Visual Portfolio Analysis

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Abstract:

We provide a practical and model independent technique that enables the risk manager

- to understand and visualize credit portfolio structures,
- to compare portfolio components as to their contribution of risk and positive occasion to the portfolio,
- to receive some hints by what actions credit portfolio risk can be reduced and how its profitability can be improved,
- to be aware of the implications of strategic management decisions for portfolio analysis and development

without having to know complex mathematical methodologies.

Keywords: credit portfolio risk, risk measure, portfolio analysis, portfolio improvement, portfolio optimization

JEL Classification: A23, B41, C63

Introduction

In credit portfolio risk management the focus of model vendors and of most academic research is on portfolio modeling and on the definition and calculation of risk measures. For a proactive risk management and the application of state-of-the-art risk management methods in financial institutions, however, a number of further steps are essential. This is

- to understand and visualize portfolio structures,
- to compare portfolio components as to their contribution of risk and positive occasion to the portfolio,
- to receive some hints by what actions portfolio risk can be reduced and how its composition from the risk management's point of view and its profitability can be improved,
- and to be aware of the implications of strategic management decisions for portfolio analysis and development such as the institutions risk policy, the choice of risk measures and the intended target return on equity for new investments.

In this paper, we provide a practical and model independent way how these questions can be tackled that does not require the risk manager to know and handle complex mathematical techniques. We describe the concepts of marginal risks and expected risk adjusted returns. We also show how they can be combined with the portfolio's exposure distribution to construct further risk measures, to define various types of limits, and to display the results in a 'risk management cockpit'. A risk management cockpit is a set of graphical visualizations that summarize the results and outline the portfolio components that need the risk manager's immediate attention. Finally, we show how the implications of strategic management decisions can be detected.

The paper is organized as follows: In the first section we describe the portfolio and the portfolio model used to construct an example analysis. Section two provides the visualization of risk and return measures and of limits in a risk management cockpit. It is shown how this technology can be used to localize particular problems and opportunities in the portfolio and to improve portfolio quality. Section three focuses on strategic management decisions. Section four concludes.

1. Example portfolio and portfolio model

To illustrate the notion of risk contributions and the risk analysis and risk management techniques, we successively analyze an example portfolio. The example portfolio is moderately heterogeneous in the sense of Wehrspohn (2003b), i.e. it is composed of heterogeneous segments which are homogenous in themselves and fully diversified and there is only one systematic risk factor. This means that each portfolio segment contains an infinite number of identical exposures, but that exposures in different segments may differ. All exposures are dependent only through the systematic risk factor.

For this type of portfolio there is an analytic solution of the portfolio loss distribution in the asset value credit risk model[1]. Note, however, that the choice of this particular model is not a prerequisite for the visual portfolio analysis technique described in the following. It merely helps avoiding computer simulations for the calculation of risks and marginal risk contributions. In practice it is only relevant that a portfolio model is used at all.

The example portfolio comprises clients in ten disjoint segments which are characterized by the following default probabilities, exposures, loss given default rates, and risk index (or asset value) correlations[2]:

	Segment									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Default Probability	0,03%	0,10%	0,30%	0,80%	1,00%	1,20%	1,70%	2,30%	3,50%	6,00%
Unsecured Exposure	3	8	12	20	24	26	22	18	20	10
Loss Given Default	30%	33%	36%	39%	42%	45%	48%	51%	57%	60%
Correlation	40%	38%	36%	34%	32%	30%	28%	26%	24%	22%

Table 1: Definition of the example portfolio

For simplicity, but without real loss in generality, it is assumed that the only type of financial products consists of one year zero bonds[3].

Figure 1 shows the portfolio loss distribution of the example portfolio. The values at risk at various confidence levels are highlighted.

1 For a derivation of the analytic portfolio loss distribution in this framework refer to Wehrspohn 2003b, theorem 1 and 2, pp. 6ff..

2 Risk index correlations (sometimes also refered to as asset value correlations) are the measure of dependence between exposures in the asset value model and, thus, the way to model portfolio structures in this setting. In moderately heterogeneous portfolios the correlation parameter describes the risk index correlation between two exposures within the same segment. Two exposures in segments i and j then have the risk index correlation $\rho_{ij} = \sqrt{\rho_i} \cdot \sqrt{\rho_j}$.

3 The types of financial products that are traded by a bank affects only the methodology how the fair risk premium is to be calculated. It does not affect the calculation of expected risk adjusted returns and the risk management techniques.

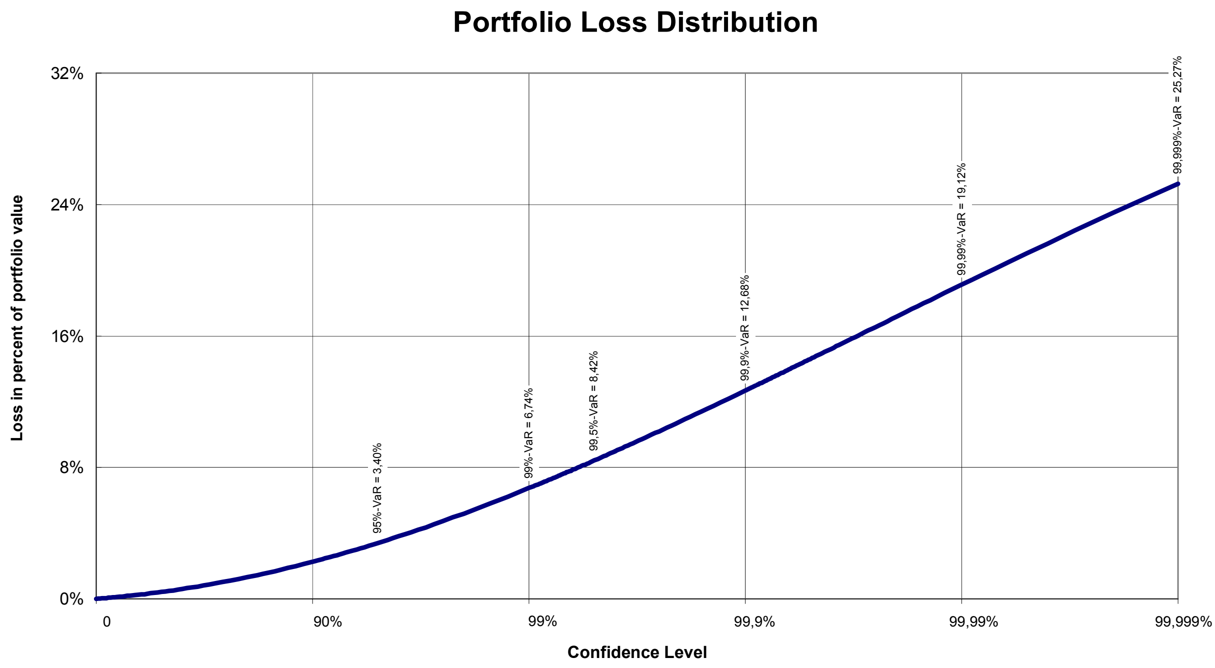

Figure 1: Loss distribution of the example portfolio

2. Portfolio analysis

Marginal risks

For any risk measure, a portfolio segment's marginal risk is defined as its contribution to the total value of the risk measure for the entire portfolio. Thus, for instance, a segment's marginal 99.5%-value at risk[4] is calculated as follows:

- Calculate the 99.5%-value at risk V_1 for the entire portfolio (in the example 8.42% of total portfolio exposure as can be seen from Figure 1).
- Remove the segment from the portfolio.
- Recalculate the 99.5%-value at risk V_2 for the remaining portfolio.
- The segment's marginal 99.5%-value at risk is then the difference V_1 - V_2 of both values.

[4] The α-value at risk (VaR) of the portfolio is defined as the α-percentile of the portfolio loss distribution, i.e. as the smallest portfolio loss that is not exceeded with a probability of α.

Marginal risks conditional to default

The simplest concept of risk contributions are marginal risks conditional to default of a specified portfolio segment. In this case, the segment's risk contribution is identical with its (unsecured[5]) exposure, i.e. its absolute loss given default.

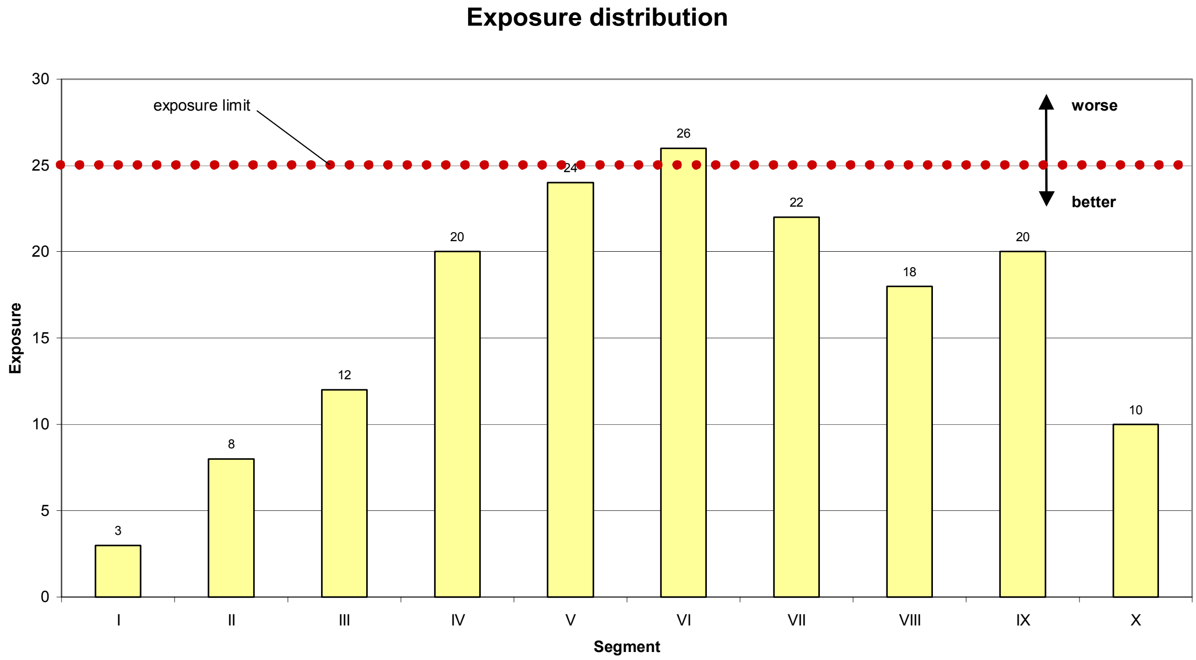

Figure 2: Exposure distribution and exposure limits

Figure 2 shows the exposure distribution of the example portfolio and indicates a possible exposure limit[6]. Note that since a segment's exposure is its marginal risk conditional to default, the results are independent of clients' default probabilities. Exposure limits are, therefore, equivalent to the statement

"I want to be sure not to lose more than X € if one segment defaults."

In the example, segment 6 exceeds the set limit. As a consequence, the risk manager would have to inform the bank's management that exposures in this segment should be reduced.

[5] In many models it is assumed that an exposure's secured part cannot be lost, even in case of default of the creditor. In practice, however, it frequently occurs that the value of securities turns out to be much lower than expected. In consequence, many banks account for the entire exposure as a client's or a segment's marginal risk conditional to default. The definition of a transaction's exposure at default by the Basel Committee on Banking Supervision (BCBS) in the third consultative paper also follows this practice (see BCBS 2003, § 277).

[6] In the example, we only consider one limit of each type for the entire portfolio. In general, every segment and even every single exposure can have its own individual limit.

Marginal risks prior to default

Marginal risks prior to default or simply marginal risks have many more facets than mere exposures. It is important to note that a segment's marginal risk does not only depend upon creditworthiness and exposure of the segment itself, but very importantly also on the other components of the portfolio if the portfolio standard deviation, the value at risk or the shortfall[7] are used as basic risk measures in the analysis. The concept of marginal risk is, therefore, suited to analyze the risk structure of a portfolio and to localize areas of high risk concentrations and others that are better diversified in the portfolio.

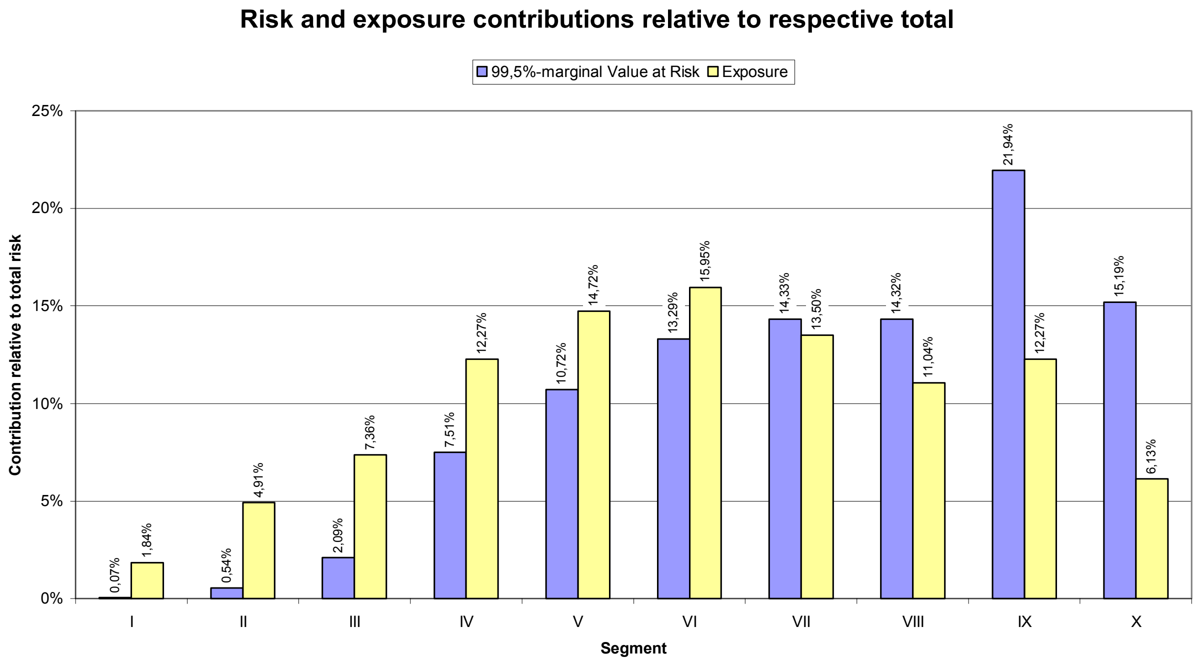

Figure 3: Risk and exposure concentrations

In the definition of the example portfolio, we assumed that the set of all segments under consideration is a partition of the total portfolio. A segment's risk concentration in the portfolio is then defined as its marginal risk divided by the sum of the marginal risks over all segments. Exposure concentrations are defined respectively. Note that the concept of risk concentrations can also be used to distribute economic capital to portfolio components. This is particularly so because they sum up to 1.

Figure 3 compares the segments' concentrations of exposures and of the 99.5%-marginal values at risk. It is evident that risk and exposure concentration differ greatly for almost all segments. Risk concentrations are much lower than exposure concentrations particularly for segments with high creditworthiness. For instance, segment 2 contributed 4.91% to portfolio

[7] The α-shortfall of the portfolio is defined as the expected portfolio loss on condition that the portfolio loss exceeds the α-VaR.

exposure, but only 0.54% to portfolio risk due to its extremely low probability of default. The opposite is true for segments with low creditworthiness. Segment 9 represents 12.27% of portfolio exposure, but not less than 21.94% of total portfolio risk. In other words, approximately 1/8th of portfolio exposure may stand for more than 1/5th of portfolio risk.

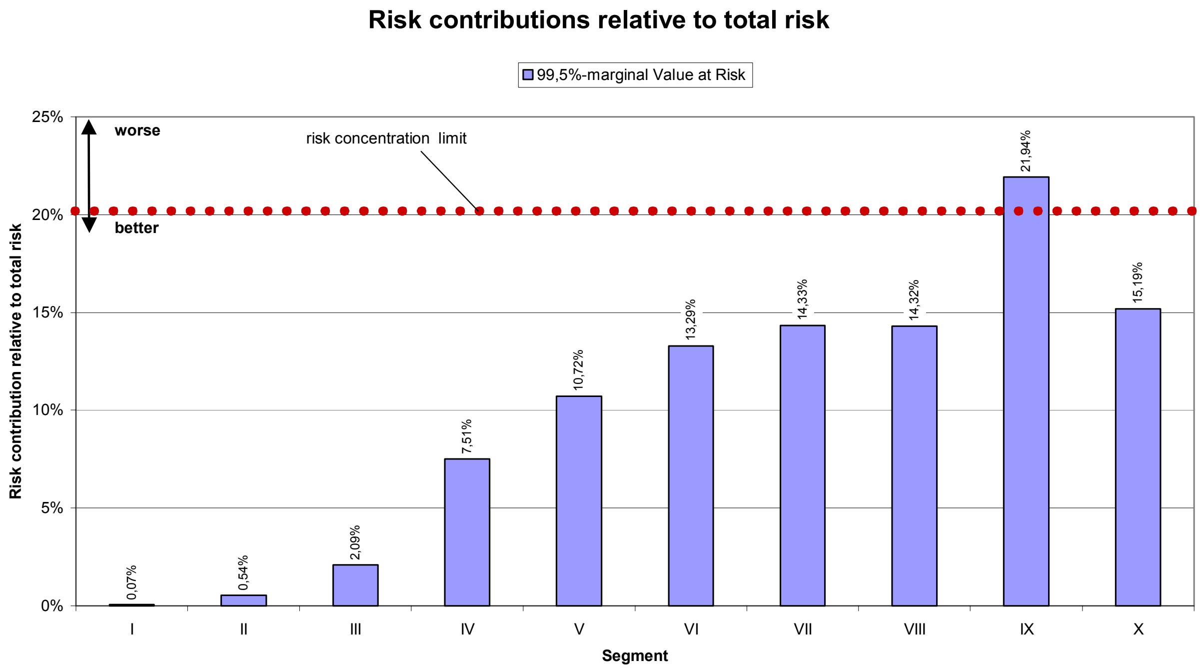

Figure 4: Risk concentrations and concentration limits

Similar to losses given default also risk concentrations can be limited. Here, the limit corresponds to the conviction

> "I don't want to concentrate more than X% of the total portfolio risk in one segment."

Note that segment 6, which surpassed the exposure limit, is well away from going beyond the concentration limit. On the other hand, exposure should be reduced in segment 9 in favor of other segments.

Complementary to risk concentrations, absolute marginal risks can be compared and limited (Figure 5).

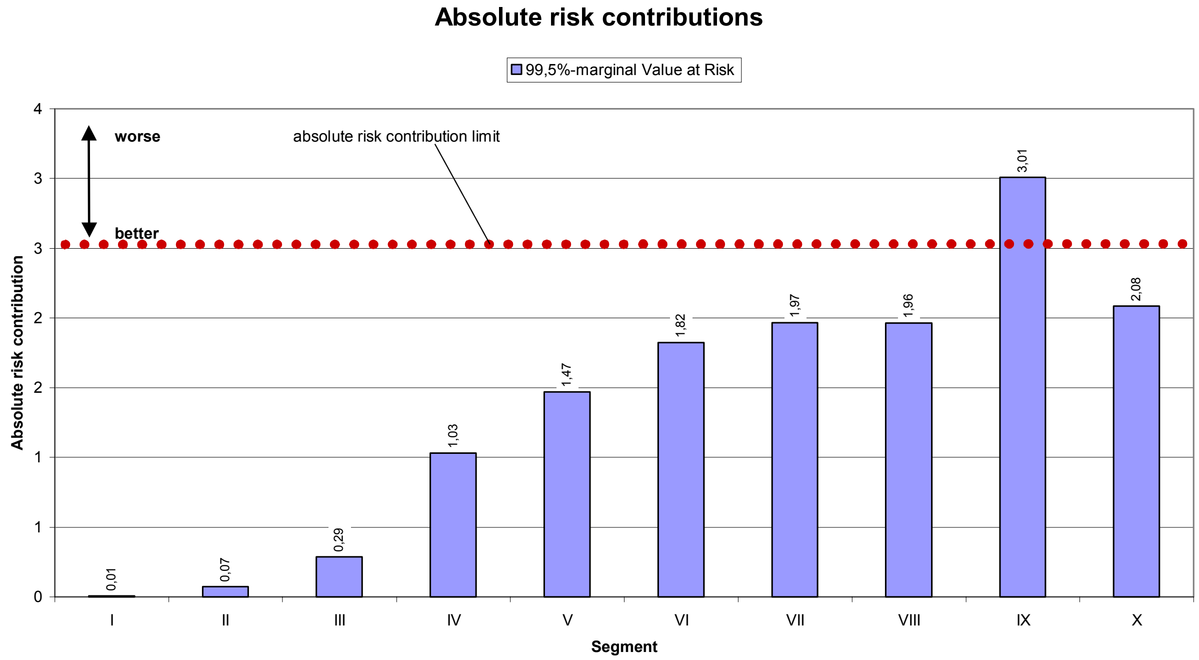

Figure 5: Absolute risk contributions and risk limits

Absolute risk contributions may, however, increase with the size of the portfolio. This is particularly true for the portfolio standard deviation as a basic risk measure, which monotonously increases in portfolio exposure if default correlations are positive[8]. Less systematically, similar effects can occur if other risk measures are used. Limits to risk contributions are, therefore, much more difficult to interpret and have to be adjusted from time to time if the size of the portfolio changes.

Combinations of exposure and marginal risk

So far only simple risk measures were considered. However, sometimes it can be helpful to combine different risk measures to get a more complete picture of the situation.

8 Positive default correlations are the standard case in most portfolio risk models.

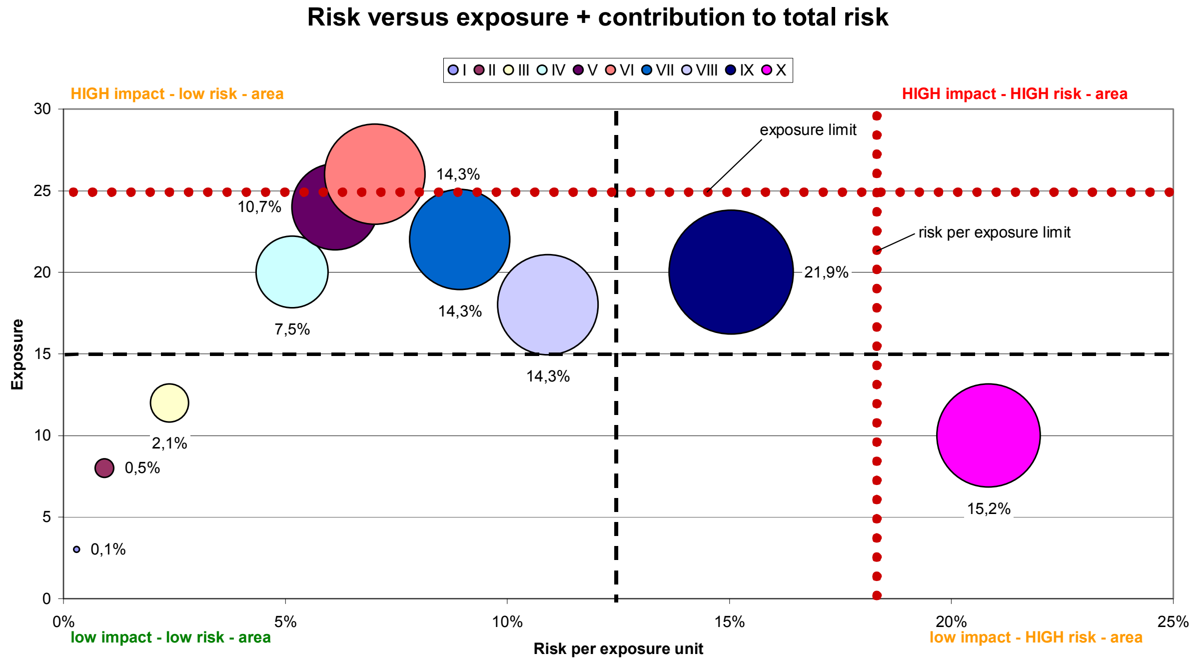

Figure 6: Risk versus exposure and risk concentration

Figure 6 displays three quantities at a time: on the axes the segments' absolute exposure versus their marginal risk contribution per exposure unit. The size of the bubbles indicates the risk concentration in each segment.

The segments of interest for the risk manager can be identified in several ways. Firstly, by the size of the bubbles: this analysis boils down to the same result as Figure 4.

Secondly, segments can be compared by absolute exposure and exposure limits can be applied. We see even more clearly than in Figure 2 that segment 6 just breaks the set limit.

Thirdly, segments can be contrasted by risk per exposure unit. Particularly, risky segments can be ruled out by the definition of risk limits. In our example, segment 10 clearly is in excess of the outlined limit.

Finally, all three features can be evaluated simultaneously. To do so the chart can be divided into four quadrants. The lower left quadrant contains the small exposures that are subject to relatively low risks. Segments in this sector are inconspicuous. Moreover, limits and credit production could even be increased in the particular segments. This is the case with segments 1 to 3 in the example.

The upper left and the lower right quadrants in a way correspond to a yellow traffic light. They are comprised of respectively large exposures of relatively low risks and small, but risky exposures. Segments in these areas do not need urgent action, but they need close attention.

This is more immediate if a segment represents a large risk-concentration in the portfolio. Segments 7 and 8 certainly need to be watched more carefully than segment 4.

In this context, the reporting of risk-concentrations does not only supply an information that is valuable in itself, but it helps to prioritize the risk manager's monitoring activities and the establishment of both a watch list and an early warning system. In practice, the detection of imminent problems of segments in this area can lead to some action such as the reduction of individual limits, the hint to the bank's sales unit not to produce more exposure in the respective segments or the sale of parts of a segment's risk with the help of a credit derivative.

The upper right quadrant contains the explosives in the portfolio. It comprises the large and risky exposures where serious losses for the bank can be expected at any moment. Segments in this area require immediate action such as the instant reduction of exposure limits preventing the production of new credits in the respective areas, the selling of risk via credit derivatives and the obligation of the affected clients to supply additional securities or guarantees.

Expected risk adjusted returns

Limit management in the sense of limit supervision is reactive by definition. A methodical risk analysis and a functioning early warning system as discussed in the previous section are already much more proactive because they frequently indicate which limits should be redefined and supply background information that has a certain relevance for the management of a bank's credit production.

In order to establish a full-fledged proactive risk management that systematically seeks opportunities and tries to increase a bank's profitability at the same time as to homogenize the portfolio risk structure it is necessary to also include the segments' expected risk adjusted return into the examination.

A contract's expected risk adjusted return is defined as the contract's market interest rate less its 'fair' price[9] including the bank's refinance costs, operating expenses, costs of default risk, and costs of equity calculated with the bank's target return on equity. A segment's risk adjusted return then simply is the average of the risk adjusted returns of all contracts belonging to the segment weighted with each contract's contribution to the segment's total exposure. We assume in the following that credit production is managed as a profit center with positive profits if pay-offs from new credits exceed the target return on equity and losses otherwise.

9 For the calculation of the fair price of a transaction refer to Wehrspohn (2003a).

In the example, we suppose that the amount of equity to be supplied for a transaction is equal to its economic capital, which we calculate as the maximum of its marginal 99.5%-value at risk and its regulatory capital requirement calculated with the IRB-Foundation Approach[10] assuming a standardized loss given default rate of 45%.

	Refinance Rate		**Long Term Risk Free Rate**			**Target Return on Equity**			**Confidence Level**	
	4,80%			8,00%			12,00%			99,50%
	Segment									
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Market Rates	4,80%	4,94%	5,20%	5,80%	6,10%	6,50%	6,80%	6,90%	7,45%	9,00%

Table 2: Definition of the example: relevant interest rates

Table 2 states the values of the relevant interest rates for the analysis in our example. Market rates refer to a one-year zero bond with a counterparty from segment 1-10. Our bank can lend one-year-money at the refinance rate. Equity is invested at the long term risk free rate. Granted loans are intended to earn the difference to the target return on equity[11].

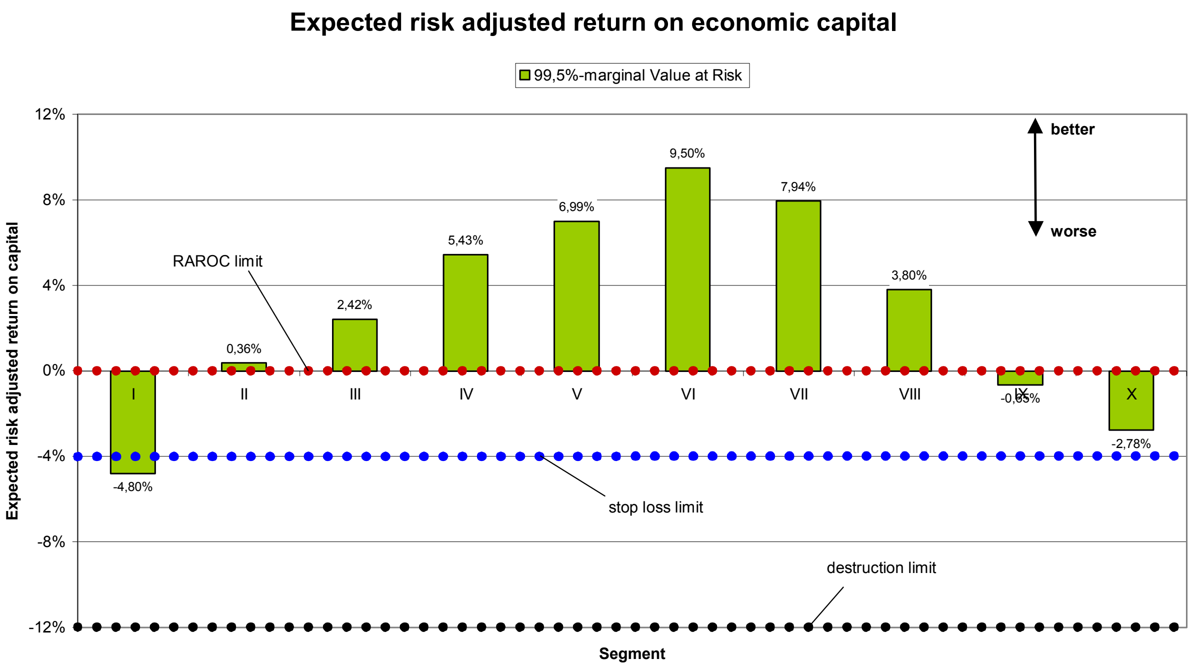

Figure 7: Expected risk adjusted return on economic capital

Figure 7 shows the results for the expected risk adjusted return on economic capital (RAROC) for the example portfolio in the various segments and three types of limits. The RAROC limit

10 See BCBS 2003, § 241.

11 See Wehrspohn (2003a) for more details on the role of the interest rates and all calculations. Particularly, we assume that on the one hand the whole credit volume is refinanced by leverage capital and that on the other hand the entire equity is invested at the long term risk free rate so that lent out money only has to earn the difference between target return on equity and the long term risk free rate.

marks the level of RAROC where the bank meets the target return on equity exactly. The stop loss limit stands for a RAROC where the bank misses the intended target return on equity, but still earns the long term risk-free rate. Finally, the destruction limit marks the point below which the expected return on equity becomes negative.

As a consequence, four different areas can be distinguished in this chart. Firstly, a portfolio segment with a RAROC above the RAROC limit earns a higher return on equity than the intended target return. These segments are most profitable and, therefore, of particular interest for a proactive risk management. If credit sales is a profit center and if sales managers are paid dependent on their ability to reach the target return on equity in their price-negotiations with clients, this is usually the only area where they can get positive results. In our example, segments 2 to 8 belong to this group.

Secondly, segments with a RAROC between the RAROC limit and the stop loss limit still increase the bank's return on equity above the long term risk-free rate, although their profitability is too low to meet the target return on equity. It is still better to invest in segments in this area than to stop granting credits at all if counterparties in the first group are not available as creditors. Segments 9 and 10 fall in this area in the example.

Thirdly, below the stop loss limit, but above the destruction limit the bank's risk adjusted return on equity is reduced below the long term risk-free rate, but still remains positive. Since a safe profit is lost, it is not worthwhile investing in segments in this area unless for very good reasons such as massive cross selling opportunities. It is not unusual that firms with a very good financial standing are not the most profitable clients in the lending business. This is particularly so if a firm's creditworthiness equals or is even higher than the creditworthiness of the lending institution itself. Segment 1 embodies this group in the example.

Finally, below the destruction limit, a segment's RAROC is so low that it fully absorbs the pay-off of the investment of equity at the long term risk-free rate. In this area, the bank expects to lose money from business with the respective segments and should immediately stop producing new contracts.

However, it is important to note that RAROC is a measure of risk adjusted return relative to economic capital. This implies that the absolute value of RAROC is high *ceteris paribus* if the amount of economic capital needed is low, and complementary that the absolute value of RAROC is low *ceteris paribus* if the amount of economic capital needed is high. For this reason, it is often helpful to also look at a segment's expected value added (EVA), i.e. to its expected risk adjusted profit in absolute terms.

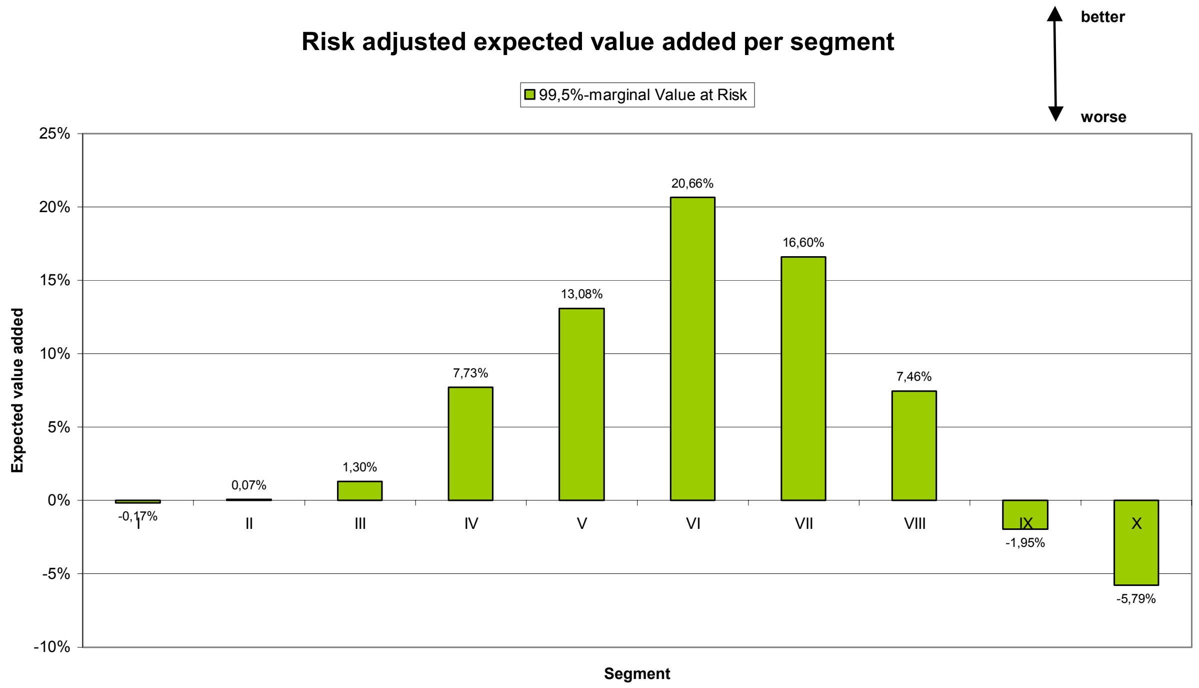

Figure 8: Risk adjusted expected value added

Figure 8 shows that RAROC and EVA always have the same sign since both are derived from the risk adjusted return, but that they may differ considerably in proportion. This is particularly obvious for segments 1, 9 and 10. Segment 1's RAROC was largely negative, even breaking the stop loss limit. However, its EVA is close to zero due to the high creditworthiness of the segment so that it may indeed be that cross selling activities are successful here.

Inversely, in segment 9 and 10 EVA is the lowest in the entire portfolio even though both segments did not break the stop loss limit.

In the example, additional business with segment 9 and especially segment 10 is not desirable. Instead, credit production should be directed to segments 2 to 8 and cross selling activities should be increased in segment 1.

Once again, the measures of expected return are not the whole story since the size of accepted risk necessary to produce, for instance, a certain RAROC may vary significantly between portfolio segments. It is, therefore, valuable to plot RAROC against the accepted risk per exposure unit (see Figure 9).

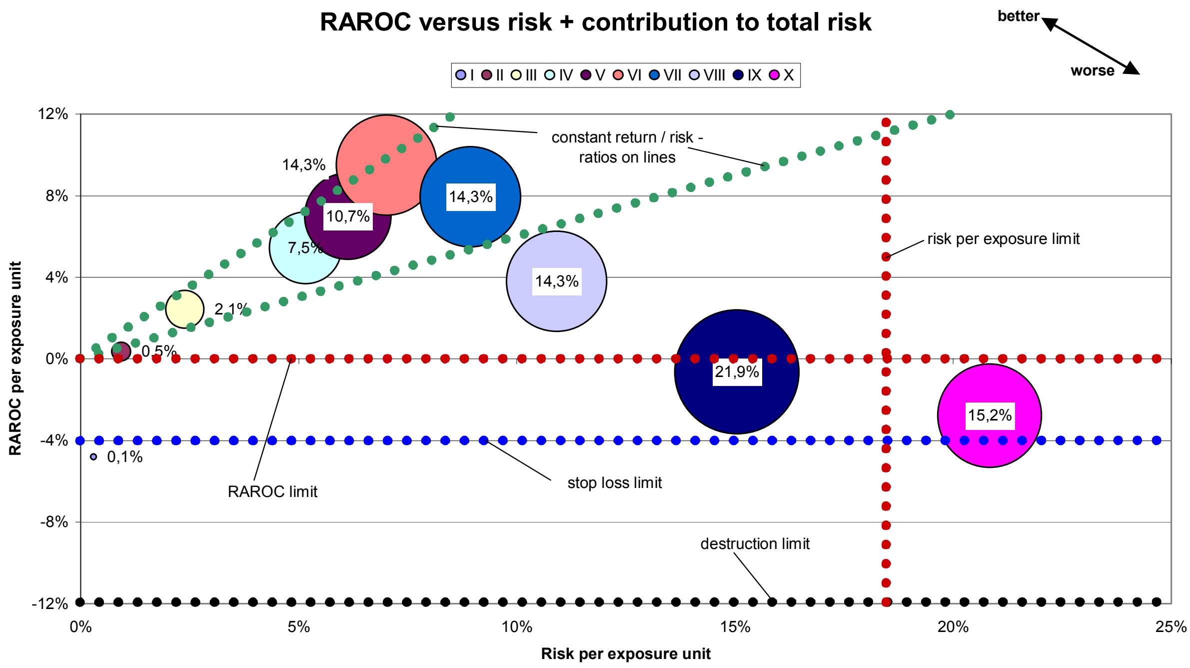

Figure 9: Accepted risk per exposure unit versus RAROC and contribution to total risk

In the exhibit, RAROC, risk and risk concentration are combined showing that segment 10 misses several limits at a time. Conversely, segments 2 to 6 have high return to risk ratios and appear particularly favorable from the point of view of satisfying all three criteria simultaneously. Segments 7 and 8 are still above the RAROC limit, but carry a medium sized risk per exposure unit and already represent considerable risk concentrations in the portfolio.

Summary

It has become clear from the discussion above that credit portfolio analysis is a multidimensional task. Being unobtrusive or even positive from one point of view, a segment may be less or even undesirable from another.

In the example, segment 6 has the most favorable RAROC and EVA, carries moderate risk per exposure unit and represents only a middle sized risk concentration in the portfolio so that one would want to enlarge business in that area. Unfortunately, segment 6 already exceeds the exposure limit, though, so that additional credit production is impossible here. Although less pronounced, the same argument holds true for segments 5 and 7.

On the other hand, segments 9 and 10 are so risky and so little profitable that credit granting should be avoided in this area. This is especially so as a result of the poor profitability of both segments and of the surpassing of the risk concentration limit by segment 9 and of the risk per exposure limit by segment 10.

This analysis leads to the following actions:

- Stop credit production in segments 9 and 10.
- Possibly redefine the exposure limit in segment 6. If this is not possible, stop credit production here as well.
- Observe exposures in segments 5, 7 and 8.
- Increase credit production in segments 2, 3 and 4.
- Use cross-selling opportunities in segment 1 agressively. Do not actively increase credit production here.

3. Strategic management decisions

Credit portfolio risk and the result of a portfolio analysis are not objective quantities that are only functions of the portfolio under consideration and the actual situation of financial markets. Besides on the portfolio itself and the market situation, the results of risk measurement and analysis also depend on the portfolio model applied, on the chosen risk measures, on a bank's risk policy as expressed, for instance, by the confidence level of value at risk and shortfall measures, on the desired target return on equity and on other factors.

It is important to note that these secondary influences on risk and risk analysis are strategic choices made by the senior bank management that can in practice lead to significantly different analysis results and risk management actions.

Say, for instance, in the example above, the senior bank management is highly risk averse choosing the 99.99% confidence level for value at risk calculations. Total portfolio risk in this case increases from 8.42% to 19.12% of total portfolio exposures, i.e. it more than doubles. Moreover, the choice of the confidence level also has an impact on the segments' marginal risks.

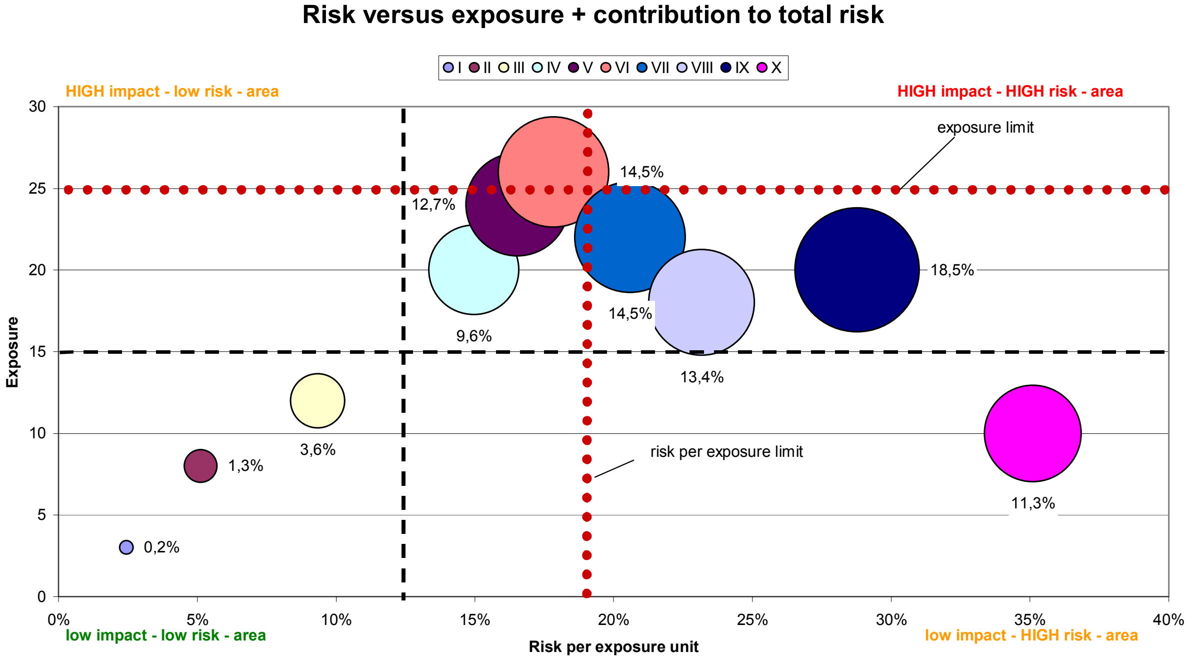

Figure 10: Risk versus exposure and risk concentration at the 99.99%-confidence level

Figure 10 illustrates that now not only segment 9, but also segments 4 to 8 are in the high impact-high risk-area and would need high priority risk management attention leaving only segments 1 to 3 for new credit production. Segments 7 to 10 even exceed the risk per exposure limit.

The picture becomes more complete if we also look at the segments' RAROC.

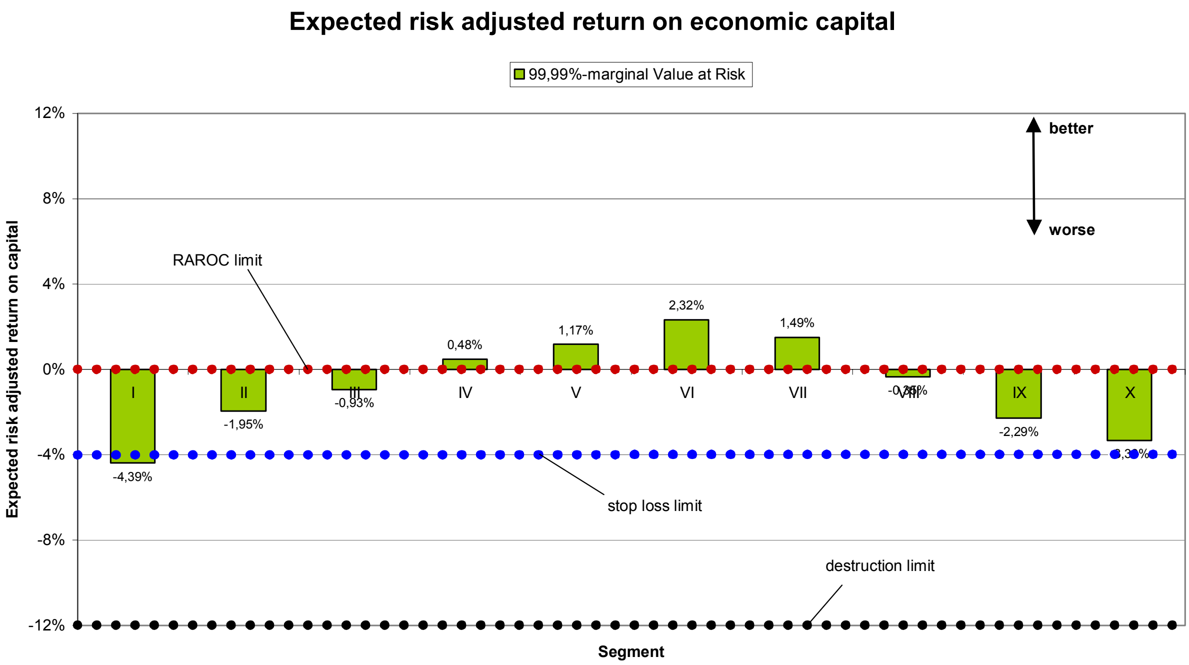

Figure 11: Expected risk adjusted return on economic capital at the 99.99% confidence level

Here it turns out that due to the high marginal risk per segment risk adjusted returns on economic capital have declined sharply as a consequence of increased costs of equity. What is more, risk adjusted returns are positive only in segments 4 to 8 where additional credit production is impossible due to the already too high exposure in combination with the respective marginal risk.

This implies that in the given market situation of the choice of the 99.99% confidence level for value at risk calculations leads risk management and credit production into a cheque mate situation unless risk and exposure limits are substantially increased. A reduction of the desired target return on equity should also be considered because otherwise credit production is only possible in four segments making future risk and exposure concentrations inevitable.

The brief example shows that management decisions need to be balanced in themselves and tuned to the market. The choice of extreme tail measures for risk analysis and economic capital allocation leads to the reporting of higher risks and lower returns in any given situation making risk management actions seem more urgent in many areas of the portfolio and also narrowing the corridor for profitable new credit production. This effect can be partially compensated if the limits and the profitability targets are adapted.

4. Conclusion

We have given an example for a model independent technique that enables the risk manager to visually analyze credit portfolio structures, to localize areas of particular risk and opportunity in the portfolio and to prioritize risk management actions. Moreover, the method can be used to evaluate the consequences of strategic management decisions on portfolio analysis and credit production. Further potential applications are portfolio stress tests and scenario analyses. The technique is easy to use and does not require the practician to know and handle advanced mathematical methods.

The risk management cockpit used for the above analyses can be obtained from the author upon request.

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