Bachelor Thesis

A Macro-financial Model for Credit Risk Stress testing: The Case of Latvia

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Abstract

This paper investigates the sources of credit risk in Latvian banking system. Using a three-step rigorous methodology we estimate resilience of Latvian banking system to shocks in chosen macro-financial variables. We build reduced form VAR model to uncover the relationship between macroeconomic and financial variables and forecast their development over a period of one year. Next, to identify the influence of macro-financial variables on banks' credit risk, measured as a share of non-performing loans to gross loans, we use panel data regression including chosen macro-financial variables as independent regressors. After we establish the relationship between NPLs and those variables, we introduce a plausible shock to the system based on a historical scenario of GDP development. Shocked NPL values are later used to calculate new capital adequacy ratios (CAR) for banks in order to check if they are still above the threshold of regulatory requirement of CAR equal to 8%. Results of the analysis indicate that not all the banks in the Latvian banking system would withstand a crisis that would entail a drop of GDP equal to that during the recent financial crisis. However, the Latvian banking system overall is quite resilient to macro-financial shocks due to its sound capitalisation.

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1. Introduction

The lessons of the recent global financial crisis have proved to be very insightful on many accounts, but one thing they have demonstrated particularly well is the drawbacks of the risk management systems banks used to have prior to the crisis. Building up liquidity pressure and credit risk losses, which transformed into the system-wide risk during the years of crisis, indicated that prudential risk assessment and monitoring were often neglected by banks worldwide as economies were experiencing their boom years. The dramatic destabilisation of financial systems alarmed both policy makers and supervisory authorities to take action in ensuring the quality of precautionary measures banks take as part of their risk management.

Stress testing, whose popularity had been growing even in pre-crisis years, became one of the most widely advocated tools for banks. Authorities such as the European Banking Authority, the European Commission, the Basel Committee introduce regulations that specify requirements for the use and quality of stress tests by financial institutions. A methodological approach for examining the "potential vulnerability to exceptional but plausible events", *stress testing* has proved to be an integral part of banks' risk management practices.

The scope of this paper is to assess the resilience of the Latvian banking system to external shocks affecting its credit risk parameters. Credit risk[1] is, by far, the most relevant risk factor in contemporary banking, and Latvia is no exception. Usually regulatory capital provisions for credit risk considerably surpass capital charges for other categories of risk (Bonti, Kalkbrener, Lotz, & Stahl, 2005). With loans amounting to nearly two thirds of the Latvian banks total assets (Bank of Latvia, 2012), the counterparty risk appears to be the major individual source of risk.

In this paper we scrupulously devise and discuss an approach for stress testing the banking system with respect to credit risk, given the Latvian context. In line with the literature, we measure credit risk as the proportion of non-performing loans to the total loans. Additionally, we formulate our own specification for the regression equation for the case of Latvia, examining whether shocks to macro-financial variables result in escalation of non-performing loans and subsequent capital losses.

In the post-crisis years the health of macroeconomic and financial environment in Latvia, including that of its banking system, has been slowly improving. However, development of a prudent credit risk stress testing methodology remains extremely relevant because both old and new sources of risk have to be identified and monitored on a constant basis. Stress testing is an

[1] Credit risk is usually referred to as counterparty risk in the context of commercial banking.

indispensable tool when it comes to examining the system's resilience to plausible shocks. Even though Latvian macroeconomic situation has stabilised, there exist plausible internal and external risks that can endanger its sustainable growth. Internally, the main risks, especially in the medium term, are connected with gradual labour market overheating. Externally, Latvian macroeconomic stability significantly depends on economic growth of its trading partners. A newly emerging risk stems from the conflict between Russia and Ukraine, which, in case of imposition of economic sanctions, could have dire implication for Latvian economy. Examining effects of changes in macro-financial variables on banks' credit risk and capital adequacy, should such risks materialise, could give an indication of how stable the Latvian banking system is and whether it would withstand such adverse developments. Therefore, our paper makes a highly relevant contribution both to the existing academic literature on stress testing and the body of empirical analysis for Latvian case specifically.

We formulate the research problem at hand into the following research question:

How resilient is the Latvian banking system to adverse macro-financial shocks simulated through the credit risk model?

The remainder of the paper is organized as follows: section 2 provides a brief overview of the Latvian banking system as well as macroeconomic trends that can potentially affect its stability. Section 3 provides an extensive literature review of the risks in the banking sector and stress testing methodologies. In section 4, step by step, we develop a rigorous methodology, applying which we arrive to an answer to the proposed research question. We discuss the empirical findings of our work in section 5. Section 6 highlights implications and suggestion to the future research, whereas section 6 draws concluding remarks.

2. Overview of Latvian Banking System

The year 2014 started off with 3 credit institutions halting their operations – GE Money bank, UniCredit Bank and Latvijas Hipotēku un zemes banka - and 26 institutions present on Latvian market, 9 of them being branches of foreign banks operating in Latvia. Quality of the loans extended to households kept improving but at a pace slower than expected. Since its spike of 19.4% in the third quarter of 2010, the share of loans past due 90 days NPLs has been contracting, but at the end of 2013 it was still almost 6 times higher than before the crisis and equalled 8.3% (Figure 1). Besides, the ratio of provisions to the principal amount of the loans with payments of more than 90 days overdue remains high (around 74%). With regards to credit risk, the banking sector remains well-capitalised: the capital adequacy ratio reached an all-time

high of 18.94% at the end of 2013 versus regulatory minimum of 8% (Figure 2). Currently, it is well above the Euro Area average of 15%. Also, the lending pace remains slow - the loan portfolio continued to decline and contracted by 6.5% in 2013. At the same time, due to the introduction of euro, there has been a substantial increase in resident deposits (13.3%), which slightly improved the liquidity situation (Financial and Capital Market Commission, 2014).

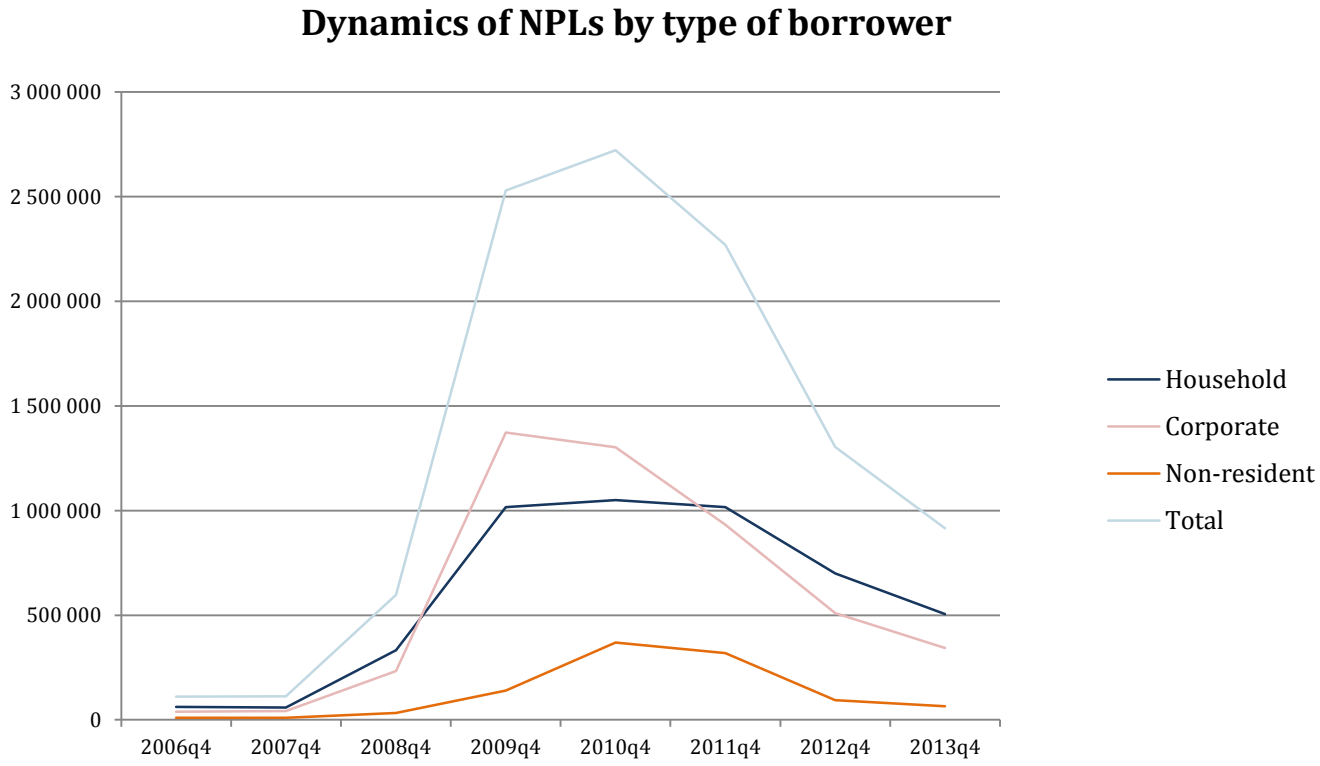


Figure 1 – NPL statistics by type of borrower (created by the authors based on data from FCMC)

In spite of gradually improving banking indicators, external risks coming from the sluggish growth and sovereign debt crisis in the euro area, can have a negative impact on the pace of Latvian financial system's recovery. The beginning of the year 2014 brought concerns over Latvian economic situation with regards to the crisis between Russia and Ukraine. If the European Union imposes economic sanctions against Russia, and Russia does so in return, Latvian economy will be the one affected most. There are in particular three industries that would bear the consequences of such sanctions in the first place. Firstly, Russia is Latvia's second largest partner for exports of agricultural and food products. Secondly, 70% of all transit through Latvia is connected with Russia. Thirdly, the country is fully dependent on Russia in its natural gas imports (Ivanova, 2014). Thus, existing risks can potentially transform into tangible losses, which have to be estimated. All these question the credit losses absorption capacity of Latvian banking and demonstrates the necessity of thorough banks' monitoring.

Domestically, risks Latvian economy is facing are connected with several factors. The most alarming issue is labour market overheating: real gross wages have seen a slightly faster growth than productivity in the past year, which might pose a risk for competitiveness if the trend strengthens. Also, exports and investments have been quite sluggish; however, they are expected to pick up in 2014-2015 (Swedbank, 2014). Given these and other developments, there is a critical need for constant, quality monitoring of financial stability and banks' ability to withstand crises (Bank of Latvia, 2012).

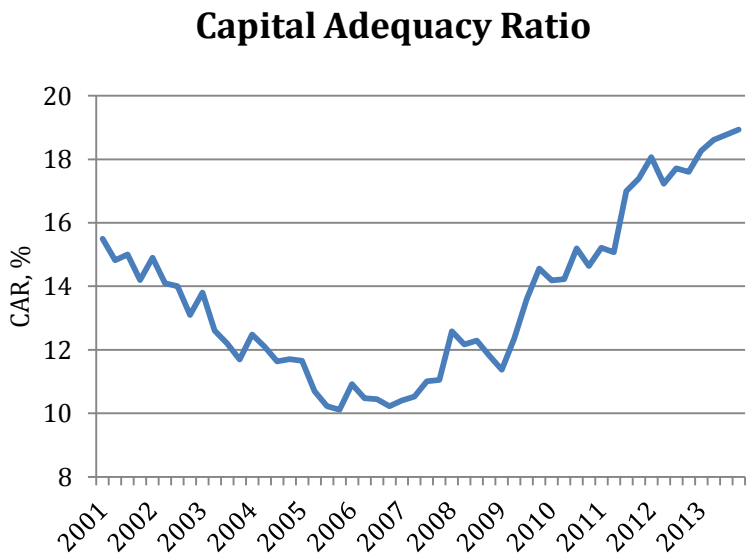


Figure 2 - Capital adequacy ratio dynamics (created by the authors based on data from FCMC)

Given the trends and expectations outlined above, in particular strong capitalisation of Latvian banks, we put forward the following hypothesis that should allow us to answer the research question in a more quantitative fashion:

The capital adequacy ratio of Latvian banks will not fall below the minimum regulatory requirement of 8% in response to adverse macro-financial shocks.

3. Literature Review

3.1 Banking Risks

Within the financial system, which is a complex set of closely interlinked markets and institutions used for financial contracting and the exchange of assets and risks, banks play a crucial role. These financial institutions take on the role of intermediation between borrowers and lenders: they channel the funds from investors with an excess of them to those who experience a shortage of funds. Banks, along with other financial institutions, start operating in response to the existing market frictions, such as transaction costs and information asymmetry,

and by their activities facilitate resource allocation. The ability of institutions to acquire and process large amounts of relevant information – something that is impossible to do on an individual level - as well as the ability to agglomerate and distribute capital while assuming risks faced by individuals lowers individuals' transaction costs and moral hazards, thus, facilitating exchange (Levine, 1997). In a very basic sense, banks make profits by charging an interest rate on the loans they extend to borrowers that is higher than the rate they pay to depositors whose funds they hold on their balance sheets. Through credit they issue to governments, businesses and households, banks become interwoven with the real economy, which they can have a remarkable impact on through their actions. These links are further strengthened because banks can in fact issue a larger amount of loans than the deposits they have. They can raise the required funds in interbank lending market or, if needed, from the discount window, i.e. from the 'lender of last resort' (Prince, 2013). Banks are profit-seeking organisations and, naturally, in the course of time they have been very prolific at developing more and more complicated financial instruments that would allow them to circumvent the restrictions imposed by regulatory authorities. Such financial innovations without doubt increase the market efficiency, however, they further complicate the relations between participants of financial and real markets, which leads to a higher exposure to each others' risks.

Due to their very nature, banks are accompanied by multiple risks in their activity. As any organisation, a bank is exposed to operational risk, the risk of loss due to the failure of internal systems and processes through which the company operates, as well as reputational risk – that of a loss due to damages in a company's reputation. The movements in market prices may cause losses for a bank's investment or trading portfolios, which is defined as market risk, with interest rate risk and currency risk being the most relevant for banks. Especially in the light of the recent events in the global financial markets, regulatory changes present a substantial risk for banks. For example, participants of the Bank Governance Leadership Network highlighted that uncoordinated changes in regulation may lead the occurrence of new strategic or even systemic risks. They also voiced their concerns over the emergence of geopolitical risks such as the risk of cyber attacks (Ernst & Young, 2012).

As illustrated by the global financial crisis of 2008-2009, risks connected with liquidity are among the ones that have the most crucial effects on the whole banking system. In the relevant literature, the notion of liquidity refers to the unrestrained ability of economic agents to exchange their wealth for other assets (Williamson, 2008). Funding liquidity is the ability of banks to meet their liabilities as they are due and fund more assets, as in BIS (2008). The inherent funding liquidity risk stems from the maturity mismatch of loans and deposits, with the former having

longer maturities and the latter having short maturities. The focus of the literature, especially recently, has been largely on transitions from funding liquidity risk to market liquidity risk.

Banks are highly interlinked among themselves, thus, the risk of a contagious failure of financial system due to the rise in any of the mentioned risks has been termed as systemic risk. It is in particular the systemic nature of the risks that endangers the stability of the whole financial system.

However, exposure to credit risk, arguably, remains to be the most pervasive and important source of problems for the banks worldwide, as discussed, among others, by Ali and Daly (2010), Mileris (2012), Castro (2013). Credit risk is the risk of loss of principal or financial reward due to a borrower's failure to repay a loan or otherwise meet a contractual obligation (Jorion, 2001). It stems from the fact that a borrower expects to cover the current obligations with the future cash flows that are uncertain, and thus, he may be unable or unwilling to perform the given obligations. As banks assume this risk, they require a compensation for lending their capital. During the underwriting process, a credit institution has to assess the credit risk of lending to a particular potential borrower; naturally, the required return will increase if the perceived credit risk increases. Banks generally aim at maximising risk-adjusted rate of return while keeping credit risk exposure within acceptable limits. Not only should banks monitor the risk of individual credits, but they also need to manage the credit risk of the whole portfolio they hold and consider the relations of credit risk with other risks. Whereas loans are the biggest source of credit risk, nowadays there are multiple sources of credit, or counterparty, risk for banks, including financial derivatives, interbank transactions, securities, etc. (Basel Committee, 1999).

Often credit risk is used interchangeably with default risk. In assessing default risk of a given counterparty, there are several factors to be considered. Firstly, the bank should arrive at a certain default probability measure – the likelihood of a default over a specified time period. Second factor is credit exposure, which is the total amount of credit provided to a borrower by a credit institution, and it indicates the magnitude of the potential loss in the event of default. Thirdly, a bank should assess what part of the exposure that can be recovered in the event of default – recovery rate. Using these parameters, a bank can arrive at a measure of the default risk. It is rather difficult to give a precise estimation or measurement of credit risk because some of these factors that form it are particularly hard to quantify, such as correlations between default probabilities, for example (Pesaran, Schuermann, Treutler, & Weiner, 2006).

When performing credit risk analysis, a bank should take into account the debtor's credit history, collateral assets, revenue-generating ability, etc. It might be complicated because of asymmetric information and moral hazard issues, which played a crucial role in the unfolding of the global financial crisis. Uncertainty surrounding a counterparty's default probability brought the freezing of credit markets, especially those for interbank lending, which resulted in many financial institutions failures (Ali & Daly, 2010).

Another crucial part of analysis of borrowers' creditworthiness involves measurement and control of credit risk determinants that affect the ability of borrowers to repay at the aggregated level. Such variables can be generally broken down into macroeconomic, banking sector and microeconomic variables (Fainstein & Novikov, 2011). Many authors have studied the influence that the development of macroeconomic variables can have on default risk faced by banks, highlighting that these factors are among the most crucial in determination of risk (Jakubík, 2007), (Bohachova, 2008), (Figlewski, Frydman, & Liang, 2012). Typical macroeconomic variables that have been found to have an influence on credit risk across many works include real GDP growth rate, unemployment rate, inflation rate, fixed capital formation, export, real exchange rate, nominal interest rate and some others. When it comes to banking sector variables, there are several of them that are typically included as dependent in the analysis of credit risk. For example, Pesola (2001, 2005) suggests the growing aggregated indebtedness as the main driver of credit risk growth. Other variables include loan-to-asset ratio, market concentration, and bank capitalisation (Babihuga, 2007). There have been studies that attempted to look at the internal functioning of the banking system as the reason for growth in credit risk. They explain that intense competition and high profit targets of the industry may lead to inadequate credit analysis as banks pursue higher growth extending more new credit to the market (Fainstein &Novikov, 2011). For the context of our study, important findings were made by Festić, Kavklera, and Repina (2011), who support the previous research by suggesting that the rapid credit growth and the rise in the amount of available finance for the newly admitted EU member states, among which Latvia can be found, can have a deteriorating effect on the performance of the countries' banking sectors reflected in the non-performing loans dynamics. They state that the risk which is accumulated in a boom while consumption, investment, capital accumulation grows, materialises in the downturn, which was clearly demonstrated during the last crisis. In many cases a sharp rise in crediting was accompanied by lax credit standards and irresponsible assessment of credit risks. In Latvia, the rapid growth of GDP was possible due to the substantial growth in loan portfolio, which, paired with insufficient analysis, led to instability and growth in non-performing loans (Fainstein &Novikov, 2011). Similar results were achieved in a study on

Croatia, in which the authors concluded that rapid growth in loans increased the probability of a rise in credit risk (Kraft & Jankov, 2005).

The global financial crisis has not only proven this relationship, but also demonstrated the inadequacy of the prevailing regulatory requirements, in particular, Basel II Accord. A few distinct points of criticism addressed towards the role of Basel II in the crisis included the cyclical nature of capital requirements, inadequate capital level requirements, discouragement of the long-term hold of assets, the assumption that banks' internal models for measuring risk based on historical data are superior to other, and some others (Simpson Grierson, 2010). Thus, despite a great deal of attention to credit risk before the crisis, after it, regulatory and supervisory authorities took even a more serious stance on its assessment and control. The Basel Committee on Banking Supervision addressed the issue by introducing Basel III framework, which is supposed to improve banks' ability to absorb various shocks by strengthening global capital and liquidity rules. In Europe these concerns resulted in introduction of the *regulation on prudential requirements for credit institutions and investment firms* by the European Parliament and the Council passed in June 2013 (CRR/CRDIV). Another authority that is concerned with European banks' regulation is European Banking Authority (EBA). Supervisory authorities, individual banks, commercial banks employ many techniques of risk management. However, especially after the crisis, stress testing has become the most widely used tool for assessing the resilience of financial institutions to various shocks. So, EBA, for example, conducts EU-wide stress test, which ensures comparability and consistency of stress testing outcomes across banks in the European Union. EBA has just recently announced the details of its 2014 EU-wide stress test. The CRR has also put a significant focus on the importance of stress testing for banks, outlining the definite requirements for stress testing practices (EUR-Lex, 2013).

We have shed the light on the critically important role credit risk plays in financial stability of credit institutions, including the case of Latvia, as well as highlighted that currently the most effective recognised way to test banks' resilience to crises is stress testing. Therefore, we have once again underlined the relevance of our work, and now we can turn to the discussion on existing methodologies for credit risk stress testing.

3.2 Stress Testing

3.2.1 Introduction to Stress Testing

In the last decade, especially in the context of the global financial crisis that highlighted the necessity of developing improved methodological and practical approaches to risk identification and monitoring in banks, stress testing has gained huge popularity among academicians,

supervisory authorities, international organisations such as IMF as well as in banks internally. Defined as a methodological approach for examining the "potential vulnerability to exceptional but plausible events" ((Bank for International Settlements, 2000); (Virolainen, 2004)), *stress testing* proved to be an integral and most comprehensive tool for an on-going assessment of banks' resilience to various shocks.

In essence, a stress test represents an ample form of sensitivity analysis to adverse events such as a dramatic fall in exports, deterioration in total factor productivity, hyperinflation and other macroeconomic shocks as well as shocks in banking, financial systems, etc. In fact, they can be designed for testing any of the risks described in the previous section: liquidity, market, credit, etc. Yet, one cannot view the effect of each of these factors in isolation since banks are strongly interconnected both on national and international levels. Thus, there has been an increasing focus from supervisory authorities on the development of complex stress tests, which combine effects of various types of risks on banks' stability and also examine second-round effects, or feedback loop effects to the real economy. The EU-wide stress test conducted by EBA, which was mentioned before, is an example of such a complex test.

The rationale for using stress tests is three-fold. Firstly, they complement the value-at-risk (hereafter *VaR*) approach by showing the direction of exposure, by computing the magnitude of exposure and by looking at the long-term effects of a shock. Secondly, it is highly recommended that stress tests are applied by financial regulators. Stress testing unveils the systemic risks incorporated in the banking sector, and makes these risks more transparent via calculating potential losses exacerbated by a given shock. Thirdly, on a microeconomic level, the results obtained in stress tests are insightful for projecting capital allocations and checking the effectiveness of organizational systems (Vazquez, Tabak, & Souto, 2012).

3.2.2 Typology of Stress Tests

Stress tests can vary in their complexity and an approach to scenario design, therefore, we shall describe the most common types of stress tests below.

- A simple ***sensitivity test*** allows measuring the impact of one or several shocks to a given type of risk on the portfolio value in the short-run; e.g., currency devaluation/revaluation by -10% and +10% in the context of exchange rate risk or yield curve shifts by +/-100 basis points in the context of interest rate risk. Nevertheless, the model looks at each risk factor in isolation, thus, disregarding the movements in other factors (*ceteris paribus* basis).

- A ***scenario analysis*** examines how the portfolio value changes for a combination of extreme shifts in risk indices. Researchers distinguish the two types of scenarios: historical and hypothetical.
  - *Historical scenario analysis* simulates the same macro-financial environment as it used to be in the times of various crises. This is a precautionary risk monitoring tool because it can be inferred how financial institutions would have stood the by-past extreme shocks. For example, in October 1987 Dow Jones fell by 23% resulting in a total loss of $1 trillion. Under historical scenario analysis, the analogous shock would be interpolated in the U.S. stress tests to compare the cumulative capital losses. Yet with this approach it is very troublesome to justify which events are plausible to re-occur.
  - *Hypothetical scenario analysis* does not duplicate any specific historic conditions, though it rests on some theoretical underpinnings. Typically, risk managers/regulators model the following scenarios: economic recessions, political perturbations, oil price shocks, terrorist attacks, etc., which might often be based on expert judgement. Though hypothetical scenarios are better tailored to the current market environment, they lack objectivity and probability assigned to their occurrence.
- A **maximum loss approach (MLA)** deals with the "objective" worst-case scenarios. In a nutshell, this technique identifies the most plausibly harmful co-movements of risk factors within the range of plausible outcomes. The group of factors that jointly would lead to the maximum loss are applied to design the portfolio performance in the future. Unlike hypothetical scenario analysis, maximum loss approach eliminates subjectivity in the choice of scenarios. However, practitioners do not tend to rely on its [MLA's] outcomes when setting exposure limits meaning that the combination of adverse events is rather arbitrary (their probabilities are unknown).
- **Extreme value theory (EVT)** is a statistical approach to stress testing. EVT argues that the series of extreme events should converge to a known distribution, regardless of the distributions of the underpinning returns. According to the EVT, the mean and variance of the distribution of extreme events are normal, but an additional parameter, *tail index*, is critical to estimating the shape of the density function. This tail measure makes it possible to adjust for skewed or kurtic distributions. One notable drawback of such a model is failure to consider the distribution of the underlying returns.

In this paper, we employ scenario analysis based on a historical adverse macro-financial shock to the Latvian economy described later on. This method has proved to be the most commonly used both among academicians and practitioners, and it allows great flexibility when it comes to the calibration of particular conditions that the economy can face.

3.3 Credit Risk Stress Testing

A considerable effort has been made to analyse and quantify the resilience of the banking industry in respect of credit risk. Numerous papers are published on the topic of credit risk stress testing, ranging from the IMF single-factor sensitivity tests to the scholarly papers on structural macro-financial models that link real economy with banks' balance sheets (and, as a result, loan portfolio). In the following chapter we will describe the existing approaches to credit risk stress testing.

3.3.1 Piecewise approach

The first strand of literature is dedicated to the "**piecewise**" approach to credit risk stress testing. By definition, it implies estimating the causal relationship of a system-wide shock on a separate financial variable (e.g. loan write-off rates). The coefficients of interest are obtained employing historical data for macroeconomic parameters (X) and different proxies for credit risk measurement (Y). Econometrically, papers that use this approach follow either reduced form models (time-series or panel data regressions) or structural macroeconomic specifications. For example, panel data analysis was used by Vazquez, Tabak, & Souto (2012), who examine the relationship between the amount of non-performing loans in the Brazilian banking system (clustered by industry), its lagged value and the GDP growth accounting for the bank-level fixed effects. The estimated results are used to simulate the development of the loan quality in response to several macroeconomic shocks (drop in GDP, rise in credit growth, etc.)

Yet a more widespread approach to modelling the credit risk framework requires time-series techniques, commonly vector autoregression models (VARs). Hoggarth, Sorensen, & Zicchino (2005) employ a VAR in order to capture the link between the UK banks' fragility (expressed as the loan write-off rates) and the GDP gap. Their results suggest that in the event of a GDP decrease, both corporate and aggregate write-off rates increase substantially. Pesaran *et al.* (2006) and Alves (2004) designed a global VAR and co-integrated VAR models, respectively, in their cross-country studies. Pesaran *et al.* (2004) examine how strongly corporate default probabilities are correlated with the nation-wide and international economic cycles, and

arrive at the conclusion that the impact of adverse shocks on expected losses is non-symmetric, thus, highlighting the non-linearity in the estimated model.

An obvious advantage of the VAR paradigm is a more ample characterization of the adverse macroeconomic shocks on other system variables. Additionally, VARs are a useful tool for evaluating a macro-financial policy implementation since they can track the trade-offs emerging in the search for financial stability. On the other hand, the piecewise approach fails to describe credit loss distributions and disregards non-linearity in its specifications.

3.3.2 Integrated approach

Another cohort of authors argues in favour of the "**integrated**" stress testing approach, which investigates the financial system vulnerability in a multi-factor setting. In other words, financial system becomes subject to a range of risk factors (credit and market), which further results in a single estimate of predicted losses. Adrian & Shin (2008), Sorge (2004) and Jandacka, Breuer, & Krenn (2005) all advocate the use of integrated stress testing, since it gives the possibility to obtain a probability loss distribution for any stress scenario. It also allows for quantifying the expected losses with the help of the VaR function that is dependent on a combination of macroeconomic factors. Jandacka, Breuer, & Krenn (2005) argue that the aggregated model testing credit and market risks provides more reliable results than the two models testing each risk in isolation. The authors illustrate their hypothesis by referring to the Russian Rouble Crisis of 1998. At that time, financial institutions used to hold the USD/RUR forwards along with the offsetting RUR/USD forward contracts for hedging purposes. It had been assumed that in an event of default the losses from this position should be zero provided that the exchange rate doesn't change. However, when the crisis eventually hit, the rouble had been devalued, and the American counterparts suffered significant losses because the same amount of dollars was no longer worth the predetermined amount of roubles. The authors conclude that the additivity principle for the two risk factors (credit and market risk) doesn't hold meaning that the expected losses from a simultaneous variation in risks appeared to be higher than the ones achieved in the independent settings.

Clearly, integrated stress testing enables researchers to visualise feedbacks effects on the real economy and banking, which allows for a more precise forecasting. However, the endogeneity of most of the macroeconomic indicators is still questionable (Assouan, 2012). To be on a safe side, we would follow the piecewise approach using time series econometrics in our main regression model, where all macroeconomic parameters are exogenous.

Summarizing various approaches, Lakstutiene, Breiteryte, & Rumsaite (2009) outline the following sequence of a typical credit risk stress testing methodology:

1. Assessment of the contemporary macroeconomic conditions in the country based on central bank reporting and expert judgements.
2. Identification of the main risk factors associated with the economy.
3. Evaluation of the current bank asset (loan) quality and (if applicable) computation of default probabilities.
4. Selection of the macroeconomic indicators affecting default probabilities (deterioration of asset quality of banks).
5. Estimation of the causal relationship between macroeconomic factors and default probabilities.
6. Formulation of stress scenarios and scenario analysis.
7. Assessment of the financial system's resilience to adverse macroeconomic shocks.

4. Methodology

4.1 Overview of conventional models

In order to arrive at a proper specification, we shall consider the existing practices in credit risk stress testing models. The summary of approaches is presented in the table below.

Table 1 - An Overview of Credit Risk Models **Source: Created by the authors**

Author(s)	Country of Analysis	Period	Methodology		
			Model	Dependent Variable	Independent Variable(s)
Virolainen (2004)	Finland	1986-2003	Panel	The logit-transformed default rate $\ln\left(\frac{1-p_{i,t}}{p_{i,t}}\right)$ $P_{i,t}$ – probability of default of industry *i* at time *t*	Real GDP growth Nominal short-term interest rate The ratio of debt/value added of a given industry
Nordal & Syed (2010)	Norway	1988-2008	Panel	The logit-transformed debt-weighted default rate $\ln\left(\frac{1-DWPD_t}{DWPD_t}\right)$ $DWPD_t$– debt-weighted probability of default at time *t*	GDP growth Real exchange rate Growth in household wages Rise in house prices Bank's lending rate Loans-to-enterprises index

Hoggarth, Sorensen, Zicchino (2005)	The UK	1988-2004	VAR	The loan write-off rate (write-off-to-loan ratio)	GDP gap CPI Nominal short-term interest rate Change in REER
Pesola (2004)	Nordic countries	1983-1998	OLS	Banks' losses to outstanding lending stock	Lagged dep. var. GDP growth Indebtedness (lending/GDP) Regulation dummy
Pesaran (2004)	11 EU member states	1979-1999	Global VAR	Corporate probabilities of default	GDP, CPI, REER Nominal money supply Equity prices Nominal interest rates
Vazquez, Tabak, & Souto (2012)	Brasil	2001-2009	Panel, time series, VaR	The logit-transformed default rate $\ln\left(\frac{1-NPL_{i,t}}{NPL_{i,t}}\right)$ $NPL_{i,t}$– the ratio of non-performing loans to gross loans of industry *i* at time *t*	Lagged dep. var. Growth in real GDP Fixed bank-level effects
Festic, Kavkler, & Repina (2011)	Central and Eastern Europe	1995-2009	Panel	The first difference of the share of NPLs in gross loans	Deposit to loan ratio Net foreign assets to net assets ratio FDI
Mannasoo & Mayes (2009)	CEE	n/a	Panel logit model	The logit-transformed default rate $\ln\left(\frac{1-NPL_{i,t}}{NPL_{i,t}}\right)$ $NPL_{i,t}$– the ratio of non-performing loans to gross loans of industry *i* at time *t*	Liquidity ratio\ Inverse liquidity ratio Loan to asset ratio Equity to asset ratio

Note: The Table summarizes various methodological approaches to credit risk stress testing. Among other proxies for the probability of default, the ratio of NPLs to gross loans remains the most canonical. We proceed with the most common indicators of credit risk in our specifications.

4.2 Research Methodology

4.2.1 Dependent Variable

One of the most commonly used proxies for the probability of default is the ratio of non-performing loans to gross loans. By non-performing loans regulators and practitioners usually mean impaired loans and loans whose repayments are 90 or more days overdue. The definition may vary from country to country; however, the conventional notion used by the European Central Bank is 90+ days overdue. Originally, this metric characterizes the loan quality of a

lender: the higher the ratio, the worse the quality of his/her loan portfolio. The on-going deterioration of the EU-wide loan portfolio quality provides additional incentives to study their dynamics (European Banking Authority, 2013). If the amount of non-performing loans increases, a bank has to increase its loan loss provisions (LLPs), allowances for doubtful and bad loans. However, given that LLPs do not magnify equally with NPLs, they [LLPs] would capture less information about the overall loan quality. Thus, we find it reasonable to employ the share of non-performing loans to the gross amount of loans as a proxy for the probability of default.

In case of Latvia, data on non-performing loans is quite limited. Quarterly data on NPLs classified as loans >90 days overdue is available from the fourth quarter of 2004 till the fourth quarter of 2013 on aggregated level (total for all banks) from the Financial and Capital Market Commission (FCMC). Data on individual banks' NPLs is available at yearly frequency from year 2006 to year 2012 from Bankscope database, however, data is missing for several banks (e.g. Danske Bank, Expobank), and for others it's not available for the whole period. In Bankscope, NPLs are classified as impaired loans. In order to include data for the longest period possible and get the maximum number of observations, we pick 15 banks that have balanced data on NPLs from year 2008 to year 2012, leaving us with 75 observations. The list of the banks in the sample can be found in Appendix 3.

4.2.2 Explanatory Variables

There is consensus among economists that the probability of default is associated with changes in macroeconomic and financial indicators (Hamerle, Dartsch, Jobst, & Plank, 2011); (Festic, Kavkler, & Repina, 2011). As suggested by Figlewski, Frydman, Liang (2012), there are three groups of macro-factors that influence a firm's (a system's) creditworthiness:

1. factors related to general macroeconomic conditions (e.g. unemployment, inflation, etc.);
2. factors characterizing real economy (e.g. growth of real GDP, terms of trade, etc.);
3. factors reflecting financial market conditions (e.g. interest rates, equity returns, etc.).

Now, we have to come up with a set of exogenous macro-financial variables that would best explain the variation in the probability of default. We first consider different macro-financial variables that are most common in the literature, and then justify the choice of variables for our regression that are applicable specifically for Latvia. Below we present the ratio of NPLs to gross loans as a function of those variables and provide the expected signs of their coefficients:

$$y_t = NPL_t = f(\underset{-}{\text{GDP growth}}, \underset{+}{\text{CPI}}, \underset{-}{\text{REER}}, \underset{+}{\text{Interest Rate}}, \underset{-}{\text{Stock Market Index}}, \underset{+}{\text{U}}, \underset{+}{\text{Loans-to-assets}})$$

Let us briefly provide the economic motivation behind each of the coefficients:

GDP growth (–) – the higher growth in total output would increase real salaries, lessen unemployment, thus, leading to greater loan repayment rates.

Consumer Price Index (+) – an increase in consumer prices would erode a part of the individual/corporate budget, thus, limiting the loan repayment ability.

Real Effective Exchange Rate (–) – an increase in REER means an increase in a country's competitiveness, implying higher loan quality of the banking system.

Interest rate (+) – higher interest rates mean higher interest payments on loans for borrowers, therefore, they should be positively related with NPLs.

Stock Market Index (+) – an increase in financial development leads to an increase in the overall economic growth, thus benefiting the loan quality. However, because of the marginal development of the Baltic stock market, this measure is inapplicable for Latvia.

Unemployment (+) – as mentioned above, the higher unemployment rates implies the lower loan quality because of the less repayment ability.

Loans-to-assets (+) – share of a bank's total loans in assets is considered as a proxy of risk taken by a bank. Rising loan-assets ratio is leads to increases in NPL ratio.

In our specification, we use the most significant indicators of default probability for the Latvian banking system, which are the changes in real GDP growth, changes in harmonised consumer price index, changes in unemployment, changes in interest rate (3-month Euribor), changes in real effective exchange rate, and changes in loan-to-asset ratio. These variables, except for loan-to-asset ratio, enter the VAR model as well in order to get forecasts of their development over a specified period. The justification for the choice of these particular variables follows.

As findings of other research papers demonstrate, GDP growth is often among the most significant determinants of NPL development, and we expect it should hold in Latvian case as well because in a small economy GDP developments have a pervasive effect on corporate as well as household incomes. Unemployment and inflation follow similar logic; especially in case of Latvia a high level of unemployment still remains a significant pressure. Latvia is a very open economy, with exports accounting for more than 40% of GDP, thus we expect real effective exchange rate to have an important influence on NPL dynamics. Rise in interest rates, in its turn,

can have a direct impact on borrowers' probability of default as it increases the burden they should return to a bank in form of interest payments. We include loan-to-asset ratio as a bank-specific factor and we expect relation between NPLs and it to be significant because evidence from previous research demonstrates that as banks are extending their credit lines, often their lending standards deteriorate.

The data have been retrieved from the Central Statistical Bureau of Latvia and Eurostat. All data are seasonally adjusted and are collected at both quarterly and annual frequency.

4.2.3 Methodological Approach

We employ a three-stage approach in order to test the resilience of the Latvian banking system to the adverse macro-financial scenarios. Firstly, we estimate the relationship between the macroeconomic indicators to forecast their evolution over a one-year period. Secondly, we estimate the relationship between the banking loan quality and the macro-financial variables used in the first stage. Further we assess how banks would react to an adverse but plausible macro-financial shock over the one-year period by looking at the change in the ratio of non-performing loans to total loans. Finally, we calculate new capital adequacy ratios for banks, taking into account the increase in loan loss provisions to account for the increase in NPLs.

1. The first stage of our methodological approach is estimation of the relationship between macroeconomic and financial variables that supposedly affect the banks' loan portfolio quality. To forecast their development, we employ the reduced form VAR model that uses 5 variables (namely, change in GDP growth, change in Inflation, change in unemployment, change in 3-month EURIBOR, and growth in real effective exchange rate (REER)). Our regression specification contains only one lag of every explanatory variable. The rationale behind this approach consists in the attempt to preserve degrees of freedom in our small sample.

At first, we have to ensure the stationarity of the variables that enter our time series model. In a nutshell, the assumption of stationarity means that the variance and mean of a series are constant over time. We perform the canonical Augmented Dickey-Fuller test for unit root in order to check for stationarity. The results show that all of the variables contain unit root and, thus, have to be differenced in order to obtain stationary series. After differencing, all of the variables, except for change in HICP, exhibited stationarity. We difference the inflation rate once again and arrive at a stationary series, which is used in future regressions (see Figure 3).

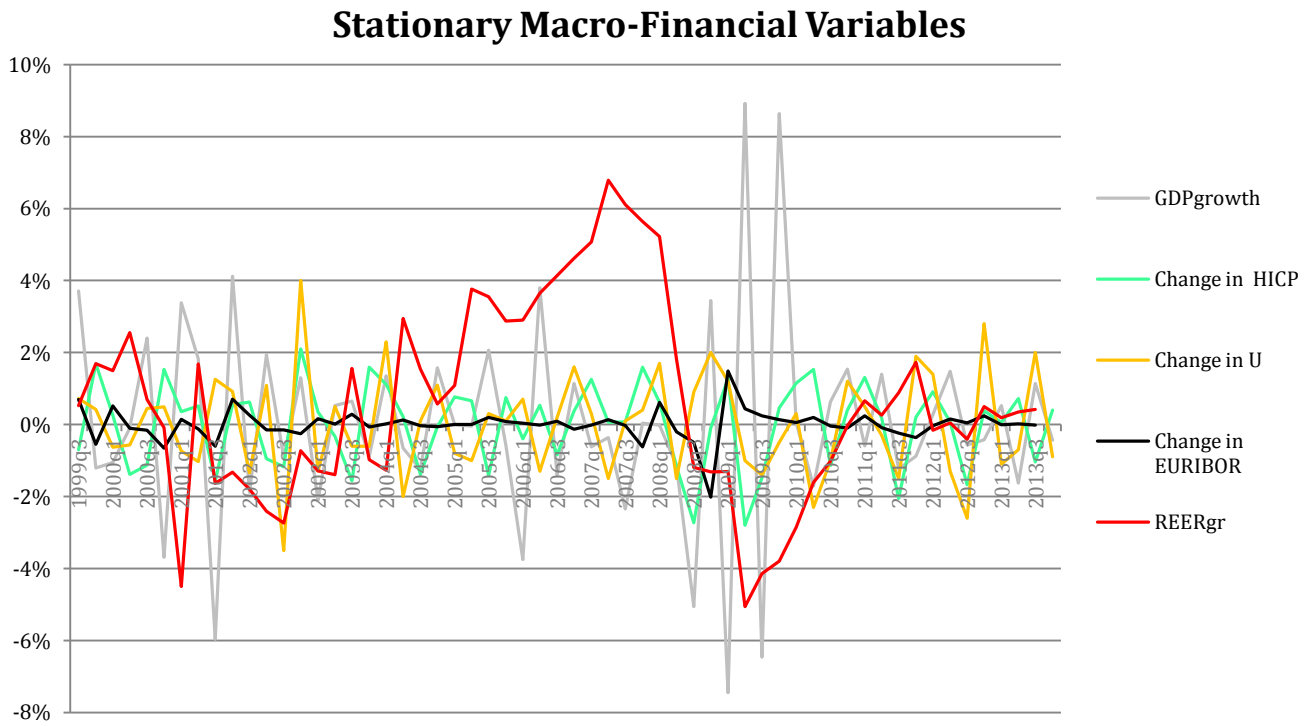


Figure 1 Stationary Series of Variables (Created by authors)

From the plot above it can be seen that all series are stationary and I(0).

Lastly the system-wide shocks are introduced to the model and are reiterated to check the resilience of the Latvian banking sector:

$$\begin{cases} \Delta(GDPgr_t^{real}) = \beta_{10} + \sum_{n=1}^{k} \gamma_{1n} \Delta(GDPgr_{t-n}^{real}) + \sum_{m=1}^{l} \delta_{1m} \Delta HICP_{t-m} + \sum_{d=1}^{k} \phi_{1d} \Delta Euribor_{t-d} + \sum_{b=1}^{c} \varphi_{1b} \Delta U_{t-b} + \sum_{e=1}^{r} \rho_{1e} \Delta REERgr_{t-e} + \varepsilon_{1t} \\ \Delta HICP_t = \beta_{20} + \sum_{n=1}^{k} \gamma_{2n} \Delta(GDPgr_{t-n}^{real}) + \sum_{m=1}^{l} \delta_{2m} \Delta HICP_{t-m} + \sum_{d=1}^{k} \phi_{2d} \Delta Euribor_{t-d} + \sum_{b=1}^{c} \varphi_{2b} \Delta U_{t-b} + \sum_{e=1}^{r} \rho_{2e} \Delta REERgr_{t-e} + \varepsilon_{2t} \\ \Delta Euribor_t = \beta_{30} + \sum_{n=1}^{k} \gamma_{3n} \Delta(GDPgr_{t-n}^{real}) + \sum_{m=1}^{l} \delta_{3m} \Delta HICP_{t-m} + \sum_{d=1}^{k} \phi_{3d} \Delta Euribor_{t-d} + \sum_{b=1}^{c} \varphi_{3b} \Delta U_{t-b} + \sum_{e=1}^{r} \rho_{3e} \Delta REERgr_{t-e} + \varepsilon_{3t} \\ \Delta U_t = \beta_{40} + \sum_{n=1}^{k} \gamma_{4n} \Delta(GDPgr_{t-n}^{real}) + \sum_{m=1}^{l} \delta_{4m} \Delta HICP_{t-m} + \sum_{d=1}^{k} \phi_{4d} \Delta Euribor_{t-d} + \sum_{b=1}^{c} \varphi_{4b} \Delta U_{t-b} + \sum_{e=1}^{r} \rho_{4e} \Delta REERgr_{t-e} + \varepsilon_{4t} \\ \Delta REERgr_t = \beta_{50} + \sum_{n=1}^{k} \gamma_{5n} \Delta(GDP_{t-n}^{real}) + \sum_{m=1}^{l} \delta_{5m} \Delta HICP_{t-m} + \sum_{d=1}^{k} \phi_{4d} \Delta Euribor_{t-d} + \sum_{b=1}^{c} \varphi_{4b} \Delta U_{t-b} + \sum_{e=1}^{r} \rho_{4e} \Delta REERgr_{t-e} + \varepsilon_{5t} \end{cases}$$

2. At the next step, we use panel data regression to estimate the relationship between probability of default and the set of macro-financial indicators:

$$\Delta NPL_{i,t} = \alpha_0 + \alpha_1 GDPgr_t^{real} + \alpha_2 \Delta HICP_t + \alpha_3 \Delta Unemployment_t + \alpha_4 \Delta Loantoasset_{i,t} + \alpha_5 \Delta Euribor_t + \alpha_6 REERgr_t + \upsilon_{i,t}$$

where

$\Delta NPL_{i,t}$ is change in the ratio of *NPL*s to gross loans of bank *i* at time *t*

$GDPgr_t^{real}$ is GDP growth at time *t*

$\Delta HICP_t$ is change in inflation (based on harmonized consumer price index) at time *t*

$\Delta Unemployment_t$ is change in unemployment rate at time *t*

$\Delta Loantoasset_t$ is change in ratio of a bank *i*'s total loans to total assets at time *t*

$\Delta Euribor_t$ is change in European interbank offer rate at time *t*

$REERgr_t$ is growth of real effective exchange rate at time *t*

$\upsilon_{i,t}$ is the white noise process, which is assumed to be independently and identically distributed with a mean of 0 and a variance of 1.

With this approach, we aim to estimate the impact of various macro determinants on the loan quality.

Next, we calculate the expected change in NPL ratio over one year using the coefficients from panel regression and values of macro-financial variables forecasted for the case of a system-wide shock in the first part of the analysis.

3. At the last step, we make calculations that answer the research question in a quantitative fashion. Using the predicted change in NPLs and additional assumptions, we estimate banks' new capital adequacy ratios and compare them to a regulatory minimum of 8%. The following equation is used for this calculation:

$$CAR^* = \frac{OwnCapital - \Delta P}{RWA - \Delta P}$$

Here, OwnCapital is bank's own funds, RWA is risk weighted assets[2], and ΔP is the expected increase in loan loss provisions in response to an increase in non-performing loans. It is calculated as ΔP = ΔNPLs * *Loss given default*, meaning that the amount of the additional loan loss provisions that the bank is supposed to make will equal to the amount of the loans that it doesn't expect to recover. In line with the recovery rate typically assumed in Financial Stability Reports by the Bank of Latvia, we assume it to be equal to 40%, thus LGD is 60% (Bank of Latvia, 2012). When performing this calculation we make a conservative assumption that a bank's profit for the forecasted year equals zero, thus, own capital is not increased by the amount of profit. The data on own funds and RWA are retrieved from the FCMC.

[2] Risk-weighted assets (RWA) – a bank's assets weighted according to risk of different asset classes, used in order to calculate minimum capital needs (Jakubík, 2007).

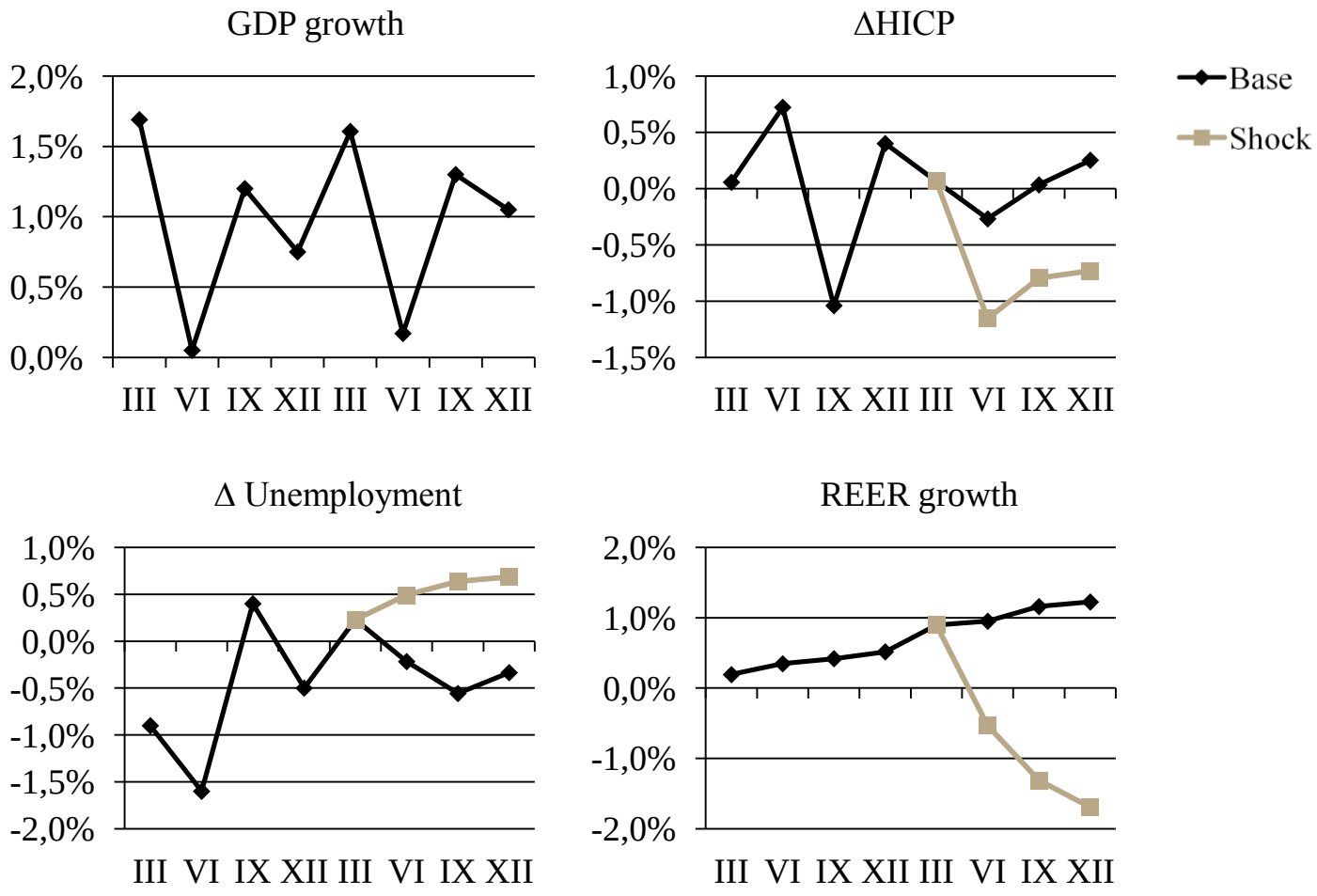
4.3 Limitations

This model is unique in that it is staged in three phases and includes some macro-financial variables, such as loan-to-asset ratio and real effective exchange rate, that haven't been tested before for Latvian banking system. But it is also subject to several pitfalls. First, it fails to account for non-linearity between the variables of interest. Second, it doesn't distinguish between the boom-and-bust events (fails to consider the business cycle). Third, it disregards the feedback effects, which are infeasible to incorporate due to data restrictions.

5. Review of Empirical Findings

5.1 After-shock Macro-financial Variables Development

We choose the historical scenario analysis in order to test the resilience of the Latvian banking system. In our set-up, we design the dramatic fall in GDP equal to 19%[3] over the year of 2014, with assumed equal drops of 5.13% in each quarter. Below one can study the dynamics of forecasted values for variables over the next 4 quarters (created by authors):



[3] A 19% drop in GDP corresponds to the all-time maximum drop of GDP in the Latvian contemporaneous history. GDP soared to this record low in 2009 (Bank of Latvia, 2012).

Appendix 2 exhibits the end-of-period values of the predicted variables in both scenarios, baseline and after shock. The forecasted figure for GDP growth at the end of 2014 is equal to 4.19%, which is in line with expert forecasts by European Commission, Euromonitor Intl, etc. The same applies to other indicators: the unemployment rate is expected to fall to 11.02% in 2014 and HICP will marginally increase by 0.08%. Under the stress scenario (the abrupt fall in GDP growth by 19% over the year of 2014), the macro-financial situation would destabilize: REER growth would diminish, indicating the drop in the country's competitiveness as such; HICP would fall to -2.62%, meaning deflationary economic environment. As a result, predicted change in the NPL ratio under the shock scenario is 12.00%, which is a similar reaction to the one actually observed during the recent crisis.

5.2 Results of the Panel Data Regression

We estimate the equation with changes in NPL ratio as dependent variable using the data on 15 Latvian banks for 5 years, starting with 2008 till 2012. The chosen 15 banks are the ones that have balanced NPL data during the period of 2008-2012, and they comprise more than 70% of total Latvian banking sector's assets as of 2012. We run the regression using several different approaches. First, we use ordinary OLS regression to estimate the coefficients of the independent variables with heteroscedasticity-robust standard errors. Secondly, taking an advantage of panel data properties, we run the fixed effects regression with individual fixed effects using least square dummy variables (LSDV) regression with heteroskedasticity and autorcorrelation consistent standard errors. As OLS regression may suffer from omitted variable bias, we choose fixed effects approach which controls for individual fixed variables that are constant over time. Euribor variable was omitted due to collinearity, so the final equation we used for regression is:

$$\Delta NPL_{i,t} = \alpha_0 + \alpha_1 GDPgr_t^{real} + \alpha_2 \Delta HICP_t + \alpha_3 \Delta Unemployment_t + \alpha_4 \Delta Loantoasset_{i,t} + \alpha_5 REERgr_t + \upsilon_{i,t}$$

We report the coefficients of the regressors in Appendix 1.The results of the regression are broadly in line with our expectations. All coefficients have expected signs. Loan-to-asset ratio has a significant coefficient with a positive sign: increasing ratio proxies for a rise in a bank's risk, thus causing NPLs to increase as well. GDP growth has also proven to have a statistically significant negative effect on NPL growth: as expected, as the economy's growth accelerates and both household and corporate incomes rise, there is a positive effect on banks' credit risk as proxied by NPL decreases. Besides, the coefficient before GDP growth is the largest in magnitude out of all variables – a one percentage point increase in GDP growth results in 0.7 percentage point decrease in NPL share in total loan portfolio. This confirms our expectations of

a pervasive impact GDP growth has on Latvian borrowers' probability of default. The rest of the coefficients have expected signs, but lack statistical significance. It is largely attributed to a small number of observations; however, coefficients will be used for further analysis, because insignificance is a natural outcome of a small number of observations for such type of regressions, and in general they show the right effect on the dependent variable. Changes in inflation also seem to have a strong impact on borrowers' ability to repay loans. An increase in inflation is associated with a substantial rise in NPL ratio. The effect of changes in unemployment rate is somewhat less considerable but this might be due to the fact that it takes more time for these effects to take in. Even though the effect might not be straightforward, when growth in real effective exchange rate is associated with increasing productivity and, thus, increasing country's competitiveness, it should have a positive effect on borrowers' probability of default. And that is what we see in our results, however, the effect is quite small: appreciation of REER by 1% leads to 0.01 percentage point decrease in NPL ratio. The model explains 29.58% of variation of the dependent variable. Having looked at the correlation in the residuals, we haven't found strong evidence for autocorrelation (correlation measure equalled -0.3), but we expect that dynamic panel estimation might have improved the predictive power of the model. However, this is out of the scope of our work.

5.3 Capital Adequacy

At the final stage of the analysis we assess the resilience of the Latvian banking system to the specified shock using capital adequacy ratio (CAR) as a metrics. According to the Basel Agreement, which applies to all Latvian banks, the minimum requirement for CAR is 8%, meaning that the banks' own funds be should at least 8% of its risk-weighted assets (RWA).

Using the coefficients acquired in the panel data regression of NPL ratio on macro-financial variable, we calculate the estimated change in NPL ratio that will happen in the year 2014. Materialisation of the baseline scenario, according to which the macro-financial environment is expected to develop in a favourable way, would lead to a decrease in NPL ratio of 3.07%. If, however, the shock in a form of a 19% drop of GDP materialises, NPL ratio is expected to rise by 12%. During the recent financial crisis after an actual drop of GDP of 18.74% in year 2009, NPL development was akin to the one simulated through our model. Then, NPL ratio for the whole banking sector increased from 3.6% in the fourth quarter of 2008 to 16.4% in the fourth quarter of 2009.

Next, we study the effect of a 12% rise in NPL ratio on banks' capital adequacy ratio (Table 2). Using the formulas described in the methodology part and banks' existing own capital,

CAR, RWA and total loans data as of the end of 2013, we calculate the changed CAR for all banks in response to increased loan loss provisions. This forecast is not made for the three banks that seized their operations in 2013 and for Reverta Bank, whose financial results for the year 2013 have not been published yet. The results indicate that while for some banks the fall in CAR is not critically large, for two of them (DNB Bank and Norvik Bank) the ratio actually falls below the regulatory minimum of 8%, 5.44% for DNB and 7.70% for Norvik . For SEB Bank and SMP Bank the ratio decreases to quite a low level as well, being just slightly above 8%. Under this scenario the required capital injection in order to absorb the rise in credit risk and bring the CAR up to 8% again is 27 829 thousand lat (19 506 thousand euro), or 1.71% of total assets for DNB Bank and 1 159 thousand lat (812 thousand euro), or 0.21% of total assets for Norvik Bank. The estimation of this amount was made under the assumption that the capital injection is not used for an immediate increase in RWA (Appendix 4).

The following results show that the Latvian banking system is overall resilient to a shock in macroeconomic environment in the country due to the high capitalisation of its largest banks. However, deteriorating CAR ratios, which fall below the regulatory requirement for 2 out 11 analysed banks, indicate that concerns over credit risk's impact on stability of Latvian banks remain highly relevant in today's environment.

Table 2 Forecasted 2014 CAR by banks
(Figures are given in thousand lat) Source: simulation; FCMC

Bank	Own Capital	CAR	RWA	Loans	Change in NPLs	Change in provisions	CAR*
ABLV Bank	187 318	17,53%	1 068 556	562 371	67 485	40 491	14.28%
Baltikums Bank	33 891	19,12%	177 254	31 190	3 743	2 246	18.08%
DNB Bank	157 241	13,27%	1 184 935	1 362 851	163 542	98 125	**5.44%**
Norvik Bank	39 617	10,11%	391 859	142 320	17 078	10 247	**7.70%**
PrivatBank	35 017	17,01%	205 861	86 015	10 321	6 193	14.44%
Regional Investment Bank	32 949	21,21%	155 346	49 090	5 890	3 535	19.38%
Rietumu Bank	208 798	18,46%	1 131 083	826 460	99 175	59 505	13.93%
SEB Bank	273 675	16,19%	1 690 395	1 874 385	224 926	134 956	8.92%
SMP Bank	15 734	12,86%	122 348	86 311	10 357	6 214	8.20%
Swedbank	625 049	27,95%	2 236 311	2 304 123	276 495	165 897	22.18%
Trust Commercial Bank	28 766	16,65%	172 768	79 723	9 567	5 740	13.79%

6. Implications for Further Research

In this paper we have presented a broad review of credit risk determinants as studied in academic literature and institutional empirical papers, as well as developed the methodology to stress test Latvian banking system with regards to its credit risk. While we specified a complex, multi-step approach to study the relationships between banking system's credit risk and macro-financial variables and examine its resilience to adverse shocks, further exploration of relevant variables could improve the fit of the model; more bank-specific variables such as deposit-to-loan ratio or loan-to-GDP ratio could be added.

Moreover, significant contribution to existing literature could be made by developing a model that accounts for feedback loops between banking system and real economy. Leitner (2005) defines financial contagion as a shock initiated by one institution that is widely translated to the other parts of the system.The main motivation for analysing financial contagion is that the risks may multiply and materialise into a market-wide spiral. In case of Latvia, no similar research has been done yet.

7. Conclusion

In the recent years Latvian macroeconomic environment has been gradually picking up after the crisis. Robust household consumption has been supported by the growth in real wages and became the main driver of GDP growth in 2013. In the forthcoming years, exports are expected to take on the lead in driving GDP growth. Naturally, these factors affect the ability of both households and corporations to repay their obligations to banks, which has been reflected in a decreasing ratio of non-performing loans in banks' loan portfolios. It means that credit risk that has mounted up in the Latvian banking system has been gradually alleviating. However, being a small country, Latvia is not favoured for rigorous banking system's credit risk research. Thus, we aim to fill in this gap by examining various aspects of credit risk present in the Latvian banking system. Primarily we are interested in testing the resilience of the banking system to macro-financial shocks that affect its credit risk parameters.

In this paper, we pursue several objectives while performing our analysis. First of all, we perform an extensive review of the existing literature on credit risk determinants and justify the ones that would best suit Latvian context. Secondly, we build macro-financial VAR model that allows to examine relations between macroeconomic and financial variables, and make their forecasts for future periods. Thirdly, we use panel data to identify how responsive ratio of NPLs

to gross loans is to changes in macro-financial variables. Lastly, we introduce a plausible shock into the system and check how banks' CARs react to it.

By performing the last part of the analysis we are able to get the answer to the research question we posed at the outset of our research: **How resilient is the Latvian banking system to adverse macro-financial shocks simulated through the credit risk model?** Our analysis shows that we can reject our hypothesis: **the capital adequacy ratio of Latvian banks will not fall below the minimum regulatory requirement of 8% in response to adverse macro-financial shocks**. Two banks, DNB Bank and Norvik Bank, fail to comply with the requirement in response to a rising credit risk. Despite this, the results of our analysis demonstrate the general health of Latvian banking system and its overall resilience: even in the case of such an adverse macroeconomic development as a 19% fall in GDP, the majority of Latvian banks, including the four largest ones by assets, remain well-capitalised with the capital adequacy ratios above 8%. However, the failure of the two banks to withstand the shock shows that credit risk remains a highly relevant source of vulnerability for Latvian banks. Even though the overall macroeconomic outlook for Latvian economy is positive, prudential credit risk monitoring should stay among top priorities in banks' risk assessment procedures. Using our model effects of other shocks to macro-financial variables on the banking system's credit risk can be examined, which might be of particular importance in the current environment of crisis escalation between Russia and Ukraine.

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9. Appendices

Appendix 1

Output of panel regression on NPLs

Source: Created by the authors

Dependent variable: change in ratio of NPLs to Gross loans (dNPL)	
Explanatory variables	**Regression coefficients**
GDP growth	-0.701893* (0.3835481)
REER growth	-0.0188962 (0.7755508)
Δ *Unemployment*	0.1174022 (0.0798654)
Δ *HICP*	0.6227669 (0.5628968)
Δ *Loans-to-Assets*	0.2194955** (0.0949454)
Constant	4.729479 (4.469601)
Summary statistics	
R^2	0.2958
N	75

Note: The table exhibits results of the basic regression of changes in ratio of NPLs to Gross loans. Regression is run on the data from 15 companies over 5 years, from 2008 to 2012. Heteroskedasticity and autocorrelation consistent standard errors are given in parentheses. Coefficients of dummy variables resulting from LSDV regression are not reported.

* - significant at the 10% significance level

** - significant at the 5% significance level

*** - significant at the 1% significance level

Appendix 2

Macro-financial variables and change in NPL ratio forecast for year 2014: baseline and shock scenarios

Source: Created by the authors

Variable	**2013 values**	**Baseline forecast value**	**Shock forecast value**		
GDP growth	5.58%	4.19%	-19.00%		
REER growth	1.46%	4.30%	-2.63%		
HICP	0.00%	0.08%	-2.62%	Predicted change in NPL ratio (baseline)	Predicted change in NPL ratio (shock)
Unemployment	11.90%	11.02%	13.94%	**-3.07%**	**12.00%**

Note: The table exhibits the figures for the quarter 4 of the year 2014 (forecasted) values under shock and baseline scenarios. The baseline scenario suggests the continuation of economic recovery, whereas in the case of shock (19% fall in GDP) NPLs will plummet to 12% of total gross loans. This discrepancy is further used to compute the amount of provisions needed to cover the losses.

Appendix 3

The sample of banks used in the analysis

Bank name	Bank's Assets as % of Total Banking Sector Assets (as of 31.12.2012)
Swedbank	17.01%
SEB	13.70%
ABLV	10.53%
Rietumu	8.16%
DNB	8.15%
UniCredit	2.84%
PrivatBank	2.65%
Norvik	2.57%
Mortgage and Land Bank of Latvia (Latvijas Hipoteku un zemes banka)	1.78%
Reverta	1.77%
Regional Investment Bank (Regionala investiciju banka)	1.68%
Baltikums	1.62%
Trust Commercial Bank (Trasta Komercbanka)	1.50%
SMP	0.92%
GE Money Bank JSC	0.38%
Total	**73.49%**

***** In 2013 GE Money Bank JSC license was cancelled by the FCMC; Mortgage and Land Bank of Latvia decided to surrender the bank's credit institution license; UniCredit Bank stopped providing banking services in Latvia. Thus, these banks will not continue their operations in 2014.

Appendix 4

Banks' Capital Adequacy Ratios before and after the shock

Source: Created by the authors