Research Paper

Capital for Structured Products

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Capital for Structured Products

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1. Introduction

Structured products are complex instruments the payoffs on which depend on the performance of pools of correlated underlying assets and that possess a tranche structure, i.e., a set of rules that prescribe how cash flows on the underlying pool are split between the holders of several classes of claim of different seniorities.

This chapter describes a methodology we have developed for calculating ratings-based capital charges for structured products like structured exposures. The *Risk Controller*[2] model we employ is a generalisation of industry-standard, ratings-based credit portfolio models.

As a check of our approach, we exposit and implement a simple asymptotic model for calculating capital for structured exposures developed by Pykhtin and Dev. This asymptotic model is related to the one-factor models of Gordy (2003) and Gordy and Jones (2003). We show that when restricted to a one-year structured transaction of negligible size compared with the bank's wider portfolio and when parameterised consistently, *Risk Controller* yields the same capital requirements as the Pykhtin and Dev approach. Using *Risk Controller*, we show that one may calculate capital charges under more general and less stylised assumptions, for example for longer maturity structures and for structures that are non-negligible compared to the bank's wider portfolio.

Employing both the Pykhtin-Dev model and *Risk Controller*, we provide an analysis of appropriate capital charges for structured exposure tranches with different rating categories. The issues we examine are:

1. *Global consistency*

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[1] This paper was prepared for the Securitisation Sub-Group of the Basel Committee. Earlier drafts of this paper were entitled "Capital for Asset Backed Securities".

[2] *Risk Controller* is the credit portfolio model of Risk Control Limited, a specialised risk management consulting firm that supplies software to major financial institutions. The authors of this paper have worked with Risk Control Limited on the development of this model. The model permits one to calculate economic capital for investments in securitisation tranches held within larger portfolios of credit exposures and is hence well suited for analysing appropriate capital charges for structured products. *Risk Controller* is a registered trademark.

How total capital implied by the current RBA for all the tranches in an structured exposure compares with the total economic capital implied by our models and with the capital structured exposure issuers would have to hold against the underlying pool under the current proposals if the exposures were held directly on balance sheet, i.e., Kirb.

2. *Rating category-specific consistency*
   How the current RBA capital requirements for different rating categories compare with the charges implied by the model under different correlation assumptions?
3. *Granularity effects*
   How capital charges vary as granularity decreases when the structured exposure is small or large compared with the wider bank portfolio.
4. *Sector effects*
   How capital charges vary when the underlying asset pool is made up of exposures to different sectors, for example, credit card receivables, C&I loans or residential mortgages.
5. *Maturity effects*
   How capital charges implied by the model vary for different maturities.

The structure of the paper is as follows. Sections 2 and 3 describe the Pykhtin-Dev and *Risk Controller* approaches respectively. Section 4 sets out the analysis of ratings-based structured exposure capital charges. Section 5 concludes.

2. Asymptotic Models

Building on derivations in an unpublished note by Vasicek (1991), Pykhtin and Dev (2002a) and (2002b) examine capital requirements for tranches in a structured product that comprises a negligible fraction of a larger bank portfolio.[3] Their approach generalizes the single common factor approach that is the basis for the work of Gordy (2003) and Gordy and Jones (2003) by allowing for possibly imperfect correlation between (i) a common factor driving credit risk in the bank's wider portfolio and (ii) a common factor driving the credit quality of the exposures in the structured product pool.

Pykhtin and Dev suppose that the wider portfolio of the bank in question has a single risk factor and is diversified so that aggregate losses are a function simply of this common factor. In this case, one may show that the marginal VaR (at a confidence level of α) for a small additional exposure equals its expected loss conditional on the common factor in the bank portfolio equalling its α quantile.

For very thin tranches in a structured exposure, the loss given default is 100% so the expected loss is simply the probability that losses exceed the protection level of the tranche. In this case, the marginal VaR on such a tranche is just the conditional expected loss, i.e., the probability that losses exceed the tranches protection conditional on the common factor in the bank portfolio equalling its α quantile.

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[3] A related model was developed earlier by Lucas, Klaassen, Spreij and Straetmans (2001).

To derive marginal VaRs for thin tranches, it therefore suffices to calculate the distribution of total losses on the pool of exposures conditional on the factor driving the bank portfolio equalling its α quantile.

Pykhtin and Dev use the results of Vasicek who derives a simple closed formula for the distribution of aggregate losses on a credit portfolio. The modifications they make are (i) to derive this distribution conditional on a given level of losses on the wider bank portfolio, and (ii) to allow for random loss given default.

The basic assumptions of the Vasicek-Pykhtin-Dev approach are as follows. Suppose that the ith exposure in the structured exposure pool defaults over a single period of time such as a year if a normally distributed latent variable Z_i falls below zero. Assume that:

$$Z_i = \sqrt{\rho}\, X + \sqrt{1-\rho}\, \varepsilon$$

where X is a common factor and ε is an independent exposure-specific error. Suppose that X is correlated with a single factor denoted Y driving the wider bank portfolio in that

$$X = \sqrt{\rho_Y}\, Y + \sqrt{1-\rho_Y}\, \eta$$

Suppose that Y, ε and η are standard normal random variables so that X and Z_i are also standard normal random variables. Conditional on Y, X is then distributed as $N\left(\sqrt{\rho_Y}Y, 1-\rho_Y\right)$. Since, conditional on X, defaults by individual exposures in the structured product pool are independent, it follows (see Vasicek (1991)) that that the probability of k defaults in a year out of n exposures conditional on losses of Y on the wider bank portfolio is:

$$P_k = \binom{n}{k} \int_{-\infty}^{\infty} \left(\Phi\left(\frac{1}{\sqrt{1-\rho}} \Phi^{-1}(p) - \sqrt{\rho}\, u \right) \right)^k \left(1 - \Phi\left(\frac{1}{\sqrt{1-\rho}} \Phi^{-1}(p) - \sqrt{\rho}\, u \right) \right)^{n-k} d\Phi\left(\frac{u - \sqrt{\rho_Y} Y}{\sqrt{1-\rho_Y}} \right)$$

The cumulative probability that the percentage of losses on the pool does not exceed θ is then:

$$F_n(\theta) = \sum_{k=0}^{[n\theta]} P_k$$

Using the substitution $s = \Phi\left(1/\sqrt{1-\rho}\, \left[\Phi^{-1}(p) - \sqrt{\rho}\, u\right]\right)$ yields:

$$F_n(\theta) = \sum_{k=0}^{[n\theta]} \binom{n}{k} \int_0^1 s^k (1-s)^{n-k}\, dW(s)$$

where $W(s) \equiv \Phi\left(\frac{1}{1-\rho_Y} \left(\frac{1}{\sqrt{\rho}} \left(\sqrt{1-\rho}\, \Phi^{-1}(s) - \Phi^{-1}(p) \right) - \sqrt{\rho_Y}\, Y \right) \right)$.

When loss given default (LGD) is random and can be well approximated by independent normally distributed random variables with identical means μ and variances σ^2, then the conditional distribution of losses becomes:

$$\hat{F}_n(l) = \sum_{k=0}^{[n\theta]} \binom{n}{k} \int_0^1 s^k (1-s)^{n-k} \, dW(s) \, \Phi\left(\frac{l\,n - \mu\,k}{\sigma\sqrt{k}} \right)$$

Capital charges appropriate for a very thin tranche with protection l are then simply: $G_n(l) = 1 - \hat{F}_n(l)$

When the portfolio for the structured exposure is highly granular, Vasicek shows that the distribution of losses simplifies. The conditional loss distribution that one obtains then implies a capital charge function for a thin tranche with protection l is then

$$G(l) = 1 - \Phi\left(\frac{1}{1-\rho_Y} \left(\frac{1}{\sqrt{\rho}} \left(\sqrt{1-\rho}\,\Phi^{-1}(l/\mu) - \Phi^{-1}(p) \right) - \sqrt{\rho_Y}\,\Phi^{-1}(\alpha) \right) \right)$$

To obtain the marginal capital charge for a tranche with discrete thickness t_2-t_1 and protection level t_1, one may simply use the fact that marginal VaRs sum for different exposures. The capital for such a thick tranche is therefore just $\int_{t_1}^{t_2} G(l)dl$, i.e., the integral of $G(l)$ from t_1 to t_2.

In fact, the approximation used by Pykhtin and Dev that losses given default on different exposures are independent and normally distributed is unsatisfactory when the granularity is extremely low as in this case the probability of a loss rate greater than unity or less than zero may be significant. In our implementation of the Pykhtin-Dev approach, we therefore employed both the approach described above and, as an alternative, a numerical solution in which independent beta distributed LGDs were simulated by Monte Carlo. For granularity levels of 4 or less, this approach yielded estimates that were somewhat different from those obtained with the standard Pykhtin-Dev model described above. As we shall see in Section 3.7, the results with our beta-distributed recoveries are identical apart from sampling error to those obtained using the *Risk Controller* model under identical assumptions.

3. The *Risk Controller* Model

3.1 Ratings-Based Models

To analyse portfolios including structured products, we used the ratings-based credit risk model, *Risk Controller*. As in standard, ratings-based credit portfolio models, in *Risk Controller* the ratings of different exposures are driven by realisations of normally distributed latent variables. The correlations of these variables are taken to equal those of weighted averages of equity-indices, where the weights are selected appropriately given the relative importance of different industries and countries for the obligor in question.

Risk Controller generalises standard one-period, ratings-based models in that it may be run for any horizon with intermediate cash flows (including recoveries in the event of default) being cumulated up to some terminal date. If the terminal date exceeds the maturity of the longest-dated exposure, the model yields hold-to-maturity risk measures for the portfolio one is analysing.

3.2 Structured Products within Ratings-Based Models

Risk Controller has the feature that one may include investments in structured products as exposures within wider credit portfolios. The primary difficulty in achieving this is that in ratings-based models, for each Monte Carlo replication, one needs to value all exposures with maturities greater than the terminal horizon of the VaR calculation conditional on the realised rating at that date. This is non-trivial for securities such as structured products as they represent levered positions in portfolios of credit sensitive exposures and hence contain non-linearities comparable to those of option contracts. Unlike standard option contracts, however, structured products are too complex for one to deduce closed form valuation expressions.

To solve this difficulty, *Risk Controller* employs a flexible but accurate approach to calculating structured products values. In brief, this consists of “pre-processing” the structured product exposures before one runs the main VaR Monte Carlo so as to obtain reduced form pricing expressions. These functions are then used in a second stage as the full model is simulated.

3.2 Structured Product Pre-Processing

Here we describe the pre-processing approach in somewhat more detail. Suppose the initial date is 0 and the horizon for the VaR calculation is T. To pre-process a structured product, one conducts an initial Monte Carlo within *Risk Controller* using risk adjusted rating transition matrices on the structured products alone and retaining in memory for each structured product tranche several thousand cash flow histories for different Monte Carlo replications. One then discounts the cash flow history after period T back to T and then, for each structured product tranche, one estimates a non-linear statistical model relating the mean of the discounted cash flows to statistics of the distribution of ratings in the structured product pool.

Since the simulations are performed using risk-adjusted transition matrices, the mean of these discounted future payoffs equals their market value at T. The statistical model gives the mean conditional on statistics of the ratings distribution of the underlying structured product pool, in other words a pricing function linking ratings statistics to value. For a given Monte Carlo replication, plugging structured product rating pool statistics into the estimated function, one obtains the conditional value of the structured product tranche. This approach resembles one independently developed by Longstaff and Schwartz (2001) in a recent paper on pricing American options by Monte Carlo.

Introducing different types of structured products in the *Risk Controller* model is straightforward as the techniques employed for reduced form valuation are flexible. The structures examined in this chapter are a simplified version of those discussed by Duffie and Garleanu (2001). An arbitrary number of tranches may be accommodated, a reserve account is maintained for excess interest payments and precise rules are followed for the accruals in principal that arises if coupons are unpaid.

3.4 The Statistical Pricing Model

We now consider in more detail the reduced form pricing approach employed within *Risk Controller*. The discounted payoffs on structured product tranches have the feature that for some discrete atom of probability, they yield the full contractual cash flow of the tranche, whereas if there is some default they yield somewhat less. We suppose that for a given tranche if a random variable z is positive, the tranche pays the contractually agreed series of coupons, the value of which is V. However, if z is negative it defaults and the discounted cash flow equals a random variable y times the no-default price V. y is in effect like a recovery rate.

The expected discounted payoff Y on the tranche is then

$$\begin{aligned} E(Y) &= \left(E[y1(z<0)] + E[1(z>0)] \right) V \\ &= \left(E(y \mid z<0)\Pr(z<0) + \Pr(z>0) \right) V \end{aligned}$$

Here, *Pr(.)* indicates a probability and *E(.)* is the expectations operator. We assume that:

$$E(y \mid z<0, X) = \gamma' X \qquad \textit{and} \qquad \Pr(z<0) = \frac{\exp(\beta' X)}{1+\exp(\beta' X)}$$

Our statistical modelling of discounted payoffs therefore consists of estimating a logit model (by non-linear Maximum Likelihood) that there is a default on the tranche in question and then estimating the recovery rate in the event of default as a linear regression. The explanatory variables we use in both the logit modelling and the regression consists of shares of the value of the underlying structured product pool in different rating categories.

3.5 Risk Adjustments and Pricing

As mentioned above, one may run *Risk Controller* either with actual rating transition matrices or with risk-adjusted transition matrices. The former approach is appropriate if one wishes to calculate quantities such as VaRs or probabilities that a portfolio will default over some given horizon. The latter approach is appropriate if one wishes to price a cash flow.

The exercises involved in the risk analysis of structured products include both kinds of simulation as the calculations include VaRs and pricing. The historical rating transition matrix we use in this study is a matrix for all obligors calculated by Standard and Poor's. To calculate a risk-adjusted transition matrix, we follow an approach similar to that of Kijima and Komoribayashi (1998) and Jarrow, Lando and Turnbull (1997). They employ benchmark spreads from the corporate bond market to deduce risk-adjusted transition probabilities by shifting probability weight so that bonds are correctly priced as discounted expected payoffs.

Both Jarrow-Lando-Turnbull and Kijima-Komoribayashi calculate risk-adjusted transition matrices that change over time and depend on prices of risk in a somewhat arbitrary manner. We prefer to assume that the risk-adjusted matrix is time homogeneous and calculate it from one-, three- five and seven-year maturity spreads. We verified that this is a good approximation to the term structure of credit spreads with which we are working (namely the average Bloomberg credit spreads for US industrials over the 1991 to 2000 period) by calculating the risk-neutral spreads that would be implied by this transition matrix for medium and long maturities.

3.6 Marginal VaR Calculations

The accuracy of the marginal VaR calculations within *Risk Controller* are increased by the application of Extreme Value Theory smoothing to the tails of the relevant distributions. The approach taken is to fit Pareto distributions to the 1% worst portfolio value outcomes with a view to improving estimates of the 0.1% VaR quantiles. Such fitting is performed for the total portfolio and then successively to the portfolio less each individual exposure. The marginal VaR is then estimated by taking the difference between the 0.1% quantile of the smoothed total portfolio value tail distribution and the corresponding quantile when a given exposure is excluded from the portfolio.

3.7 Checks of the Methodology

To check the approach, one may first examine whether it yields the correct mean price. To do this, we calculate the expected cash flow on tranches up to various different horizons plus the value of the structured product at that horizon. Given that we use risk neutral transition probabilities and discount values consistently, when the calculation is done for a horizon equal to the structured product maturity, we obtain by this method the exact tranche value. If our model is working correctly then the average discounted cash flows up to some horizon T plus the average discounted value of the tranche as given by our pricing function, should be the same for any value of T less or equal to the structured product maturity.

We find that for horizons significantly earlier than the structured product maturity and for reasonably senior tranches, we obtain very small biases of the order of 10 basis points. For very junior tranches, the biases can be greater but in general not more than 1%. For the equity tranche and for tranches that default more than 50% of the time, we use a simple regression without any logit modelling and find that this yields unbiased results.

As a further check of our pricing approach, we examined whether aspects of the distribution of values apart from the mean are correctly fitted. To achieve this, we constructed hedged positions that are long a portfolio of loans and short a position consisting of all the tranches of a structured product containing the same loans as in the first portfolio. If the calculations are accurate, there should be little volatility in the hedge position and the VaRs for different quantiles of the hedged position payoff distribution should be very small. We found in these calculations that the VaRs of the hedge position were around 5% of the VaRs of the original portfolio of loans and that volatility was extremely small on the hedged position.

3.7 Comparison of Pykhtin-Dev and Risk Controller

Adopt the assumptions:

1. The VaR horizon is a year and that the maturity of all the loans in the bank's portfolio and in the structured product pool is one year.
2. There is a single common factor in the structured product pool and another single common factor in the wider bank portfolio.
3. The structured product exposure is negligibly small compared with the wider bank portfolio.

Then, the Pykhtin-Dev model and *Risk Controller* should yield identical capital charges.

Figure 1 shows capital charges based on marginal VaRs for tranches in a structured product. The wider bank portfolio and the structured product underlying pool within *Risk Controller* are assumed to consist of 500 BBB-rated loans and 4 BB-rated loans respectively. The par value of the exposures in the structured product pool are assumed to equal 0.5% of the par value of the loans making up the wider bank portfolio. Parameters are chosen so that the latent variables for pairs of exposures in the bank portfolio have 20% correlations and likewise for pairs of loans in the structured product pool. The common risk factor in the bank portfolio and the common risk factor in the structured product pool are assumed to have a correlation of 60%. LGDs are taken to be independent and to have means of 45% and volatilities of 25%.

As may be seen from Figure 1, the capital charges implied by the two models are almost identical. The *Risk Controller* calculations are performed with 200,000 Monte Carlo replications so the slight discrepancies are attributable to sampling error.

3.8 Rating-Specific Capital Charges within Risk Controller and the Pykhtin-Dev Models

For a given structure, one can calculate the marginal capital requirement for each tranche using either the *Risk Controller* or the Pykhtin-Dev model in a straightforward fashion. Inferring the correct capital charge for tranches that have a given rating is a somewhat more complicated issue. The approach we take is to calculate capital and expected losses for the tranches in a given structure and then to fit a curve through the observations of (capital, expected loss) pairs. Evaluating these curves at benchmark expected loss levels associated with different rating categories gives us capital charges for those rating categories.

The data generated from the Pykhtin-Dev model tends to be highly smooth so our curve-fitting approach is just linear interpolation. In some cases, the *Risk Controller* model data is noisier so we fit it to a function consisting of a weighted sum of power functions. The fitting is done using a weighted least squares approach that attributes more weight to the high credit quality tranches for which the capital charges are less noisy. We systematically examined the data to ensure that the fits were accurate.

The benchmark expected loss levels associated with different rating categories are obtained by calculating the expected losses over different time periods of bonds with different initial ratings assuming (i) a historical Standard and Poor's rating transition matrix, (ii) a recovery rate of 50%, and (iii) that the coupon rates on the bonds equal those implied by time series averages of Bloomberg yield data for different rating categories from 1991 to 2001.[4]

Note that we employ expected loss benchmarks to obtain ratings rather than the obvious alternative approach of default probability benchmarks. For very thin tranches, it makes no difference, as LGDs on very thin tranches are invariably 100%. However, for thick tranches a tranche may be less risky than a thin tranche with the same rating if the rating is based on default probabilities.

Peretyatkin and Perraudin (2002) discuss differences between expected-loss and default-probability based structured product ratings. As they show, thick senior tranches tend to have superior ratings if the expected loss approach is taken. This observation is consistent with the common view that Moody's (who employ an expected loss methodology) enjoy greater market share for senior thick tranches while Standard and Poor's and Fitch (who use default probability-based rating techniques) obtain a relatively larger share of the thinner mezzanine tranches.

It is in our view better in capital calculations like those of this paper to use an expected loss methodology since for thin tranches there is no difference and thick senior tranches (for which differences may exist) tend to be rated in the market following an expected loss approach.

4. Analysis of Capital for Structured Product Tranches

4.1 Comparative Statics

[4] The benchmark expected losses for several maturities are given in Table 11.

We begin by looking at some key sensitivities of capital charge calculations to model assumptions. Figure 2 shows capital charges for thin tranches plotted against protection for several structures assuming different levels of correlation between the common factor driving the structured product pool and the common factor driving the wider bank portfolio. The structured product pool is assumed to comprise 64 equal-sized, B-rated loans.

As is evident from Figure 2, the greater the correlation, the steeper is the capital charge curve. In the limit as correlation goes to 1 and as the granularity of the portfolio approaches infinity, the capital curve approximates to a step function with a 100% weight for all levels of protection below the capital that the underlying structured product pool would attract if held on balance sheet, and 0% otherwise.

Decreasing the degree of correlation between the structured product pool and the wider bank portfolio factors smoothes out capital for investments in high granularity structured product and is therefore comparable to the approach taken by Gordy and Jones in their work on the parameterisation of the Supervisory Formula Approach. Gordy and Jones achieve smoothing by supposing that the seniority of different tranches is random and then integrating over a suitable distribution for levels of protection.

It might be argued that the assumption of imperfect correlation between bank portfolio and structured product pool factors is inconsistent with the approach taken elsewhere in work on capital charges for loans for the Basel review. This is not necessarily the case as one could suppose that loans in the structured product pool have less idiosyncratic risk than do loan in the broader bank portfolio. In this case, the pair wise correlation of loans in the structured product pool and in the broader bank portfolio could be set equal to the correlation between pairs of loans in the broader bank portfolio. This would be both realistic (in that structured product pools will often be fairly concentrated in exposure type) and would yield total capital for the structured product pool if it were held on balance sheet equal to what one would obtain with perfect correlation.

Figure 3 shows capital charges for different granularities for a representative structured product with thin tranches based on an underlying pool of BB-rated loans. As expected, the capital curves become flatter as the granularity is reduced. The intuition is that capital charges equal the expected loss on a tranche conditional on the bank's total losses being at their VaR quantile level. Lower granularity increases idiosyncratic risk and hence shifts expected losses from junior tranches (which, like conventional equity, resemble call options) to senior tranches (which, like conventional debt, resemble short positions in put options).

4.2 Global Consistency

An important basic question one may wish to ask about ratings-based capital charges is how the implied levels of capital for a bank if it held all the tranches compares with what an originator would have to hold against the underlying pool of exposures if the latter were held on balance sheet.

Tables 1,2 and 3 show total capital for some representative structured product structures assuming different correlation levels for the bank-portfolio and structured product -pool factors and assuming different deduction rules. (Recall that under the current Ratings-Based Approach (RBA) contained in the Basel Committee's proposals for structured exposure regulatory capital charges, tranches rated less than BB- are subject to full deduction.)

To understand the entries in the tables, one may consider an example. The uppermost element in the column headed B+ in Table 1 is the sum of the capital for all the tranches in a structured product assuming that a 60% correlation and that exposures rated B+ and below are deducted.

Below the main block of numbers in Table 1 is a small sub-table showing the total capital for all the tranches in the structured product (i) based on capital charges derived from our model but with perfect correlation between risk factors, (ii) implied by the Basel Committee's October 2002 working paper[5] thick tranche RBA weights (see Table A1), (iii) implied by the October 2002 working paper thin tranche RBA weights (see Table A1), and (iv) implied by the QIS 3 formula if the loans were held on balance sheet and no maturity adjustment were made.

The numbers in the Table show that if the loans were held on balance sheet, they would be subject to a 7.2% charge. This figure is confirmed by the perfect-correlation case calculation using the model. The capital implied by the RBA are somewhat lower being 6.0% and 5.6% depending on whether the baseline charges are used or the concessionary weights for thick senior tranches. As one may see from the upper block of numbers, assuming a 90% correlation, deduction for BB+ and below would be needed if the correct model-based charges were used in order to replicate the 7.2% on-balance-sheet capital charge.

Tables 2 and 3 show total capital for structured products similar to that employed in Table 1 but with underlying pool quality of B-rated and BBB-rated loans respectively. The results in Tables 2 and 3 confirm those in Table 1 in that on-balance-sheet capital is slightly higher than that implied by the RBA even without the concessionary treatment of thick senior tranches. Again, using the model-based capital charges and a correlation of 0.9, deduction must start at a higher level than B+ to yield total capital equal to the on-balance sheet charge.

4.3 Rating Category-Specific Consistency

The next issue we examine is the consistency of RBA capital charges from the Basel Committee's October 2002 working paper with those implied by the model for different individual rating categories. Table 4 looks at capital charges for tranches

[5] See Basel Committee on Banking Supervision (2002).

from a structured product with a highly granular underlying portfolio of 256–rated loans under different correlation assumptions.

The results in Table 4 show that the capital charges for the higher rating categories are justified if the correlation between the bank factor and the factor driving the structured product pool is around 60% (although in this case the capital charges on the BB- to BB+ grades in the RBA would perhaps be too high). If a higher correlation is assumed (which is necessary as we saw in the last section if the total capital under the RBA is to approximate to the total on-balance-sheet capital of the structured product pool, then the capital charges for most of the investment grade categories appear too low.

4.4 Granularity Effects

Tables 5, 6 and 7 show capital charges for different rating categories based on underlying structured product pool portfolios with different credit qualities and granularities. In each case, a curve is fitted to the data. In the lower part of the tables (labelled 5b, 6b, and 7b), the results for different credit qualities are averaged.

The Table 5 results are calculated assuming that the structured product exposure is negligibly small compared with the wider bank portfolio. (The par value of the structured product pool exposures is 0.5% of the par value of the exposures in the wider bank portfolio.) Tables 6 and 7 contain results assuming that the structured product exposure is a larger fraction of the total par of the bank's portfolio (3% and 5% respectively).

The results show that when the structured product pool is large relative to the wider bank portfolio, if granularity is low, tranches attract distinctly larger capital requirements than do otherwise comparable tranches of structured product s with well-diversified pools. If the structured product is 5% of the bank portfolio, capital charges for 1-loan securitizations are several times higher than those for securitizations of well-diversified pools. On the other hand, when structured product pools are very small compared to the wider bank portfolio, capital charges for tranches of widely diversified pool structured products are systematically higher than for those of low granularity structured products.

In fact, the granularity results shown in Tables 5 to 7 suggest that there is a significant size effect even leaving aside the granularity of the structured product pools in question. Comparing the model-based capital calculations we report for large structured product exposures with those for negligibly small structured product exposures, it is apparent that the latter have capital charges about a third to a half higher in many cases even if one restricts attention to the high granularity calculations.

4.5 Sector Effects

To investigate the impact on capital charges of the sector from which the underlying assets are taken, we ran a series of simulations under different assumptions about asset correlation and loss given default. The sectors we looked at included (i) credit card receivables, (ii) residential mortgages, (iii) other retail, (iv) small and medium enterprises (SME), and (v) commercial and industrial (C&I). The assumptions adopted coincided with the assumptions made in work completed as part of the parameterisation of the IRB on capital charges for whole loans from these sectors held on balance sheet.

The assumptions on asset correlation and loss given default are given in Table 14. The correlation assumption for residential mortgages was set relatively high in the work on the IRB in an attempt to proxy for their relatively long maturity. Rather than adjust this to more plausibly low levels, we preferred to maintain consistency with the IRB parameterisation work by adopting the same correlation.

The results of our simulations for underlying assets from different sectors are shown in Table 8. As usual, the rows correspond to different underlying pool credit qualities and the columns correspond to different ratings of individual tranches. All the calculations are performed assuming thin tranches and 60% correlation between the underlying pool common factor and the common factor driving the wider bank portfolio.

The consistent finding is that appropriate capital charges for retail exposures to structured product tranches with retail underlying pools are lower than for exposures to tranches with C&I or SME pools. Among structures with retail pools, those requiring highest capital are those with mortgage pools. These results reflect the different assumptions about correlations shown in Table 14. The differences between capital charges across retail and corporate underlying pools disappear for tranches with very low ratings (i.e., sub BB-). However, they appear consistently for tranches with higher ratings and are most marked when the credit quality of the underlying pools is low.

4.6 Maturity Effects

Table 9 shows capital charges by rating category generated using the *Risk Controller* model for one- and three-year maturities. In each case, the maturities of the structured product and of the underlying pool of loans are assumed to be equal. The numbers shown in the table are obtained by fitting curves to capital calculations for three different underlying credit qualities (BBB, BB and B) and then averaging the capital charges for these three curves evaluated at the benchmark expected loss levels corresponding to the ratings.[6]

The results provide evidence of a clear maturity effect. Sampling errors in the Monte Carlos mean the AAA and AA results are not monotonically increasing in maturity

[6] Of course, for a given rating category, the benchmark expected loss for the three-year case is distinctly higher than that for the one-year case.

but for lower rating categories an obvious upward trend in capital charges is evident as maturity rises.

Even though maturity affects the appropriate capital charge for tranches with particular ratings, it is not obvious that the total capital for a structured transaction (i.e., the sum of the capital for all the tranches if they are held by banks) will be inappropriate under the RBA if maturity is higher. The reason is that raising the maturity of the structure and of the underlying assets may lead to a greater fraction of the tranches having lower ratings and hence being subject to the relatively high capital charges the RBA imposes for low-rated tranche exposures.

This point is confirmed by the results shown in Table 10. This compares total RBA capital for a structured transaction entirely held by banks with the capital that a bank would have to hold against the underlying loans under the IRB approach if the loans were held on balance sheet. As one may see, the total RBA capital rises substantially as maturity increases reflecting the fact that the proportion of the deal subject to full deduction increases with maturity.

4.7 Input data

Tables A2, A3, A4 and A5 provide information about the data inputs employed in our calculations. These include a fine-rating category transition matrix used to calculate benchmark expected losses for different fine rating categories, a coarse rating transition matrix used to simulate changes in the ratings of the exposures in the underlying structured product pool and the broader bank portfolio, and the benchmark expected losses used to determine the capital charges associated with each rating category. Table 14 shows the assumptions about asset correlation and LGD assumed in the parameterisation of capital charges for loans from different sectors in the IRB approach.

5. Conclusion

This paper has documented an approach one may use to calculate ratings based capital charges for exposures to structured product tranches. We have employed (i) a simple analytical model, the Pykhtin-Dev model, and (ii) a more elaborate Monte Carlo model, *Risk Controller*. When *Risk Controller* is restricted to cases covered by the Pykhtin-Dev model, the two approaches yield identical results. The *Risk Controller* approach permits one to analyse capital under a wider set of situations, for example when the structured product is large or of maturity greater than one year. (It can also handle many real-world complications of structured products such as collateral and interest coverage triggers, reinvestment periods and more or less aggressive reinvestment policies by collateral managers but these features of the model are not employed in this study.)

We have focussed (i) on the consistency of ratings-based capital weights with the capital that originators would have to hold if they maintained loans on balance sheet,

(ii) on the consistency of the RBA weights proposed by the Basel Committee with model-based measurements of appropriate capital requirements under different assumptions, and (iii) on granularity and maturity effects.

We conclude that, for all except AAA tranches, the capital requirements for investment quality tranches are broadly consistent with the model based capital charges under the assumption that the correlation between risk factors driving the structured exposure pool and the bank's wider portfolio are about 60%.

On granularity, we find that there is a case for an upward adjustment in capital for low granularity structured products when the structured product exposure in question contributes a significant fraction of the credit risk of the bank in question. When the structured product exposure is negligibly small compared with the bank's wider portfolio, the high granularity charges are a conservative estimate of what the true capital should be.

On sector of underlying assets, we find that tranches of structures with underlying pools of retail exposures generally merit less capital than tranches of structures with corporate (either SME or C&I) underlying exposures. This reflects the differences in the asset correlations of exposures coming from these different sectors.

On maturity, we find that longer maturity structures have consistently higher capital charges than one-year maturity structures. In some cases, the longer maturity leads to capital charges that are more than twice as high. However, when structures are of longer maturity, a greater fraction of the total par value of the deal tends to have a lower rating. The effective supervisory over-ride in the RBA by which B-rated and below tranches are deducted from capital means that total capital is significantly higher for long maturities. Hence, despite the lack of an explicit adjustment for maturity in the RBA, the total capital for longer maturity structures is relatively conservative therefore.

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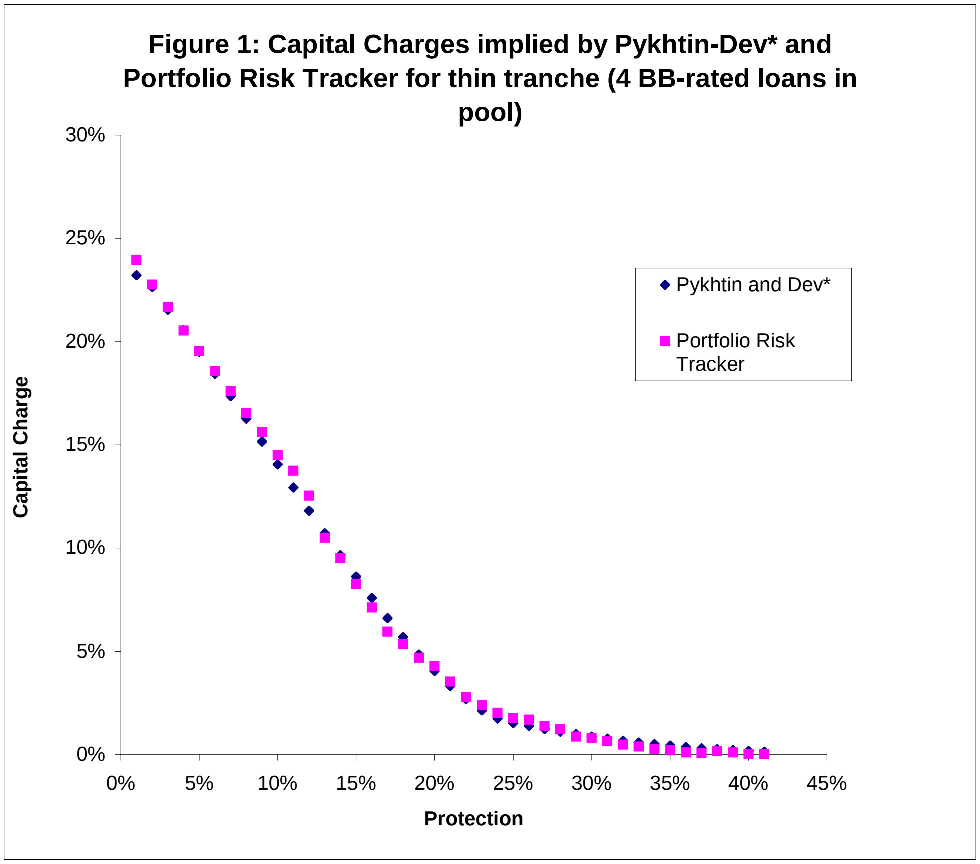

*** A modified version of Pykhtin and Dev model for granular structured products was used which assumes beta-distributed rather than normally-distributed losses given default.**

Figure 2: Thin tranche VaRs under different factor correlation assumptions (64 B-rated loans)

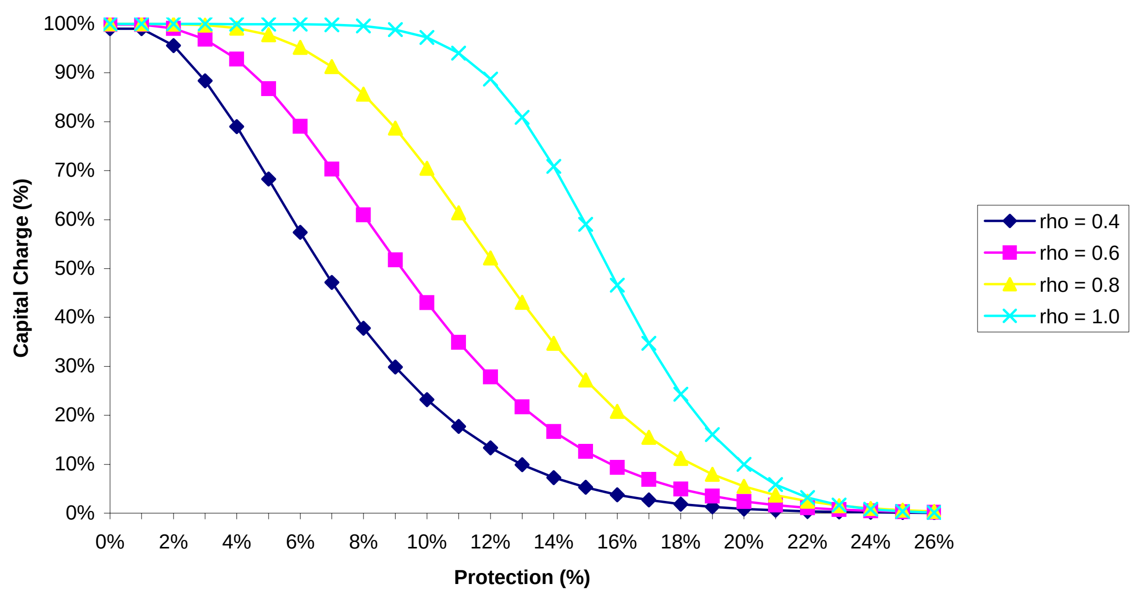

Figure 3: ABS thin tranche capital charges for different granularities (BB-rated loans, 60% correlation)

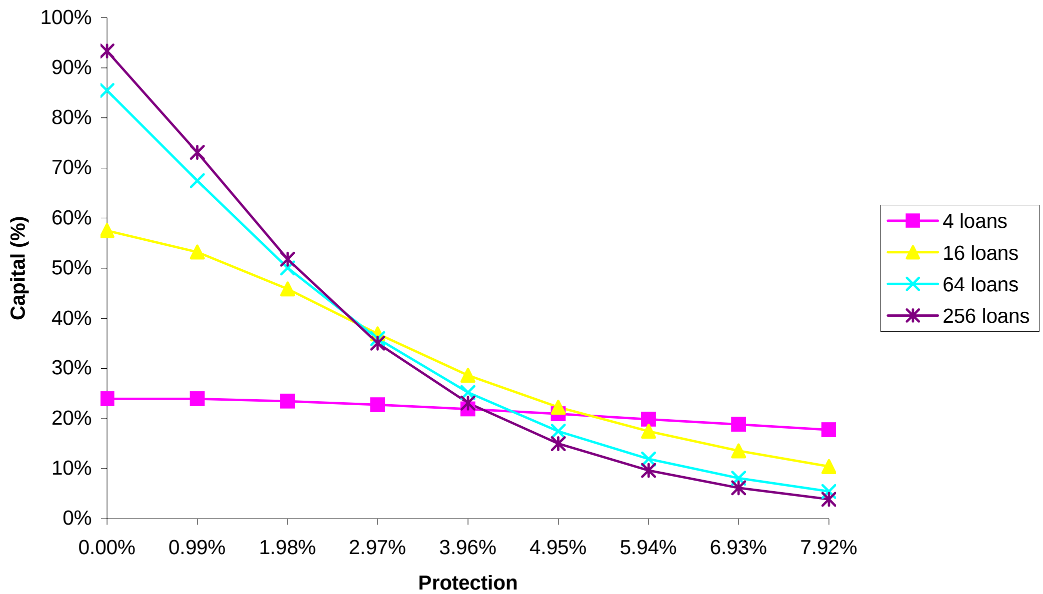

Table 1a

Capital for the entire structure under different deduction rule assumptions (256 BB-rated loans in the pool) *								
Factor correlation	No floor	B-	B	B+	BB-	BB	BB+	BBB-
0.6	3.15%	3.69%	4.09%	4.76%	5.33%	5.95%	6.83%	7.28%
0.7	3.93%	4.24%	4.53%	5.06%	5.56%	6.12%	6.93%	7.36%
0.8	4.85%	4.97%	5.14%	5.50%	5.88%	6.35%	7.07%	7.47%
0.9	5.93%	5.95%	5.99%	6.15%	6.36%	6.68%	7.25%	7.59%

Note:
* Entries in the table are equal to the total capital implied by model using different bank and structured exposure pool factor correlations and different deduction rules. A deduction rule of B+ implies that capital of 100% is imposed on any tranche rated B+ or below. “No floor” column indicates deduction is not imposed for any rating category.

Table 1b

Perfect correlation model capital (1)	7.18%
Thick tranche RBA weights capital (2)	5.61%
Thin tranche RBA weights capital (3)	6.01%
QIS 3 whole loans capital (4)	7.20%

Note:
(1) Capital for entire structure if the structured exposure risk factor and main portfolio risk factor are perfectly correlated.
(2) Capital for entire structure using RBA approach weights from October 2002 working paper.
(3) Capital for a entire structure using RBA approach weights from October 2002 working paper.
(4) Capital for loans using QIS 3 technical guidance formula assuming no maturity adjustment.

Table 2a

Capital for the entire structure under different deduction rule assumptions (256 B-rated loans in the pool)*								
Factor correlation	No cap	B-	B	B+	BB-	BB	BB+	BBB-
0.6	8.68%	9.68%	10.44%	11.59%	12.34%	13.37%	12.34%	14.92%
0.7	10.03%	10.54%	11.07%	11.99%	12.64%	13.56%	12.64%	15.02%
0.8	11.50%	11.68%	11.96%	12.57%	13.07%	13.84%	13.07%	15.14%
0.9	13.11%	13.12%	13.19%	13.44%	13.71%	14.24%	13.71%	15.30%

Table 2b

Perfect correlation model capital (1)	14.83%
Thick tranche RBA weights capital (2)	12.57%
Thin tranche RBA weights capital (3)	12.93%
QIS 3 whole loans capital (4)	14.84%

*See note for tables 1a, 1b

Table 3a

Capital for the entire structure under different deduction rule assumptions (256 BBB-rated loans in the pool)*								
Factor correlation	No cap	B-	B	B+	BB-	BB	BB+	BBB-
0.6	1.08%	1.31%	1.46%	1.80%	1.99%	2.40%	2.84%	3.06%
0.7	1.42%	1.58%	1.68%	1.96%	2.13%	2.50%	2.91%	3.12%
0.8	1.86%	1.93%	2.00%	2.20%	2.33%	2.64%	3.00%	3.20%
0.9	2.40%	2.41%	2.44%	2.53%	2.61%	2.82%	3.11%	3.28%

Table 3b

Perfect correlation model capital	3.05%
Thick tranche RBA weights capital	2.47%
Thin tranche RBA weights capital	2.87%
QIS 3 whole loans capital	3.31%

* See note for tables 1a, 1b

Table 4

Individual tranche capital charges for a highly granular pool of B-rated loans under different factor correlation assumptions

Factor correlation	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
0.6	0.59	0.98	1.30	1.50	1.70	1.90	3.58	4.96	7.06	7.71	10.07	17.11	23.15	32.88	54.28	60.28	77.05
0.7	0.87	1.47	1.98	2.29	2.61	2.92	5.60	7.76	11.02	12.02	15.61	25.81	34.03	46.34	69.47	75.03	88.29
0.8	1.12	1.99	2.75	3.22	3.70	4.18	8.41	11.84	16.97	18.51	23.97	38.62	49.37	63.72	84.77	88.68	95.95
0.9	1.08	2.12	3.16	3.85	4.54	5.24	12.06	17.85	26.48	29.01	37.80	58.72	71.35	84.49	96.03	97.23	98.72
RBA thin tranche*	0.96	1.20			1.60			4.00	6.00	8.00	20.00	34.00	52.00	1.00	1.00	1.00	1.00

*** Based on capital charges from Basel Committee on Banking Supervision (2002).**

Table 5a

Capital charges for individual tranches assuming 60% factor correlation with main bank portfolio and thin tranche structure

	Pool rating	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
1 loan	BBB	0.04	0.08	0.12	0.14	0.17	0.19	0.46	0.72	1.19	1.35	1.99	---	---	---	---	---	---
	BB	0.02	0.05	0.07	0.09	0.10	0.12	0.28	0.44	0.72	0.82	1.21	2.74	4.51	---	---	---	---
	B	0.01	0.03	0.04	0.05	0.06	0.06	0.16	0.24	0.40	0.45	0.67	1.52	2.50	4.66	13.44	17.47	---
	CCC	0.01	0.02	0.03	0.03	0.04	0.04	0.10	0.16	0.26	0.29	0.43	0.98	1.61	3.01	8.69	11.29	23.62
4 loans	BBB	0.13	0.24	0.31	0.34	0.36	0.39	0.66	0.92	1.37	1.52	2.13	4.47	7.14	---	---	---	---
	BB	0.10	0.17	0.24	0.29	0.33	0.37	0.80	1.21	1.75	1.87	2.28	3.75	5.38	8.85	22.18	---	---
	B	0.07	0.12	0.17	0.21	0.24	0.27	0.59	0.85	1.24	1.37	1.86	3.57	5.43	9.10	17.04	20.32	34.73
	CCC	0.03	0.06	0.09	0.11	0.13	0.15	0.35	0.55	0.87	0.97	1.38	2.81	4.35	7.47	17.29	20.98	35.83
16 loans	BBB	0.27	0.46	0.61	0.71	0.79	0.87	1.60	2.22	3.20	3.47	4.37	6.60	8.90	13.73	---	---	---
	BB	0.27	0.45	0.62	0.72	0.82	0.92	1.74	2.41	3.43	3.77	4.95	8.28	11.36	16.90	28.23	32.50	49.95
	B	0.20	0.36	0.49	0.58	0.66	0.74	1.48	2.11	3.05	3.37	4.48	7.94	11.14	16.66	31.37	36.10	51.90
	CCC	0.13	0.23	0.34	0.40	0.47	0.53	1.12	1.63	2.45	2.72	3.69	6.98	10.19	15.90	31.87	37.20	55.34
64 loans	BBB	0.51	0.82	1.10	1.25	1.40	1.55	2.85	3.86	5.39	5.92	7.42	12.31	15.80	22.96	34.86	40.31	60.74
	BB	0.51	0.83	1.10	1.28	1.45	1.60	3.01	4.13	5.81	6.35	8.25	13.84	18.59	26.17	44.03	48.65	64.23
	B	0.44	0.73	0.99	1.16	1.31	1.46	2.81	3.91	5.56	6.07	7.98	13.74	18.70	26.83	46.29	51.89	68.77
	CCC	0.32	0.57	0.79	0.93	1.07	1.20	2.39	3.39	4.96	5.48	7.32	13.04	18.17	26.79	47.02	53.12	71.03
256 loans	BBB	0.69	1.04	1.35	1.54	1.74	1.93	3.55	4.89	6.77	7.43	9.74	15.67	21.22	26.35	47.13	50.45	59.84
	BB	0.68	1.05	1.38	1.57	1.76	1.95	3.66	5.03	7.09	7.78	10.07	16.93	22.86	32.52	51.78	56.97	71.95
	B	0.65	1.01	1.33	1.53	1.72	1.90	3.59	4.96	7.04	7.72	10.05	17.01	23.00	32.69	54.37	59.95	77.07
	CCC	0.56	0.90	1.21	1.40	1.59	1.77	3.39	4.75	6.78	7.43	9.75	16.72	22.83	32.54	54.38	60.46	77.41

Table 5b

Capital charges for individual tranches assuming 60% factor correlation with main bank portfolio and thin tranche structure (average over all underlying pool qualities for each granularity)

1 loan	0.02	0.04	0.06	0.08	0.09	0.10	0.25	0.39	0.64	0.73	1.08	1.74	2.87	3.84	11.07	14.38	23.62
4 loans	0.08	0.15	0.20	0.23	0.27	0.30	0.60	0.88	1.31	1.43	1.91	3.65	5.57	8.47	18.84	20.65	35.28
16 loans	0.21	0.38	0.52	0.60	0.68	0.76	1.49	2.09	3.03	3.33	4.37	7.45	10.40	15.80	30.49	35.27	52.40
64 loans	0.45	0.74	1.00	1.15	1.31	1.45	2.77	3.82	5.43	5.96	7.74	13.23	17.81	25.69	43.05	48.49	66.19
256 loans	0.64	1.00	1.32	1.51	1.70	1.89	3.55	4.91	6.92	7.59	9.90	16.58	22.48	31.02	51.92	56.96	71.57

Table 6a

Portfolio Risk Tracker tranche capital charges for 1 year structure constituting 3% of main bank portfolio with average rating of BBB

	Pool rating	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
1 loan	BBB	0.55	2.77	4.53	5.54	6.46	7.31	13.58	17.40	21.59	22.58	24.97	---	---	---	---	---	---
	BB	1.00	2.56	3.90	4.72	5.49	6.23	12.78	18.12	26.39	29.08	38.98	50.85	51.68	---	---	---	---
	B	1.01	1.96	2.79	3.31	3.81	4.28	8.72	12.54	18.74	20.82	28.70	39.53	47.23	57.12	72.15	74.82	---
	CCC	0.37	0.70	0.99	1.15	1.31	1.46	2.76	3.78	5.33	5.82	7.62	12.55	17.84	26.75	49.00	55.90	76.55
4 loans	BBB	0.36	0.52	0.66	0.74	0.82	0.90	1.59	2.17	3.12	3.44	4.64	8.40	11.65	---	---	---	---
	BB	0.46	0.85	1.17	1.35	1.52	1.68	2.93	3.79	4.95	5.28	6.39	8.64	11.33	16.58	33.70	---	---
	B	0.72	1.01	1.23	1.36	1.47	1.58	2.42	3.00	3.80	4.04	4.85	10.34	14.01	19.50	32.33	36.57	52.52
	CCC	0.34	0.39	0.44	0.47	0.51	0.55	1.07	1.67	2.82	3.24	4.97	9.86	14.27	21.19	37.67	42.84	59.82
16 loans	BBB	0.48	0.69	0.87	0.97	1.07	1.16	1.91	2.48	3.35	3.63	4.62	7.92	10.67	15.66	---	---	---
	BB	0.48	0.69	0.86	0.97	1.07	1.17	2.11	2.94	4.33	4.81	6.64	12.32	16.24	22.03	35.31	39.62	55.53
	B	0.39	0.72	1.01	1.18	1.34	1.49	2.85	3.96	5.69	6.25	8.34	14.15	18.69	25.67	41.70	46.62	62.61
	CCC	0.11	0.33	0.52	0.63	0.74	0.84	1.73	2.43	3.50	3.84	5.09	10.41	15.69	23.74	41.99	47.53	65.28
64 loans	BBB	0.63	1.03	1.35	1.54	1.72	1.89	3.28	4.33	5.88	6.36	8.07	13.16	16.71	22.16	36.09	41.15	---
	BB	0.60	1.23	1.74	2.04	2.31	2.56	4.57	5.98	7.87	8.42	10.23	16.39	21.03	28.30	45.24	50.42	66.73
	B	0.40	0.78	1.11	1.32	1.51	1.70	3.43	4.91	7.29	8.09	11.09	17.68	22.97	30.92	48.57	53.83	70.36
	CCC	0.70	1.27	1.74	2.01	2.27	2.51	4.50	6.00	8.15	8.82	11.18	19.11	26.42	36.73	57.11	62.64	78.64
256 loans	BBB	0.67	1.19	1.61	1.85	2.07	2.28	3.91	5.06	6.62	7.07	8.60	16.92	22.09	30.02	47.80	53.03	---
	BB	0.80	1.38	1.84	2.10	2.35	2.58	4.40	5.69	7.45	7.98	9.74	16.04	21.19	29.51	49.43	55.51	73.89
	B	0.95	1.53	1.99	2.26	2.51	2.74	4.66	6.08	8.11	8.73	10.93	19.57	26.23	35.81	55.50	61.01	77.43
	CCC	0.45	1.08	1.60	1.91	2.20	2.47	4.73	6.41	8.82	9.56	12.13	20.78	28.45	39.10	59.57	64.97	80.23

Table 6b

Portfolio Risk Tracker tranche capital charges for 1 year structure constituting 3% of main bank portfolio with average rating of BBB
(average over all underlying pool qualities for each granularity)

	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
1 loan	0.73	2.00	3.05	3.68	4.27	4.82	9.46	12.96	18.01	19.58	25.07	34.31	38.92	41.93	60.57	65.36	76.55
4 loans	0.47	0.69	0.87	0.98	1.08	1.18	2.00	2.66	3.67	4.00	5.21	9.31	12.81	19.09	34.56	39.70	56.17
16 loans	0.36	0.61	0.81	0.94	1.05	1.16	2.15	2.95	4.22	4.63	6.17	11.20	15.32	21.78	39.66	44.59	61.14
64 loans	0.58	1.08	1.49	1.73	1.95	2.16	3.95	5.30	7.30	7.92	10.14	16.58	21.78	29.53	46.75	52.01	71.91
256 loans	0.72	1.30	1.76	2.03	2.28	2.52	4.43	5.81	7.75	8.33	10.35	18.33	24.49	33.61	53.08	58.63	77.18

Table 7a

Portfolio Risk Tracker tranche capital charges for 1 year structure constituting 5% of main bank portfolio with average rating of BBB

	Asset quality	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
1 loan	BBB	0.20	3.63	6.40	8.02	9.50	10.86	21.39	28.21	36.45	38.62	44.89	---	---	---	---	---	---
	BBB	1.53	3.77	5.70	6.88	7.99	9.05	18.49	26.19	38.13	42.01	56.32	84.20	89.88	---	---	---	---
	B	1.50	3.01	4.33	5.15	5.93	6.69	13.71	19.75	29.54	32.82	45.23	69.62	79.76	87.62	91.11	93.35	---
	CCC	0.58	1.57	2.42	2.93	3.42	3.88	7.92	11.16	16.10	17.68	23.47	33.75	42.26	53.92	75.20	80.37	92.77
4 loans	BBB	0.85	1.15	1.39	1.53	1.66	1.79	2.85	3.70	5.03	5.46	7.08	12.16	15.51	---	---	---	---
	BBB	1.08	1.95	2.63	3.02	3.37	3.69	6.12	7.67	9.52	10.01	11.41	14.83	18.87	26.15	44.41	---	---
	B	1.34	2.64	3.66	4.24	4.78	5.27	8.98	11.37	14.26	15.03	17.27	24.80	29.77	36.73	50.83	54.92	68.63
	CCC	0.56	1.78	2.76	3.34	3.87	4.36	8.28	10.96	14.48	15.48	18.69	25.30	31.03	39.30	56.33	61.12	75.40
16 loans	BBB	0.52	0.76	0.95	1.06	1.16	1.26	2.04	2.62	3.46	3.73	4.65	7.89	10.65	15.71	---	---	---
	BBB	0.56	1.00	1.36	1.57	1.77	1.96	3.56	4.80	6.64	7.22	9.32	14.94	18.84	24.52	37.40	41.62	57.76
	B	0.66	1.13	1.52	1.76	1.97	2.18	3.96	5.37	7.51	8.19	10.70	16.79	21.69	29.15	45.94	51.00	67.00
	CCC	0.34	0.68	0.97	1.14	1.30	1.46	2.76	3.77	5.27	5.74	7.44	13.99	19.96	28.77	47.74	53.27	70.41
64 loans	BBB	0.77	1.29	1.70	1.94	2.17	2.38	4.07	5.30	7.03	7.55	9.36	14.40	17.82	22.94	35.87	40.66	---
	BBB	0.74	1.40	1.93	2.24	2.53	2.80	4.97	6.54	8.71	9.36	11.58	18.04	23.01	30.66	48.02	53.21	69.21
	B	0.52	0.95	1.33	1.56	1.79	2.00	4.03	5.79	8.67	9.64	13.33	21.39	27.55	36.45	54.85	60.04	75.60
	CCC	0.75	1.38	1.91	2.22	2.52	2.80	5.20	7.09	9.94	10.85	14.15	23.13	30.99	41.82	62.25	67.54	82.22
256 loans	BBB	0.74	1.29	1.72	1.96	2.19	2.40	4.07	5.23	6.77	7.21	8.68	17.11	22.32	30.33	48.46	53.84	---
	BBB	0.89	1.60	2.15	2.47	2.77	3.04	5.15	6.58	8.43	8.96	10.64	17.92	23.37	31.99	52.09	58.11	76.12
	B	0.96	1.63	2.16	2.48	2.77	3.05	5.33	7.05	9.53	10.31	13.04	22.48	29.52	39.46	59.14	64.48	79.91
	CCC	0.60	1.30	1.87	2.21	2.53	2.82	5.27	7.09	9.69	10.48	13.25	22.97	31.04	42.13	62.94	68.30	83.07

Table 7b

Portfolio Risk Tracker tranche capital charges for 1 year structure constituting 5% of main bank portfolio with average rating of BBB
(average over all underlying pool qualities for each granularity)

	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
1 loan	0.95	3.00	4.71	5.74	6.71	7.62	15.38	21.33	30.06	32.78	42.48	62.52	70.63	70.77	83.15	86.86	92.77
4 loans	0.96	1.88	2.61	3.03	3.42	3.78	6.56	8.43	10.82	11.49	13.61	19.27	23.80	34.06	50.52	58.02	72.01
16 loans	0.52	0.89	1.20	1.38	1.55	1.71	3.08	4.14	5.72	6.22	8.03	13.40	17.79	24.54	43.69	48.63	65.06
64 loans	0.69	1.26	1.72	1.99	2.25	2.49	4.57	6.18	8.59	9.35	12.11	19.24	24.84	32.97	50.25	55.36	75.68
256 loans	0.80	1.45	1.98	2.28	2.56	2.83	4.96	6.49	8.61	9.24	11.41	20.12	26.56	35.98	55.66	61.18	79.70

Table 8a

Pykhtin-Dev-based tranche capital charges for credit card receivables pool assuming 60% correlation and thin tranche structure																	
	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
BBB	0.61	0.94	1.25	1.45	1.61	1.76	3.33	4.4	6.2	6.8	8.7	14.1	19.8	24.8	45.2	48.2	56.5
BB	0.60	0.93	1.24	1.41	1.59	1.77	3.30	4.5	6.5	7.1	9.0	15.1	20.9	28.9	48.3	54.2	69.8
B	0.38	0.65	0.88	1.03	1.18	1.32	2.51	3.4	4.9	5.5	7.0	12.1	16.8	24.1	43.1	48.0	65.3
CCC	0.16	0.32	0.46	0.53	0.60	0.67	1.39	2.1	3.4	3.8	5.5	12.3	17.9	26.2	46.1	51.8	69.7
Average	0.44	0.71	0.95	1.10	1.24	1.38	2.63	3.61	5.24	5.79	7.57	13.41	18.87	25.99	45.68	50.52	65.32

Table 8b

Pykhtin-Dev-based tranche capital charges for residential mortgages pool assuming 60% correlation and thin tranche structure																	
	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
BBB	0.48	0.81	1.15	1.35	1.44	1.52	2.42	3.3	4.9	5.4	7.6	11.2	11.9	13.5	20.1	23.1	37.5
BB	0.62	0.95	1.28	1.50	1.66	1.81	3.41	4.7	6.4	7.0	9.4	15.0	20.5	29.4	45.5	52.8	65.2
B	0.64	0.98	1.32	1.51	1.69	1.87	3.52	5.0	6.9	7.6	9.9	16.9	23.2	32.6	53.7	59.5	76.2
CCC	0.45	0.79	1.06	1.24	1.42	1.60	3.12	4.4	6.4	7.0	9.2	16.1	22.3	32.1	54.3	60.5	77.8
Average	0.54	0.88	1.21	1.40	1.55	1.70	3.12	4.35	6.14	6.77	9.03	14.78	19.47	26.92	43.39	48.99	64.17

Table 8c

Pykhtin-Dev-based tranche capital charges for other retail pool assuming 60% correlation and thin tranche structure																	
	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
BBB	0.65	1.00	1.31	1.49	1.67	1.85	3.39	4.8	6.5	7.1	9.4	14.9	20.9	26.6	47.5	49.9	58.5
BB	0.65	1.01	1.32	1.52	1.71	1.89	3.50	4.8	6.9	7.5	9.7	16.4	21.8	30.7	50.6	57.3	72.8
B	0.46	0.77	1.02	1.19	1.36	1.50	2.86	3.9	5.6	6.1	8.0	13.7	18.5	26.7	46.5	51.8	68.9
CCC	0.20	0.34	0.48	0.58	0.67	0.77	1.76	2.7	4.5	5.1	7.4	13.0	17.9	26.0	45.5	51.7	69.8
Average	0.49	0.78	1.03	1.19	1.35	1.50	2.88	4.07	5.84	6.42	8.62	14.48	19.77	27.50	47.50	52.69	67.48

Table 8d

Pykhtin-Dev-based tranche capital charges for small and medium enterprises pool assuming 60% correlation and thin tranche structure																	
	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
BBB	0.68	1.04	1.35	1.53	1.72	1.90	3.49	4.9	6.7	7.3	9.3	15.4	19.6	28.8	39.9	42.3	54.0
BB	0.68	1.05	1.36	1.57	1.77	1.95	3.62	5.0	7.0	7.7	10.0	16.8	22.9	31.5	51.5	59.0	71.4
B	0.63	1.00	1.33	1.51	1.70	1.88	3.57	4.9	6.9	7.6	9.9	16.8	22.7	32.3	53.5	59.7	76.2
CCC	0.44	0.88	1.22	1.41	1.60	1.79	3.39	4.7	6.7	7.4	9.7	16.7	22.7	32.7	54.6	60.6	77.9
Average	0.61	0.99	1.31	1.51	1.70	1.88	3.51	4.88	6.86	7.50	9.73	16.43	21.97	31.33	49.87	55.42	69.88

Table 9

*Portfolio Risk Tracker tranche capital charges for a highly granular BB-rated small structures with different maturities**																	
	AAA	AA+	AA	AA-	A-	A+	A+	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC
1 year	0.54	0.99	1.36	1.58	1.77	1.96	3.50	4.63	6.25	6.75	8.75	14.78	19.87	28.30	49.53	56.21	76.26
2 years	0.17	0.86	1.72	1.89	2.27	2.70	4.99	6.98	9.30	11.83	14.65	20.50	26.31	35.74	55.72	62.58	78.81
3 years	0.67	1.55	2.68	2.80	3.31	3.93	6.29	8.55	10.91	14.59	18.66	24.57	30.93	40.79	58.84	65.15	77.46
4 years	1.41	2.53	3.86	3.99	4.62	5.45	7.88	10.38	12.86	17.32	20.97	26.49	32.83	42.27	56.79	61.28	67.66
5 years	1.29	2.49	3.82	3.96	4.67	5.62	7.96	10.51	13.03	17.83	23.05	29.14	35.98	45.27	57.17	60.41	64.02

***Note: 0.5 recovery rate was assumed.**

Table 10

Portfolio Risk Tracker total capital charges for a BB-rated pool on and off balance sheet			
Maturity	Whole loans IRB	Off balance sheet (RBA thin)	Off balance sheet (RBA thick)
1	8.0	5.8	5.4
2	9.1	8.2	7.9
3	10.2	10.4	10.1
4	11.3	13.2	12.9
5	12.4	15.7	15.5

Table A1

Tranche capital charges in October 2002 Basel proposals		
External rating	Thin Tranche Capital Charge (%)	Thick Tranche Capital Charge (%)
AAA	0.96	0.56
AA+	1.2	0.8
AA	1.2	0.8
AA-	1.2	0.8
A+	1.6	1.6
A	1.6	1.6
A-	1.6	1.6
BBB+	4	4
BBB	6	6
BBB-	8	8
BB+	20	20
BB	34	34
BB-	52	52
Below B+ and unrated	Deduction	Deduction

Table A2

Standard & Poors fine rating grades transition probabilities matrix (adjusted for withdrawn ratings) used in calculation of benchmark expected losses*

	AAA	AA+	AA	AA-	A-	A	A+	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC	D
AAA	0.93266	0.03372	0.02373	0.00416	0.00146	0.00177	0.00114	0.00062	0.00031	0.00000	0.00000	0.00031	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010
AA+	0.02055	0.83468	0.09624	0.03232	0.00289	0.00878	0.00072	0.00000	0.00217	0.00072	0.00000	0.00000	0.00000	0.00072	0.00000	0.00000	0.00000	0.00020
AA	0.00641	0.01251	0.85768	0.07194	0.02419	0.01468	0.00269	0.00465	0.00217	0.00093	0.00052	0.00021	0.00021	0.00021	0.00000	0.00021	0.00052	0.00030
AA-	0.00052	0.00303	0.03208	0.83403	0.08578	0.03406	0.00502	0.00199	0.00115	0.00031	0.00031	0.00000	0.00000	0.00000	0.00136	0.00000	0.00000	0.00037
A-	0.00000	0.00062	0.00624	0.04132	0.83377	0.07723	0.02592	0.00604	0.00364	0.00125	0.00042	0.00104	0.00021	0.00104	0.00062	0.00000	0.00021	0.00043
A	0.00063	0.00094	0.00492	0.00754	0.04787	0.82801	0.05604	0.03185	0.01163	0.00325	0.00178	0.00178	0.00136	0.00147	0.00010	0.00000	0.00031	0.00050
A+	0.00126	0.00052	0.00146	0.00439	0.01046	0.07072	0.79041	0.07459	0.02762	0.00774	0.00220	0.00335	0.00126	0.00167	0.00021	0.00021	0.00073	0.00120
BBB+	0.00031	0.00031	0.00052	0.00157	0.00481	0.01706	0.07136	0.77315	0.08266	0.03055	0.00513	0.00377	0.00157	0.00241	0.00157	0.00000	0.00136	0.00188
BBB	0.00021	0.00021	0.00096	0.00096	0.00426	0.00778	0.01865	0.06875	0.79599	0.05756	0.01983	0.01066	0.00426	0.00330	0.00234	0.00000	0.00117	0.00309
BBB-	0.00064	0.00000	0.00096	0.00192	0.00192	0.00447	0.00511	0.02109	0.07605	0.76835	0.05464	0.03004	0.01118	0.00703	0.00383	0.00383	0.00543	0.00351
BB+	0.00108	0.00000	0.00000	0.00054	0.00162	0.00313	0.00313	0.00789	0.03555	0.11183	0.69789	0.05543	0.03706	0.01567	0.01145	0.00205	0.01048	0.00519
BB	0.00000	0.00000	0.00088	0.00044	0.00000	0.00252	0.00120	0.00164	0.01259	0.03865	0.06591	0.73109	0.07303	0.02891	0.01259	0.00756	0.01128	0.01172
BB-	0.00000	0.00000	0.00000	0.00033	0.00066	0.00033	0.00186	0.00252	0.00351	0.00823	0.02940	0.07810	0.71570	0.08413	0.02940	0.01327	0.01327	0.01930
B+	0.00000	0.00022	0.00000	0.00089	0.00000	0.00067	0.00167	0.00089	0.00134	0.00212	0.00456	0.01659	0.05087	0.77201	0.06034	0.02572	0.02605	0.03607
B	0.00000	0.00000	0.00101	0.00000	0.00000	0.00235	0.00235	0.00000	0.00190	0.00101	0.00526	0.00671	0.01902	0.07442	0.67995	0.04868	0.05338	0.10396
B-	0.00000	0.00000	0.00000	0.00000	0.00114	0.00000	0.00114	0.00216	0.00114	0.00114	0.00216	0.00329	0.00432	0.03783	0.06804	0.63342	0.10917	0.13507
CCC	0.00126	0.00000	0.00000	0.00000	0.00126	0.00000	0.00126	0.00515	0.00252	0.00000	0.00252	0.00389	0.01018	0.02172	0.03453	0.04608	0.58701	0.28264
D	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000

***Note: Non-zero default probabilities were assumed for AAA, AA+, AA rating grades and default probabilities for AA-, A+, A, A- rating grades were adjusted in such a way that default probabilities are monotonically increasing in rating category.**

Table A3

S&P coarse rating grades transition probabilities matrix used in Credit Explorer to simulate rating transitions for structured exposures								
	AAA	AA	A	BBB	BB	B	CCC	D
AAA	0.9327	0.0616	0.0045	0.0009	0.0003	0.0000	0.0000	0.0000
AA	0.0062	0.9163	0.0704	0.0053	0.0005	0.0009	0.0002	0.0001
A	0.0006	0.0219	0.9175	0.0527	0.0045	0.0018	0.0004	0.0005
BBB	0.0003	0.0024	0.0462	0.8942	0.0440	0.0077	0.0024	0.0028
BB	0.0002	0.0007	0.0045	0.0628	0.8297	0.0770	0.0119	0.0133
B	0.0000	0.0009	0.0030	0.0039	0.0533	0.8287	0.0436	0.0666
CCC	0.0013	0.0000	0.0025	0.0077	0.0166	0.1023	0.5870	0.2826
D	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Table A4

Benchmark expected losses implied by Standard & Poor’s fine rating grades transition probabilities matrix*					
	1 year	2 years	3 years	4 years	5 years
AAA	0.000045	0.000096	0.000157	0.000231	0.000320
AA+	0.000090	0.000200	0.000341	0.000520	0.000738
AA	0.000135	0.000360	0.000649	0.000987	0.001367
AA-	0.000165	0.000395	0.000687	0.001037	0.001442
A-	0.000195	0.000480	0.000853	0.001311	0.001852
A	0.000225	0.000583	0.001078	0.001710	0.002474
A+	0.000540	0.001251	0.002124	0.003152	0.004327
BBB+	0.000848	0.001999	0.003408	0.005042	0.006876
BBB	0.001391	0.003050	0.005029	0.007323	0.009901
BBB-	0.001582	0.004412	0.008112	0.012404	0.017078
BB+	0.002334	0.006865	0.012688	0.019237	0.026143
BB	0.005272	0.012609	0.021198	0.030448	0.039934
BB-	0.008687	0.020063	0.032879	0.046215	0.059437
B+	0.016231	0.035917	0.056519	0.076552	0.095223
B	0.046783	0.087340	0.121296	0.149192	0.171906
B-	0.060780	0.112385	0.153212	0.184540	0.208352
CCC	0.127190	0.198327	0.240227	0.266255	0.283353

***To calculate expected losses on a loan with rating R, we assumed that the loan pays an annual coupon rate payment equal to $r+S_R$, where r is the average interest rate over loan’s maturity, S_R is the average spread associated with rating R.**

Table A5

Assumed asset correlation parameters and LGD					
	C&I	Credit Cards	Retail	MBS	SME
ρ_{BBB}	0.223	0.132	0.155	0.150	0.203
ρ_{BB}	0.181	0.086	0.114	0.150	0.161
ρ_{B}	0.124	0.024	0.034	0.150	0.104
ρ_{CCC}	0.120	0.020	0.020	0.150	0.100
LGD	0.45	0.8	0.75	0.25	0.45