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# South African Reserve Bank Working Paper

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# A macroeconomic credit risk model for stress testing the South African banking sector

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## Abstract

In this study a macroeconomic credit risk model for stress testing the South African banking sector was developed. The findings demonstrate that macroeconomic shocks have a large impact on credit losses. However, owing to a high level of current capitalisation, the South African banking sector is resilient to severe economic shocks. At the same time, banks are rather sensitive to changes in real interest rates and property prices due to the high share of mortgages at flexible interest rates in their credit portfolios.

JEL classification: G10, G21, E37

Keywords: macro stress testing, financial stability, credit risk

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## Abbreviations

| | |
|---|---|
| DOLS | Dynamic ordinary least squares |
| GDP | Gross domestic product |
| GFCF | Gross fixed capital formation |
| JSE | JSE Limited |
| REER | Real effective exchange rate |
| Repo | Repurchase rate |
| StatsSa | Statistics South Africa |
| UK | United Kingdom |
| US | United States of America |

## Glossary

| | |
|---|---|
| Basel II | *International Convergence of Capital Measurement and Capital Standards: A Revised Framework* |

# 1 Introduction

The current financial turmoil that originated with the sub-prime crisis in the United States of America (US) in 2007–2008 has emphasised the importance of credit risk for banking institutions. It also underlined the need for improved methodologies to better quantify banks' vulnerabilities to different types of shocks with the use of stress tests. Well-functioning financial markets contribute to economic growth via more efficient allocation of resources and risk diversification (Levine, 1997; Rajan and Zingales, 1998; Aryeetey, 2003; Khan and Senhadji, 2003; Reinhart and Tokatlidis; 2003). However, financial liberalisation can also render the banking sector more fragile, which calls for adequate banking regulation and supervision.

The Basel II framework requires banks to conduct stress tests on their potential future minimum capital requirements and consider at least the effect of mild recession scenarios. The International Monetary Fund (IMF) and World Bank have been using stress testing as a part of the Financial Sector Assessment Programme (FSAP) since 1999. In 2008, for the first time they undertook stress testing of the South African financial sector, relying on publicly available data (IMF, 2008). The present paper contributes to their work by focusing on credit risk stress testing and using data provided by banks to the South African Reserve Bank. It can serve as a framework for future stress testing exercises by individual banks and regulatory authorities in South Africa and other developing countries.

There are two main approaches to stress testing. On the one hand, "bottom up" approach requires individual large banks to perform stress testing of their portfolios and then these individual results are aggregated. On the other hand, "top down" stress-testing - the subject of this paper - is performed by a central bank on the sample of all or the largest financial institutions and can be used for two purposes. First, it can be used to verify the robustness of individual banks methodologies. Second, it should be viewed as a tool of macro-prudential regulation and supervisors, when banking regulators and supervisors do not just focus on the health of individual institutions but consider risks to the stability of the whole financial system. This approach has been emphasized by all proposals for reform of the financial regulation published in the wake of the crisis (Turner Report (2009), The Geneva Report on the

World Economy (2009), de Larosiere Report (2009), US Treasury White Paper (2009)).

Relying on the recent literature on stress testing of credit risk, this paper proposes models that were constructed for different economic sectors of the economy, such as households, mining, transport, electricity and other. As the dependent variable, the loan loss provisions on a bank level were used for each economic sector. Macroeconomic scenarios were then developed that describe severe, but plausible, economic shocks. Finally, based on the estimated coefficients, the impact of these scenarios on additional loan loss provisions and capital-adequacy ratios was predicted.

The findings demonstrate that macroeconomic shocks have a large impact on the credit losses of South African banks, which is in line with recent finding showing that stress events have a larger impact in less-developed countries (Jakubik and Schmieder, 2008). However, owing to the high level of current capitalisation, the South African banking sector is resilient to rather severe economic shocks, which can be absorbed by banks' capital. At the same time, banks are sensitive to changes in real interest rates and property prices. Property prices have a disproportional impact, because mortgages constitute the largest share of banks' portfolios. A decrease in property prices might leave borrowers with negative equity, increasing defaults on existing mortgages. In addition, since most borrowers have loans with flexible interest rates, they have greater difficulty repaying loans when interest rates go up. Other factors, such as GDP growth, exchange rate and commodity prices, have a much smaller impact on the credit risk of banks.

Due to such sizable impact of property prices on credit risk in our model, the results of the stress-testing exercise depend to a great extend on the chosen scenario of property prices development. Hence, we offer a rigorous analysis of this variable which shows that recent increases in property prices are likely to have reflected fundamentals and therefore should not decline significantly. This investigation helps us to construct plausible macro-economic scenario for property prices development in South Africa.

A key limitation of the study is the short span of available data, which is a common problem for developing and transition economies. The data employed in this study cover the period of eight years from 2001 to 2008. A robustness check is performed with the data that cover the period between 1994 and 2007, but was discontinued due to the transition to Basel II reporting standards in 2008. The starting point for stress testing was June 2008.

The rest of the paper is organised as follows. Section 2 provides a description of the methodology and data. Section 3 presents univariate and multivariate regressions. Section 4 presents macroeconomic stress scenarios, and reports on their impact on credit impairments and capital-adequacy ratios. Section 5 concludes.

## 2 Empirical methodology and the choice of data

The most popular approach to stress-testing in countries with less developed banking systems is a simple mechanical exercise, in which banks' balance sheets items (nonperforming loans or provisions) are shocked directly and a link to the macro economy is not modeled explicitly. Such tests assess the capitalization of the sector if banks were forced to raise their loan loss provisioning to reflect loan quality deterioration either overall or in particular parts of their portfolio**.**

In this paper, we can rely on a methodology used in countries with more advanced banking sectors, which is based on modeling NPLs or loan-loss provisions as a function of various macroeconomic variables. This approach has been used as part of FSAP of IMF in Austria, Czech Republic, France, Iceland, Ireland, Israel, Romania, Russia and Sweden (Stolz and Swinburne, 2008).[2] This approach has been also used by central banks in developed countries and increasingly in developing ones.

Following these approaches, we plan to estimate the following model:

$$Credit\ risk_{it} = \alpha_1 + \alpha_2 GDP_t + \alpha_3 Prices_t + \alpha_4 Interest_t + \alpha_5 Household_t + \alpha_6 External_t + \varepsilon_{it}$$

[2] Since January 2008, South African banks have adopted Basel II and report probability of default, which would be the best proxy and has been used in stress testing models in many developed countries. However, this measure could not be used in the present study, because it aimed to estimate a macroeconomic credit risk model and this requires relatively long time series.

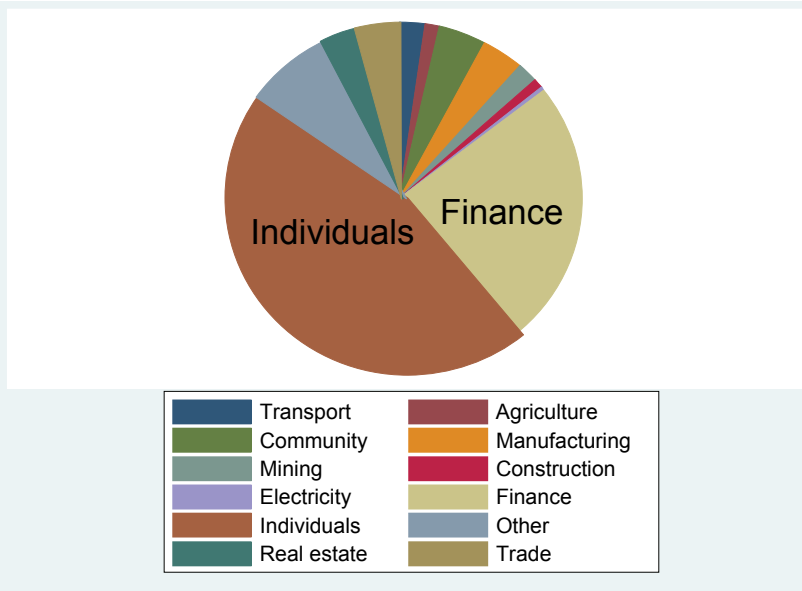
where *Credit Risk*$_{it}$ is a variable that measures the quality of the loan portfolio, *GDP*$_t$ - business environment, *Interest*$_t$ - cost of borrowing, *Prices*$_t$ - stability of prices, *Household*$_t$ - household sector indicators, and *External*$_t$ - external sector indicators that can influence credit risk of banks. Next two sub-sections describe these variables in more detail.

### 2.1 Credit risk proxies

There are a number of credit risk indicators that can be used as proxy for credit risk. For this paper, the preferred measure is loan loss provisions raised against loans extended to different economic sectors. This is one of the most commonly used measures in stress testing (Moretti et al., 2008).

Loan loss provisions are raised by banks against non-performing loans and are available on a quarterly basis. South African banks are required to report credit exposure and loan loss provisions with respect to loans extended to different sectors of the economy: households; agriculture, forestry and fishing; mining; construction; electricity, gas and water; trade and accommodation; transport and communication; finance and insurance; real estate and business services; community, social and personal services; and other. In practice, the data on a number of sectors such as agriculture, manufacturing, construction, finance, real estate and community services are very limited. Still, data are available on a number of important sectors, in particular loans to households, which amount to more than 40 per cent of the total loans (Figure 1).

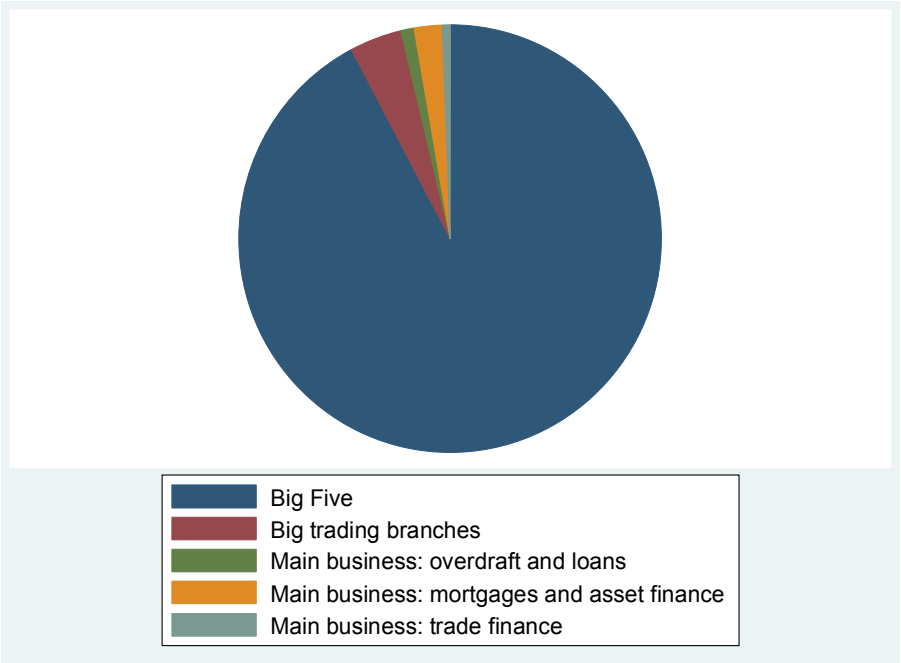
**Figure 1 Sectoral composition of credit to the private sector in 2008**




Source: South African Reserve Bank

The estimation made in the present study relied on the data for the largest five banks, also known as the 'big five', (i.e., Absa Bank LTD, FirstRand Bank LTD, Investec LTD, Nedbank LTD and The Standard Bank of South Africa LTD). These institutions constitute 92 per cent of the total banking assets (June 2008), which makes them systemically important banks (Figure 2). Moreover, these banks have very similar credit portfolios, which react in a similar manner to various macroeconomic shocks. Other banks can be described as niche banks: they focus on very different lines of business (e.g., trading or overdraft), which makes it difficult to model an econometric relationship between their credit risk and macroeconomic environment.

**Figure 2 Market shares of different groups of banks in South Africa in 2008**

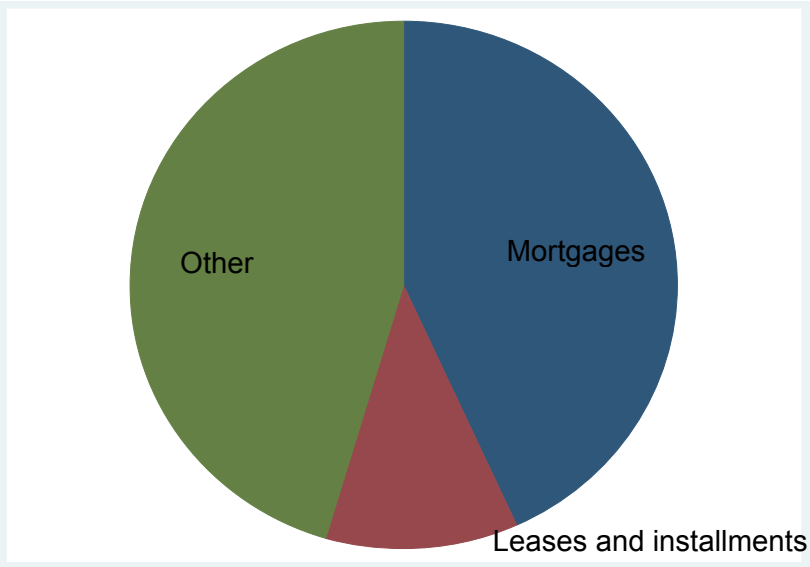



Source: South African Reserve Bank

The only disadvantage to using loan loss provisions as a measure of credit risk in this study is the fact that it starts in 2001. Since that period, South Africa has enjoyed steady economic growth, which only started to slow down now in the wake of the financial turmoil in 2007. Therefore, a relationship between credit risk and the macro-economic environment during economic downturns cannot be estimated.

To overcome the problem of short time series of data, a robustness check was done with overdue loans as a dependent variable. Prior to the introduction of Basel II in 2008, banks were required to report overdue loans with respect to different credit products. The data on overdue mortgages, leases and instalment debtors, and other loans go back to 1994. This made it possible to estimate a model over the whole business cycle for such an important credit product as mortgages, which amounted to over 40 per cent of total loans in 2007 (Figure 3).

**Figure 3 Product-based composition of loans and advances in 2008**



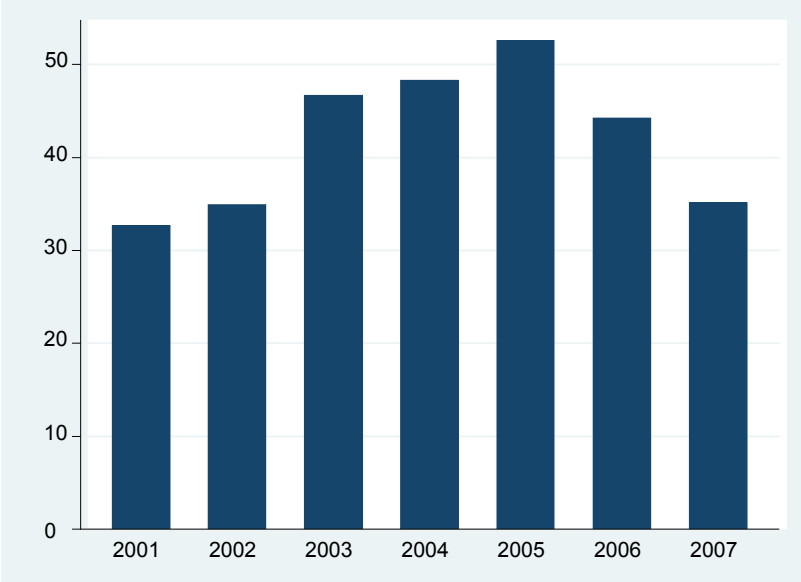

Source: South African Reserve Bank

Since most of mortgages are extended to individuals, this measure of credit risk is closely correlated with loan loss provisions for individual loans. However, a ratio of loan loss provisions to overdue loans has not been constant. In fact, it rose after 2001 and peaked in 2005, declining thereafter (Figure 4). One of the possible explanations for this is banks' increased risk averseness after the banking turmoil that shook the South African banking sector in 2001 (IMF, 2008).

Despite availability of data for the period 1994–2000, overdue loans might not provide a very reliable measure of credit risk. The definition of 'overdue loans' changed a few times throughout this period. Before September 1996, banks reported overdue loans with cut-offs at one, three and six months. Between 1996 and September 1998, banks used four- and six-month cut-offs. The Asian crisis motivated the South African Reserve Bank to tighten its definition of overdue loans, and loans that were overdue by one and three months had to be reported. In order to harmonise the data in this study, three months was used as the cut-off for the definition of 'overdue loans' whenever possible, but the changes in reporting and

data availability necessitated a four-month cut-off for the period between September 1996 and September 1998.[3]

**Figure 4 The ratio of total loan loss provisions to overdue loans**




Source: South African Reserve Bank

## 2.2 Macroeconomic variables

As measures of macroeconomic environment, a number of indicators that should have a significant impact on the South African banking sector were selected. These indicators are classified in the following groups: business, interest rate, price stability, household and external. Definitions of all variables are presented in Table 1.

The choice of macroeconomic variables used in the study was motivated by Boss (2002), Gray and Walsh (2008), and Kalirai and Scheicher (2002). The data were provided either by the South African Reserve Bank or Statistics South Africa (Stats SA). Summary statistics of these variables are given in Table 2.

[3] One of the alternative variables as a measure of credit risk could be liquidations of firms, and insolvencies of individuals and partnerships. The advantage of these indicators is long time series that go back over the entire business cycle. The disadvantage is the lack of data on total number of companies, individuals and partnerships, so that the default ratio cannot be calculated. Therefore, one can only look at growth of liquidations and insolvencies, which appear to be negatively correlated with a business cycle. Another disadvantage of this proxy is the fact that it includes all firms in the economy, many of which might not have access to the banking sector. Changes in liquidations might be driven by problems among small and medium enterprises, which could have a very limited impact on the banking sector.

**Table 1 Definition of macroeconomic variables**

| Variable | Definition |
|---|---|
| **Business activity** | |
| GDP growth | Real GDP growth |
| GFCF | Real growth in gross fixed capital formation |
| Index | Change in All-share index at the *Johannesburg Stock Exchange* |
| **Interest rate** | |
| Prime rate | Nominal prime overdraft interest rate set by the South African Reserve Bank |
| Real prime | Real prime overdraft interest rate set by the South African Reserve Bank |
| BA rate | Real interest rate at which banker's acceptances are traded |
| **Prices** | |
| Inflation | Inflation without housing costs |
| M1 growth | Growth in M1 aggregate |
| M2 growth | Growth in M2 aggregate |
| M3 growth | Growth in M3 aggregate |
| **Household sector** | |
| Property | Nominal growth in property prices |
| Consumption | Growth in real consumption |
| Debt/Income | A ratio of debt to disposable income of households |
| Employment | Change in the employment index |
| Wage | Change in wage index |
| **External economy** | |
| Commodities | Change in commodity price index |
| Oil price | Change in oil prices |
| REER | Change in real effective interest rate |
| Terms of trade | Change in terms of trade |

Note: All variables are expressed in per cent and represent annual changes.
Source: Constructed by author

The first group of indicators relates to business activity and the underlying assumption is that loan quality is sensitive to an economic cycle. Gross domestic product (GDP) growth, gross fixed capital formation and the stock market index are included and are assumed to be negatively correlated with credit risk. As growth slows down, falling incomes, unemployment and business failures increase credit risk.

Interest rates represent the direct cost of borrowing and thus should have a positive impact on credit risk, as firms and household face higher repayment costs and are more likely to default on their payments. This impact should be especially strong in South Africa, where banks extend most of their loans at flexible interest rate, passing

interest rate risk to borrowers. Three rates are examined in this study: (1) nominal prime interest rate, (2) real prime interest rate, and (3) bankers' acceptance rate. While prime rate moves in line with the repurchase (repo) rate, which is set by the Monetary Policy Committee of the South African Reserve Bank, the bankers' acceptance rate is market-driven.

**Table 2 Summary statistics for macroeconomic variables (1994–2008)**

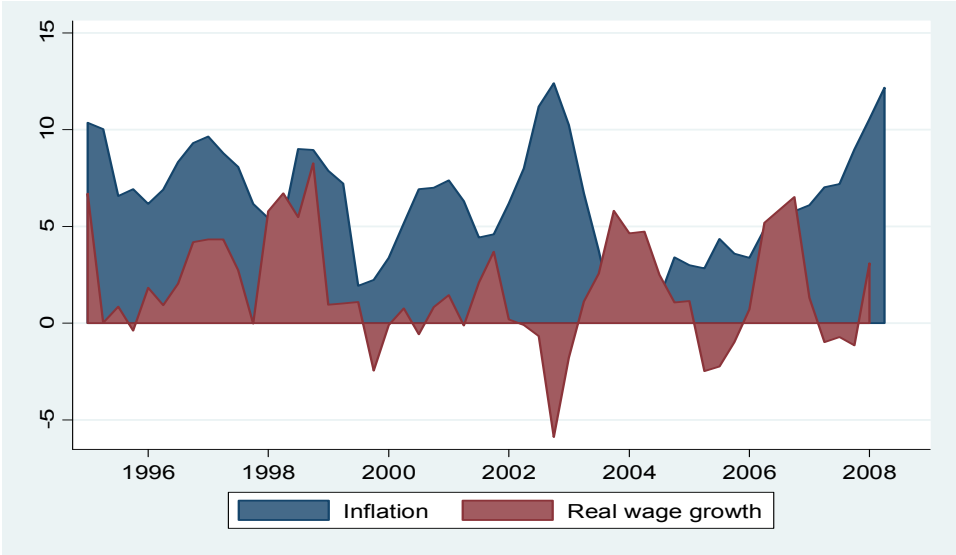
| Variable | Mean | Standard Deviation | Minimum | Maximum | Minimum | Maximum |
|---|---|---|---|---|---|---|
| | | | 1994–2008 | | 2001–2008 | |
| **Business activity** | | | | | | |
| GDP growth | 3,62 | 2,00 | -0,90 | 7,60 | 1,10 | 7,20 |
| GFCF | 7,61 | 9,07 | -2150 | 22,55 | -5,32 | 22,55 |
| Index | 16,47 | 20,22 | -31,77 | 68,33 | -31,77 | 68,33 |
| **Interest rate** | | | | | | |
| Prime rate | 15,59 | 3,57 | 10,50 | 25,50 | 10,50 | 17,00 |
| BA rate | 4,66 | 2,65 | -0,11 | 11,32 | -0,11 | 7,41 |
| Real prime | 8,74 | 2,98 | 2,97 | 16,18 | 2,97 | 11,13 |
| **Prices** | | | | | | |
| Inflation | 6,66 | 2,15 | 2,99 | 12,35 | 2,99 | 12,35 |
| M1 growth | 17,26 | 9,23 | -3,50 | 39,25 | -3,50 | 25,45 |
| M2 growth | 15,60 | 4,43 | 5,56 | 24,26 | 9,14 | 24,26 |
| M3 growth | 16,11 | 4,79 | 6,17 | 28,06 | 10,81 | 28,06 |
| **Household sector** | | | | | | |
| Property | 14,37 | 7,99 | 2,57 | 35,68 | 2,57 | 35,68 |
| Consumption | 4,55 | 2,32 | -0,20 | 9,50 | 1,20 | 9,50 |
| Debt/Income | 59,89 | 7,80 | 49,82 | 78,16 | 49,82 | 78,16 |
| Employment | 0,53 | 1,84 | -3,95 | 4,52 | -3,95 | 4,52 |
| Wage | 1,68 | 2,64 | -5,89 | 8,26 | -5,89 | 6,52 |
| **External economy** | | | | | | |
| Commodities | 10,54 | 18,72 | -25,74 | 62,19 | -25,74 | 62,19 |
| Oil price | 19,48 | 35,94 | -41,94 | 160,89 | -41,85 | 84,64 |
| REER | -0,74 | 11,34 | -25,04 | 32,62 | -25,04 | 32,62 |
| Terms of trade | 0,63 | 3,07 | -7,16 | 6,79 | -5,41 | 6,79 |

Sources: South African Reserve Bank and Statistics South Africa

Consumer price inflation is also included as a measure of price stability. Higher inflation may assist borrowers in repaying their debt, since the real value of the debt repaid at some point in the future is less than the loan. At the same time, higher inflation could force central banks to set interest rates higher, which might increase the repayment burden, especially if wages do not compensate for the growth in inflation. Figure 5 shows inflation and real wage growth for the period 1995–2008,

and indeed real wages grew the least during higher inflation and this negative relationship intensified after 2000. There are some periods when high inflation even made real wages decline, which would have made loan repayment problematic. Money growth, which is linked to inflation, is also included.

**Figure 5 The relationship between inflation and real wages**



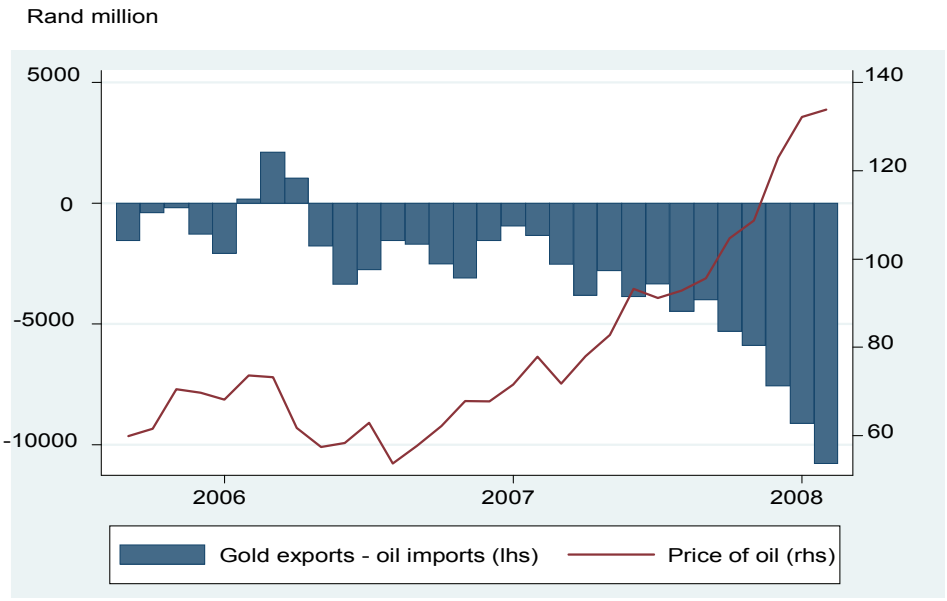

Source: South African Reserve Bank

Another important explanatory variable is property prices. Higher property prices are associated with higher rate of loan repayment due to positive wealth effects. Even if borrowers are having trouble making payments, they will always prefer to sell their homes rather than default, as long as the equity in their homes is positive so they can pay off their outstanding mortgage balances with the proceeds of the sales. In contrast, lower property prices can lead to negative equity for homeowners, meaning that the outstanding balance on their mortgage exceeds their home's current market value. Such a situation could reduce their ability and motivation to repay a loan. The situation can be exacerbated in a country where many borrowers are first-time homeowners.

Since the largest share of loans is extended to individuals, household-sector indicators could be central to estimations. Therefore, consumption, employment and wage growth are examined, and are expected to have an inverse relationship with credit losses. Household indebtedness measured as a ratio of debt to disposable income is also studied.

The South African economy is closely integrated into the world economy due to trade and financial linkages. Therefore, the commodity price index, oil price index, real effective exchange rate and the terms of trade are included. It should be stated that these indicators have been very closely correlated since 2000. Theoretically, as an exporter of gold and platinum, South Africa should benefit from higher prices of metals and as an importer of oil; it should be negatively affected by growth in oil prices. In practice it is almost impossible to differentiate between these two impacts on economic growth because of the high correlation between all commodity prices after 2000. However, as oil prices grew at a faster rate than metal prices, South Africa experienced a deteriorating trade balance. Figure 6 shows the difference between gold exports and oil imports, and as the price for oil skyrocketed during 2007–2008, the difference grew increasingly negatively.

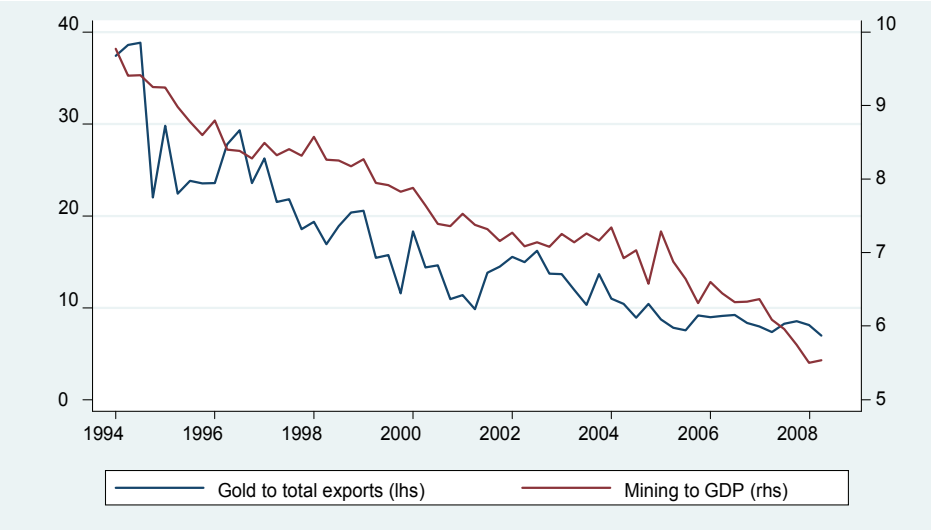
**Figure 6 Difference between gold export and oil import (US dollar per barrel)**




Source: South African Reserve Bank

At the same time, the importance of mining in South Africa should not be overstated. Figure 7 shows that the share of mining in total GDP declined from almost 10 per cent in 1994 to 5,5 per cent in 2008, whereas a share of gold exports to total exports went down from almost 40 to less than 10 per cent. This explains why in the following section, the price of gold is included only in the model for the mining sector and is excluded from other sectoral models.

**Figure 7 Importance of mining for the South African economy (in per cent)**




Source: South African Reserve Bank

# 3 Estimation

## 3.1 Preliminary univariate regressions

This sub-section presents results of univariate estimations. These regressions are intended to show all variables that were considered to be drivers of credit risk, and which were studied as candidates for the multivariate model presented in the sub-section 3.2. Table 3 reports findings for two different measures of credit risk: loan loss provisions and overdue loans. For overdue loans, results for the period between 1994 and 2007 are reported, as well as for a shorter period between 2001 and 2007 to make them more comparable with regressions for loan loss provision ratios.

The following conclusions can be drawn: First, the signs of coefficients are mostly in line with the theory. When economic activity picks up, credit risk goes down, whereas higher interest rates and inflation increases have a positive impact on credit risk. Second, the explanatory power of coefficients often drops significantly when one considers the sample between 1994 and 2007 for overdue loans. This is driven by lack of any meaningful relationship between overdue loans and the macroeconomic environment for the period before 2001, which leaves one without a reliable

estimated model during a downturn phase of the economic cycle.[4] This issue will be revisited in the analysis of multivariate estimations below.

**Table 3 Univariate regressions**

| Dependent variable | Loan loss provision 2001–2008 | | Overdues 2001–2008 | | Overdues 1994–2008 | |
|---|---|---|---|---|---|---|
| | Coefficient | $R^2$ | Coefficient | $R^2$ | Coefficient | $R^2$ |
| **Business activity** | | | | | | |
| GDP growth | -0,09*** | 0,11 | -0,50*** | 0,18 | -0,09* | 0,01 |
| GFCF | -0,02*** | 0,20 | -0,05*** | 0,05 | -0,05*** | 0,09 |
| Index | -0,01*** | 0,08 | -0,03*** | 0,12 | -0,02*** | 0,06 |
| **Interest rate** | | | | | | |
| Prime rate | 0,02 | 0,01 | 0,34*** | 0,15 | 0,04** | 0,01 |
| BA rate | 0,09*** | 0,16 | 0,04 | 0,00 | -0,03 | 0,00 |
| Real prime | 0,09*** | 0,19 | 0,10*** | 0,01 | -0,01 | 0,00 |
| **Prices** | | | | | | |
| Inflation | -0,02 | 0,02 | 0,27*** | 0,08 | 0,18*** | 0,06 |
| M1 growth | -0,03*** | 0,27 | -0,07*** | 0,07 | -0,06*** | 0,13 |
| M2 growth | -0,05*** | 0,21 | -0,13*** | 0,06 | -0,12*** | 0,11 |
| M3 growth | -0,06*** | 0,37 | -0,11*** | 0,08 | -0,09*** | 0,10 |
| **Household sector** | | | | | | |
| Property | 0,01*** | 0,08 | -0,04*** | 0,04 | -0,02** | 0,01 |
| Consumption | -0,04*** | 0,05 | -0,37*** | 0,22 | -0,15*** | 0,06 |
| Debt/Income | -0,02*** | 0,07 | -0,16*** | 0,29 | -0,10*** | 0,16 |
| Employment | -0,11*** | 0,13 | -0,34*** | 0,13 | -0,28*** | 0,09 |
| Wage | 0,00 | 0,00 | -0,05** | 0,01 | -0,07*** | 0,01 |
| **External economy** | | | | | | |
| Commodities | -0,01*** | 0,05 | -0,05*** | 0,16 | -0,03*** | 0,05 |
| Oil price | -0,00** | 0,03 | -0,02*** | 0,10 | -0,01*** | 0,02 |
| REER | 0,01*** | 0,04 | -0,01** | 0,01 | -0,01 | 0,00 |
| Terms of trade | 0,00 | 0,00 | -0,01 | 0,00 | -0,02 | 0,00 |

***, ** and * correspond to 1, 5 and 10 significance levels respectively.
Source: Computed by author

## 3.2 Multivariate regressions

In this section, multivariate regressions with loan loss provisions as the dependent variable were estimated. This measure of credit risk was chosen because it allows for an analysis of banks' credit risk within different economic sectors. Despite longer

[4] A robustness check with liquidations and insolvencies as dependant variable was also done, but in this case also it failed to establish meaningful and significant relationships for the period before 2001.

time series for other proxies for credit risk, such as overdue loans and firm liquidations, they were discarded because no observable statistically significant relationship existed for the period before 2001. One of the reasons for this is frequent change of definitions, as well as poorer reporting standards during the earlier period analysed.

Because of the high correlation between various macroeconomic variables presented in univariate regressions, they could not all be included simultaneously. Therefore, at the outset at least one variable from each group of indicators is included. All explanatory variables are lagged by one year due to the fact that loan loss provisions are often criticized for being backward looking due to their event-driven nature required by the current international accounting standards. This also controls for potential endogeneity of some explanatory variables. All models in this study were estimated using random effects panel data methodology, relying on Hausman test results that indicate that random effects regressions are consistent and efficient. We have further allowed observations to be correlated within the same bank and adjusted robust standard errors accordingly for each cluster. Before turning to the regression analysis, the univariate time series properties of the data were analysed. Since changes in property prices turn out to be non-stationary, they were input in first differences. Finally, after testing various specifications and relying on Akaike and Schwartz criteria, industry-specific models that are the most useful in describing historic loan loss provisions were obtained. The results are presented in Table 4.

The model for total loans is driven by the model for loans to individuals (the largest share in banks' portfolios) and so they both include GDP growth, inflation, property prices, and real effective exchange rate as explanatory variables, and they all have expected sign. During an economic upswing, it is easier for individuals to repay loans because of higher wages and lower unemployment. Higher interest rates increase the repayment burden for borrowers with flexible interest rate contracts, making them more likely to default. Since a large share of loans to individuals are mortgages, rising house prices increase borrower wealth, facilitating loan repayment.[5]

[5] An attempt was also made to input a dummy to control for the introduction of Basel II, but it turned out to be insignificant. The introduction of massive changes in reporting of credit risk did not have any significant impact on loan loss provisions, after controlling for changes in macroeconomic environment.

**Table 4 Multivariate regressions**

| | Total | Household | Mining | Transport | Electricity | Other |
|---|---|---|---|---|---|---|
| GDP growth | -0,08*** | -0,08*** | | | | -0,77** |
| Inflation | 0,08*** | 0,14*** | | | | 0,76*** |
| BA rate | 0,14*** | 0,18*** | | | | 0,68* |
| Property | -0,08* | -0,09* | | | | |
| REER | 0,01*** | 0,01*** | -0,029* | | -0,06* | |
| Gold | | | -0,016 * | | | |
| GFCF (transport) | | | | -0,03* | | |
| Oil | | | | | 0,33*** | |
| Commodity | | | | | | 0,03** |
| Basel II | | | | | | |
| Constant | 0,50 | 0,09 | 1,36*** | 1,78*** | 1,65 | -4,50 |
| $R^2$ | 0,16 | 0,20 | 0.04 | 0,03 | 0,10 | 0,13 |
| Observations | 135 | 135 | 116 | 119 | 103 | 119 |

Dependant variable: loan loss provisions ratio. The models are estimated using a random effects panel data methodology, with robust standard errors adjusted for intra-bank correlation.
***, ** , * correspond to 1, 5, and 10 significance levels , respectively.
Source: Computed by author

Despite all variables in the model being statistically significant, the main driver of credit risk is changes in nominal property prices. Table 5 presents the economic significance of coefficients. A two-standard deviation decline in property prices (16 per cent) would increase loan loss provisions ratio by 1,47 percentage points. The second variable in order of economic significance is interest rate: a two standard deviation increase in real interest rate would add 0,96 percentage points to loan loss provisions ratio. Other variables have a considerably lower impact on loan loss provisions. For example, since most loans are extended in domestic currency, exchange rate fluctuations have only limited impact on credit losses. This has important implications for stress testing, since large shocks to property prices and interest rates would lead to larger increases of credit risk, then shocks to GDP growth or exchange rate.

**Table 5 Economic significance of coefficients of model for total loans**

| Variables | Two-standard deviations | Impact on loan loss provisions |
|---|---|---|
| GDP growth | 4,00 | -0,31 |
| Inflation | 4,30 | 0,59 |
| BA rate | 5,26 | 0,96 |
| Property | 15,98 | -1,47 |
| REER | 22,68 | 0,18 |

Source: Computed by author

Next, separate models for mining, transportation, electricity and other sectors were constructed. In line with expectations, an increase in the price of gold (the main South African export item) is manifested in lower loan loss provisions for the mining sector. At the same time, higher oil prices make it more difficult for the electricity sector to remain profitable, which leads to higher defaults and therefore higher loan loss provisions for banks.

Appendix A demonstrates the performance of the estimated models for the households, mining, transportations, and electricity sectors, as well as total loan loss provisions. The model for the household sector correctly captures a decline in loan loss provisions between 2004 and 2006, and an increase in 2008. The performance of models for other sectors is less precise, but nevertheless, they all capture time pattern of loan loss provisions in a meaningful way.

### 3.3 Robustness test

Before moving to stress testing of the South African banking sector, a robustness check was constructed and a model with an alternative measure of credit risk – overdue loans for mortgages − was estimated. After testing various specifications, a model was arrived at that includes GDP growth, real interest rate, inflation and growth in commodity prices. This model was estimated for the periods between 2001−2007 and 1995−2007. The results are presented in Table 6. All variables have expected signs, but the significance of coefficients diminishes significantly in the model estimated for the whole period (1995−2007). In fact, when attempting to estimate the model only for the period before 2001, one cannot come up with any specification where at least one explanatory variable is significant and has a meaningful interpretation. This leaves one with no estimated model for the earlier

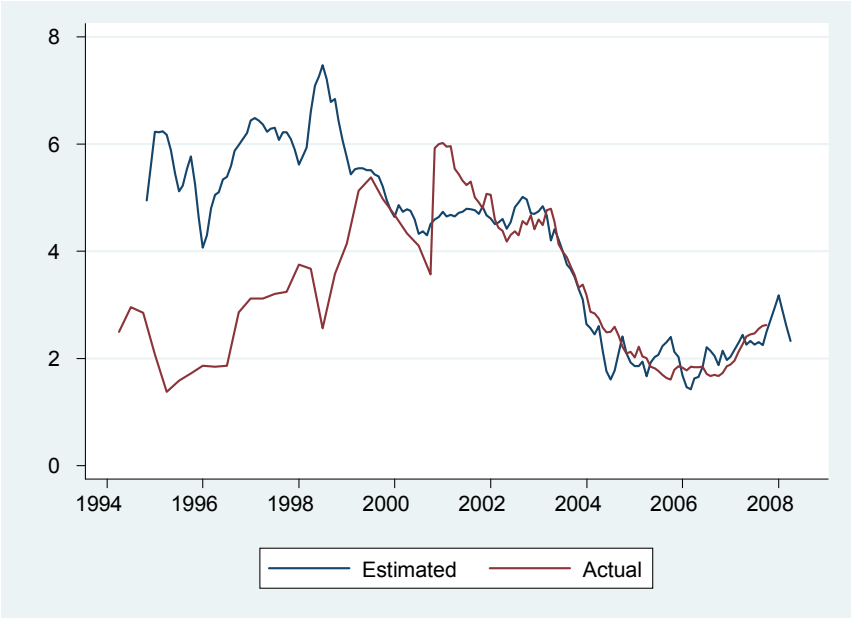
period during which the South African economy experienced a significant downturn in the wake of the Asian crisis.

**Table 6 Multivariate regressions**

| | Overdues for mortgages 2001–2007 | Overdues for mortgages 1994–2007 |
|---|---|---|
| GDP growth | -0,4*** | -0,05 |
| Inflation | 0,5*** | 0,243*** |
| BA rate | 0,32*** | -0,01 |
| Commodity | -0** | -0,02* |
| Constant | 0,91 | 2,122 |
| R2 | 0,38 | 0,085 |
| Observations | 135 | 246 |

Dependent variable: overdue ratio. The models are estimated using random effects panel data methodology, with robust standard errors adjusted for intra-bank correlation.
***, ** and * correspond to 1, 5, and 10 significance levels, respectively.
Source: Computed by author

**Figure 8 Performance of the model for mortgages**




Source: Constructed by author

Given that the data do not allow for an estimation of a model for the period before 2001, the forecasting power of the model estimated for the period between 2001 and 2007 when it is applied to the period before 2001 was tested. Theoretically, upswings and downturns do not have a symmetric impact on credit risk and therefore it is important to test how the present model (estimated for an upward phase) will perform

during a downward phase of the economic cycle. Results are presented in Figure 8. Similar to previous models, this estimated model correctly captures the decline in overdue loans between 2003 and 2006, and an increase afterwards. However, the model is less precise in predicting the ratio of overdue loans for the period before 2001. One of the plausible reasons for this is the frequent change in definition of 'overdue loans', which was explained in section 2.1. The estimated overdue loans overestimate actual overdue loans, which must be kept in mind when predicting future credit risk under different macroeconomic scenarios.

# 4 Macroeconomic stress scenarios

## 4.1 Development of macroeconomic stress scenarios

A crucial aspect of employing stress tests is the selection of scenarios. On the one hand, stress tests are aimed at exploring the impact of extreme events. On the other hand, if these events are highly unlikely, the results have little importance for policy makers. Most of the criticism of stress testing studies is directed at the choice of stress scenarios, which depict either a too-rosy or a too-bleak picture of financial system vulnerabilities. To overcome this problem, three approaches to defining scenarios were chosen: (1) worst historic scenario, (2) a change of two standard deviations from the current value and (3) a scenario based on expert opinions. All scenarios are presented in Table 7.

**Table 7 Macroeconomic scenarios**

| | Worst historic scenario | Unfavourable change of two standard deviations from current value | Expert opinion |
|---|---|---|---|
| | **Scenario 1** | **Scenario 2** | **Scenario 3** |
| GDP growth (in %) | -0,9 (1998) | 0,9 | -2 |
| Inflation (in %) | 14,09 (2008) | 16,64 | 15 |
| Real interest rate (in %) | 12,01 (1998) | 5,14 | 5 |
| Nominal property prices growth | 2,57 (2008) | -12,44 | 0 |
| REER | -25,03 (2001) | -31,07 | -35 |
| Price of gold (in US$) | 256,14 (1999) | 573,01 | 600 |
| Price of oil (in US$) | 132,15 (2008) | 181,74 | 100 |
| Growth in GFCF (transportation) | -44,04 (1999) | -19,92 | -44 |

Source: Computed by author

One possibility is to examine the impact of historically observed values of macroeconomic variables, which appear to be plausible, since these events had already taken place in the past. In the case of South Africa, the maximum or minimum value of each macroeconomic variable for the period between 1994 and 2008 was chosen. The values of each variable and year in which it occurred are presented in Table 7. The current economic situation, however, presents additional challenges, since many of the worst historic values are reported in the year 2008. Unlikely events with low probability become reality. This raises the question of whether one should choose even more severe macroeconomic scenarios than those observed in the past. It should be mentioned, that the full impact of the current macroeconomic environment has not yet been fully passed on to banks in terms of higher loan loss provisions. In the present model the explanatory variables were lagged by one year, which means that the model forecasts the full impact of the current economic environment only for June 2009.

An alternative way of designing a macroeconomic scenario is to change the value of the macroeconomic variable in an unfavourable direction by two standard deviations. This method has two main advantages over the historic worst scenario method. First, the change happens in a more plausible manner and not in an abrupt way. Consider, for example, the change in real interest rate, which currently amounts to - 0,11 per cent, but could jump to 12,01 if the worst historic scenario is applied. A more plausible event is the increase of real interest rates by two standard deviations (to 5 per cent). Second, this method allows one to design a more severe stress test in cases where a variable has been growing in a favourable direction during the analysed period. For example, nominal house prices have never been negative in South Africa since 1994, but if two standard deviations are subtracted from their current value, one arrives at a decline of 12 per cent.

Finally, macroeconomic scenarios can be based on expert opinions. In this case, scenarios are constructed in such a way that they reflect current expectations in the movement of the macroeconomic variables, but with additional stress. For half of variables, the scenario based on expert opinions appears to be even more severe than the worst historic scenario. This is the case with GDP growth which, historically,

has been as low as -0,9, but which is not considered by experts as stressful enough for the South African economy. Instead, a 2 per cent decline was considered.

Very careful consideration should be given to property prices, which have the largest impact on future credit losses for two reasons. First, they have an impact on loans to households, which have the largest share in portfolios of South African banks. Second, the economic significance of property prices coefficient is much larger than that of any other variables, such as interest rate, inflation or GDP growth.

In order to decide which property price change is plausible, a thorough examination of house prices is warranted. There are a number of approaches to addressing this question. First, one could look at the growth of property prices relative to growth in rent rates for equivalent property. Second, one could construct an econometric model that looks at the main drivers of property prices. Finally, one should consider the burden of mortgage debt on households, since even if housing prices reflect fundamentals; high debt-to-income ratios might signal the difficulty of households to repay their mortgages. A detailed analysis of these issues is presented in Appendix B. Taking into account all the arguments, the present study assumes a zero percent increase in nominal property prices as a stressful scenario, which leads to a 15 per cent decline in real property prices. While this scenario can be considered as too mild by some economists, our analysis shows that growth in property prices in the past has reflected economic fundamentals, and therefore one should not observe any drop in nominal property prices.

Because of the boom−bust behaviour of oil prices, which dropped from a high of US$140 in June 2008 to US$55 in November 2008, the historic scenario appears to be irrelevant. Therefore, an increase in the oil price to US$100 was assumed as a more plausible economic scenario. Because of the high level of economic uncertainty, a severe decline in gold price is not foreseen, as gold preserves its status as a safe haven. It should be mentioned that commodity prices have limited impact on credit risk in the present model, since they only impact on credit risk for two sectors: mining and electricity.

## 4.2 The impact on loan loss provisions and capital

Before discussing the impact of different macroeconomic stress scenarios on banks' capital-adequacy ratios, the underlying assumptions should be stated.

First, the assumption is made that the estimated historic relationship is going to hold for the future, which is a very stringent assumption considering that the available data did not allow for estimating a meaningful model for the period before 2001. Therefore, a symmetrical reaction of credit risk to macroeconomic environment during upswing and downturn phases of the business cycle is assumed. However, it should also be reminded that model estimated for the upswing phase of the cycle overestimated credit risk when applied to actual data in the downturn phase.

Second, the assumption is made that future profits are going to be zero and thus additional loan loss provisions were directly subtracted from current capital, only controlling for a tax reduction of 28 per cent. In reality, the South African banking sector is highly profitable and profits can serve as a buffer against future credit losses. In addition, the assumption is made that no managerial or regulatory actions take place when macroeconomic conditions start to deteriorate or first signs of distress are visible. While this is an unrealistic assumption, the reality is impossible to model.

Despite the above assumptions that render the estimations in this study rather conservative, the assumption is also made that there is no contagion between banks, no bank runs and no second-round effects, which leads to underestimation of the impact.

Based on the above assumptions, additional loan loss provisions and new capital-adequacy requirement ratios for the South African banking sector were computed under three different macroeconomic stress scenarios, which are described in section 4.1. The computations are first done for the largest five banks, which are systemically important institutions, and then for all banks, including foreign branches. In addition, the findings are based on a model for total loan loss provisions (columns 2−3), and then on separate models for different economic sectors (columns 4−5). The implications of different macroeconomic scenarios on loan loss provisions and capital adequacy ratios are reported in Table 8.

The results of this study indicate that loan loss provisions increase significantly under all scenarios. The results are not very sensitive to the model used or the number of banks that were taken into account. The five largest banks had a loan loss provision ratio of 0,88 in June 2008, but that increases to 3,39 – 3,54 under the second scenario depending on a model used. This large increase is primarily driven by the assumption of 12 per cent decline in nominal property prices, which corresponds to 29 per cent decline in real prices. Under other scenarios, a slightly smaller deterioration of credit quality is predicted.

**Table 8 The impact of various scenarios on capital adequacy and credit impairments to total credit ratio**

| | Model for total loans | | Sectoral models | |
|---|---|---|---|---|
| | Capital | Loan loss provision | Capital | Loan loss provision |
| **Applied to five largest banks** | | | | |
| Current ratio for five largest banks | 12,37 | 0,88 | 12,37 | 0,88 |
| Scenario 1: worst historic | 9,68 | 3,21 | 9,63 | 3,25 |
| Scenario 2: two standard deviations | 9,48 | 3,39 | 9,31 | 3,54 |
| Scenario 3: expert | 10,46 | 2,50 | 10,51 | 2,45 |
| **Applied to all banks** | | | | |
| Current ratio for all banks | 12,7 | 1,02 | 12,7 | 1,02 |
| Scenario 1: worst historic | 10,02 | 3,34 | 9,99 | 3,36 |
| Scenario 2: two standard deviations | 9,82 | 3,52 | 9,67 | 3,66 |
| Scenario 3: expert | 10,78 | 2,63 | 10,85 | 2,57 |

Source: Computed by author

Despite large credit losses, the South African banking sector remains adequately capitalised by international standards due to the high level of current capital adequacy. Under the most plausible scenario 3, the capital-adequacy ratio amounts to around 10,5 for the five largest banks and 10,8 for all banks. As mentioned earlier, property prices play a large role in the present model and therefore the results are very sensitive to the assumption on developments in property prices. For illustrative purposes, one could change the scenario 3 assumption of zero nominal property price growth. However, the capital adequacy of the five largest banks remains above the required level of 9,5 per cent even if one assumed an 11 per cent decline in nominal property prices, which corresponds to 26 per cent decline in real prices.

Based on our investigation of property prices presented in Appendix B, such a large decline is extremely unlikely in the South African context,

## 5 Conclusions

The study applied macroeconomic credit risk modelling to the South African banking sector.

In the first step, separate models for household, mining, electricity, transportation and other sectors are constructed, relying on loan loss provisions in each sector for the period 2001−2008. The findings uncover that the main drivers of credit risk are high interest rates and declining property prices. This reflects the situation where the largest share of a credit portfolio consists of mortgages at flexible interest rates. Because of the high importance attached to property prices, an analysis was made of whether the recent growth in property prices reflected fundamentals. The finding is that the main drivers of growth in property prices are inflation, interest rates and construction costs, and these variables accurately describe changes in property prices. In the second step, three macroeconomic scenarios that describe extreme, but plausible, stressful scenarios are developed. Finally, additional loan loss provisions and new capital-adequacy ratios under these scenarios were computed.

The findings show that South African banks' risk-bearing capacity is more than adequate. Under very severe crisis scenarios, when real property prices decline by 26 per cent, considerable losses to the household credit portfolio are accumulated, but they are sufficiently covered by the current capital-adequacy ratios.

Future work is needed to address issues discussed in this paper. Most importantly, there is a need to enhance a reliable database with a long-term horizon over upswing and downturn phases of economic cycles. Ideally, it would be useful to build a model relying on firm level data provided by credit registries.

There is also a need to address feedback effects (IMF, 2007). When faced with an adverse macro scenario, banks will re-optimise their behaviour accordingly and their responses may not follow similar reactions as in the past. Risk-minimising responses that are perfectly rational at the level of individual institutions have unintended

consequences and lead to more risk in the aggregate (Sorge, 2004). In the South African case, one of the possible feedback effects that deserves to be analysed is property prices. Declining property prices prompt banks to curtail their financing of mortgages by raising their lending standards in order to minimise risk. However, the diminished availability of mortgage financing would diminish demand for property, driving property prices down further.

Finally, what has not been addressed in this paper is the trade-off between monetary policy and financial stability. The study has shown that South African banks are very sensitive to interest rate increases. Therefore, when designing monetary policy, serious consideration should be given to the potential impact on the stability of the banking sector.

## Appendix A. Performance of the models

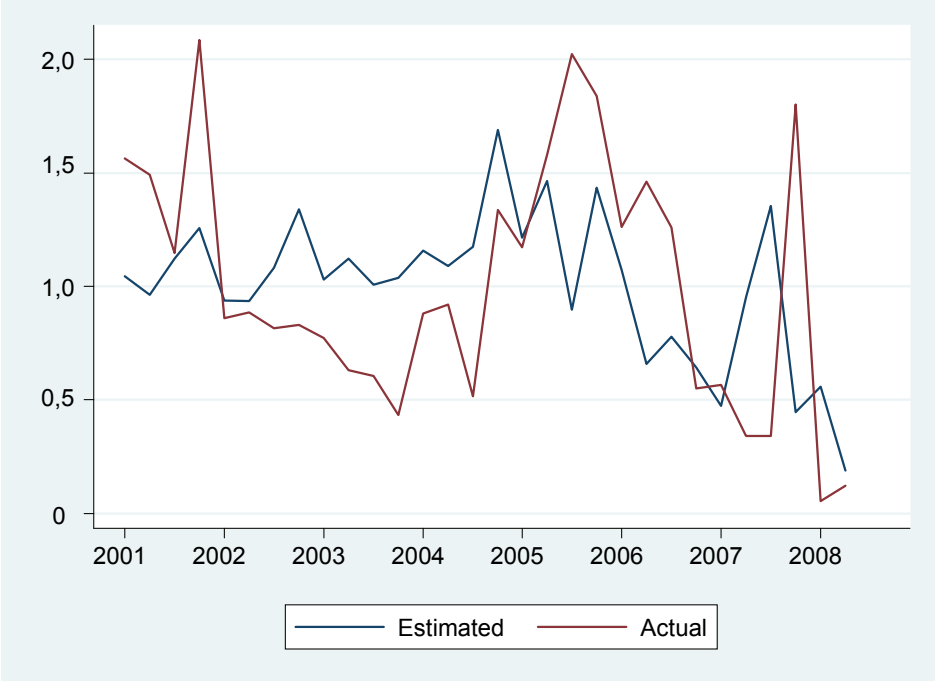
### Figure A1 Performance of the model for total loans


Source: Constructed by author

### Figure A2 Performance of the model for loans to individuals

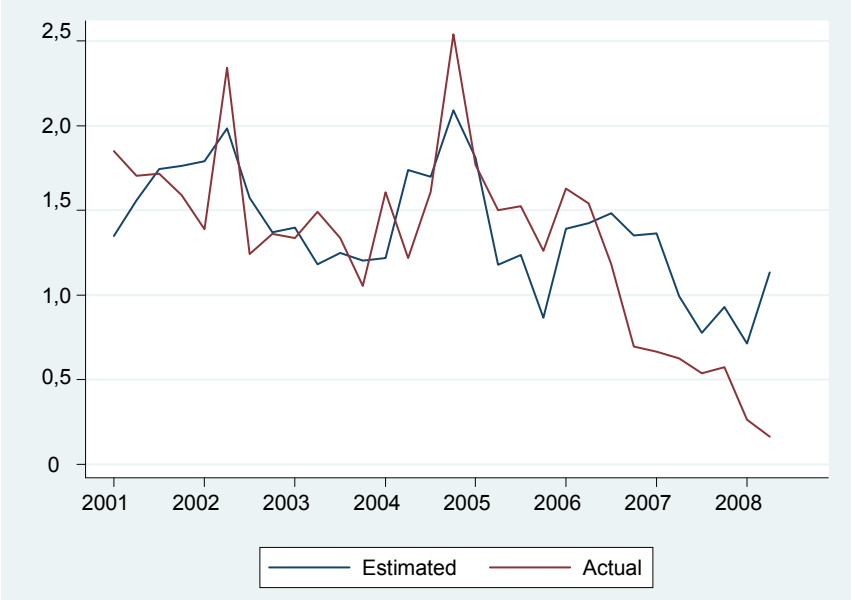

Source: Constructed by author

**Figure A3 Performance of the model for loans to the mining sector**



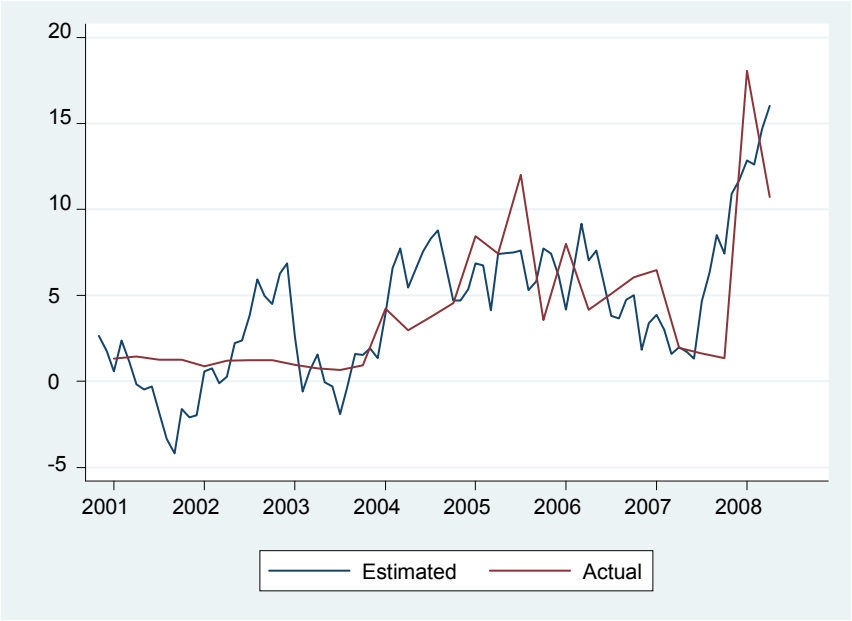

Source: Constructed by author

**Figure A4 Performance of the model for loans to the transport sector**




Source: Constructed by author

**Figure A5 Performance of the model for loans to the electricity sector**




Source: Constructed by author

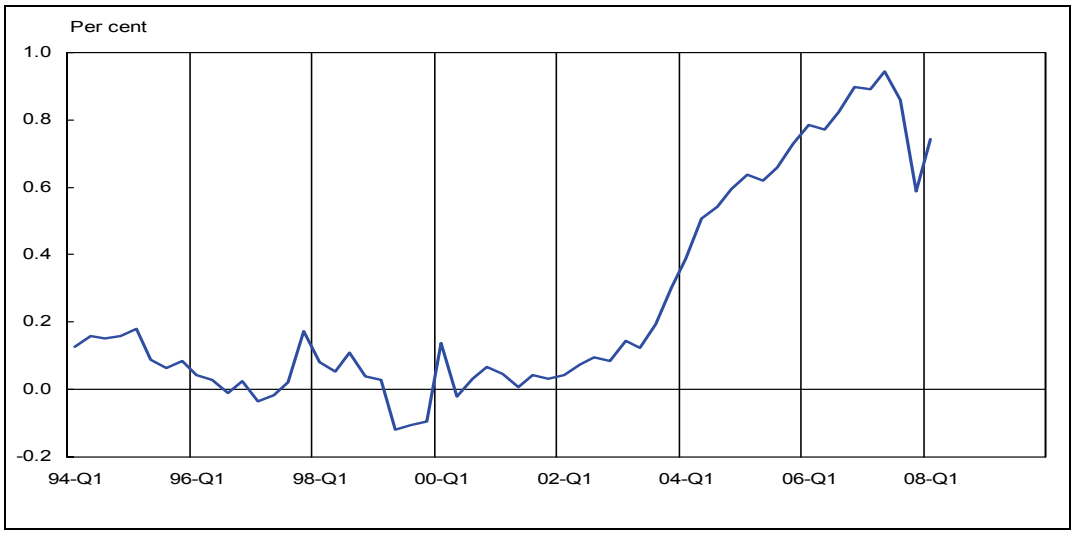
## Appendix B. House prices and economic fundamentals

### B.1 Price-to-rent ratio

One of the ways to test whether property price changes reflect fundamentals is to look at the ratio of house price to rent of an equivalent house. This price-to-rent ratio is similar to the price-to-earnings ratio observed in capital markets and the underlying idea is that the price of a house should be equivalent to income derived from future rent of the house or saved from paying rent. Rent is generally very closely tied to supply and demand fundamentals, and one rarely sees an unsustainable "rent bubble". Therefore, a rapid increase of home prices which is not accompanied with booming rental market can signal a property bubble.

There is no public data available either for property prices or rents in South Africa. One of the most reliable indicators is the house price index, calculated by ABSA, one of the largest banks. Unfortunately, there are no data on the rent index of houses, but Rode & Associates publish a rent index for flats in four of the largest cities in South Africa (i.e., Cape Town, Johannesburg, Pretoria and Durban). Therefore, a proxy for the price-to-rent ratio can be calculated, namely a ratio of house price index to flat rent index. This indicator is presented in Figure B1.

**Figure B1 The ratio of house price index to flat rent index**




Source: Computed by author

Figure B1 shows that house prices and rents increased at a similar pace at the beginning of the analysed period, but house price growth overtook rent growth after 2002. This might signal an overshooting in housing prices. However, the ratio of housing prices to rent still remains below the international standards, and this recent increase might rather reflect the catching-up of housing prices due to higher credit availability for large segments of the South African population.

## B2. Model-based forecasting of property prices

House price dynamics can also be modelled in terms of changes in housing demand and supply. On the demand side, the key factors are typically taken to be expected change in house prices (P), household income (Y), the real rate on housing loans (r), financial wealth (W), demographic and labour market factors (D), and a vector of other demand shifters, such as location, age and state of housing, or institutional factors that facilitate or hinder households' access to the housing market (Egert and Mihaljek, 2007).

$$D^H = f(\overset{-}{P}, \overset{+}{Y}, \overset{-}{r}, \overset{\pm}{W}, \overset{\pm}{D})$$

The supply of housing is usually described as a positive function of the profitability of construction business which, in turn, positively depends on house prices and negatively on real costs of construction (C).

$$S^H = f(\overset{+}{P}, \overset{-}{C})$$

If one assumes that prices are in equilibrium, with demand equal to supply all the time, house prices can be expressed by the following reduced form equation:

$$P^H = f(\overset{+}{Y}, \overset{-}{r}, \overset{+}{D}, \overset{+}{C})$$

In the first step, the long-term relationship between house price index and a set of long-term drivers, such as GDP per capita and population (Table B1), is analysed. Non-stationarity is tested for, relying on the panel unit root tests of Levin, Lin and Chia-Shang (2002); Im, Pesaran and Shin (2003); Maddala and Wu (1999); and

Hadri (2000). All tests show that GDP per capita and population is non-stationary. Since there is evidence of the presence of unit roots in the present time series, the test is for the panel cointegration among the variables using tests suggested by Kao (1999) and Pedroni (1995) with the null hypothesis that the estimated equation is not cointegrated. The findings of this study strongly point to the existence of a cointegrating relationship between housing price index and other variables.

**Table B1 Long-term determinants of house price index**

Dependent variable: House price index

| | Coefficient | Economic significance |
|---|---|---|
| GDP per capita | 0,046*** | 163,64 |
| Population | 214,2063*** | 31,51 |
| Constant | -4650,66*** | |
| $R^2$ | 0,99 | |

***, ** and * correspond to 1, 5, and 10 significance levels, respectively.
Source: Computed by author

After running unit root and cointegration tests, a dynamic OLS methodology is used to estimate the long-run cointegrating relationship. An analysis of whether the housing price index lies above or below its long-term equilibrium level is conducted and a measure of imbalances that is a deviation of the house price index from its long-term trend is constructed. In the second step, this measure is incorporated into the predictions of real property prices growth, which additionally include such explanatory variables as interest rate, inflation, GDP growth, stock exchange index growth and building costs (Table B2).

The results show that recent growth in property prices can be attributed to both demand and supply factors. On the one hand, low inflation and interest rates increased demand for housing due to affordable mortgages. On the other hand, higher building costs were translated into higher property prices. A two-standard deviations increase in building costs (an 8,6 percentage point increase) leads to a 9 percentage point increase in real property prices. By contrast, higher GDP growth had a limited impact on the growth of property prices.[6]

[6] An effort was also made to input wage and/or employment growth, but this had either no impact or a significantly lower impact than GDP growth.

**Table B2 Short-term determinants of property prices**

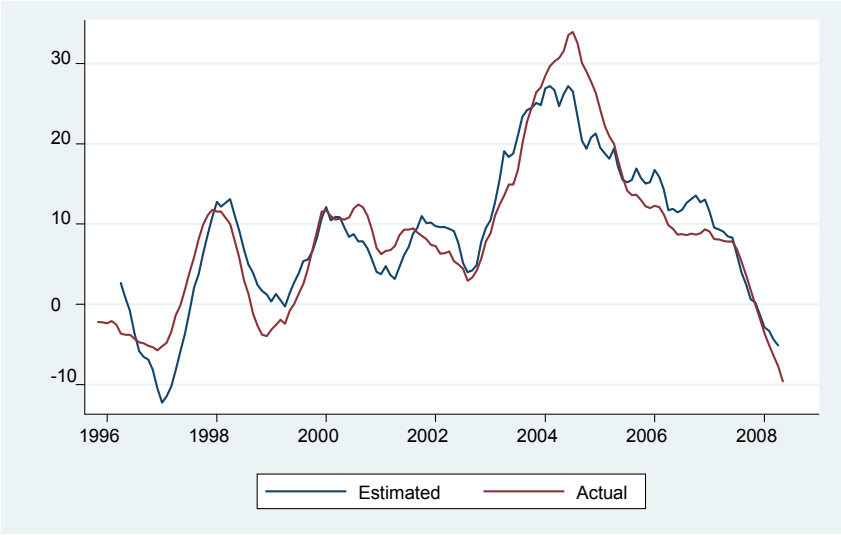
Dependent variable: Real property price growth

| | (1) | (2) | (3) | (4) | (5) | Economic significance |
|---|---|---|---|---|---|---|
| Interest rate | -1,14*** | -1,18*** | -1,40*** | -1,48*** | -0,61*** | -3,21 |
| Inflation | -2,88*** | -3,15*** | -3,33*** | -3,79*** | -2,33*** | -13,85 |
| GDP growth | | | -0,62** | 0,89*** | 0,77*** | 2,819 |
| JSE index | | | | -0,24*** | -0,10*** | -4,04 |
| Building costs | | | | | 1,06*** | 9,08 |
| ECT | | -0,19*** | -0,18*** | -0,11** | -0,11*** | |
| Constant | 31,42*** | 33,37*** | 37,79*** | 39,72*** | 12,60*** | |
| $R^2$ | 0,65 | 0,68 | 0,69 | 0,77 | 0,88 | |

***, ** and * correspond to 1, 5, and 10 significance levels, respectively.
Source: Computed by author

In order to see whether real growth in property prices during the past few years reflected fundamentals, the actual and estimated house price growth were plotted (Figure B2). The figure shows that the estimated model is very accurate in describing movements in housing prices.

**Figure B2 Actual and estimated house price growth**

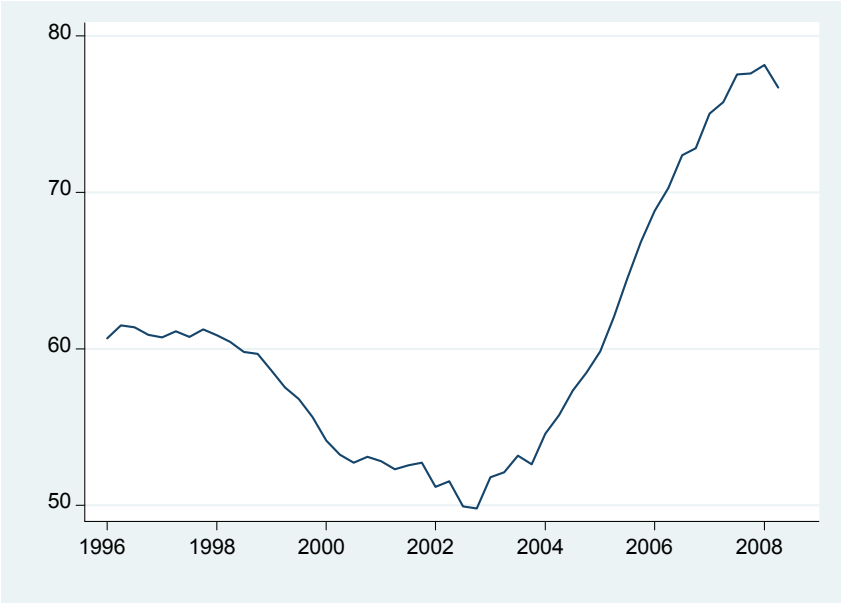



Source: Absa Bank Ltd and author's calculations

Despite the fact that growth in housing prices reflected fundamentals, little of it was driven by higher income or employment. And this is reflected in the skyrocketing debt-to-income ratio presented in Figure B3. Higher indebtedness leads to higher

repayment costs for households, undermining affordability of housing. This is particularly crucial in the South African environment, where mortgages are extended at flexible interest rates. It should also be taken into account that a large part of mortgages is extended to new borrowers, whose propensity to repay their loans has not been tested.

**Figure B3 Ratio of household debt to disposable income**




Source: South African Reserve Bank

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