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Stress testing of real credit portfolios

Ferdinand Mager
(Queensland University of Technology and School of Economics and Finance)

Christian Schmieder
(Deutsche Bundesbank and European Investment Bank)

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-1
Telex within Germany 41227, telex from abroad 414431

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

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Abstract

Stress testing has become a crucial point on the Basel II agenda, mainly as Pillar I estimates do not explicitly take portfolio concentration into account. We start from the credit portfolio of the German pension insurer being a cross-sectional representation of the German economy and subsequently compose three bank portfolios corresponding to a small, medium and large bank. We apply univariate and multivariate stress tests both by using the Internal Rating based (IRB) model and by a model that additionally allows for variation of correlation. In a severe multivariate stress scenario based on historical data for Germany IRB capital requirements increase by more than 80% with little differences between the credit portfolios. If stress testing is additionally applied to correlation, the Value-at-Risk increases by up to 300% and portfolio differences materialize.

Keywords: Credit Portfolio, Exposure concentration, Stress Testing, Basel II, Economic Capital

JEL-Classification: G21, G28

Non-technical summary

Recent US subprime crisis has evidently shown that credit risk remains the major threat to the solvency of single financial institutions, but also for financial stability. The crisis has also shown that bundling credit risk into innovative products and selling it at the capital markets does not necessarily result in diversification benefits. The importance of credit risk is also clearly reflected in the Basel II framework, which foresees wide-ranging instruments to measure and control credit risk, both under Pillar I, but also under Pillar II. Recently, the interest is more and more moving towards the Pillar II arena, with validation, concentration and stress testing being the most important instruments.

The application of Pillar II measures does require data, which turns out to be a major shortage in most financial institutions. There have been various measures to overcome this shortage, but this has also been the major reason why internal credit portfolio models were not (yet) recognized under Basel II. The lack of data results to publicly available empirical studies on Pillar II issues being very rare.

This is the starting point of this study, which focuses on micro stress testing, i.e. stress testing of single banks' credit portfolios. The data are mostly taken from Deutsche Bundesbank's balance sheet data, amended by German credit register data, data from the German Statistical Office, S&P and Moody's KMV. In this way, three credit portfolios resembling those held by small, medium-sized and large German banks are composed.

The study investigates univariate and multivariate stress scenarios. Based on the Basel II IRB model, the PD is stressed by 5% up to 50% in form of a univariate sensitivity analysis. In addition, historical simulation based stress testing with a combined stress of the PD by 61% and the LGD by 51% is being applied. The outcome shows that portfolio differences do not materialize and that the combined effect of a stress of several parameters leads to a more than additive effect. Furthermore, it turns out that univariate PD stress by 10% in relative terms translates into an increase of IRB capital requirements by 4% to 5.5% and that the adverse historical scenario can result to an increase of IRB minimum capital requirements by up to 80% within one year. In the next step, a simulation based model resembling the Basel II IRB model is used to additionally stress correlations by 10%, 20% and 71%. It turns out that portfolio differences start materializing and that the credit Value-at-Risk may increase by up

to 300% within one year if a severe historical scenario is being applied, denoting a joint stress of the PD by 61%, 51% of the LGD and 71% of asset correlations.

Overall, the outcome shows that stress testing can be perceived as an important means to investigate potential adverse effects and to test the sensitivity of credit portfolios to various different shock events.

Nichttechnische Zusammenfassung

Die Immobilienkrise in den USA hat erneut gezeigt, welche zentrale Rolle Kreditrisiken für das Auftreten von Bankenkrisen und für die Finanzstabilität spielen können. Die Krise zeigt aber auch, dass die Nutzung von modernen Finanzinstrumenten zum Verkauf von Kreditrisiko an den Finanzmärkten nicht notwendigerweise zu Diversifikationseffekten führen.

Die hohe Bedeutung von Kreditrisiken für Banken spiegelt sich auch in Basel II wider, welches zahlreiche Maßnahmen zur Messung und Steuerung von Kreditrisiken sowohl in Säule 1, als auch in Säule 2 vorsieht. In letzter Zeit rückt der Fokus immer mehr auf Säule 2, und damit auf die Anwendung von Validierungsmethoden, Konzentrationsrisiko-Untersuchungen und Stress Tests.

Die Anwendung von Instrumenten der Säule 2 erfordert jedoch umfangreiche Daten, die vielfach nicht verfügbar sind. Trotz zahlreicher Anstrengungen, die Datensituation zu verbessern (z.B. Pooling von Daten, systematisches Sammeln von Daten) war dies auch ein zentraler Grund für die nicht erfolgte Anerkennung von internen Kreditrisikomodellen in Basel II. Dies ist auch die Ursache dafür, dass es bisher kaum öffentlich verfügbare empirische Studien zum Problemkreis Säule 2 gibt. Hier setzt die vorliegende Studie an, die sich mit dem Thema Stress Testing von Bankenportfolios beschäftigt.

Die in der Studie verwendeten Daten stammen insbesondere aus der Bilanzdatenbank der Deutschen Bundesbank, sowie aus weiteren hochwertigen Quellen wie der Millionenkreditdatenbank der Deutschen Bundesbank, dem Statistische Bundesamt, S&P und Moody’s. Durch Verknüpfung dieser Daten stellen die Autoren typische Kreditportfolios für kleine, mittlere und große deutsche Banken zusammen.

In der Studie werden sowohl univariate als auch multivariate Stress-Szenarios für die IRB Kreditrisikoparameter untersucht. Im univariaten Fall werden die Ausfallwahrscheinlichkeiten (PDs) um 5% bis 50% gestresst und im multivariaten Fall wird ein adverses historisches Szenario untersucht, bei dem sowohl die PDs um 61% als auch die Verlustraten bei Ausfall (LGD) um 51% erhöht werden. Die Anwendung von Stress Tests mit Hilfe des Baseler IRB Modells zeigt, dass Portfoliounterschiede hinsichtlich der Auswirkungen von Krisenszenarien eine untergeordnete Rolle spielen, und dass sich der gemeinsame Effekt eines Schocks mehrerer Kreditrisikoparameter überproportional auswirkt. Bei einer Erhöhung der PDs um

10% ergibt sich ein Anstieg der IRB Mindesteigenkapitalanforderungen um 4 % bis 5,5 % und für das adverse historische Szenario können die IRB Mindesteigenkapitalanforderungen innerhalb eines Jahres um rund 80% ansteigen.

Im nächsten Schritt verwenden die Autoren ein simulationsbasiertes Ein-Faktor-Modell, das dem Basel II IRB Modell entspricht, aber eine Variation der Korrelationen ermöglicht. Es zeigt sich, dass bei einem Schock der Korrelationen um 10%, 20% bzw. 71% Portfoliounterschiede eine wichtige Rolle spielen. Im multivariaten Fall, einem adversen historischen Szenario, bei dem neben der Erhöhung der PDs um 61% und der LGDs um 51% auch die Korrelationen um 71% gestresst werden, kann der Value-at-Risk je nach Portfolio um bis zu 300% ansteigen.

Insgesamt zeigt sich, dass Stress Tests ein wertvolles Instrument für die Untersuchung der Auswirkung adverser Szenarien sowie die Sensitivität von Kreditportfolios für bestimmte Schockszenarien ist.

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1 Introduction

Credit Risk modeling and management has seen various advances during the last two decades, notably the move from a borrower level perspective to portfolio analysis.[1] An important development in credit risk management is Basel II, applied by EU financial institutions since January 2007.[2] Other countries, especially the US, are supposed to follow in the near future.

To ensure the appropriateness of Pillar I credit risk estimates, the Basel II framework foresees Pillar II measures such as validation, concentration risk analysis and stress testing, which are increasingly at the focus of both banks and supervisors (BCBS 2007). While validation aspects have widely been discussed and various solutions were suggested (BCBS 2005), credit risk stakeholder only more recently focus more intensely on concentration risk and stress testing. The reason is two-fold: First, many financial institutions face data shortages particularly in the domain being relevant for Pillar II (for example correlations) and real portfolio data are unlikely to be disclosed. Given that the availability of meaningful data constitutes a fundamental prerequisite for Pillar II analysis, concentration risk and stress testing have hardly been addressed in the empirical financial literature. This is what the current study aims at, namely to reveal Pillar II analysis for real portfolios.

Our empirical analysis is based on balance sheet data of Deutsche Bundesbank, which have, in the first step, been applied to the analysis of the portfolio of the Pensions-Sicherungs-Verein (PSVaG). The PSVaG is a mutual insurance organization for occupational pension schemes in Germany and its portfolio is a cross-sectional representation of the German economy.[3] The well recorded track record of the insurance scheme of more than 30 years is exceptional and goes far beyond most credit portfolios in banks. The Bundesbank balance sheet data applied to the analysis of the PSVaG 'from the outside' are used to estimate individual probabilities of default (PDs) for the firms in the database underlying this study. Next, the balance sheet data are used as a starting point to compose three credit portfolios for small, medium and large German banks. In this way, we seek to overcome in a pragmatic way the lack of real Pillar II portfolio analysis in the literature to date, exceptions being Peura and Jokivuolle (2004) and Rösch and Scheule (2007).

1 We thank Thilo Liebig and Peter Raupach for valuable comments and support.
2 Basel II has been approved in 2006 for the European Union (2006/48/EC and respective national legislation).
3 Traditionally, German companies use a book reserve system to finance occupational pension schemes. Pension liabilities appear on the balance sheet and are reported in a uniform manner. By nature they are not funded and constitute unsecured debt. The portfolio of the PSVaG can, in fact, be treated as a credit portfolio of standardized loans where the pension liabilities of the corporations are the insured exposure.

Credit portfolio stress testing is being applied in the form of univariate and multivariate stress tests to different credit portfolios both by using the Internal Rating based (IRB) model as well as by applying a simulation based one-factor model that additionally allows for a variation of correlation. Stress tests are generally applied across the whole portfolios in a uniform way.

A severe multivariate scenario based on historical data for Germany shows an increase of IRB minimum capital requirements by more than 80% with little differences between the credit portfolios. If stress testing is additionally applied to correlation, portfolio differences start materializing and the credit Value-at-Risk may increase considerably by up to 300%.

This paper is organized as follows. In section 2, we provide an overview on the database, on PD estimation and the portfolios used for stress testing. Section 3 outlines the methods used for credit portfolio analysis and stress testing. In section 4, we present the results. Section 5 concludes.

2 Data

This study is based on the balance sheet database of Deutsche Bundesbank, complemented with data from the German credit register, the German Statistical Office, from S&P and Moody's KMV (MKMV). The data are being used to ensure that the portfolios being analyzed in this study resemble those held by German commercial banks, i.e. take the form of real portfolios. Most of the data has been taken from Deutsche Bundesbank's balance sheet data, namely the universe of portfolio data as well as the probability of default (PD) information calculated from the database. In the next step, credit register data has been used to ensure that the credit portfolios referred to, namely a portfolio of a small German bank, a medium-sized one and a larger one are realistic. Finally, we made use of MKMV data to determine firm-size dependent individual correlations. For the stress tests, historical data from the German Statistical Office and S&P are used.

2.1 Balance Sheet Data

As a means to ensure the representativeness of the balance sheet data referred to in terms of the PDs for the German economy, we first benchmark the initial data to the portfolio of the Pensions-Versicherungs-Verein (PSVaG). The PSVaG is the German counterpart to the Pension Benefit Guarantee Corporation (PBGC) in the United States, ensuring occupational pensions against bankruptcy. Like the PBGC the PSVaG was founded in 1974. The PSVaG operates as a private mutual insurance association with compulsory membership for all firms running pension plans which might be adversely affected in the case of bankruptcy. It is regulated by the German federal financial supervisor ("Bundesanstalt für Finanzdienstleistungsaufsicht").

The balance sheets of the firms ensured by the PSVaG have been identified in a straightforward way in Bundesbank's balance sheet data, namely by the accrued book reserves corresponding to the present value of the pension commitments appearing as liabilities on their balance sheets. The reason for that is that Germany is one of the few countries where the internal financing of pension obligations via book reserves is an accepted standard. The reporting of pension liabilities follows strict rules. It is based on a uniform discount rate of six percent and standardized biometric assumptions. The pension liabilities are unsecured debt and no separate funding is required.[4] We can therefore directly link the risk faced by the PSVaG to the default risk of its counterparties.

The portfolio of the PSVaG becomes a credit portfolio as the pension obligations are mutually insured by the Pensions-Sicherungs-Verein VVaG for the case of insolvency. The portfolios credit volume is extensive, with a total notional value of insured pensions (i.e. credit exposure) of €264 billion in 2006.

By means of the balance sheet database of Deutsche Bundesbank, we can directly observe about 70 percent of the total portfolio volume of the PSVaG from the outside based on 145,347 balance sheet datasets including 839 bankruptcies from 1989 to 2002. In our sample, the book reserves make up an average of 10.8% of the balance sheet total. The representativeness of the data has carefully been ensured by benchmarking our dataset to publicly available information as well as structural data on the PSVaG, namely historical insurance losses over the period from 1975 to 2004, the annual total volume of insured pensions, and the size and default information structure of the PSVaG portfolio.[5]

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4 In principle, a company running a pension plan on book reserves could issue a corporate bond and use the proceeds to finance a (Anglo Saxon type) pension fund. Thereby, pension liabilities are cancelled out of the balance sheet and the new corporate bonds appear on balance sheet. The opposite process is also possible. Treynor (1977) and Gerke et al. (2005) show within an augmented balance sheet approach that pension liabilities and pension fund assets should be added to the corporate balance sheet for an economic analysis. Historically, the book reserve system was seen as a way to keep cash flows as long as possible within the corporation.

5 More specifically, when cross-checking the portion of bankruptcy cases in the Bundesbank database against the corresponding portion of defaults of the PSVaG, we found that the Bundesbank database contains a disproportionate (lower) number of bankruptcies. To account for this fact and to prevent estimation bias we applied weighted default probabilities. Moreover, as a second measure to preclude a potential quality bias in the sample that has been found for smaller firms since 2000 (see Ismer et al. (2007, in German), who found that Bundesbank's balance sheet dataset is representative for medium-sized and large companies), we excluded corporations with pension provisions below Euro 100,000, also as they account for less than two

Table 1 summarizes the premium history of the Fund, which closely resembles the historical annual portfolio loss, for the last three decades, ranging from 0.03% to 0.69%, the primary information that has been used to benchmark the Bundesbank data with PSVaG data.[6]

Table 1: Descriptive statistics on the Annual Insurance Premiums of the PSVaG

Table 1 shows the annual insurance premiums (corresponding to credit portfolio losses) of the portfolio of the German pension insurer (Pensions-Sicherungs-Verein VVaG, PSVaG) for the period from 1975 to 2006. Source: Pensions-Sicherungs-Verein VVaG (2006).

	Mean	Median	Min	Max	Std. dev.
Annual insurance premium	0.22%	0.20%	0.03%	0.69%	0.14%
Defaults per year	333.4	330.0	154	705	143.8

Accordingly, annual default probabilities of each borrower (PD_i) have been determined based a binary logistic regression model which is calibrated to the portfolio of the PSVaG in a cross-sectional context. Below, the procedure and outcome of this exercise carried out by Gerke et al. (2008) is summarized.

The binary logit model takes the common form:

$$PD_i = \frac{1}{1 + \exp(-a - \sum_j b_j y_{i,j})} \tag{1}$$

where (PD_i) is the default probability of firm i. As shown in Table 2, six regression variables ($y_{i,j}$) were used, namely four financial ratios and two sector dummies to distinguish the default industry, industrials from the trade sector and the remaining industry sectors. We also included year dummies in order to control for macroeconomic effects by means of a panel regression model, but it turned out that the results were similar overall, so we referred to the cross-sectional model, calibrated on data covering two economic cycles with both benign epochs as well as periods of severe macroeconomic stress such as the Asian and Russian crisis, respectively. The calibration of the level of the PDs to the PSVaG was done as follows: First, we used balance sheet data with a time gap of 12 to 24 months prior to default to characterize insolvent firms. Second, due to missing bankruptcy data in the data sample to

percent of the total exposure and are therefore of subordinated importance in terms of credit portfolio risk. See also Gerke et al. (2008).

[6] This information is not explicitly used for portfolio analysis, but implicitly included in the PDs calculated based on the logit model as outlined below.

represent the default history of the German Pension Fund, equation (1) has been estimated based on a weighted logit procedure to correct the bias towards underreporting bankruptcies.[7]

Table 2 shows the outcome of the regression: all variables are highly significant and the signs of the variables are as expected (see Gerke et al. 2008). The discriminatory power of the calibrated logit model yields an area under the receiver operating characteristic (ROC) curve of 0.8181, constituting an equivalent level with other empirical studies.[8]

Table 2: Outcome of the logistic regression model

The table displays the outcome of a cross-sectional logistic regression for the portfolio of the PSVaG. It is based on 145,347 observations from 1989-2002 including 839 bankruptcies. Trade and other industries ("Other") are dummy variables. All variables included in the model have been found to be highly significant. The significance and robustness of the outcome is supported by the Pseudo R^2 (0.1622), the Wald test and the likelihood ratio test.

Variable	Coef.	Std. Err.	P>|z|
Constant	-3.4794***	.10002	0.000
Equity/Assets	-4.6610***	.3746	0.000
log Assets	-.11557***	.02699	0.000
Short-term assets/Short-term liabilities	-1.6456***	.11960	0.000
Result from ordinary operations	-5.6924***	.27496	0.000
Trade	-.50999***	.11001	0.000
Other	.51713***	.13569	0.000

***/**/* indicate statistically significant results at the 1%, 5% and 10% level.

2.2 Credit Portfolio Data

For the subsequent analysis of credit portfolio risk, we use the data for 2002, comprising 6,298 firm datasets. This PSVaG portfolio (PF0), being diversified in terms of industrial and geographical sectors, will be considered as a cross-sectional portfolio of the German economy.[9] Besides, three bank portfolios have been composed as further explained below.

For the PSVaG, the firm's one-year PDs range from 0.000007% to 16.7%. The exposure-weighted mean PD for the 2002 portfolio, 0.4% (see Table 1), closely resembles the portfolio losses communicated by the PSVaG for this time (see Gerke et al., 2008), indicating that 2002 was a worse than average year in cyclical terms when compared to the 30-year average portfolio losses of the PSVaG (0.22%). To arrive at credit portfolio analysis additional parameters are required, namely the Loss Given Default (LGD), the Exposure at Default (EAD) and credit correlations. For the PSVaG which does hardly apply a work-out process,

7 The reason is that bankruptcies mainly occurred for small firms which are less represented in the dataset.

8 For Moody's RiskCalc model for Germany, the area under the ROC curve yields to 70.9%, being substantially lower that in the underlying study, see Escott et al. (2001).

9 To verify this assumption, the industry sector distribution in the sample has been compared with findings of other studies, for example Düllmann and Masschelein (2006).

the LGD is about 95% (see Gerke et al., 2008). For the bank portfolios, the LGD is fixed at 45%, corresponding to the parameter value foreseen for senior debt under the Foundation IRB approach. In the case of the PSVaG, the EAD corresponds to the pension provisions. For the bank portfolios, we refer to the firm's total assets, which are being size-adjusted to reflect credit exposures as further outlined below. The credit correlations have been inferred from a study of Düllmann et al. (2007) based on MKMV data. More specifically, we proceeded in two steps: First, we applied a logarithmic fit function to the asset values and asset correlations for 2002. Next, we used the asset values in the current portfolio to apply the formula.[10] In case of the IRB model, we used the regulatory asset correlations based on PDs and a flat maturity of 2.5 years, being the reference value for the Foundation IRB approach in most countries.[11]
Next, it is outlined how the three portfolios for banks of different size groups have been composed, namely a portfolio for smaller banks, one for medium-sized banks and a credit portfolio for large banks. The portfolio characteristics of the bank portfolios and the PSVaG portfolio are shown in Table 3.

We mainly referred to two main assumptions: First, small banks tend to lend to small firms, medium banks to small and medium firms and large banks, in principle, to all size groups of firms. Second, we take into account that the number of lenders increases with firm size[12] and that larger firms do increasingly have access to other financing sources than bank credit only. Accordingly, the portfolios are being aligned with the portfolio exposure distribution (single name concentration) indicated by the German credit register (see Gordy and Lütkebomert, 2007).

For the portfolio of small banks (PF1), we assume that only SMEs are relevant (i.e. firms with total sales of up to EUR 50m). To account for an adequate level of single name concentration, we randomly chose only every second firm in the database with sales of more than EUR 10m, yielding an overall portfolio size of 3,255 counterparts as shown in Table 3. For this portfolio, we did not apply an adjustment for the number of lenders, as SMEs in Germany are typically customers at only a very limited number of banks (typically one or two), so the relative size of the firms corresponds to the relative size of credit exposures. As shown in Table 3, the

10 The asset correlations determined by Düllmann et al. (2007) have been calculated directly from monthly MKMV asset values (and the respective asset returns) based on sliding windows of 24 months. Further information can be found in Düllmann et al. (2007).

11 For the PSVaG portfolio, the choice of the maturity should, in principle, be oriented on the risk horizon of the insurance, being long-term. We thus refer to a maturity of 2.5 years as a means to enable a better comparison with the bank portfolios. For a maturity of 5 years that could be justified based on the risk horizon, the IRB capital requirements for the PSVaG would approximately be 50% higher than indicated in the results, for example 12.6% instead of 8.6% in the base case (Table 6).

12 We use the results of Memmel et al. (2007) to account for that.

average PD is substantially higher than for the original portfolio, while the respective figure for the asset correlations does yield a considerably lower level. This observation reflects common expectations and previous findings in the literature (see e.g. Lopez 2004).

For the portfolio of the medium-sized German banks (PF2), we chose all exposures corresponding to firms with a turnover below €500m. Next, we randomly removed every second exposure corresponding to firms with sales less than EUR 25m and more than EUR 100m, respectively, in order to account for the assumption that medium-sized banks concentrate their lending to larger SMEs. Furthermore, we account for the number of lenders and for potential other financing sources. Accordingly, the exposure (i.e. the asset values) of firms with more than EUR 50m of sales has been weighted at 90% (corresponding to 1.1 bank relationships for each firm) and for firms with more than EUR 100m at 75% (1.3 bank relationships). As shown in Table 3, the Herfindahl-Hirschman-Index (HHI) thereby yields a value (0.0046), being slightly above the typical interval for medium-sized German banks (0.001-0.004). It is also shown that the exposure-weighted average PD (0.76%) is lower than for the small bank portfolio and that the average correlation increases more than 2 percentage points, being in line with our expectations.

Table 3: Descriptive Statistics of the credit portfolios used in this study

Table 3 displays descriptive statistics of the portfolios used for stress testing. The PD and asset correlation are displayed in percent as arithmetic mean and exposure-weighted, respectively. The asset correlations have been inferred from a fit function applied to the end of 2002 data determined on an individual firm basis depending on asset values in Düllmann et al. (2007). The recovery rate of the PSVaG was set to 95 percent and for the banks to 45% in line with the Foundation IRB approach. We use the Herfindahl-Hirschman-Index (HHI) to measure exposure concentration in single names. In the last column, we compare the exposure concentration of our portfolios with data from the German credit register (see Gordy and Lütkebohmert, 2007).

Credit Portfolio	**N**	**PD (%)**	**LGD (%)**	**Asset correlation (%)**	**HHI**	
					Sample	**Credit register**
(PF0) PSVaG	6,298	1.15/0.40	95	9.07/20.87	0.0215	NA
(PF1) Small bank	3,255	1.37/0.99	45	6.65/12.15	0.0148	0.004-0.015
(PF2) Medium-sized bank	4,087	1.17/0.76	45	8.78/15.02	0.0046	0.001-0.004
(PF3) Large bank	3,633	1.05/0.60	45	9.94/16.75	0.0018	< 0.001

For the portfolio of a large German bank (PF3), the number of assumptions to be made is the highest. In the first step, we randomly removed every second exposure corresponding to firms with sales less than EUR 100m, as the largest banks are likely to concentrate less on small firm financing than medium and small banks do. Similarly to the case of the medium-sized banks, we also account for the number of lenders and for potential other financing sources, being particularly important for the very largest firms in order to arrive at meaningful data. The exposure of firms with more than EUR 50m of sales has been weighted at 90% and for firms with more than EUR 100m at 75%. For firms with sales of more than one billion Euros the exposure has been weighted at 25% (corresponding to up to 4 bank relationships and/or other financing opportunities) and for those with more than EUR 10bn of sales at 10% (up to 10 bank relationships and/or other financing opportunities). In this way, the single name exposure concentration falls towards levels in the German credit register. As shown in Table 3, the PDs become the lowest of all bank portfolios, and the correlations the highest ones after applying the adjustments described above. In terms of exposure concentration, we followed a conservative approach when compared to credit register data, denoted by the HHI of 0.0018, which slightly exceeds the typical level for credit portfolios of larger German banks.

Overall, the PDs and the correlations of the portfolios are in line with our expectations, both in terms of level (exposure-weighted PD, mean asset correlation) and in terms of consistency (higher PDs for small banks, lower correlations for small banks).

3 Concentration Risk Analysis and Stress Testing

From a conceptual stance, we focus on the second Pillar of the Basel II framework, namely concentration risk analysis and stress testing. When following a Pillar II regime, it becomes essential to briefly review the cornerstones of the Pillar I estimates. The assumptions of the Asymptotic Single Risk Factor Model (see Gordy, 2003) underlying the IRB are, first, that credit portfolios are infinitely granular, i.e. that there is no exposure concentration, and, second, that there is no sectoral concentration in terms of geography and industry. While the first assumption has originally been complemented by means of a granularity adjustment, this amendment has finally not been taken up into the Pillar I framework and is therefore subject to Pillar II. Due to the limitation of the ASRF model to one risk factor the incorporation of subportfolio characteristics, namely to account for industry sector and regional specific differences via multiple risk factors, has been sacrificed for simplicity. Nevertheless, recent analysis on the comparison between regulatory capital requirements and the outcome of multi-factor economic capital models show that by the ASRF correlation estimates have been chosen in a relatively conservative way. Hence, the IRB capital requirements do implicitly assume an “average” concentration in credit portfolios (see e.g. Düllmann et al., 2007).

While concentration risk analysis have been subject to an intensified research activity with several contributions during the last years (BCBS 2006a), stress testing becomes recently highly focused with the two frameworks playing a complementary role.[13]

3.1 Credit Risk Modeling

Credit portfolio risk is usually traced by means of two central parameters characterizing the portfolio loss probability distribution function (Loss PDF), namely the expected loss (EL) and the unexpected loss (UL). The EL denotes the average portfolio loss to be expected ex ante and the UL is usually defined as the difference between a particular quantile value of the Loss PDF and the EL. According to the Basel II framework, we refer to the Value-at-Risk (VaR) as a quantile value of the Loss PDF and a time horizon of one year. From a conceptual perspective, the analysis can also be applied to the Expected Shortfall (ES, see Artzner et al., 1999), which is, unlike the VaR, a coherent risk measure.

If we further denote PD_i as the annual default probability of a counterpart i and LGD_i (loss given default) the portion of the credit exposure (EAD_i, exposure at default) lost in a default event, then the expected loss of the portfolio exposure (EL_p) may be written as the sum of the single firms' expected losses:

$$EL_p = \sum_{i=1}^{n} PD_i \bullet LGD_i \bullet EAD_i \tag{2}$$

While the EL_p is by definition not affected by credit correlations and can therefore be determined analytically the unexpected loss of a credit portfolio, by contrast, depends on the credit correlations of the exposures in the portfolio. There are two general ways to determine the unexpected loss of a portfolio, numerical closed-form approaches and Monte Carlo simulation. A very prominent approach in the previous case is the Basel II ASRF model[14], while the foundation of the second approach was laid down by means of the CreditMetrics™ framework (see Gupton et al. 1997). We refer to the Basel II IRB model and a Monte Carlo simulation based one-factor model.

Within this study, the credit risk default process is modeled based on a stylized Merton-type asset value model (see Merton 1974) with one common systematic risk factor and the remaining disturbance being idiosyncratic. We assume that each firm's creditworthiness is represented by its asset value, which fluctuates over time and reflects the actual state of the

[13] The evolution of stress testing practices has been particularly monitored by the BIS' Committee on the Global Financial System issuing a summary note in 2005 (CGFS 2005).

[14] See Gordy (2003). A more complex closed-form solution has been proposed by Tasche (2006).

firm's creditworthiness. We control for asset values falling below a certain barrier (usually the liabilities of a firm) during a one year time horizon, what implicates a default event. It has been shown in the literature that the asset values of larger firms tend to have a higher correlation with the systematic factor, i.e. implying that they are more strongly influenced by macroeconomic developments (see, for example Lopez 2004), which is also assumed in our study.[15]

The simulation based approach will be used to arrive at a higher flexibility in terms of credit correlations, which are – in case of the IRB – modeled conditional on the PD. The simulation of the default process is done as follows. Let us suppose that a firm defaults if its asset value x_i falls short of a specific default barrier y_i. We first assume that each firm's default barrier can be inferred via its default probability (PD_i):

$$x_i \le y_i = \Phi^{-1}(PD_i) \tag{3}$$

where Φ^{-1} is the inverse cumulative standard normal distribution.

We then randomly draw a systematic factor Z and an idiosyncratic shock ε_i for each firm and thereby determine the asset returns of the firms in the sample (x_i):

$$x_i = \rho_i Z + \sqrt{1-\rho_i^2}\varepsilon_i \tag{4}$$

where ρ_i is the correlation of the firm's asset return with the systematic factor. The commonly known asset correlation does then equal the squared correlation of the firm's asset returns with the systematic factor. Following this procedure we arrive at the Loss PDF.

3.2 Concentration Risk Analysis

We consider two dimensions of concentration, single name concentration and sector concentration in industry and geographical terms. We begin our analysis with the portfolio of the PSVaG, which is very well diversified across the German economy in terms of industry and regional concentration. However, in terms of a single name concentration, the portfolio of the PSVaG can be understood as an extreme case where every corporate has one credit relationship with only one single (house) bank. Hence, the PSVaG portfolio tends to be

15 This assumption is also implicitly incorporated in the Basel II framework, by assigning higher correlation to firms with a lower PD (BCBS 2005). The simple arithmetic average as well as the exposure-weighted asset correlations statistics on the asset correlations used in this study are shown in Table 3 for the four portfolios. The level of the simple arithmetic average is in line with other studies, for example Lopez (2004).

concentrated in single names.[16] Subsequently, we relax this assumption to analyze typical credit portfolios of banks. Sector concentration effects are not explicitly reviewed. However, we will consider firm size-dependant cyclical effects via credit correlations. Overall, the aim of this study is to investigate the impact of portfolio concentration on the outcome of stress testing.

3.3 Stress Testing

In terms of stress testing, the focus of this study lies on the credit portfolio level, with cyclical effects being incorporated via a stress of credit risk parameters. For the stress testing of the credit risk single of portfolios, a general standard to be followed has not emerged yet (CGFS 2005) despite various contributions in the literature[17], implying that stress testing remains an art to be tailored by each specific financial institution according to its specific requirements. The Basel II framework (BCBS 2006b) asks to investigate possible future scenarios that may threaten the solvency of banks. In the case of credit, this notably includes an assessment of economic or sector-specific downturn events, which must be "meaningful" and "reasonably conservative" and thereby represent at least "mild recession scenarios", but not necessarily a "worst-case scenario" (BCBS 2006b, para. 435). Typically, a stress testing exercise would refer to plausible, but unlikely events. Nevertheless, the specific choice of the stress scenario lies in the discretion of the bank and has to be justified vis-à-vis the supervisory body.

Within the Basel II framework, a stress test for credit risk essentially comprises a univariate stress of IRB credit risk parameters, namely the PD (both for borrowers and guarantors), LGD and the EAD (credit conversion factors), and/or a joint stress of the parameters (multivariate case). For IRB banks, who typically also use economic capital models, e.g. for benchmarking purposes (for example through the Internal Capital Adequacy Assessment Process, *ICAAP*), stress testing additionally comprises an assessment of different levels of confidence, credit correlations and portfolio concentrations. In the latter dimension, stress testing of concentration risk by Bonti et al. (2006) can be seen as a seminal work.

When one now seeks applying stress tests to a real credit portfolio, the natural question will be the choice of the scenarios, being potentially the most difficult challenge. Ideally, a stress

16 More precisely, the reason for the PSVaG portfolio being highly concentrated in single names results from the sheer size of the largest exposures, which cannot be counterbalanced by the high number of small firms in the portfolio, clearly indicated by the high HHI of the PSVaG (Table 3). See also Gerke et al. (2008).

17 See e.g. Kupiec (1998), Kim and Finger (2000), Lopez (2005), Deutsche Bundesbank (2004) and CGFS (2005). A recent analysis for a US retail portfolio has been carried out by Rösch and Scheule (2007).

testing exercise would begin with a model-based prediction of an adverse macroeconomic event (i.e. a macroeconomic stress event) that is then being endogenously translated into credit risk, market risk, operational risk and liquidity risk scenarios, respectively, denoted as a macro stress test in Table 4 below. However, such comprehensive modeling within one single framework does hardly exist, at least for credit risk, where multi-factor credit risk models are likely to be exogenously fed by the outcome of the macroeconomic stress scenarios, for example (see also Bonti et al., 2006). In the absence of a single comprehensive (factor) model to endogenously stress risk factors (macro stress tests), this is typically done by means of taking historical stress scenarios for the risk factors used in multi-factor models (Historical simulation). Sensitivity analysis and regression analysis are the corresponding stress tests in case of single risk factor models. Accordingly, a broad classification of stress tests according to the number of risk factors of the underlying credit risk model (one-factor or multi-factor) and the way how the stress scenarios are being determined (endogenously or exogenously) is shown in Table 4.[18]

Table 4: Classification of stress tests for factor models

	One Risk Factor	**Several Risk Factors**
Exogenous	Sensitivity analysis	Historical simulation
Endogenous	Regression analysis	Macro stress test

In the case of the Basel II IRB model, there is only one single risk factor, so stress tests can, in principle, take the form of regression analysis (endogenous case) and sensitivity analysis (exogenous case). However, given that the IRB model has been pre-calibrated in terms of cyclicality[19], stress testing does take the form of sensitivity analysis or historical simulation of the underlying credit risk parameters rather than an explicit stress of the single risk factor. Both techniques will be applied to the credit portfolios below.

[18] Further information on the classification of stress tests and those carried out by Deutsche Bundesbank can be found in Deutsche Bundesbank (2007).
[19] For a theoretical model of the cyclical effects of Basel II see e.g. Heid (2007).

4 Results

As outlined in the previous section, stress tests will be carried out in two different frameworks, namely based on univariate scenarios (sensitivity analysis) (1) as well as univariate (2a) and multivariate (2b) historical simulation scenarios as shown in Table 5.

Table 5: Overview on the Stress Scenarios used within this study

The historical default rates are taken from the German National Statistical Office ("Statistisches Bundesamt"). The S&P data for the loss given default (LGD) are taken from Franks et al. (2004). We use asset correlations based on MKMV data taken from Düllmann et al. (2007) in the historical simulation of the 1FM.

Parameter	(1) Univariate Sensitivity Analysis	(2a) Univariate Historical simulation	(2b) Multivariate Historical simulation
PD	IRB model: +5%, +10%, +20%, +30%, +50%	Historical default rates	Historical default rates
LGD	NA (Linear effect)	S&P data (Franks et al., 2004)	S&P data (Franks et al., 2004)
EAD	NA (Linear effect)	NA (Linear effect)	NA (Linear effect)
Correlations	IRB: NA, as PD dependent; 1FM: +10%, +20%	IRB: NA, as PD dependent; 1FM: Based on MKMV data (Düllmann et al., 2007)	IRB: NA, as PD dependent; 1FM: Based on MKMV data (Düllmann et al., 2007)

Our aim is to thereby apply specific instances of stress test methods in a pragmatic way to realistic credit portfolios, rather than offering a comprehensive and ultimate way how to stress test credit portfolios under the IRB framework. The scenarios are applied via the Basel II IRB model and a simulation based one-factor model (1FM), where correlations were modeled unconditional on PDs and may therefore be stressed separately.

4.1 Stress Testing based on the Basel II IRB model

Table 6 shows the outcome of univariate sensitivity scenarios for the PD (1) based on the Basel II IRB model applied in a uniform way to the portfolio.[20] As the exposure and the LGD do linearly enter the IRB model they have not been considered for univariate stress tests. When it comes to a univariate stress of PDs, there is also a direct influence on the level of asset correlations being modeled conditional on the PD, so an IRB stress of PDs translates into a combined PD/correlation stress. However, IRB asset correlations do - in line with empirical evidence - decrease with increasing PDs, so there is a smoothening effect on the overall outcome of stress. The reason to assume a negative relationship between PD and correlations is that PDs tend to be higher for smaller firms, which are less affected by

[20] We applied the IRB formula foreseen for corporates for all exposures (BCBS, 2006b, para. 272), in order to make results better comparable.

macroeconomic developments than larger firms, but more dependent on firm-specific idiosyncratic circumstances. While this general relationship between PDs and correlations integrated into the IRB model therefore constitutes a legitimate concern improving the model's risk sensitivity it is less useful for stress testing purposes. This is, in fact, the purpose of using the 1FM as a means for the assessment of the independent effect of correlation stress. Furthermore, we will indicate what the increase of IRB capital requirements would be if asset correlations would remain unchanged with PD stress.

The outcome of univariate PD stress for the IRB model shows that the sensitivity of IRB minimum capital requirements against an increase in the PD is rather decent, with a uniform relative increase of PDs by 10% translating into an increase of IRB capital requirements by around 4% (3.7% for PF1 up to 4.5% for PF0), and an increase by 50% yielding IRB capital requirements' increase by 16% (PF1) to 20% (PF0).

If one eliminated PD-correlation dependency and assumed that asset correlations remain unchanged with increasing PDs, then a 10% rise of PDs resulted to an increase of IRB capital requirements by 5.3% (PF1) to 5.7% (PF0, PF3). This outcome indicates that the smoothening effect of asset correlations in the IRB model is relatively moderate, but should, nevertheless, be carefully taken into account when it comes to an interpretation of the outcome of IRB stress testing.[21]

Table 6: Sensitivity Analysis for the Basel II Model

Table 6 shows the IRB minimum capital requirements in percentage as a portion of the portfolio exposure for the four different portfolios referred to in this study. Besides the unstressed "Base case", the outcome of five different PD stress scenarios is displayed, based on a relative increase of the PD by the percentages indicated.

Portfolio	Base Case	+5%	+10%[22]	PD +20%	+30%	+50%
(PF0) PSVaG	8.58	8.77	8.97	9.33	9.68	10.31
(PF1) Small bank	5.69	5.79	5.90	6.09	6.27	6.62
(PF2) Medium-sized bank	5.22	5.33	5.43	5.62	5.79	6.11
(PF3) Large bank	4.82	4.92	5.02	5.20	5.38	5.69

Overall, the outcome of the univariate sensitivity analysis shows that the portfolio structure does not play a material role for IRB capital requirements, being highly in line with our expectations.

[21] The corresponding outcome for a 50% PD stress is an increase of capital requirements by 24.6% (PF1) to 26.2% (PF0).

[22] If one stressed PDs at a level of 10% together with the asset correlations of the base case, the capital ratios as a portion of portfolio exposure would be 9.07 (PF0), 5.99 (PF1), 5.52 (PF2) and 5.09 (PF3).

Next, we consider univariate (2a) and multivariate (2a) scenarios based on historical data both for the IRB model and for the 1FM. The historical values for the credit risk parameters for Germany are taken from three sources that we considered being of high quality each: The default rates are taken from the German National Statistical Office (*"Statistisches Bundesamt"*), the loss severity rates are from Franks et al. (2004) and asset correlations are from Düllmann et al. (2007). In case of the loss severity rates reported by Franks et al. (2004), we refer to the data on the defaulted German firms only.[23] The asset correlations are based on MKMV data for European firms, with German firms being among the most represented countries in the sample. The three time series span the period from 1996 to 2002, covering a period of seven years and thus an entire business cycle (see Table 7). Asset correlations data will only be considered for the 1FM.

Table 7: Time Series of Credit Risk Parameters used for Stress Testing

Table 7 displays the historical default rates, loss severity rates and asset correlations used for stress testing. The default rates correspond to the corporate insolvency rates reported by the German National Statistical Office ("Statistisches Bundesamt"). The loss severity rates for Germany are taken from Franks et al. (2004). The asset correlations for Germany are taken from Düllmann et al. (2007). We use the e.g. value for December 1997 for the year 1996 as these asset correlations have been estimated for the 24-month time sliding window starting in January 1996 and ending in December 1997.

Year	Default rates	Loss Severity Rates	Asset Correlations
1996	0.78%	29.0%	10.3%
1997	0.80%	35.0%	14.2%
1998	0.79%	35.0%	11.4%
1999	0.64%	41.0%	4.6%
2000	0.68%	35.0%	6.9%
2001	1.11%	53.0%	11.8%
2002	1.28%	34.0%	12.9%
Mean	0.87%	37.43%	10.3%

Next, the crucial question becomes how these historical time series should be used for forward-looking stress testing. In order to reflect a stress event, practitioners would typically refer to a 'worst year in x years scenario' (or second worst in x years[24]) or to quantile values of the historical credit risk parameters (PD, LGD, correlations) on the upper end of the distribution (75%, 80%, 90%), for example. As the time series are relatively short (as it will

[23] Araten et al. (2004) provides a time series of 18 years from 1982 to 1999 for 3761 defaulted loans, mainly US loans. Further information on LGDs can be found in Altman et al. (2005). As these data are essentially based on US data and partially also on bond data, we did not consider them in this study.

[24] As long as time series are relatively short, a "worst year in x years" scenario would not necessarily constitute an ultimate worst case scenario, so it appears to be feasible to choose the worst year. In addition, the second and third worst years would typically be additionally taken into account, notably as the Basel II framework does not necessarily ask for the simulation for a worst-case scenario.

be the case in many banks), we will refer to a pragmatic rule, namely a 'worst year in 7 years scenario' and thereby assess a scenario that tends to constitute a conservative ceiling for Basel II type stress testing.

This rule would generally allow for two potential cases to identify the year corresponding to 'worst year in x years scenario', namely referring to the worst year in terms of absolute risk levels or to the year with the most substantial increase of portfolio risk. In the first case, one would assume that the worst historical level would also correspond to a (very) adverse scenario in the future, so stress testing would simulate the occurrence of a comparable level in the future. In the latter case, the current portfolio risk is taken as a basis to apply a relative stress event. The advantage of the second case is that it is less backward-looking, particularly also as absolute levels may change over time as recent developments have shown and stress tests would become difficult in case of periods where portfolio risk is at maximum historical levels. However, this does also apply to relative changes, so they have to be chosen in an appropriate way, but potentially in a magnitude around historical maximum levels if one seeks for conservative estimates, particularly if the current level of portfolio risk is relatively low. Furthermore, it has to be decided which parameter is being used to define the reference year.

In line with the regulatory discussion on the definition of an economic downturn in the context of Basel II regulation, we focus on the development of the PD and use the relative notion to determine stress.[25] As displayed in Table 7, the PD shows a relatively stable development until 2000, before it rises considerably. The increase from 2000 to 2001 is the most extensive one, amounting to an increase of the PD by 61% (from 0.68% to 1.11%). We consider this year as an economic downturn. In the same period, also the LGD and the asset correlations increased substantially, the LGD by 51% and asset correlations by 71%. Although this outcome may point to the fact that it is a given rule that the downturn scenarios for the PD, LGD and correlations fall together, this has by no means been proven, as data sources remain very limited to date and the outcome varies widely across studies. If one considers the consecutive year where the PD reaches the highest level during the seven year period, for example, we observe a PD increase by 15% and the raise of asset correlations by 9%, but a decrease in LGD by 36%. In any case, however, the underlying example shows that

[25] A relative increase has been chosen in order to better compare the impact of stress for the different portfolios. A valid alternative would be to refer to scenarios with an absolute increase of risk parameters, for example 10 percentage points in case of LGDs. For the PDs, the absolute increase could be defined for each rating class, for example.

an increase in different credit risk parameters can fall together, and it is, in fact, the purpose of stress tests is to also simulate such adverse cases.

Table 8 shows the outcome of historical simulation for the IRB model (2a, 2b). The increase of capital requirements is substantial for all scenarios except for the LGD stress for portfolio PF0, where the LGD does increase only from 95% to the LGD ceiling of 100%, which constitutes an untypical case for credit portfolios. The increase of the PD (+61%) translates into a raise of IRB capital requirements by roughly 20% and the LGD increase results to a linear increase by 51%. The aggregated affect of a PD and LGD shock leads to an increase of IRB capital requirements of more than 80% for the three bank credit portfolio, so that a joint stress of the two parameters yields a more than 10% additional increase of capital requirements compared to the simple sum of the two univariate scenarios. Among the bank portfolios, the PD stress effect as well as the aggregated stress effect is most extensive for the portfolio of the large banks (PF3), followed by portfolio PF2 and PF1, with the differences between the three portfolios being at a minor level of 1-3 percentage points.

Table 8: Historical Simulation for the Basel II IRB Model

Table 8 shows IRB capital requirements as a portion of the portfolio exposure in percentage for the four different portfolios in different stress scenarios. For the portfolio of the German pension insurer ("PSVaG"), the LGD was only increased by five percentage points in the stress event (i.e. from 95 to 100 percent). We thereby assume that the LGD has a ceiling of 100 percent. Descriptive statistics of the unstressed credit risk parameters are shown in Table 3. For the portfolio of the small bank, for example, the mean PD increases from 0.99% to 1.59% and the mean LGD from 45% to 67.95%.

Portfolio	**Base Case**	**Univariate stress (2a)**		**Multivariate scenario (2b)**
		PD +61%	**LGD +51%**	**PD +61% and LGD +51%**
(PF0) PSVaG	8.58	10.73	9.11	11.29
(PF1) Small Bank	5.69	6.79	8.58	10.25
(PF2) Medium-sized bank	5.22	6.27	7.89	9.47
(PF3) Large bank	4.82	5.86	7.28	8.84

In absolute terms, portfolio risk for the bank credit portfolios does almost double from roughly 5% to 9%-10%, the stress level thereby exceeding the loaded 8% level of the Basel I and Basel II framework. If one would seek to apply less conservative stress events, one could take fractions of the maximum increase of the parameters, for example a PD increase by 30.5% and/or an LGD increase by 25.5%. Again, the smoothening effect of asset correlations has to be taken into account. For the portfolio with the most substantial increase of capital requirements (PF3), the credit VaR for the univariate scenario (2a) would yield 5.92% if the correlations remained unchanged compared to the base case, and 8.94% for the multivariate case (2b). The smoothening effect on the relative increase would thereby be 1.2% (2a) and 2.1% (2b), respectively, being relatively minor.

4.2 Stress Testing based on an Economic Capital Model

Next, we use a simulation based one-factor model (1FM) to determine the effect of asset correlation stress both from a univariate (2a) and a multivariate perspective (2b).[26] For the two most concentrated portfolios in exposure, PF0 and PF1, the Value-at-Risk (VaR) of the 1FM for a confidence level of 99.9% closely resembles the IRB capital requirements (see Table 9). For the other two portfolios, the 1FM VaR is lower than the IRB capital requirements. The difference mainly results from the discrepancy in asset correlations modeling besides relatively minor differences due to the EL not being taken in case of the IRB. More specifically, it results from the portfolio specific exposure/PD/asset correlation combination being transformed into portfolio VaR: High correlations materialize in case of large exposures combined with increasing PDs. The differences of the 1FM VaR figures and the respective IRB capital requirements raises the question as to whether there is a kind of a benchmark portfolio with a specific concentration structure so that the economic capital requirements for a certain economic capital model (for example the 1FM or a multi-factor model such as CreditMetrics) are similar (or 50%, 75%) to the IRB capital requirements. Such a portfolio could serve the role of defining a threshold whether a portfolio is rather concentrated or not.

Table 9: Stress Testing of Correlations

Table 9 shows the results of asset correlation stress in univariate and multivariate scenarios for the credit VaR calculated for a simulation based one-factor model (IFM) as a portion of the portfolio exposure in percentage. The unstressed mean asset correlations are shown in Table 3. The table also shows the IRB capital requirements for the unstressed case ("Base Case IRB").

Portfolio	Base Case IRB	Base Case 1FM	Univariate scenario (2a)			Multivariate scenario (2b)
			Asset corr. +10%	Asset corr. +20%	Asset corr. +71%	PD +61%, LGD +51%, Asset corr. +71%
(PF0) PSVaG	8.58	8.20	8.88	9.44	15.37	18.07
(PF1) Small Bank	5.69	5.02	5.18	5.40	6.61	13.39
(PF2) Medium-sized bank	5.22	3.89	4.07	4.28	5.83	12.35
(PF3) Large bank	4.82	3.25	3.71	4.24	6.15	12.83

[26] More specifically, we used a confidence level of 99.9% on a one year basis, so the result is comparable to the Basel II IRB outcome, except for the fact that the VaR does include the EL, whereas the IRB capital requirements do not. However, as the EL is only a relatively small fraction of the UL, the comparison remains valid. The results have been determined based on 50,000 simulation runs.

In the case of the 1FM, the impact of the portfolio structure on the credit VaR becomes clearly evident in the stress test results: A 10% stress of correlations translates into a VaR increase of 3% (PF1) to 14% (PF3), i.e. an increase in correlations does translate into a more than linear VaR increase in the latter case. For the univariate historical scenario (2a), namely an increase of the correlations by 71% from 2000 to 2001, the VaR increases by 32% (PF1) to almost 90% (PF3) ceteris paribus. This outcome clearly demonstrates the crucial effect that correlations play for the evolution of credit portfolio risk, but also how portfolio-dependent their effect is, even in case of the application of a one-factor model.

For the multivariate scenario (2b) the VaR increase ranges from 120% (PF0) to 300% (PF3) which seems quite extreme. Such a scenario could indeed be understood as a worst-case scenario and thereby sets a conservative limit to the outcome of stress testing carried out in this study. As outlined before, in case of a stress event in relative terms one has to also consider the current level of portfolio risk in order to avoid misleading conclusions. In the underlying case, it has to be taken into account that 2002 was a year of light recession and stress testing has thus been applied to already elevated credit risk parameters.

5 Conclusion

We address stress testing as one of the core Pillar II issues of Basel II. Most recently, this has become a crucial part of the public agenda of the framework, also due to US subprime crisis. The main reason is that Pillar I estimates do only implicitly take into account portfolio concentration.

Stress tests are only vaguely defined by supervisory bodies. Flexibility is a key aim of the Basel II framework to appropriately deal with specific situations in the highly diverse universe of financial institutions. In our study we built different typical credit portfolios for German banks of different sizes and applied univariate and multivariate stress tests. To overcome the lack of publicly available data we used the outcome of a previous study where the balance sheet data of Deutsche Bundesbank were calibrated to the portfolio of the German pension insurer, the PSVaG, which constitutes a cross sectional representation of the German economy. Based on this database, we derive credit portfolios by means of benchmarking with the German register to thereby arrive at a unique set of real credit portfolio data.

The outcome shows that stress tests based on historical scenarios can have a huge impact on minimum capital requirements in the IRB model, amounting to up to 80% in a multivariate scenario with PD/LGD stress. Furthermore, in multivariate scenarios with a rise of several credit risk parameters at the same time the stress effect results to an increase of portfolio risk more than the aggregation of the univariate outcome would indicate. If we additionally stress correlations in a simulation based one-factor model, the credit Value-at-Risk may raise up to 300%, which outlines the crucial effect of correlation stress tests. Moreover, portfolio differences become material, as the increase of the VaR for the bank portfolios ranges from 170% (small bank portfolio) to 300% (large bank portfolio). In the terms of the relative contributions of the parameters, the stress effect is, by definition, linear both for the LGD and the EAD. In case of univariate PD stress, an increase by 10% in relative terms approximately translates into an increase of IRB capital requirements of roughly 4%, but there is a smoothening effect of correlations. If one eliminates PD-correlation dependence and leaves correlations unchanged while increasing PDs, the effect of a 10% relative, univariate increase of the PD yields an increase of IRB capital requirements by around 5.5%. In fact, it might be more appropriate to refer to the latter treatment in case of IRB stress tests, particularly to assess less substantial PD stress. For univariate correlation stress (independent of the PD), the effect highly depends on the portfolio structure, and may yield a more than linear increase of the credit VaR. Apart from the numerical outcome, this study has presented a set of stress tests that can be composed in a relatively straightforward way, thereby also taking into account the criteria foreseen by the regulatory framework. In this way, the study may contribute to the evolution of a standard for credit risk stress tests.

In sum, this study shows that it is important to carry out different types of stress tests to gain a comprehensive view on portfolio risk, notably to facilitate IRB stress testing by means of economic capital based stress tests. The analysis also points out that stress testing can clearly reveal portfolio risk that is not readily visibly with standard credit risk analysis.

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