Macroeconomic Stress Testing: Preliminary Evidence for Austria

Harvir Kalirai,
Martin Scheicher

1 Introduction

Financial stability is gaining importance among monetary and financial authorities as the process of globalization continues. In the last few decades, there has been a decrease in the impediments to trade and capital flows and an increase in information flows, financial innovation, deregulation and advances in technology, which has all contributed to the formation of closer links among global financial markets. While this has aided the efficiency and overall functioning of the global economy, there is a downside risk arising from this interdependence of markets. Namely, financial crises have a greater potential to spread beyond national borders and have a magnified impact on the global economy. With increased risks of contagion, central banks must be more vigilant to potential vulnerabilities that may threaten financial stability on a national and global level.

Episodes such as the near failure of Long-Term Capital Management (LTCM), the Asian crisis, the Scandinavian banking crisis and Argentina's recent debt default highlight the urgency for action on the part of policymakers to maintain and ensure financial stability. The Asian crisis showed how trade and financial linkages can propagate a financial disturbance internationally. A currency crisis which started in Thailand spread rapidly to other emerging Asian economies including Indonesia, Malaysia and South Korea. The crises in the Asian countries exposed the weakness of their banking systems and prompted the International Monetary Fund (IMF) to step in with various bailout packages to prevent a total economic collapse in these countries. The Scandinavian banking crisis in the first half of the 1990s coincided with the bursting of the property price bubble. Property prices had escalated to exuberant levels; as real estate was used as collateral to finance ever-increasing loans, the sharp fall in property prices led to significant losses for banks that had large exposures to the sector. The Scandinavian banking crisis is estimated to have cost 5% to 7% of GDP.

Central banks have a vital role in ensuring financial stability and minimizing fragility in the financial system. In a number of countries, central banks take part in supervisory activities. More generally, a key responsibility of monetary authorities is the lender-of-last-resort role. In this context, the question arises as to how vulnerabilities in the financial systems can be detected. Observing potential signs of heightened risks present in the financial system is important for central banks as they rely on such insights to be able to take both preventive measures and adequate action in crisis management. A key method supporting policymakers in the task of conserving financial stability is macro stress testing, because it performs quantitative analyses of financial fragility.

The purpose of this paper is to perform macro stress tests for the Austrian banking system. Our focus is on the impact of credit risk. This risk category has recently been the topic of considerable analysis for a number of reasons. First, credit risk is still the preeminent risk category for banks in the euro area. Second, the changing regulatory framework and the development of new products have generally strengthened the focus on modeling default risky assets. In particular, the ongoing Basel II process and the rapid development of credit derivatives have motivated researchers to undertake quantitative work on credit risk. By means of a scenario analysis, we estimate the impact of an increase in risk provisions on the risk-bearing capacity of Austrian banks. Our scenarios are based on changes in key macroeconomic variables. We compare the outcome of a number of scenarios to total capital available to Austrian banks. Here, we observe that a number of variables, including industrial production and real or nominal short-term rates, have a statistically significant impact on changes in loan loss provisions. As regards the economic impact of our scenarios, generally, the evidence is limited due to the fact that we test the impact of changes in single variables as opposed to changes in a scenario that covers a group of variables. In order to conduct multi-factor analysis, a comprehensive macroeconomic model would be needed, which is beyond the scope of this paper.

The rest of this paper is organized as follows: In section 2, we present a brief overview of stress testing, section 3 gives some details about credit risk in the Austrian financial system. Section 4 describes the methodology and the empirical results. Section 5 summarizes and concludes.

2 Methodology of Stress Tests

The basis for stress testing comes from the methods that banks use to manage the market risk of their trading books. Here, the primary tool is the daily analysis of the value at risk (VaR). Stress testing is a key tool that complements VaR analysis. The difference is that stress testing measures the risk arising from abnormal market events whereas VaR analysis focuses on the risk arising from low probability events in normal markets. VaR analysis assigns a single quantitative value to the maximum potential loss that can result for a portfolio within a specific confidence interval and over a specific holding period. For example, a financial institution may have a 90-day VaR of USD 100 million on its equity portfolio within a confidence band of 95%. That is, there is a 95% probability that the maximum possible loss on the portfolio over the next 90 days will be USD 100 million (this is the value that is at risk). The remaining 5%, which are captured in the tails of the loss distribution function, are not taken in account in the VaR analysis. These 5% represent the probability of incurring losses greater than USD 100 million. Such potential extreme losses can be estimated via stress tests.

Some assumptions of VaR analysis are not easily supportable, which lends further backing to stress testing (see Oesterreichische Nationalbank, 1999; or Krenn, 2001, for more details). First, VaR analysis assumes that markets remain constant over a given time horizon when in reality breaks in markets do occur. Such periods of market breaks are often characterized by an increase in financial fragility, and stress tests can be used to assess the potential losses arising from such breaks. Second, VaR analysis usually assumes that changes in the financial time series (the risk factors) are normally distributed when they are in fact characterized by fat tail distributions. This assumption can lead to a fatal flaw since the likelihood of extreme events is understated when using a normally-distributed loss function as opposed to a fat-tail distribution. (CGFS, 2001; 2001)

Stress tests measure risks in abnormal market conditions but they do not assign any probabilities to the likelihood of such losses occurring. As discussed, they are used to quantify the risks associated with the tails of the distribution of losses ignored by VaR analysis. History has repeatedly shown that abnormal market events do occur and often have a substantial impact on financial markets. As such, there is a large cost associated with ignoring such abnormal events during risk assessment exercises.

Examples of abnormal events include the oil shock of the 1970s, the October 1987 stock market crash, the Exchange Rate Mechanism (ERM) crisis in 1992, the "tequila crisis" in 1994 when the Mexican peso collapsed, the 1997 Asian crisis and the 1998 Russian crisis. It is often not difficult to explain why and how these events arose, after the fact. However, regulators need to be aware of possible risks to the financial system prior to the occurrence of such abnormal events. There is increasing demand by authoritative bodies on financial institutions to put in place mechanisms or tools that can aid in the full assessment of risks present in the financial system. The focus is thus shifting towards including stress tests along with VaR analysis.

Central bankers, unlike corporate risk managers, are interested in conducting aggregate stress tests in order to evaluate the vulnerability of the financial system to potential risks. Their focus is not on a single financial institution or portfolio but rather on the entire financial system and its stability. Analysis of financial stability extends stress tests from the level of a single bank to modeling the entire banking system. These aggregate stress tests are used to measure the risk-bearing capacity of the financial sector for a specific stress scenario. Aggregate stress tests differ from portfolio stress tests because they have different objectives. Portfolio stress tests are used by risk managers or traders to determine whether the amount of risk inherent in a portfolio is justified by the expected returns. Hence, the main goal in portfolio stress testing is to determine how much risk is acceptable for a given level of expected return. Conversely, aggregate stress testing is used to measure structural vulnerabilities and the risk situation in the entire financial system. Such vulnerabilities are important to regulators as they may lead to massive turmoil in financial markets. Thus, aggregate stress tests must be able to assess the impact of potentially adverse events on the entire financial system and provide policymakers with the option to take counteractive measures before a full-blown crisis develops.

A leading role in the development of aggregate stress tests has been performed by the IMF, in cooperation with the World Bank. These institutions started the Financial Stability Assessment Program (FSAP) in May 1999. The aim of this program is to "increase the effectiveness of efforts to promote the soundness of financial systems in member countries." In the FSAP's pilot project, which covered 12 countries, tests were conducted on various types of risks, including interest rate risk, credit risk, exchange rate risk and equity market risk (Blaschke et al., 2001). By identifying weaknesses in a country's financial sector and suggesting remedial policies, the FSAP should, over time, contribute to reducing the incidence of crises.

There are two main approaches to conducting stress tests on an aggregate level, each with its own limitations and difficulties. One approach is to use the individual stress tests conducted by financial institutions' risk management teams and simply add up the results to obtain an aggregate stress test result. The second approach is for a regulatory or supervisory body to first aggregate portfolio and balance sheet data from individual financial institutions and then to conduct stress tests on this aggregated data.

The first approach requires consistent stress testing methodologies to be applied by all financial institutions. It may, however, not be cost-effective for firms to make operational changes to ensure similar risk management modeling techniques. Furthermore, with this approach, the same stress test scenario must be applied across all institutions. Developing a common risk scenario can be problematic as different institutions have different portfolio compositions with different exposures to risk. One bank, for example, may have higher exposure to Latin America since it engages in lending in these foreign currencies. Another bank may have a strong focus on domestic issues or on the housing market via relatively large mortgage loans. Non-customized stress tests may not provide the relevant information needed at the portfolio manager and trader level, although it may be more useful to a regulatory authority. In its survey of stress testing practices in financial institutions, the Bank for International Settlements (BIS; see CGFS, 2001) reported the presence of such asymmetry in risks. Risk managers surveyed stated that they are focusing on stress testing in some situations where there is the possibility of mismeasuring risk when using VaR analysis. These situations can arise when there is the lack of good historical data, in cases of market illiquidity or with estimating non-linear exposures related to options trading. The advantage of this aggregation approach is that the central coordinator will use the results of stress tests that have already been run, thus easing the burden on the central coordinator. The BIS survey refers to this approach as "low burden, low accuracy."

The second approach to conducting aggregate stress tests requires the coordinator or regulatory body to obtain the relevant raw data from the individual financial institutions. These institutions must follow the same reporting and accounting guidelines in order for the data to allow comparison and aggregation. The stress test scenario to be applied to the aggregated data will be relevant from the broader perspective of studying fragility in the overall financial system, as opposed to testing the robustness of a single institution. Our paper is exclusively concerned with this second approach.

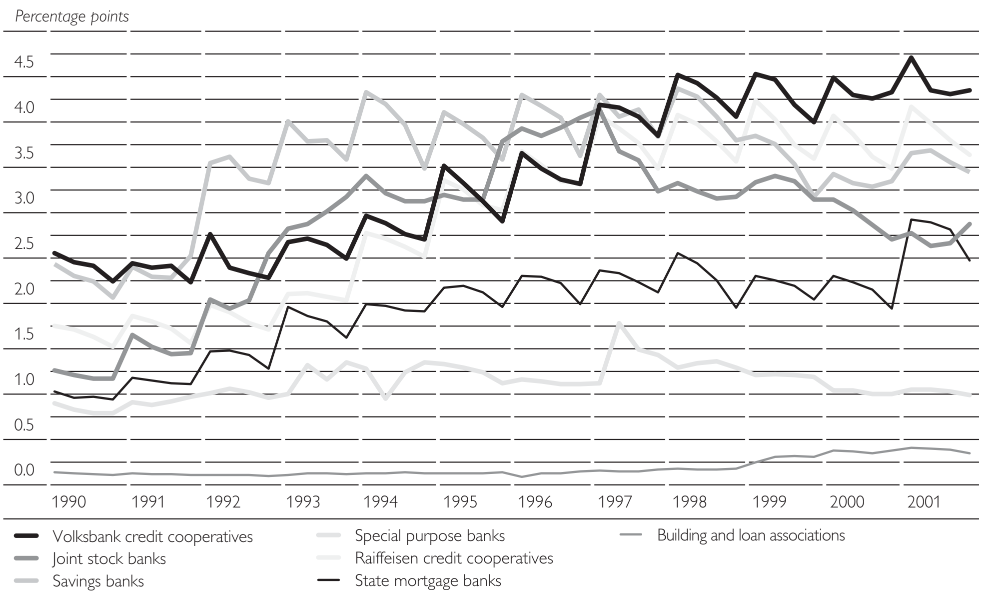
3 Credit Risk in the Austrian Financial System

Despite a number of structural changes, the most important part of Austrian credit institutions' operations is still the lending business. A significant source of risk is therefore the development of credit exposure, i.e. the risk that a borrower or a contracting party may default on its obligations. The continuing importance of the default risk is evidenced by a comparison of capital requirements. For covering the market risk arising from the trading book, i.e. the equity, interest rate and foreign exchange risks, the monthly banking statistics data show a sum of EUR 1 billion. In contrast, the solvency requirement amounts to EUR 22 billion. Hence, a deterioration of the loan books can be considered as a primary source of potential fragility in the Austrian financial system.

The calculation of credit exposure, which provides the basis for the statements made in this study, is currently based on the 1988 Basel Accord, as the new Basel II standards have yet to be finalized and implemented (see BCBS, 2001). These profound changes in capital adequacy regulations will lead to credit exposure being calculated on an entirely new basis. The aim is to reduce

Figure 1

Loan Loss Provisions



Source: OeNB.

the difference between economic and regulatory capital and to recognize risks more effectively. The current debate focuses on issues of implementation including, in particular, the potential impact of procyclical movements in regulatory capital requirements (see ECB, 2001).

An analysis of lending by economic sectors shows that 56% of loans were granted to businesses. More than one quarter of banks' claims are on households. The share of loans made to the government has been declining for quite some time and now stands at 12%. Less than 10% of banks' claims are on domestic nonbank financial intermediaries, mostly insurance companies.

A key indicator in measuring credit quality is the level of loan loss provisions (see figure 1). Loan loss provisions (LLP) are documented by banks in their monthly reports to the supervisors. Loss provisions are set up in respect of loans where the bank doubts the borrower's ability to meet his financial obligations. The level of LLP relative to claims on nonbanks has been low for some years and, in December 2001, remained flat at 3.1% (0.2 percentage point higher than in December 2000). At that date, the Volksbanken sector (4.4%), the Raiffeisen sector (3.6%), and the savings banks sector (3.5%) were above the average, while the building and loan associations sector reported below-average loss provisions (0.4%). Overall, the data on loan loss provisions show that the quality of the domestic credit institutions' loan portfolios is good. At the time the study was compiled, the data in hand did not point to any major rise in bad loan charge-offs. For the empirical study in the next section, we take the LLP as a share of total loans as the dependent variable.

A more detailed analysis of the quality of the Austrian banks' loan portfolios can be carried out on the basis of the prudential report, which includes observations on the overall situation of credit institutions by the bank auditors required under the Austrian Banking Act (BWG).[1]) On the whole, domestic banks' nonaccrual and nonearning assets (measured as a percentage of loans) remained at a low level during the past years. At year-end 2000, the global mean value of nonaccrual and nonearning assets was 1.15%. A breakdown of loans by risk categories shows that the volume of problem loans (nonperforming and irrecoverable) as a proportion of total credit volume has declined over recent years. In the year 2000, some 2.2% of loans were classified as nonperforming. As collateral is not considered in this context, forecasts about the recovery rate cannot be made. These data thus represent conservative assessments of credit quality.

4 Macro Stress Tests for Austria

Our empirical section consists of three steps: Estimations to find significant factors, scenario analysis and considerations of risk-bearing capacity. Given the importance of credit risk underlined in the previous section, our focus is only on this risk category. In order to measure credit risk, the literature offers a broad variety of models (see Saunders, 1999; or Nandi, 1998, for details). Our definition of credit risk is concentrated on the impact of defaults and hence on loan losses arising from the inability of a debtor to repay a loan. Therefore, we neglect losses in the market value of loan books arising from the downgrading of debtors. The basis for our approach is the hypothesis that the development of loan losses is linked to the macroeconomic environment. Hence, we model the systematic component of credit risk by means of its relation to the state of the business cycle, inflation or external factors and neglect the idiosyncratic, i.e. firm-specific component of credit risk. Among the models discussed in the literature, the Credit Portfolio View concept is closely related to ours as it specifies a relation between the conditional transition matrix and macroeconomic variables (see Crouhy et al., 2000, for an overview).

The starting point for our analysis is the method which the IMF proposes to assess credit risk (Blaschke et al., 2001). The impact of external shocks on unexpected credit losses can be modeled using a linear regression. Nonperforming loan (NPL) ratios are regressed against various macroeconomic variables, such as the nominal interest rate, inflation rate, real GDP growth and percentage change in the terms of trade. The regression coefficients capture the sensitivity of loan quality to specific macroeconomic factors.

As pointed out also by the IMF, in the field of stress testing, data limitations pose significant constraints on the construction of models. This is also the case currently with the Austrian banking data. However, changes in data collection and monitoring have already started in the process of Basel II, and in the future there will be a greater set of readily available data for the purposes of assessing financial system stability.

1 *The following performance categories are used in the prudential reports: without default risk, watch list loans (loans that might be at risk in the future), nonperforming (defaults are expected to occur), irrecoverable (default has already occurred), nonaccrual and nonearning assets (payment of outstanding principal or interest accruals is not expected at present / in the near future).*

4.1 Estimation of Factor Regressions

Our first step is to model the relation between a measure of credit risk and macroeconomic factors. For this purpose, we estimate Ordinary Least Squares (OLS) regressions on a comprehensive data set (see Arpa et al., 2000, for a related study in the context of macroprudential analysis). We analyze changes in LLP, as data on NPLs are only available on an annual basis. This does not detract from the analysis since changes in LLP are expected to have a high correlation with changes in NPLs. That is, banks are expected to adjust their LLP over time to the degree and variation in NPLs. Besides credit risk, the LLP are also affected by other measures which banks conduct to manage their balance sheets.

A key assumption in our procedure is that the time series of our variables do not contain unit roots. The evidence for the stationarity of the yearly differences of the LLP is slightly ambiguous. The Augmented Dickey Fuller test shows non-stationarity whereas the Philips Peron procedure indicates stationarity.[1]) The test procedures for unit roots may be problematic due to the small sample. For our estimations, we proceed by assuming stationarity. Hence, our hypothesized model is as follows:

$$\Delta LLP_t = \alpha_0 + \alpha_1 x_{1t} + ... + \alpha_i x_{it} + u_t$$

with:

LLP total loan loss provisions / total loans
x_{it} change in factor i at date t
u_t residual with $u_t \sim N(0, \sigma^2)$

Our sample consists of quarterly data from 1990 to 2001. For presentation purposes, we divide the macroeconomic variables which enter the above equation into the following six categories: cyclical indicators, price stability indicators, household indicators, corporate indicators, financial market indicators and external variables. Our categorization contains some ambiguity; for example, industrial production could also be included among corporate indicators, but we choose this categorization purely for the purpose of summarizing the set of variables. All variables except interest rates, inflation rate and unemployment rates and the yield curve are real and log differenced.[2]) For the variables mentioned, we use absolute differences. A caveat in our study is the small size of our sample, i.e. we do not observe a complete economic cycle. This is a common problem in the area of default risk modeling. In the following, we outline our set of factors in more detail. The descriptive statistics of the variables are given in table 1. A summary of the variables together with the hypothesized sign is provided in table 2.

1. Cyclical indicators

This category includes variables that relate to the general economic activity. The assumption is that loan quality is sensitive to the economic cycle. A deterioration in economic activity leads to falling incomes, rising payment difficulties and more business failures and hence default risk rises, causing a decline in the qual-

1 Results of the unit root tests are omitted for reasons of space but are available from the authors.

2 Austrian industrial production growth is calculated as [IP/IP(–4)]–1 and not using log differences.

Table 1

Descriptive Statistics of Variables

	Mean	Standard Deviation	Maximum	Minimum	Skewness	Kurtosis
GDP	2.43	1.39	5.03	− 0.06	−0.02	1.99
Industrial production	3.80	4.36	10.63	− 5.45	−0.25	2.03
Output gap	0.02	0.99	1.91	− 2.56	−0.62	3.59
Inflation	0.01	0.73	1.70	− 1.37	0.43	2.60
M1	4.19	5.79	16.17	− 6.07	0.20	2.27
Consumption	2.50	1.45	5.13	− 1.16	−0.31	2.69
Unemployment	0.09	0.51	1.03	− 0.90	−0.13	2.46
Employee compensation	4.22	2.21	8.74	0.44	0.51	2.64
New car registrations	0.47	9.60	22.30	−28.21	−0.64	4.63
Investment	2.60	4.50	11.82	− 5.70	0.29	2.28
Total gross fixed capital formation (GFCF)	2.77	3.49	9.81	− 5.71	−0.11	2.68
GFCF, construction, nonresidential	2.41	8.42	19.56	−22.31	−0.33	4.03
GFCF, construction, residential	1.85	7.70	17.83	−13.32	0.03	2.32
GFCF, machinery and equipment	3.23	7.56	17.96	−14.47	−0.08	2.46
Real productivity	2.01	1.07	4.13	0.07	0.10	1.96
Ifo business-climate index	− 1.19	8.91	16.73	−17.12	0.17	1.99
Bankruptcies	9.97	21.14	63.62	−38.99	0.22	3.17
Nominal 3-month interest rate	− 0.25	1.23	2.25	− 3.03	−0.26	2.74
Nominal 10-year bond yield	− 0.16	0.96	1.72	− 1.72	0.70	2.41
Real 3-month interest rate	− 0.27	1.06	1.42	− 2.77	−0.47	2.29
Real 10-year bond yield	− 0.18	0.93	2.37	− 1.77	0.71	3.11
ATX	− 1.31	18.06	39.58	−33.92	0.30	2.41
DJIA	12.65	9.94	33.78	− 8.33	0.07	2.24
DAX	9.83	19.21	46.55	−32.69	−0.10	2.26
Euro STOXX	13.96	17.32	41.79	−31.74	−0.58	2.82
Yield Curve	0.09	1.08	2.54	− 1.80	0.48	2.44
Exports	5.83	4.90	16.81	− 4.88	−0.12	2.72
ATS/USD exchange rate	1.34	10.40	18.85	−19.01	−0.40	2.16
ATS/GBP exchange rate	0.18	9.22	23.29	−17.19	0.29	2.95
ATS/ITL exchange rate	− 2.54	7.90	15.63	−22.73	−0.76	4.15
ATS/CHF exchange rate	1.00	3.48	8.89	− 7.36	−0.37	2.89
ATS/JPY exchange rate	2.32	13.93	30.21	−25.93	0.07	2.31
Oil price (North Sea)	3.34	29.91	87.13	−52.32	0.69	3.54
Oil price (Arab Light)	3.44	32.91	95.95	−59.42	0.64	3.67
Oil price (Brent Crude, 1 mth fwd)	3.64	28.18	82.80	−47.94	0.67	3.42
Change in LLP as ratio of total loans	0.15	0.24	0.63	− 0.28	0.29	2.36

Source: OeNB, Datastream.

ity of the banking books. As cyclical variables we include GDP, the output gap and industrial production.

GDP is the primary measure of the state of the economy. GDP growth and the output gap[1]) are expected to be related negatively with loan loss provisions. During periods of economic downturn, borrowers are less likely to be able to repay all of their debts, thus the probability of loan defaults and of loan losses by banks is expected to increase. Industrial production growth often leads the GDP growth cycle. As such, increased industrial production growth is expected to reduce loan losses since the economy is in a growth phase.

1 *The output gap is defined as actual GDP minus potential GDP. A positive output gap indicates that the economy is operating above its potential level.*

2. Price stability indicators

A measure of price stability is the index for consumer price inflation. Higher inflation may indicate that an economy is operating above its potential growth level and may be overheating. Higher inflation assists borrowers in repaying their debt since the real value of the debt repaid at some point in the future is less than loan. Conversely, falling inflation often signals that the economy is cooling down. Falling inflation also pushes real interest rates higher. This is likely to be followed by increased loan defaults given that the real cost of borrowing has increased. Money growth is included as an indicator due to its potential linkages to inflation.

3. Household indicators

Variables in this category relate to the situation of the household sector, which accounted for more than 25% of total loans in 2001. Consumption expenditure, unemployment, employee compensation and new car registrations are some variables that provide a gauge of the development of household incomes.

Generally, when households have higher disposable income, overall economic conditions are favorable and loan losses are low. Thus, consumption expenditure and new car registrations are expected to have a negative correlation with loan defaults. Unemployment is another variable that provides a measure of the state of households. Higher unemployment may indicate that households have greater difficulty repaying their debts. Higher total compensation for employees, which includes wages and salaries, implies higher disposable income which in turn suggests that employees are less likely to default on their debts. Employee compensation is thus expected to be inversely related to loan losses.

4. Corporate indicators

Corporate indicators assess the financial outlook of firms. The corporate sector is important given that it had a 56% share of total loans at the end of 2001. The primary variable examined here is investment expenditure, specifically gross fixed capital formation, wich is further broken down into residential construction, nonresidential construction, and machinery and equipment expenditures. Confidence indicators such as the frequently observed Ifo index of German business climate are also examined. Real productivity per employee and the growth rate of bankruptcies are other factors that are examined.

Corporations increase investment expenditures when the economic outlook is favorable. Thus, investment expenditures (including fixed investments, construction investment and investment in machinery and equipment) are expected to be negatively correlated with loan defaults. Corporate bankruptcies are expected to have a positive correlation with loan losses. Productivity gains enable companies to increase profit margins and such gains largely occur during economic upswings. Confidence indicators, which track the economic cycle and tend to lead real macroeconomic data such as industrial production and GDP growth, are likely to be negatively related to loan defaults. Increasing industrial confidence leads to stronger economic activity and a period where loan defaults decline as borrowers are in better financial positions.

5. Financial market indicators

Financial market variables examined in this study consist of nominal and real interest rates (3-month and10-year rates), the yield curve, and stock market indices (ATX, DAX, Dow Jones Industrial Average, Euro STOXX).

Interest rates are a central variable as they represent the direct costs of borrowing. Thus, the higher the interest rate, the greater the cost of borrowing and the greater the possibility of loan default as firms and households are less able to service their debt. The steepness of the yield curve, which is measured as the 10-year bond yield minus the 3-month interest rate, provides an indication of the impact of monetary policy and the economic cycle. For example, a relatively steep yield curve may suggest that the economy is growing at a very high rate and future interest rate hikes are expected in order to contain the buildup of inflationary pressures. In this case, the yield curve is expected to be negatively related to loan losses. However, the higher interest rates expected when the yield curve is steep suggest that the cost of borrowing is expected to rise and as discussed above, this is likely to be related to greater loan losses. Higher short interest rates eventually flatten the yield curve and possibly even result in an inverted yield curve where long rates are below short rates. This situation is often characteristic of a recession. Thus, given the dynamic nature of the yield curve, its relationship to potential loan losses is ambiguous.

Stock market indices tend to follow or lead the cyclical trends of the macroeconomy. Most stock markets of the large industrialized nations are linked to some extent and movements in the U.S. stock market in particular often have spillover effects across global markets. Rising stock markets deliver higher returns to investors and thus lower the probability of loan defaults. This linkage is captured on the level of an individual firm in the benchmark model of Merton (1974).

6. External indicators

This category refers to nondomestic factors that can impact Austria's domestic financial system. These forces primarily relate to international trade links. Exchange rates (cross rates of the Austrian Schilling against the U.S. dollar, Swiss franc, Japanese yen, British pound sterling and Italian lira), exports and oil prices are examined.

A fall in exports can adversely impact a small open economy and in turn result in greater loan defaults. For example, an export-oriented firm that suffers losses may not be able to repay all of its debts as it faces a negative cash flow. With regard to nominal exchange rates, a depreciation of the domestic currency means that the borrowers must repay less than they borrowed initially. The net real position of the borrower has, in fact, improved. Also, a lower domestic currency is positive for a country's export sector. Hence, it is expected that a depreciation in the nominal exchange rate leads to lower loan defaults and losses. This situation is reversed if the borrowers are primarily borrowing in foreign funds, in which case they stand to benefit from an appreciation of their domestic currency. Generally, the relationship between the exchange rate and loan losses is ambiguous. The one exception to this ambiguity is for loans denominated in foreign currency. In this category, the Swiss franc and Japanese yen have the largest share and it could be expected that depreciations of the domestic currency lead to increased loan losses as the repayment amounts rise. Sharp increases in oil prices can lead to a negative demand shock to the economy causing household and business energy costs to rise. Thus, an increase in oil prices is likely to be associated with a deterioration of the economic climate and, thus, greater loan losses.

For all the above explanatory variables and the LLP, table 1 summarizes the statistical properties. We observe that the mean change in LLP relative to total loans is 0.15% with a standard deviation of 0.24. The largest changes were an increase of LLPs by plus 0.24% and a fall by minus 0.63%.

4.2 Results for Bivariate Regressions

Table 2

Summary of Variables and Bivariate Regression Results[1])

Factor X_i	Expected sign	Regress ΔLLP against $\Delta LLP(-1)$, Dummy, $X_i(-1)$		
		Coefficient	T-Statistic	R^2
1. Cyclical				
GDP	–	–0.0047	–0.346	0.860
Industrial production	–	–0.0128	–3.518[2])	0.875
Output gap	–	0.0352	1.692	0.870
2. Price Stability				
Inflation	–	0.0047	0.239	0.860
Money growth	–	–0.0078	–3.341[2])	0.889
3. Household				
Consumption expenditure	–	–0.0073	–0.747	0.862
Unemployment rate	+	0.0250	0.678	0.861
Employee compensation	–	0.0152	1.834	0.875
New car registrations	–	0.0006	0.472	0.860
4. Corporate				
Investment expenditures	–	–0.0022	–0.978	0.861
Total gross fixed capital formation (GFCF)	–	0.0006	0.123	0.860
GFCF, construction, non-residential	–	0.0000	0.001	0.860
GFCF, construction, residential	–	0.0031	0.599	0.862
GFCF, machinery & equipment	–	–0.0017	–1.246	0.862
Productivity per employee	–	–0.0078	–0.694	0.861
Industrial/business confidence	–	–0.0048	–3.694[2])	0.886
Bankruptcies	+	0.0008	1.017	0.863
5. Financial markets				
Nominal short interest rate	+	0.0372	2.728[2])	0.884
Nominal long interest rate	+	–0.0132	–0.654	0.861
Realshort interest rate	+	0.0414	2.177[2])	0.885
Real long-term interest rate	+	–0.0210	–0.705	0.863
ATX	–	–0.0016	–2.747[2])	0.874
DJIA	–	–0.0017	–1.176	0.865
DAX	–	–0.0012	–2.844[2])	0.868
Euro STOXX	–	–0.0013	–3.085[2])	0.866
Yield curve	+/–	–0.0429	–3.760[2])	0.892
6. External				
Exports	–	–0.0061	–2.452[2])	0.870
ATS/USD exchange rate	+/–	0.0004	0.191	0.860
ATS/GBP exchange rate	+/–	–0.0020	–1.654	0.864
ATS/LIT exchange rate	+/–	0.0001	0.098	0.860
ATS/CHF exchange rate	+/–	–0.0051	–0.969	0.865
ATS/JPY exchange rate	+/–	–0.0005	–0.503	0.860
Oil price (North Sea)	+	–0.0006	–1.050	0.865
Oil price (Arab Light)	+	–0.0007	–1.281	0.867
Oil price (Brent Crude, 1 mth fwd)	+	–0.0006	–1.019	0.864

Source: OeNB, Datastream.

[1]) Where LLP = loan loss provisions / total loans(t) - loan loss provisions/total loans(t–4); and Dummy = 1 for the period 1995:1–1995:4 and 0 otherwise.

[2]) The variable is significant at a confidence level of 90%.

Bivariate regressions are estimated using a single macroeconomic risk factor. The models estimated include a lagged dependent variable, a dummy variable (to account for the change in risk provision definitions for the period first quarter 1995 to fourth quarter 1995) and a single macroeconomic risk factor. This systematic methodology will enable the selection of regressors to be used in a comprehensive data set. These are presented in table 2. For the purpose of comparisons, we also include the expected sign for the independent variable.

The results indicate that in each category, with the exception of the household sector, there is at least one macroeconomic variable that enters significantly (and with the correct hypothesized directional impact) into the regression. The cyclical variable with the highest predictive power is industrial production, while GDP does not enter significantly. Among measures of price stability, money growth is significant. The Ifo business-climate index is the only significant corporate sector variable. Although the Ifo index measures business confidence for Germany, it has been shown to have predictive properties for euro area growth. Significant financial market variables consist of the nominal and real short rates, the ATX, DAX and Euro STOXX indices, and the yield curve. Finally, for external factors, only exports are significant with all the bilateral exchange rates having insignificant predictive power.

In order to analyze the robustness of the specification, the models are estimated using a lag of 1 and a lag of 4 quarters for the risk factors. There was no improvement in the number of macroeconomic variables that were significant in the regressions, nor was there an improvement in the degree of significance of the variables when using a lag of 4. Based on an examination of the significance of the regressors (while also analyzing the significance of the dummy variable), the following variables (with 1 lag) are selected from each category (see table 3 for the complete estimation results):

- Cyclical variable: *industrial production*
- Price stability variable: *money (M1)*
- Household variable: *none*
- Corporate variable: *Ifo business-climate index*
- Financial market variable: *real and nominal short-term interest rate, ATX index, DAX index, Euro STOXX index*
- External sector variable: *exports*

Among financial market variables, the real and nominal short-term interest rates and the stock market indices are not highly correlated. Thus, they both affect loan losses differently. The yield curve is not included although it is significant. The linkage from the yield curve to credit risk is somewhat ambiguous. The yield curve can impact the economy and financial sector through various channels, which makes it difficult to interpret the regression results. Among other financial market variables, notably, the nominal and real 10-year interest rates do not have the correct sign. There is no household sector variable included, but the household sector closely follows the overall macroeconomic cycle and is thus captured by the cyclical variables. Hence, the cyclical variations in household income are already represented by industrial production and the Ifo index. Regarding the fit of the regressions, we note that the R^2 values are higher than 80%, indicating a satisfying performance of our simple model.

Table 3

Complete estimation results for significant factors

		Macro factor X_i								
		Industrial production	Exports	Real 3-month interest rate	Money (M1)	Ifo business-climate index	Nominal 3-month interest rate	ATX	DAX	Euro STOXX
Constant	Coeff	0.0767	0.0529	0.0103	0.0508	0.0076	0.0040	0.0059	0.0234	0.0200
	t-stat	2.5817	2.3791	0.4988	2.2699	0.3944	0.2890	0.3046	1.1916	1.0322
	p-Val	0.0137	0.0223	0.6207	0.0288	0.6955	0.7741	0.7623	0.2406	0.3097
$\Delta LLP(-1)$	Coeff	0.0767	0.8525	1.0083	0.8698	0.8603	1.0251	0.9234	0.9048	0.8269
	t-stat	2.5817	10.0473	18.4219	19.9062	13.1096	16.6921	14.8373	14.1985	13.4172
	p-Val	0.0137	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dummy	Coeff	0.0713	0.0352	0.0225	0.0562	0.0723	0.0620	0.0305	0.0232	0.0307
	t-stat	1.9937	1.1963	0.6700	1.8240	3.5529	2.2312	0.8240	0.6198	0.8671
	p-Val	0.0532	0.2388	0.5068	0.0758	0.0010	0.0315	0.4149	0.5390	0.3924
$X_i(-1)$	Coeff	−0.0128	− 0.0061	0.0414	− 0.0078	− 0.0048	0.0372	− 0.0016	− 0.0012	− 0.0013
	t-stat	−3.5179	− 2.4518	2.1768	− 3.3412	− 3.6936	2.7280	− 2.7471	− 2.8436	− 3.0845
	p-Val	0.0011	0.0188	0.0356	0.0018	0.0007	0.0095	0.0091	0.0071	0.0042
R^2		0.8753	0.8698	0.8847	0.8888	0.8862	0.8836	0.8740	0.8679	0.8660
DW Statistic		1.4931	1.4254	1.7424	1.8394	1.7626	1.9068	1.6239	1.6432	1.8634

Source: OeNB, Datastream.

When we analyze the time series of the residuals, the Durbin Watson tests show no signs of residual autocorrelation at lag 1.

4.3 Scenario Analysis

Following the estimations of the bivariate model we now turn to measuring the impact of various adverse macroeconomic events. Here, the method for choosing a scenario is a key step. For our methodology, we started by comparing historical and hypothetical shocks. The selection of the magnitude of the shocks to the macroeconomic variables was therefore based on the comparison of two events: the historical[1]) extreme values experienced in the time series of the variables and, as a hypothetical event, a 3-standard deviation change in the variable. The choice between the two approaches is driven by the aim of constructing plausible scenarios. Hence, we choose to define the adverse events by the historical extremes of the respective exogenous variables. Given that they actually happened, these historical scenarios are plausible enough to receive appropriate consideration by central bankers and supervisory authorities.

This choice of historical scenarios ensures homogeneity and therefore comparability of the tests. The following sensitivity tests were therefore conducted:

- Fall in industrial production by 10.4% (which occurred in the second quarter of 1975);
- Fall in M1 by 13.8% (which occurred in the third quarter of 1981);
- Fall in business confidence by 17.1% (which occurred in the fourth quarter of 1992);
- Rise in real short-term interest rate by 1.42 percentage points (which occurred in the first quarter of 1990);
- Rise in nominal short-term interest rate by 4.25 percentage points (which occurred in the second quarter of 1980);

1 *This is based on the availability of data for each variable.*

– Fall in the ATX, DAX and Euro STOXX indices by 33.9%, 32.7% and 31.7%, respectively (which occurred in the third quarter of 1992 for the ATX index and in the third quarter of 2001 for both the DAX and Euro STOXX indices);
– Fall in exports by 4.9% (which occurred in the second quarter of 1993).

Table 4

Single Factor Stress Tests

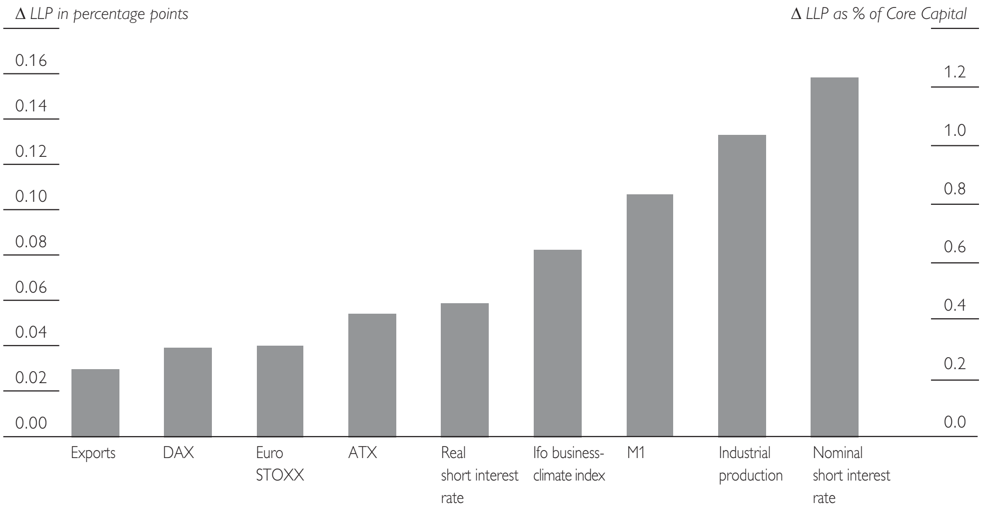
Factor X_i	Expected sign	Coefficient	Largest historical move	Change in LLP given historical move
Industrial production	−	−0.0128	−10.4000	+0.1331
Money growth	−	−0.0078	−13.8000	+0.1070
Industrial/business confidence	−	−0.0048	−17.1200	+0.0825
Nominal short interest rate	+	+0.0372	+ 4.2500	+0.1580
Real short-term interest rate	+	+0.0414	+ 1.4200	+0.0588
ATX	−	−0.0016	−33.9200	+0.0545
DAX	−	−0.0012	−32.6900	+0.0396
Euro STOXX	−	−0.0013	−31.7400	+0.0407
Exports	−	−0.0061	− 4.8800	+0.0297

Source: OeNB, Datastream.

Table 4 documents the stress test results assuming the historical extreme move in the individual macro factors. One of the strongest impacts on LLP came about from an increase in the nominal short-term interest rate. Interest rates capture the borrowing cost of capital and are expected to have a significant impact on the quality of a bank's loan portfolio. Higher interest rates lead to a greater debt servicing burden and, in turn, higher expected loan losses. The impact of a fall in industrial production, M1, business confidence and the ATX stock index amounted to an increase in the LLP ratio of 0.13, 0.11, 0.08 and 0.06 percentage points, respectively. Exports have the smallest

Figure 2

Changes in Loan Loss Provisions Ratio in Response to Changes in Single Factors[1])



Source: OeNB, Datastream.

[1]) *The left-hand scale shows the change of the LLP in response to the maximum historical change in the single factors as defined in the text. The right-hand scale measures the responses as a share of core capital.*

impact, about one-fifth of the impact from the nominal short rate. The household factors do not have any measurable impact since the coefficients from the bivariate regressions were not significant. The same holds for GDP, investment expenditures, productivity, bankruptcies, exchange rates and oil prices.

The maximal impact on LLP resulting from the sensitivity tests listed above ranges from 0.03 to 0.16 percentage points. The average change in LLP is 0.15 percentage points with a standard deviation of 0.24. These single-factor shocks do not imply a change in LLP that is significantly greater than its mean change.

In practice these single-factor shocks are not likely to occur in isolation without being combined to some degree with changes in other macroeconomic variables as well. For conducting plausible multi-factor stress tests, a comprehensive macroeconometric model would be needed. Such a model would allow for the definition of adverse events for the entire Austrian economy. This is beyond the scope of our preliminary work on stress testing and therefore left for future research. Hence, we continue with the bivariate setup. Figure 2 provides a summary of the sensitivity stress tests conducted. This figure summarizes the results presented in table 4, as discussed above.

4.4 Analysis of Risk-Bearing Capacity

The third step is to compare the risks shown by the scenario analysis to risk-bearing capacity. A key mechanism to limit the repercussions of problems arising at a bank is the capital adequacy requirement. The bank's capital is the reserve that buffers the impact of potential losses. Such losses may be incurred as a result of borrowers' defaults or, in securities trading, due to adverse market movements. The most important measure of the risk-bearing capacity of Austrian banks is the capital adequacy ratio, i.e. the ratio of capital to the bank's risk weighted assets. According to the Austrian Banking Act, there are three types of capital: tier 1 capital (core capital), tier 2 capital (supplementary capital) and tier 3 capital (special subordinated capital) to cover market risk.

Table 5

The Impact of the Stress Tests on Core Capital

Factor X_i Tested	Change in LLP ratio	Change in LLP	Change in LLP
	percentage points	*EUR million*	*as % of core capital*
Exports	+0.0297	+ 88.7466	+0.3295
DAX	+0.0396	+118.4045	+0.4397
Euro STOXX	+0.0407	+121.4879	+0.4511
ATX	+0.0545	+162.9412	+0.6050
Real short interest rate	+0.0588	+175.7011	+0.6524
Ifo business-climate index	+0.0825	+246.4670	+0.9152
M1	+0.1070	+319.6586	+1.1870
Industrial production	+0.1331	+397.7375	+1.4769
Nominal short interest rate	+0.1580	+472.1931	+1.7534

Source: OeNB, Datastream.

At the end of 2001, tier 1 capital totaled around EUR 27 billion. In terms of actual currency, LLP for the fourth quarter of 2001 totaled EUR 9.26 billion. That is, LLP were approximately 34.3% of core capital. The maximal change in the LLP ratio resulting from the stress tests is calculated in terms of core capital in order to provide a less abstract understanding of the impact of the various stress tests. These results are presented in table 5. The largest impact comes from a change in the nominal short rate. The hypothetical size in terms of core capital of this scenario is 1.8% or EUR 472 million. With regard to the other tests, the amount is 1.5% for industrial production, 0.9% for business confidence and 0.6% the ATX stock index. The size ranges from a maximum of 1.8% to a low of 0.3%, which is for exports.

Thus, we find that despite the simple model, some statistically significant effects can be observed. A judgment on the economic significance of these quantities is a complex task for a number of reasons. First, the size of our sample is quite small and, in particular, we can not observe a complete business cycle. Second, our use of a linear model to measure the impact of large shocks is restrictive because in reality, the events may have a nonlinear impact. Third, we use a bivariate framework, whereas in reality, shocks may not take place in isolation. Finally, LLP are a proxy for the measurement of credit risk and, thus, an error-in-variables problem may be present.

5 Summary

The purpose of this paper has been to perform a preliminary stress test for the Austrian banking system. Our focus was on the interdependence of credit risk and the state of the economy, as measured by macroeconomic variables. We used a simple linear regression approach to describe the relation between loan loss provisions and potential explanatory factors. Among these, a rise in the short rate, a fall in business confidence, a decline in the stock market and a decline in industrial production have effects on the LLP. Based on the regressions we then studied the hypothetical impact of historical "worst cases" in key macroeconomic variables. These changes in LLP were then compared to the risk-bearing capacity of the Austrian banking sector as it is captured by its capitalization. We find that, in our tentative simulation exercise, the greatest effect amounts to 1.8% of core capital.

For future research, two extensions seem important. As already mentioned, the first extension is to construct multi-factor scenarios. In order to realize this aim, a comprehensive macroeconomic model is required. Another key direction is to extend the linear specification. In particular, a more complex model for the relation of credit risk to the state of the economy would be a useful tool for the analysis of financial stability. Among the models discussed in the literature, one possibility is the CreditPortfolioView. It is built on a relation between the default rates and macroeconomic variables.

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