis of macroeconomic fluctuations. Tudela, Young (2005) using an overlapping generation model to explain rising household indebtedness. They also investigate the impacts of various events, such as a fall in house prices, a fall in pension income, and an increase in interest rates, on household wealth, indebtedness and consumption. Evidence of a positive effect of wealth on Italian households' consumption was found by Bassanetti, Zollino (2008), and the influence of income distribution in modelling aggregate consumption expenditure was analysed by Chakrabarty, Schmalenbach and Jeffrey (2006). For the Netherlands, the impact of financial capital losses relative to gains on household savings and consumption is investigated by Berben, Bernoth and Mastrogiacimo (2006). Their results suggest that households react more strongly to capital losses than to capital gains. Thus, the failure to take this asymmetry into account could seriously influence estimates of marginal propensity to consume from wealth. A comprehensive survey of the literature dealing with wealth and asset price effects on economic activity is provided by Altisimo at al. (2005). Impacts of banking and currency crises on consumption in 19 OECD countries are estimated by Barrel, Davis and Pomerantz (2006). Their results show that consumption plays an important role in the adjustment following a crisis and that the effects are not fully captured by the impact of crises on the standard consumption determinants, i.e. income and wealth. Additional effects, attributable to factors such as time-varying confidence, uncertainty and credit rationing, are aggravated by high and rising leverage, despite financial liberalisation and easing of liquidity constraints. High leverage in some countries implies that banking crises could have a greater incidence than in the past.

3. Theoretical Framework

Households are usually affected by an adverse negative economic scenario with some time lag, but the impact is more persistent than in the corporate sector. As a consequence of an economic crisis, firms reduce production to cope with declining aggregate demand. To do so, they need to reduce the labour force or decrease wages. However, the wages are usually "downward sticky"; so that firms need to make employees redundant. Alternatively, they could reduce the variable part of salaries such as bonuses or other benefits. As employees become unemployed they also become dependent on social benefits. Moreover, if they are indebted they are not able to cover their current payments with their current income. Thus, if they are not able to find employment, the only solution is to use their savings. In the end this provides a temporary solution that postpones their insolvency.

Elmer and Seelig (1998) investigateed household insolvency using a three period pure exchange model with no taxes. This model can easily be extended to include any arbitrary number of periods (see Fama and Miller (1972) or Hirschleifer (1970) for further details). Within this framework, a key role is played by uncertainty about future income, interest rates and house prices and a household defaults if borrowing from previous periods exceeds homeowner equity. It is quite an expected result. If an individual cannot meet his obligation, he can still sell owned real estate in order to avoid

default. However, he will default if the value of his equity does not cover his debt obligation. This simple framework helping us to understand the basic default trigger based on the shock to income. But in practice things are more complicated, as mortgages can have different maturities, which imply different annuities, and a mortgage is usually paid back in fixed monthly instalments. Moreover, contrary to the assumed framework, interest rates paying on deposits and loans might be substantial different. We also need to calculate disposable income as income purged of living costs. Moreover, Herrala, Kauko (2007) define household distress as a situation where the increment in household surplus (income diluted by debt service payment), via the incurrence of new debt, is smaller than the minimum level of consumption. They assume that households can temporarily sustain consumption by taking more debt or running down their stocks of liquid assets. Another source of change in household consumption might stem from assets price effects via the wealth channel. A comprehensive study by Maki and Palumbo (2001) provides important evidence in favour of the wealth effect on US consumer spending during the 1990s. A number of studies have analysed the relationship between equity wealth and consumption within the consumption-based capital asset pricing model, e.g. Mankiw and Zeldes (1990), Attanasio, Banks and Tanner (1998), and Brav, Constantinides and Geczy (1999). They found that the spending of stockholders is more highly correlated with stock market returns than that of non-stockholders, which supports a direct effect.

Impact of Adverse Scenario on Aggregate Consumption

From the creditor's point of view, a precise estimation of future household default is one of the most challenging issues. On the other hand, the objective of financial regulators is to assess the future course of the economy and the potential threat to financial stability. Households' inability to meet their financial obligations results not only in higher default rates and losses for the financial sector but also as in a significant decline in household consumption, which has a negative effect on the aggregate economy. To estimate this impact we can use a simple Keynesian framework (see e.g. Romer (1996))

$$C = C_0 + cY, \qquad (4.1)$$

where C denotes aggregate consumption, C_0 autonomous consumption, c marginal propensity to consume and Y disposable income. We further assume an adverse macroeconomic scenario corresponding to declines in gross domestic product and disposable income. Then a decline in consumption can be expressed as

$$\Delta C = c\Delta Y, \qquad (4.2)$$

where Δ is the operator for change in level. However, in the case of a significant increase in household default rates, there is an additional feedback effect of household insolvency on aggregate consumption. Hence, the decline in consumption calculated via formula (4.2) can be considerably underestimated due to the underestimation of the marginal propensity to consume.

To better estimate the impact of a decline in disposable income on consumption, we can simply divide consumers into two groups – defaulted [proportion d] and non-defaulted [(1-d)]. Then aggregate consumption can be expressed as a weighted average of Keynesian consumption functions for both groups of consumers which consider different propensity to consume.

$$C = dC_d + (1-d)C_n \tag{4.3}$$

where C_d denotes consumption function of the defaulted and C_n non-defaulted households. Using this formula, the decline in consumption in response to the decline in disposable income or GDP can be derived. Using the Keynesian formula, we assume that consumers reduce their consumption proportionally to the decline in disposable income, which corresponds to the decline in GDP. If we further assume that disposable income of the defaulted household group is equal to zero in the limit, then their consumption is equal to the autonomous consumption related to the essential living expense:

$$C = dC_d + (1-d)C_n = d * C_0 + (1-d)(C_0 + cY) = C_0 + (1-d)cY \tag{4.4}$$

In the case of an adverse macroeconomic scenario, GDP or disposable income declines and the household insolvency rate increases. Aggregate consumption is influenced by both these effects and can be easily derived from formula (4.4).

$$\Delta C = c[(1-d)\Delta Y - \Delta d(1+\Delta)Y)] \tag{4.5}$$

We see from equation (4.5) that we cannot omit the second term in the formula. We could omit only the terms of the second order. Hence, the term $Y\Delta d$ would still remain in the formula and the omission of the second term can cause a significant underestimation of the decrease in consumption.

If we further take into account that the marginal propensity to consume could significantly differ for the unemployed and employed consumers, we can reformulate equation (4.6) for the aggregate consumption as

$$C = C_0 + (1-d)(uc_U Y + (1-u)c_E Y) \tag{4.6}$$

where c_U and c_E are the marginal propensity to consume for the unemployed and employed consumers and u is the unemployment rate. In the case of an adverse macroeconomic scenario, we need to also take into account, together with the change in GDP and the change in household default rate, the change in the unemployment rate, to calculate the effect on aggregate consumption. Formally, after some derivation we obtain the formula (4.7).

$$\Delta C = (1-d)[u(c_U - c_E) + c_E]\Delta Y + [(c_U - c_E)(\Delta u - d\Delta u - \Delta du - \Delta d\Delta u) - \Delta dc_E](1+\Delta)Y \tag{4.7}$$

We see from equation (4.7) that - in the absence of a significant difference between marginal propensities to consume for unemployed and employed consumers - formula (4.7) resembles formula (4.5). Formula (4.7) reveals that, with a significant difference between marginal propensities to consume for unemployed and employed consumers, a change in the unemployment and default rates can have a marked impact on the change in aggregate consumption.

4. Available Data

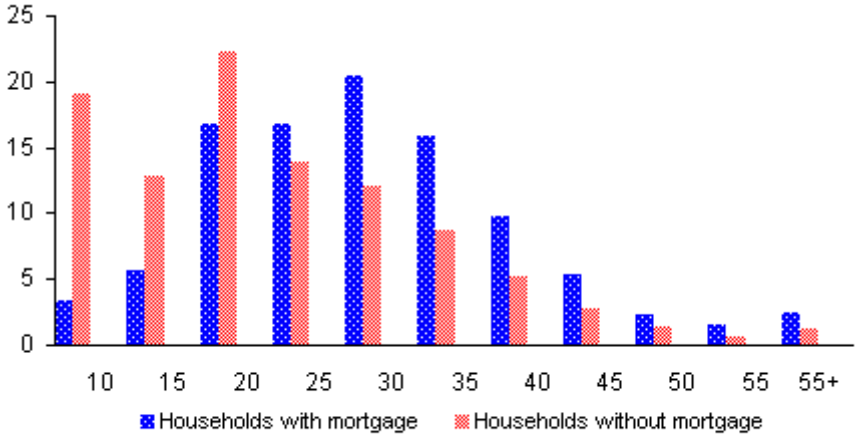
The limiting factor in modelling household insolvencies is usually the availability of the appropriate data. To estimate the household default rate we would need to know more about the distribution of income, wealth and the debt burden across the population. Furthermore, we would need an estimate of the necessary living expenses as well as information on interest rates on loans to households. We empirically tested the transmission channels for the Czech Republic as a small open and emerging economy. Unfortunately, the relevant data are not publicly available in this case.[72] We have neither micro data nor sufficient information on the income distribution. Thus we make a simplifying assumption to deal with this problem.

The Czech Statistical Office is the main data source for Czech household statistics. Apart from that, the Czech National Bank provides some additional statistics on the aggregate bases such as household financial assets, banking and non-banking loans to households. Moreover, the average bank interest rates on consumption and housing loans to household are published by the Czech National Bank. Some additional characteristics of the mortgage markets can be obtained from Fincentrum Hypoindex. However, micro data are available only from the Czech Statistical Office. These statistics are based on household surveys and include some characteristics of households. In connection with household insolvency, they provide information on household net income but not on characteristics of the debt burden except for binary (yes/no) information such as whether the given households have mortgages. Moreover, the debt burden related to consumer loans is not covered by these statistics. Another serious disadvantage is the relatively long lag; for example, the latest statistics are based on information collected in the year before the last complete year. This lack of appropriate statistics causes difficulties in making estimations.

The income distribution of households with and without mortgages reveals that the indebtedness of low income Czech households is relatively limited. The income distribution of households with a mortgage is positively skewed compared to that of households without a mortgage.

[72] The appropriate data can be obtained from credit registers or household surveys for some countries.

Chart 4.1: Household income distribution (Statistics of Family Accounts 2007)
(x axis: monthly household net income, CZK 1000; y axis: %)



Source: Czech Statistical Office

Based on statistics from Fincentrum Hypoindex, we see that since 2006 the average value of mortgage loans has been rising over time, but the rise is less than that in residential property prices (see Table 4.1). We also find slower growth in nominal wages compared to changes in residential property prices in the same period. This reflects the fact that owner-occupation is becoming less accessible to Czech households over time. Although the income situation had been improving until 2008, it still did not compensate for the increase in residential property prices.[73]

Table 4.1: Average mortgage loan

	2005	2006	2007	2008	03/2009
Average mortgage loan (end of period, in ths.CZK)	1412	1450	1707	1766	1802
Growth of average mortgage loan (in %)	11.4	2.7	17.7	3.5	2.0
Change in residential property prices (y-o-y, in %)	6.0	10.4	18.9	12.5	
Growth of average gross monthly nominal wage (y-o-y, in %)	5.3	6.5	7.3	8.5	-2.6
Consumer price Inflation (end of period, in %)	2.2	1.7	5.4	3.6	2.3

Source: Fincentrum Hypoindex
Note: 03/2009 correspond to quarterly change

[73] At the end of 2008, banks started to tighten credit standards due to the ongoing economic recession. The increasing uncertainty about future income together with the resultant negative expectations of households caused a rapid slowdown in credit growth. Moreover, the economic decline which started in 2008 is reflected in an increase in household sector credit risk.

5. Empirical Results

To evaluate the impact of the economic crisis on the household sector, we focus mainly on the income transmission channel that was most important for the Czech economy in the post-crisis period.

Due to the lack of micro data on household balance sheets[74], we employ aggregate data from a bank credit registry and a one factor model to link the household insolvency to key macroeconomic variables (see model specification e.g. in Jakubík (2007), Hamerle, Liebig, Scheule (2004) and Appendix).[75] These data includes total recent past-due loans, which are used to proxy the credit default rate. The indicator for household credit risk is calculated based on new 3-month past-due loans. However, the only short time series for the household sector covering the period 3Q/2007-3Q/2009 are available. Although these data are available at monthly frequency, for some macroeconomic variables, such as GDP growth, only quarterly data are available. In order to estimate the model on the basis of such a short time series, we use monthly data and linear interpolation for GDP growth and its components such as consumption. The model is calibrated by maximising a likelihood function (see Appendix). In line with economic theory, we consider macroeconomic variables which can drive household insolvency and whose forecasts are published by the Czech National Bank. Automatic selection based on stepwise regression minimising residual sum of squares is used to find the combination of variables with the greatest prediction power and optimal time lag. Moreover, we ensure that coefficients have signs in line with economic theory. Our final non-linear model is able to explain relatively well the historic household default rate pattern. According to our results, Czech household default rates can be explained by lagged real GDP growth, changes in the unemployment rate, lagged nominal wage growth and changes in interest rates (see equation (4.8) and Table 4.2, where the lags are in quarters and ψ denotes the cumulative normal distribution function, and, for model performance, Chart 4.2 of the Appendix - "One-factor Model with Default Barrier Depending on Macroeconomic Environment").

$$df_t = \psi(c + \beta_1 gdp_{t-4} + \beta_2 (u - u_{t-1}) + \beta_3 w_{t-1} + \beta_4 (r_{t-3} - r_{t-4})) \qquad (4.8)$$

[74] Although we have information on the historical distribution of household net income, the rest of the statistics are available on the aggregate level only.

[75] Econometric models which employ macroeconomic indicators to explain household insolvency or default rate can be found in many research studies, e.g. Rösch, Scheule (2007), Kadeřábek, Slabý, Vodička (2007), Jakubík, Schmieder (2008) or Danmarks Nationalbank (2007). They typically employ as dependent variables macroeconomic indicators as GDP, unemployment, wage growth, household income, interest rates, or indebtedness of the household sector. Some other studies directly link banks' provisions, which should ideally capture expected losses with macroeconomic indicators (see e.g. Pain 2003). Moreover Trück, Rachev (2005) investigated the effects of changes in migration matrices on credit portfolio risk in terms of expected losses and value-at-risk.

Table 4.2: Macroeconomic model for the Czech household sector

Description of variable corresponding to estimated coefficient	Notation	Estimate	Standard error	Pr>|t|
Constant	c	-2.127	0.015	<.0001
Real GDP growth (β_1)	gdp_{t-4}	-0.028	0.003	<.0001
Change in unemployment (β_2)	$u - u_{t-1}$	0.012	0.004	0.009
Nominal wage growth (β_3)	w_{t-1}	-0.012	0.001	<.0001
Change in interest rate (β_4)	$r_{t-3} - r_{t-4}$	0.034	0.007	0.0001

Note: The lag length is in quarters.

Our results showed that lagged real gross domestic product growth negatively affects default rates. Moreover, a decrease in lagged nominal wage growth, an increase in the unemployment rate and an increase in lagged interest rates each have positive effects on household insolvencies. Our model captures both the asset and liabilities side of households' balance sheet. While unemployment and nominal wages impact household income, interest rates influence household financial costs. Real GDP is used as a proxy for factors affecting disposable income not covered by the previously mentioned indicators. Household financial distress or default can be defined as a situation where a debtor is not able to service its outstanding debt. In such case, the household's disposable income is negative.

Nevertheless, the model based on individual data is usually able to better explain household defaults. Peter and Peter (2006) identify five groups of mortgage default determinants that relate to the following: income, credit history, macroeconomics, borrower location, and demographics. They pointed out that although the most important cause of mortgage default is a fall in household income, the other factors may also be important for future default estimation.

Decrease in Nominal Wages

Given the sharp fall in economic activity related to the recent economic crisis, the potential decrease in nominal wages (see Table 4.1) can be regarded as a relatively plausible scenario for the Czech economy. For this reason we try to identify a decrease in household nominal income that would cause a massive increase in loan defaults by households at the aggregate level and prompt a collapse of the mortgage market. Although individual data on household indebtedness are not available, the recently published survey of the Czech Statistical office revealed that about 10% of Czech households are repaying mortgage loans and roughly 20 % are repaying consumer credit. This means that a significant part of the population is involved and renders the issue an important one for analysis.

To quantify the effects of wage shocks, we consider two variants of a typical indebted household. In the first case, the household is only repaying a mortgage loan and in the

second case it is repaying both a mortgage loan and a consumer loan. These are being repaid in regular monthly instalments. In both cases we assume a three-member family with one child and monthly living costs of CZK 15,000.[76] As micro data reflecting the current situation are not available, we use micro data simulation to model household income, assuming a normal distribution with mean and standard deviations based on the available aggregate statistics.[77] Furthermore, we assume that each household is repaying a mortgage loan corresponding to 5 years of income with a maturity of 20 years, where household income is sufficient to cover monthly instalments and minimum living costs.[78] If household income is not adequate, the maturity is prolonged to a maximum of 30 years. If that is still not enough, the household is not granted a mortgage loan. The interest rate is assumed to correspond to the average rate on mortgages at the end of 2009.

In the second variant, we additionally consider the repayment of a consumer loan of up to CZK 100,000 with 5-year maturity and an interest rate corresponding to the average rate on such credit at the end of 2009. The amount of the consumer loan is set so that the household is able to cover the monthly payment. If household income is not sufficient to cover the monthly mortgage payment and essential living costs, a consumer loan is assumed not to be granted.

For both variants we test the impacts of a wage shock on hypothetical family budgets in relation to initial nominal incomes. We can formulate a household surplus, which is available for consumption.

$$S = Y - I - MC, \tag{4.9}$$

where S denotes the household surplus, Y household net income, I the loan instalment that household is committed to and MC household's essential living costs. We define household distress as a situation where the household surplus is close to zero and the household is only able to cover the essential living costs. In contrast to Herrala and Kauko (2007) we do not take into account a pledgeable amount of wealth, as its distribution among households with a mortgage is not available. And, contrary to Elmer

[76] For both variants we assume a family corresponding to the typical mortgage recipient in the Czech Republic. According to CZSO data, this is most often a household with two economically active members and one child. The main breadwinner is a 39-year-old man with a secondary education. His partner is a 33-year-old employee or housewife with a secondary or basic education. Essential living costs can be estimated on the basis of the household budget statistics on expenditures on food, clothing, housing, health, transport and restaurants. These expenditures can alternatively be estimated as the sum of the minimum subsistence amount and normal housing expenses, as stipulated in a government order of 16 December 2008. In both cases, the estimated amount is about CZK 15,000.

[77] We are aware of the non-normality of household income (see Chart 4.1). However, with a host of other simplifications and assuming only households with mortgages, this should not significantly bias our results.

[78] This reflects common banking practice for the mortgage granting process in the Czech Republic.

and Seelig (1998), we simplify the analysis by ignoring homeowner equity. In calculating household net income, we take account of the Czech tax code.

The results show that if households with a mortgage had no other loan, the budgets of about 30% of them would go into deficit if nominal wages declined by more than 10%. If this group of households also had a consumer loan of CZK 100,000, around 50% of them would be hit. However, the estimates of the proportion of households with difficulty in making loan repayments are extreme. For example, the assumption of constant living costs is very conservative, since households can in reality cut their living costs to some extent if needed. Moreover, a large proportion of households can cope with a potentially bad situation by selling their assets (bank deposits, life insurance, private pension schemes, building saving schemes) or are insured against the inability to repay debts.

Alternatively, the macroeconomic forecast model (8) can be employed. It suggests a much more modest impact of the shock. However, the macro model usually cannot deal well with the extreme scenario, so we could assume that the results obtained by micro-simulation would be much closer to reality. Despite a lot of simplifications and limitations, our exercise points out that a potential decrease in nominal incomes can cause serious difficulties and cause distress to a significant number of households with debt burdens. This could happen as a result of a shorter working week or cutbacks in variable wage components. In such a situation, the number of insolvencies would rise sharply and the quality of bank loan portfolios would fall. This would lead to a decline in residential property prices due to the sale of collateral. A decrease in the value of collateral (or a fall in the LTV ratio) would increase the risk to which banks are exposed. Moreover, a significant increase in household insolvencies would also have a negative social impact.

We focus on the income aspects and do not consider household wealth in our analysis due to limited data availability. However, the wealth effects are estimated to be stronger for households in the lowest income distribution (Altissimo et al., 2005). Due to the fact that the total debt burden of the Czech low-income households is relatively low they should not significantly contribute to the potential rise in the non-performing loans of the Czech banking sector.

Impact on Aggregate Consumption

The recent economic crisis has been manifested in increasing unemployment. According to the CNB (2010) baseline scenario, the default rate on banking loans to households supposed to increase by roughly 2 percentage points during 2010 due to a deteriorating labour market situation and a decline in household disposable income. In a highly unfavourable scenario this indicator could rise by as much as 5 percentage points. Using formula (4.7), we can estimate the impact on aggregate consumption for different negative changes in economic growth measured by GDP. The proportion of defaulted households can be obtained as the product of default rate and share of household with debt burden. According to a survey by the Czech Statistical Office, 20% of households are repaying mortgage loans and 10% consumer loans. We do not know

how many households with mortgage loans are also repaying consumer credit at the same time. We assume that 25% of Czech households have some debt burden. According to some studies, the marginal propensity to consume (MPC) can differ for unemployed and employed consumers. Thomson, Chung and McKibbin (2009) empirically tested MPC for households worried and not worried about their future job and pointed out that MPC significantly differs for these two groups. If we further express change in consumption as a ratio to GDP, we can reformulate equation (4.7) in formula (4.10).

$$\frac{\Delta C}{Y} = (1-dk)[u(c_U - c_E) + c_E]\frac{\Delta Y}{Y} + [(c_U - c_E)(\Delta u - dk\Delta u - \Delta dku - \Delta dk\Delta u) - \Delta dkc_E](1+\frac{\Delta Y}{Y}) \tag{4.10}$$

where parameter k corresponds to the share of consumers with some debt burden (k = 0.25) and d corresponds to household default rate (we assume d = 0.05, which corresponds to default on banking loan portfolio to households at the end of 2009). We employ the value 0.9 for the parameter c_E - marginal propensity to consume for employed consumers and 0.5 for the parameter c_U - marginal propensity to consume for unemployed consumers.[79] The following tables illustrate the change in aggregate consumption as a result of change in the GDP growth rate, default rate and unemployment rate

[79] The marginal propensity to consume can be estimated using aggregate data. Barry, Bradley, Kejak and Vavra (2000) employed the value of 0.8 for the Czech economy. Thomson, Chung and McKibbin (2009) estimated MPC for households worried about their future job at close to 0.9 and for households not worried about their future job at close to 0.5. The Czech aggregated data suggest an MPC of close to 0.9. Hence we used this value for employed consumers. For unemployed consumers, we set this parameter at 0.5, in line with the study of Thomson, Chung and McKibbin (2009), as MPC for households worried about their future job should be the upper estimate for unemployed consumers.

Table 4.3
Change in consumption as a result of a change in GDP growth rate, default rate and unemployment rate
(in % of GDP)

Δu = 1%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-1.47	-1.69	-1.91	-2.13	-2.36
	-2	-2.32	-2.54	-2.76	-2.98	-3.20
	-3	-3.17	-3.38	-3.60	-3.82	-4.04
	-4	-4.02	-4.23	-4.45	-4.66	-4.88
	-5	-4.87	-5.08	-5.29	-5.50	-5.72
	-6	-5.71	-5.93	-6.14	-6.35	-6.56
	-7	-6.56	-6.77	-6.98	-7.19	-7.40

Δu = 2%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-1.86	-2.08	-2.30	-2.52	-2.74
	-2	-2.71	-2.92	-3.14	-3.36	-3.58
	-3	-3.55	-3.77	-3.98	-4.20	-4.42
	-4	-4.40	-4.61	-4.82	-5.04	-5.25
	-5	-5.24	-5.45	-5.66	-5.88	-6.09
	-6	-6.09	-6.30	-6.51	-6.72	-6.92
	-7	-6.93	-7.14	-7.35	-7.55	-7.76

Δu = 3%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-2.25	-2.47	-2.69	-2.91	-3.13
	-2	-3.09	-3.31	-3.53	-3.75	-3.96
	-3	-3.93	-4.15	-4.36	-4.58	-4.80
	-4	-4.78	-4.99	-5.20	-5.41	-5.63
	-5	-5.62	-5.83	-6.04	-6.25	-6.46
	-6	-6.46	-6.67	-6.87	-7.08	-7.29
	-7	-7.30	-7.51	-7.71	-7.92	-8.12

Δu = 4%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-2.64	-2.86	-3.08	-3.30	-3.52
	-2	-3.48	-3.70	-3.91	-4.13	-4.35
	-3	-4.32	-4.53	-4.75	-4.96	-5.17
	-4	-5.15	-5.37	-5.58	-5.79	-6.00
	-5	-5.99	-6.20	-6.41	-6.62	-6.83
	-6	-6.83	-7.04	-7.24	-7.45	-7.66
	-7	-7.67	-7.87	-8.08	-8.28	-8.49

Furthermore, the negative feedback effect on the aggregate consumption stemming from the adverse macroeconomic scenario can be calculated using the second term in the formula (4.10). The following tables illustrate the size of this effect for different rates of GDP growth, default rate and unemployment rate.

Table 4.4
Additional feedback effect on aggregate consumption
(in % of GDP)

Δu = 1%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-0.61	-0.84	-1.06	-1.28	-1.50
	-2	-0.61	-0.83	-1.05	-1.27	-1.49
	-3	-0.60	-0.82	-1.04	-1.25	-1.47
	-4	-0.60	-0.81	-1.03	-1.24	-1.46
	-5	-0.59	-0.80	-1.01	-1.23	-1.44
	-6	-0.58	-0.79	-1.00	-1.21	-1.43
	-7	-0.58	-0.78	-0.99	-1.20	-1.41

Δu = 2%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-1.00	-1.23	-1.45	-1.67	-1.89
	-2	-0.99	-1.21	-1.43	-1.65	-1.87
	-3	-0.98	-1.20	-1.42	-1.63	-1.85
	-4	-0.97	-1.19	-1.40	-1.62	-1.83
	-5	-0.96	-1.18	-1.39	-1.60	-1.81
	-6	-0.95	-1.16	-1.37	-1.58	-1.79
	-7	-0.94	-1.15	-1.36	-1.57	-1.77

Δu = 3%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-1.40	-1.62	-1.84	-2.06	-2.28
	-2	-1.38	-1.60	-1.82	-2.03	-2.25
	-3	-1.37	-1.58	-1.80	-2.01	-2.23
	-4	-1.35	-1.57	-1.78	-1.99	-2.21
	-5	-1.34	-1.55	-1.76	-1.97	-2.18
	-6	-1.33	-1.53	-1.74	-1.95	-2.16
	-7	-1.31	-1.52	-1.72	-1.93	-2.14

Δu = 4%		Change in household default rate (in percentage points)				
		1	2	3	4	5
Change in GDP (in %)	-1	-1.79	-2.01	-2.22	-2.44	-2.66
	-2	-1.77	-1.99	-2.20	-2.42	-2.64
	-3	-1.75	-1.97	-2.18	-2.39	-2.61
	-4	-1.73	-1.94	-2.16	-2.37	-2.58
	-5	-1.71	-1.92	-2.13	-2.34	-2.55
	-6	-1.70	-1.90	-2.11	-2.32	-2.53
	-7	-1.68	-1.88	-2.09	-2.30	-2.50

These sensitivity analyses suggest that the impact of the macroeconomic shock on GDP is stronger than the impact of the original shock. However, within our simple theoretical framework, we assume that households do not expect the macroeconomic shock. Hence, they have not adjusted their consumption prior to the shock. Table 4.4 shows how important the additional consumption effects can be in the case of a significant increase in the household default and unemployment rates.

6. Conclusion

The economic downturn arguably makes it less likely that households will be able to repay their loans. Household budgets can be negatively affected by declines in nominal wages and increases in unemployment. This effect was empirically tested for the Czech economy. Our analysis describes two basic mechanisms causing the increase in household insolvency: a decline in nominal wages and an increase in unemployment. As a result of a lack of micro data on Czech household finances, the extent of their financial distress due to adverse macroeconomic shocks cannot be directly evaluated. However, with some simplifying assumptions, micro data were simulated and the impact of macroeconomic shocks on the household sector assessed. Alternatively, the macroeconomic approach utilizes a simple Merton-type one-factor model. Our analysis of a potential slump in nominal wages during 2010 suggested that under the extreme scenario the budgets of about 30% – 50% of households with debt burdens would be in deficit if their nominal incomes were to decrease by more than 10%. This corresponds to roughly 7% - 12% of the total Czech population.

The crucial second part of the empirical analysis deals with the estimation of aggregate consumption. Our relatively simple theoretical model showed the extent to which an unexpected increase in the household default and unemployment rates cause an additional decline in consumption, which is reflected in an economic slump. We illustrate that the impact of the change in unemployment on the size of that effect positively depends on the difference between the marginal propensities to consume for employed and unemployed consumers. Our analysis, based on the derived relationship for aggregate consumption, showed that for the Czech economy e.g. a 4 percentage

point increase in the default rate and a 3 percentage point increase in unemployment rate cause an additional decline in GDP of roughly 2 percentage points. If we do not take this effect into account, the expected decline in economic growth can be significantly underestimated. The study clearly shows the importance of the transmission channel via household balance sheets for the economy, which is usually not taken into account in macroeconomic and monetary policy models. Such omission of feedback effects on household consumption may produce a bias in economic policy making.

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Appendix: One-factor Model with Default Barrier Depending on Macroeconomic Environment

The one-factor model is one of the variants of the latent factor model which belongs to the class of Merton structural models (see e.g. Jakubík (2007) or Jakubík, Schmieder (2008) for the version of the one-factor model with default barrier depending on macroeconomic environment). A random variable with a standard normal distribution is assumed for the standardized logarithmic asset returns of economic agent *i* at time *t*:

$$R_{it} = \sqrt{\rho} F_t + \sqrt{1-\rho} U_{it} \qquad (4.11)$$

where R_{it} denotes the logarithmic asset return for economic agent *i* in an economy at time *t*, and F_t corresponds to the logarithmic asset return of the economy at time *t*, which is assumed to be a random variable with a standard normal distribution. This variable represents the part of the asset return which is not specific to the economic agent and can thus denote general economic conditions. U_{it} denotes the economic agent-specific asset return, which is again assumed to be random with a standard normal distribution. The two random variables are assumed to be serially independent. The portion of risk that is systematic is defined by ρ_i, the correlation of the economic agent's asset return with the systematic factor F_t.

Given these assumptions, the logarithmic asset return of economic agent *i* at time *t* is also standard normally distributed. The model is based on the Merton model, according to which a default occurs if the return on an economic agent's assets falls below a certain barrier *T*, the default threshold. Formally,

$$P(Y_{it} = 1) = P(R_{it} < T), \qquad (4.12)$$

where *Y* denotes a binary random variable with two potential states, borrower *i* defaults (1), or does not default (0), at time *t* and *T* is the default threshold.

In order to model aggregate credit risk by means of different macroeconomic indicators, it is further assumed – unlike in the case of Gordy's Basel II one-factor-model (Gordy, 2003) – that the value of the default threshold *T* depends on the economic cycle. This is modeled by taking a linear combination of macroeconomic variables (x_{jt}) to represent the value of the default threshold *T*.

The final form of the macroeconomic one-factor credit risk model used in this study is shown in equation (4.12), where Ψ denotes the distribution function of the standard normal distribution that represents the impact of a change in the macroeconomic

indicators, β_0 is a constant and β_j are the coefficients of the macroeconomic variables, x_{jt}:

$$p_{it} = P(R_{it} < T) = P(\sqrt{\rho}F_t + \sqrt{1-\rho}U_{it} < \beta_0 + \sum_{j=1}^{K}\beta_j x_{jt}) = \Psi(\beta_0 + \sum_{j=1}^{K}\beta_j x_{jt}) \quad (4.13)$$

The default probability conditional on the realization F_t of a random unobservable factor representing the state of the economy at time t corresponding to the default probability (4.13) is given by formula (4.14).

$$p_i(f_t) = P(U_{it} < \frac{\beta_0 + \sum_{j=1}^{K}\beta_j x_{jt} - \sqrt{\rho}f_t}{\sqrt{1-\rho}}) = \Psi\left(\frac{\beta_0 + \sum_{j=1}^{K}\beta_j x_{jt} - \sqrt{\rho}f_t}{\sqrt{1-\rho}}\right) \quad (4.14)$$

If we furthermore assume a homogeneous portfolio of economic agents in the economy whose asset returns follow process (4.11), the default rate in the economy is – based on the law of large numbers – equivalent to the economic agent's default probabilities. Accordingly, the model may then be applied to homogeneous sub-sectors of the economy such as the corporate sector and the household sector.

Accordingly, the specification of the model resulting from (4.13) is as follows:

$$df_t = \psi(\beta_0 + \sum_{i=1}^{K}\beta_i x_i) \quad (4.15)$$

where df_t denotes the dependent variable of the model (i.e. the default rate of the corporate or household sector), β is the coefficient vector, x is the vector of the macroeconomic variables and β_0 is a constant.

In order to estimate model (4.15), a relationship with a conditional number of defaults of economic agents depending on the realization of random variable F, the latent factor f_t is used. This number is, under the given assumptions, again random and has a binomial distribution with conditional probability $p_i(f_t)$ given by equation (4.14) and the number of economic agents N_t.

$$D(f_t) \approx Bi(N_t, p(f_t)) \quad (4.16)$$

The model is then calibrated by maximising a likelihood function (4.17).

$$l(\beta_0,\ldots,\beta_N,\rho)=\sum_{t=1}^{T}\ln\left\{\int_{-\infty}^{+\infty}\binom{n_t}{d_t}\Psi\left(\frac{\beta_0+\sum_{j=1}^{N}\beta_j x_{jt}-\sqrt{\rho}\,f_t}{\sqrt{1-\rho}}\right)^{d_t}\left[1-\Psi\left(\frac{\beta_0+\sum_{j=1}^{N}\beta_j x_{jt}-\sqrt{\rho}\,f_t}{\sqrt{1-\rho}}\right)\right]^{n_t-d_t}\phi(f_t)df_t\right\} \tag{4.17}$$

Performance of credit risk models for Czech household sector

Chart 4.2: Credit Risk Model for Czech Household Sector
(3M-default Rate, in %)