The Marginal Impact of Granularity on Banks' Credit Risk Capital Charge

by

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Abstract

This paper aims to evaluate the fine-grained assumption implied in the formula specified by the Bank for International Settlements Basel Committee on Banking's internal-ratings based (IRB) approach under Pillar 1 of Basel II: minimum capital requirement. We compared the regulatory capital charge under Basel II with true unexpected loss approximated by Monte-Carlo simulations. We showed that the fine-grained assumption in IRB formula would cause regulatory capital charge to deviate from the true unexpected loss when there is concentration in the portfolio. Meanwhile, the IRB approach gives misleading information on the risk contribution of added large loans with low probability of default, which could be exploited by banks as a means to increase risk concentrations while holding lower regulatory capital. Moreover, as both the Monte-Carlo simulation and IRB formula are Value at Risk (VaR) approaches, we set out to discuss the limitation of using VaR as a risk measure by looking at a special case where VaR seems to lose credibility. We suggested two alternatives to account for this deficiency.

Key words: Basel II, IRB, VaR, Monte-Carlo Simulation, Unexpected Loss, Granularity, Expected Shortfall

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1. Background

1.1. The 1988 Basel Accord

Back in 1980's, the so-called "less developed countries" debt crisis struck the financial industry and caused international banks to be severely undercapitalized in unregulated territories. Such trend was troublesome to banking practitioners and regulators and consequently convinced them to establish a standardized banking regulation in a global sense.

The Bank for International Settlement, composed of central banks of leading developed nations, took the initiative to work on this issue. By 1988, the original Basel Accord was organized under Basel Committee on Banking Supervision, which was set up by the BIS. The accord imposed a uniform, risk-weighted minimum capital to asset ratio of 8% on internationally active bank across their entire family of subsidiaries (Basel Committee on Banking Supervision, 1988), also known as Basel I. Under Basel I banks needed to categorize their assets into different asset classes. The purpose was to create incentives for banks to load up asset classes with lower risk, as they have to set aside additional capital for higher-risk asset classes. However, by imposing a uniform 8% capital charge, Basel I did not differentiate loans of different risk profiles within each asset class.

In the following years, the United States and Japan suffered from the economic downturn and credit crunch. In an attempt to comply with Basel's regulatory requirement, undercapitalized banks were forced to slow down lending, which exacerbated the credit crisis further (Peek and Rosengreen, 1995).

Empirically, the 1988 Accord was widely criticized for the over-simplicity in risk capital computation and the exclusive focus on commercial banks and credit risk. Furthermore, its "one size fits all" approach generated unintended incentives for banks to conduct the so called "regulatory arbitrage" (Jackson, 1999). It was argued that the uniform risk weights under Basel I did not correctly reflect the true internal risk weights across all assets. Thus banks would seek arbitrage profit between constant uniformly-set regulatory charge and highly variable internal economic risk charge. In addition, banks learned to abuse two major inventions in 1990s, the securitization and credit derivatives to move from low risk assets to high risk assets while transferring the excess risk to other parties. In summary, 1988 Basel Accord's implementation ended up worsening the internal risk allocation in banks due to its crudely designed mechanism.

1.2. Basel II

Being fully aware of the major controversy of Basel I, the Basel Committee started the contemplation in 1999 in an attempt to improve the capital adequacy standard such that regulatory capital better reflects economic capital. After several years of consultation and revision, in 2004, Basel committee proposed a revised framework generally known as Basel II, which tackled the gap between two capital charges by allowing banks to use their own risk profiles as inputs to calculate the risk capital. The proposal was carried out in the late 1990's through a general guideline and followed by two detailed drafts in response to industrial comments (Basel Committee on Banking Supervision, 2001).

The innovations in Basel II consist of the imposition of three Pillars, inclusion of market risk, introduction of operational risk and the application of internal ratings based model. Pillar II supervisory review process is intended to foster an active dialogue between banks and supervisors to ensure that banks are continuously developing a better risk management system (Basel Committee on Banking Supervision, 2004). Pillar III market discipline requires certain banks to disclose detailed risk management practices. Basel Committee aims to create incentives for banks to enhance their risk practices by encouraging market participation. The new standard also recognizes a wider range of financial features such as collaterals and guarantees used in risk deductions.

The most important innovation, also the core of Basel II framework is the internal rating based computation, generally known as IRB. In deed, the majority of the consultation and research has been dedicated to this area (Basel Committee on Banking Supervision, 2001). Under Basel II, banks are given three options in computing capital for credit risk.

1.2.1. Standardized Approach

Smaller banks with less complex forms of lending and simpler internal structure can choose to use the “standardized” approach. Like in Basel I, this approach does not require banks to provide their own input. The major distinction lies in risk weights being no longer tied to legal status as in Basel I but instead dependent on the externally estimated default probability.

1.2.2. Foundation and Advanced IRB

The IRB approach is a critical innovation in the regulatory capital treatment of credit risk. It is a credit risk model in a form of analytical solutions designed by regulators to meet their prudential objectives. It is a challenging task for Basel committee to develop a standardized formula applicable to all participating banks without oversimplifying the mathematical process. Thus this formula is far from being all inclusive and we will look at the issues later in this paper.

Under the IRB formula, each bank divides its assets into up to 14 different classes, for thirteen of those classes-except equity stock, the IRB formula applies. Then within each asset class, banks subdivide it by borrower credit grades of relatively homogenous characteristics. For each credit grade, the IRB formula requires banks to generate their own estimates for probability of default (PD), loss given default (LGD), remaining maturity (M) and exposure at default (EAD), those inputs can be derived from historical data or specific information about each asset. And then these internal bank estimates are converted into a capital charge for each asset through the IRB formula (BCBS, 2005).

1.3. Advanced IRB Approach

1.3.1. Explanation on advanced IRB

The IRB formula is designed to generate the minimum amount of capital that, in the minds of regulators, is necessary to cover the economic losses of the portfolio. Banks cover their expected losses on an ongoing basis by provisions and write-offs. The unexpected loss, on the other hand, covers potential large losses additional to regular losses that occur in rare occasions. The capital required to cover unexpected loss is based on a statistical distribution of potential losses for a portfolio measured over a given period and within a specified confidence level. The IRB approach builds on 99.9% confidence level and a one-year horizon. Unexpected loss is obtained by taking the difference between the mean loss and the potential loss represented by the confidence level of 99.9%.

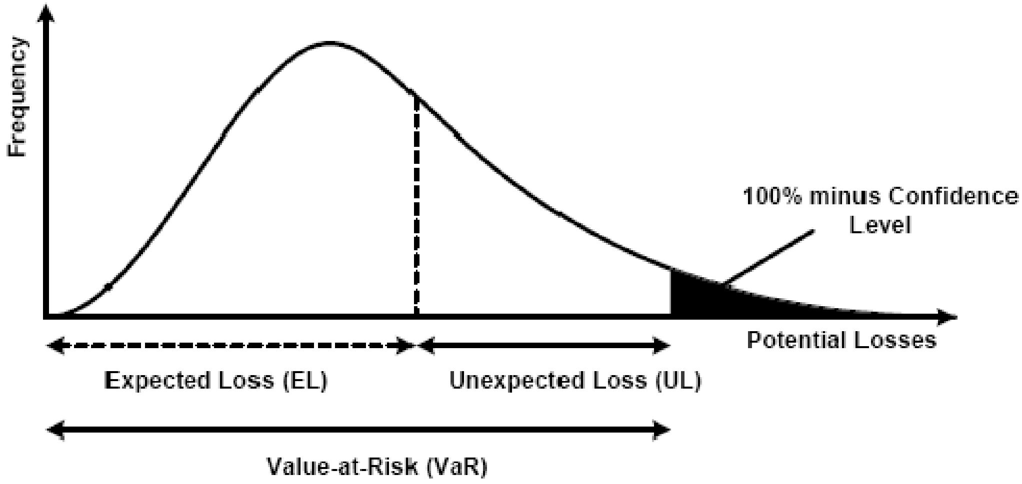

Figure 1.3 IRB from a VaR perspective (BCBS, 2005)

The Basel formula is centered on Vasicek model. The purpose of this model is to determine the expected loss and unexpected loss for a particular counterparty. Expected loss is equal to PD times LGD times EAD, whereas unexpected loss is estimated by determining the PD in a downturn situation. The model assumes that EAD and LGD are constant for an obligor at least within one year. Thus the down turn loss is calculated by multiplication of conditional PD, LGD and EAD. Unexpected loss is calculated by subtracting expected loss from loss during a downturn situation, which can be expressed as:

$$UL = (PD_{downturn} \times LGD \times EAD) - (PD \times LGD \times EAD)$$

The formula for PD downturn could be derived from Vasicek model, it is a conditional probability of default under the assumption that the economy is in a bad state. It could be written as:

$$N\left\{\frac{N^{-1}(PD) + \sqrt{\rho_v} \times N^{-1}(q)}{\sqrt{1-\rho_v}}\right\}$$

Here N(A) denotes the standard normal distribution function with critical value of A and $N^{-1}(p)$ denotes the inverse function of N(A) with probability equal to p.

The Basel II equation for the IRB capital charge for corporations, sovereigns and banks is given by

$$K = \left\{ LGD \times N\left(\sqrt{\frac{1}{1-\rho}} \times \left[N^{-1}(PD) + \sqrt{\rho} \times N^{-1}(.999) \right] \right) - PD \times LGD \right\} \times SF_{MATURITY}$$

Risk weighted assets is then calculated as $12.5 \times K \times EAD$

$SF_{MATURITY}$ is a scale factor to adjust for maturity effects, and this adjustment does not exist for retail portfolios. Later we will elaborate on the rationale for this adjustment.

1.3.2. Implicit assumptions

The foundation of IRB's framework stems from Vasicek's study on portfolio loss distribution, in which he showed that the loss distribution converges to an analytical form solution with increasing portfolio size to a limited type (Vasicek, 1991). Vasicek used a similar approach compared to Merton's (1974) in modeling default behaviour from a firm value perspective.

Gordy (2003) showed that the two important premises to apply Vasicek's formula in Basel's framework are single factor and granularity. Those two are crucial premises to insure a portfolio-invariant capital charges, i.e. the default characteristic of individual loan only depends on its own default parameters regardless of which portfolio it is placed in (Gordy, 2003). Such property of being portfolio-invariant is crucial in Basel's internal rating based model since when violated, the comparability across different banks will be jeopardized.

1. Single Factor:

One-factor risk model has been widely adopted in portfolio credit risk modeling. In the one-factor framework, credit risks come from two sources only: systematic risks and idiosyncratic risks. It has the benefit of easy computation and more importantly, it can be used to derive a simple dependent structure with significant tractability. Additionally, the information may not always be available for multi-factors (Tasche and Emmer, 2005).

One factor risk model is particularly appealing to imposition of a standardized capital charge framework since it provides an attainable dependent structure for the analytical solution of the proposed methodology of Basel IRB method. Explicitly or implicitly, the common factor in the model is referred to the economic condition. Yet commercial credit risk models such as CreditMetrics do not base on one-factor model assumption due to its rather weak theoretical justification (Credit Swiss First Boston). It is general agreed that a calibration of multiple-factor is not tractable in IRB's framework (Gordy, 2003). Recently, efforts have been made in the multi-factor adjustment in analytical form solutions and Pykhtin (2004) developed a method to conduct such computation.

2. Granularity

The analytical solution under Basel's IRB framework assumes that the portfolio under examination is asymptotic and fine-grained. Thus IRB is also known as the Asymptotic Single Risk Factor Model, i.e. ASRF model. A fine-grained portfolio requires every individual instrument account for an arbitrarily small share of the total exposure such that the idiosyncratic risks of individual instrument are diversified away.

In reality however, portfolios rarely exhibit a perfectly fine granularity. It is common to observe some degrees of concentration on a particular obligor in the portfolio. Thus by applying the Basel IRB framework, it is generally agreed that the capital output is understated since the idiosyncratic risks are not completely diversified (Gordy, 2003). The granularity assumption could be approximately valid for large institutions but less accurate with smaller and more specialized ones. The IRB approach due to its underpinning theory, completely omits the contribution of the possible undiversified idiosyncratic risks.

Thus studies have been put forward in an attempt to quantify the necessary adjustment without losing too much tractability of the framework. The basic methodology and concept of granularity adjustment was introduced by Gordy in 2000 (Gordy, 2003) where he derived the simple adds-on charge for undiversified risk by analyzing the rate of convergence between coarse and fine-grained portfolios. The Basel Committee recognized and introduced the granularity adjustment formal based on Gordy's study in 2001 (BCBS, 2001). However due to the complexity of this issue, granularity adjustment was shifted from Pillar 1 to Pillar 2 in the following consultation paper. Then the method was refined by Wilde (2001b) as well as Martin and Wilde (2003). Tasche and Emmer (2005) summarized the above methods and improved the analytical form for the adjustment. Besides, they proposed an alternative method to tackle concentration risk called semi-asymptotic approach, which allows them to isolate the concentrated instrument and regard the rest of the portfolio fine-grained. Finally Gordy and Lutkebohmert in 2007 revised the granularity adjustment method and developed an approximation approach, which would reduce banks' burden in data crunching and computation.

3. Correlation

In the IRB formula, a very important assumption is the level of the correlation parameter. As the model employs only one systematic risk factor, the degree of the obligor's exposure to the systematic risk factor is expressed by the asset correlation. The asset correlations show how the asset value of one borrower depends on the asset value of another borrower. This correlation can also be described as the dependence of the asset value of a borrower on the general state of the economy as all borrowers are linked to each other by this single risk factor.

Regulators have set predetermined values for the correlation parameter within each of the IRB formulas, which are segmented by asset class definitions specified under Basel II (corporate, commercial mortgages, residential mortgages, credit cards and consumer lending). The levels of the correlation parameters are the most important differentiator across the IRB formulas and a critical driver of the amount of Basel II capital generated across the different asset classes. So how well the correlation values have been calibrated by Basel regulators to reflect the risk profile and actual loss experience of credit portfolios is a deciding factor on the correctness of the Basel formula.

Some studies on historical data prove that correlation calculated in Basel formula does not comply with empirically based correlation results. Basel correlation assumptions are found to exceed the empirically derived correlation values across all asset classes(Hansen 2008). This conservatism would result in a higher regulatory capital reserve than using empirical correlation values.

Also there is a theoretical assumption incorporated into the IRB correlations for certain asset classes, which is that asset correlations decrease as a function of PD. The logic behind it is that the financial performance of weaker borrowers is assumed to be driven largely by idiosyncratic factors specific to the firm, so default risk depends less on the general state of the economy and thus correlation between assets would be lower. Basel II applies this assumption to corporate and commercial mortgage assets (correlation ranges from 24% to 12%) and consumer lending (correlation ranges from 16% to 3%). Correlation is constant at 0.04 for qualifying revolving exposures, and 0.15 for residential mortgage exposures. We take correlation for corporate assets as an example, which is defined as follows in Basel formula:

$$Correlation\ (R) = {0.12 \times \left(1 - e^{(-50\times PD)}\right)} \Big/ {(1 - e^{(-50)})} + {0.24 \times \left(1 - \left(1 - e^{(-50\times PD)}\right)\right)} \Big/ {(1 - e^{(-50)})}$$

However, Fitch found out that there doesn't appear to be a consistent relationship between PD and correlation values across asset classes (Hansen 2008). It found out that for consumer lending, empirical analysis of auto loans suggests a positive relationship between correlation and PD. So when this assumption does not hold, the IRB capital charge would lack accuracy.

Basel II also assumes that correlations are static values describing the behaviour of dynamic assets whose future loss experience will change over time. The variability in loss rates could be impacted by financial product innovation, changes in key risk factors and structural shifts in financial markets, and the Basel II correlation values might be less relevant.

4. Maturity Adjustment

The Basel formula also incorporates an adjustment for maturity. This adjustment is in place due to the fact that long-term credits are riskier than short-term credits, as downgrades are more likely in case of long-term credits which require more capital. So this adjustment would be higher for longer term maturity loans. In the Basel formula, maturity adjustments are a function of not only maturity but also PD, and they are higher for low PD than for high PD borrowers, which could be explained intuitively that low PD borrowers have more potential for down-grading. The formula for maturity adjustment could be written as:

$$SF_{maturity} = \frac{1 + (m - 2.5) \times b(PD)}{1 - 1.5 \times (PD)}$$

$$b(PD) = \left(0.11852 - 0.05478 \times \ln(PD)\right)^2$$

However, for very short maturities, maturity adjustment is found to be insufficient, this is a weakness in this formula.

2. Methodology

In this paper we intend to test the accuracy of risk capital computed under Basel's IRB framework. In the previous section, we discussed the granularity assumption underpinning the internal rating model. Such assumption is essential to the model setup due to its contribution to tractability of the solution. Yet by making the granularity assumption, we are running the risk of underestimating the risk capital in portfolios not precisely fine-grained.

To illustrate the potential estimation errors when assuming portfolio is fine-grained, we constructed a hypothetical portfolio and simulated its loss distribution (see appendix I for details of the portfolio). We used the distribution as a benchmark to compare with the results returned from Basel IRB formula. We conducted the test in the following sequence and derived three propositions.

1. We tested the granularity assumption by exploiting the fact that Basel IRB does not incorporate concentrations. We changed the composition of one PD band by combining many small loans into one concentrated loan. Thus we obtained a coarse-grained PD band without changing the total exposure and each band's relative weight. IRB framework will not be able to detect such effect, which will be captured by simulations. As a result, we computed the difference between two methods and verified the deficiency of IRB approach under fine-grained assumption.

2. We proceeded to test the marginal impact when we enlarged the portfolio with an additional loan. First we demonstrated how PD effect and concentration effect work separately, in influencing the true unexpected loss obtained from simulations. Then we went on to find out what the combined effect would be by assigning the additional loan to different PD grades, and also by varying its weight. Through comparing IRB and simulated unexpected loss in each case, we could find out IRB's reliability under each situation.

3. Finally, we further explored one special case when we assigned the added loan to grade 1. The corresponding PD is less than 0.001, i.e. the degree of significance α. Similar to proposition 2, Basel IRB will not capture the concentration effect thus provide misleading information regarding the unexpected loss. The accuracy of simulation method will be affected by the limitations of VaR approach since VaR only reflects the quantile loss and neglects the rest of the losses in the tail. In our example, the added loan is expected to default 12 times out of 20000 simulations. Coupled with the large potential loss of the added loan due to concentration, each time it defaults the corresponding portfolio loss is more likely to be in the worst scenario. Thus there is the chance that our 99.9% quantile loss will not include any of those 12 severe losses. We used similar framework in proposition 2 to investigate the simulation results. We proposed two solutions to this problem, by applying the Expected Shortfall approach or by increasing the degree of confidence. We computed the new risk measures under both approaches and compared the results with IRB and Simulated calculations.

2.1. Data and Model

The data used are hypothetical corporate loan portfolios, and we used two base portfolios, one is a simplified portfolio with only one PD grade, the other is a more realistic one with 15 PD grades. The base case parameters are specified in appendix A. For all three propositions, portfolios used incorporate some modifications to the base cases. The inputs of the base case with 15 PD grades are similar to the ones used in the numerical example by Van Vuuren and Ramadurai (2007) trying to compare its basic model with Basel model, here we call it Fitch portfolio.

The one-grade portfolio was constructed to simplify the illustration of some effects, so the parameters were set up to be as simple as possible.

The Fitch portfolio in our paper is supposed to meet all Basel assumptions, so the Basel regulatory capital would be very close to the true unexpected loss, thus we can find out in each proposition how much difference would be purely caused by the change made to the base portfolio. To meet the fine-grained assumption of Basel approach, the base portfolio was constructed to include 6000 loans with equal notional amount of one. And also fifteen PD grades were chosen so that the PD grade granularity was high, which would narrow the difference between Basel and true unexpected loss. In order to simplify the data and comply with Basel, we assumed that the default probability of each loan is the average PD of the PD grade it belongs to. Meanwhile, the asset correlation was set up to be the same as those derived from IRB formula, which is a function of PD, so similarly, every loan in the same PD grade would have the same correlation. LGD here was set up to be the same as 36% of the exposure for every PD grade to simplify the calculation. Confidence level was kept at 99.9% following Basel's approach.

We used two methods to calculate the capital charge, namely the IRB approach and Monte Carlo simulation. Under the IRB approach, we simply plugged three variables (PD, LGD, EAD), all specified in our portfolio inputs, into the IRB formula, and obtained the regulatory capital charge.

Under Monte Carlo simulation, we set up a one-factor model to simulate the loss distribution, as IRB also uses a one-factor model. Once we have the loss distribution, the unexpected loss can be obtained easily by taking the difference between the 99.9% loss quantile and the mean loss.

As the simulation method is intended to approximate the true unexpected loss in a real life situation, and to achieve a balance between efficiency and accuracy, we chose to run 20,000 simulations for each scenario. However, we feel that even 20,000 simulations cannot guarantee us a reliable result, but more than that would be too time-consuming, so we set up a testing mechanism aimed to check the reliability of each run of simulation. We compared the actual number of defaults of each loan with its expected number of defaults calculated as its PD multiplied by number of simulations. Only when simulation results of most of the loans stay close to the expected value, we would regard that run of simulation reliable.

3. Results and Discussions

3.1. Proposition 1: Basel IRB formula does not incorporate concentration risk

We changed the composition of one PD grade by combining a certain number of unity loans into one concentrated loan. By doing so, we maintained the total EAD of the portfolio and the respective weight of each PD grade unchanged, but the number of loans in that PD grade is smaller. Then we compared the unexpected loss derived from simulation and Basel IRB. As long as the weight and EAD of each PD grade does not change, Basel IRB cannot distinguish a grade of many loans from another of fewer loans. The following table demonstrates this point,

Table 3.1 Change the concentration of grade 8

Relative weight of new loan (percentage)	Basel Capital (percentage of EAD)	Simulated Unexpected Loss (percentage of EAD)
0	0.0278	0.02845
1	0.0278	0.0284
2	0.0278	0.0286
4	0.0278	0.0286
6	0.0278	0.03295
7.4	0.0278	0.0353

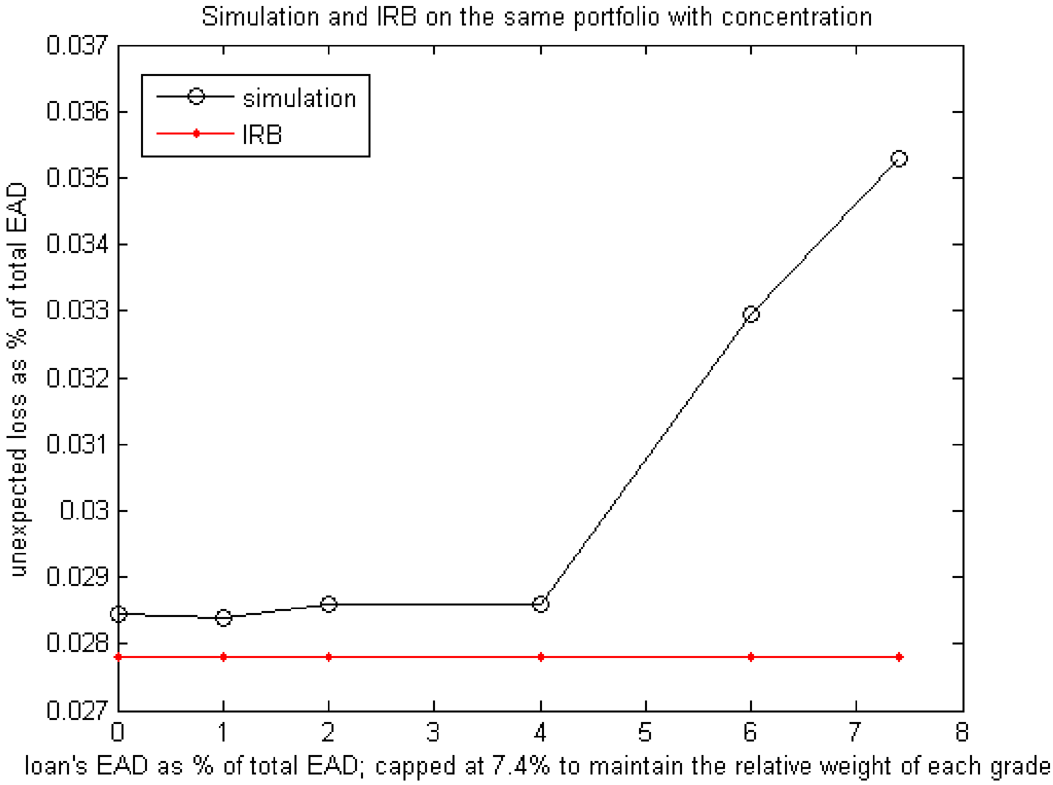

Figure 3.1 Proposition 1

The X-axis shows different levels of concentration as a percentage of the total EAD of the portfolio. The grade we selected to change is grade 8.

We found that:

1. As expected the Basel IRB does not incorporate such concentration effect and the risk cushion is unchanged at all levels of concentration.

2. The simulated losses dramatically deviate from IRB losses after the big loan takes on greater weight.

3.2. Proposition 2: The marginal capital charge of adding a significantly large loan

This is an extension of Proposition 1, which verified that IRB approach does not account for granularity effects. In this section, we demonstrated how much the true unexpected loss increased by adding a large loan, and compared it with the regulatory capital calculated under Basel II. Banks could use this weakness of IRB approach by adding large loans to their existing portfolios.

Unexpected loss is the distance between the 99.9% VaR and the mean loss in our case, which is affected by the PD of the additional loan as well as its relative weight. If its PD is lower than the average PD of the existing portfolio, the new portfolio with the additional loan would shift the loss distribution to the left, so the mean would decrease, but the quantile would decrease more, this would shorten the distance between the mean and quantile, and vice versa. We call this change in unexpected loss affected by PD of the new loan PD effect. Figure 3.2.1 illustrates this effect when there is no concentration added. At the same time, the addition of a large loan would result in fat tails in the loss distribution due to increase in correlation where losses tend to cluster. So VaR at the same significance level would increase, resulting in a bigger unexpected loss, as illustrated in Figure 3.2.2, we name it concentration effect. Both effects exist at the same time and when new loan's PD is lower than average PD of existing portfolio, they move in different direction, resulting in uncertainty in the combined effect.

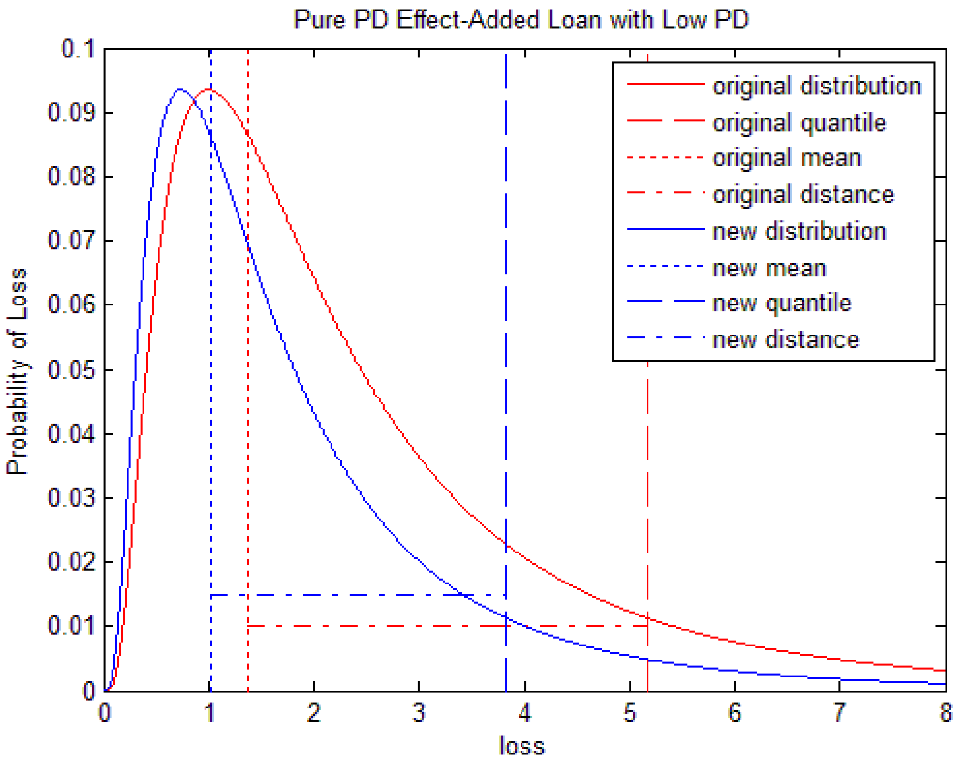

Figure 3.2.1 Pure PD effect

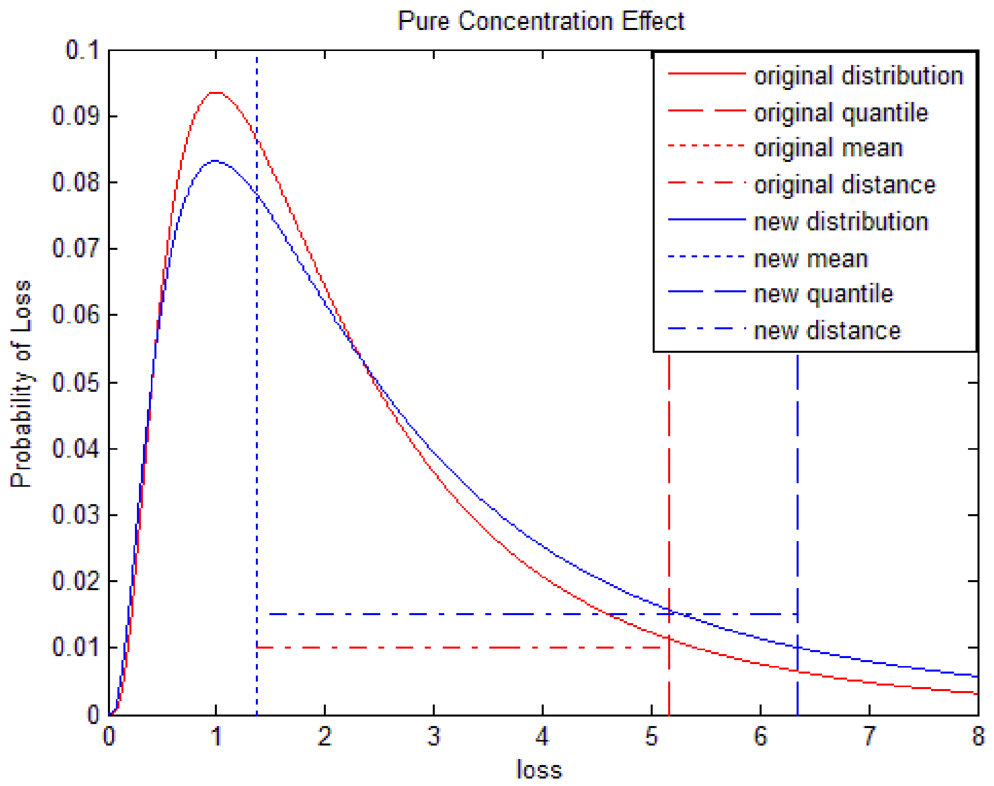

Figure 3.2.2 Pure concentration effect

Now we continue to provide statistical illustration of each effect separately. PD effect is well represented in Basel's capital charge, but because of the fine-grained assumption in Basel, it doesn't consider concentration effect. This is easily proven in table 3.2.2, where PD of the new loan is lower than the portfolio's average PD, we can see that as concentration increases, Basel's capital charge decreases linearly. Concentration effect can only be captured by simulation results, and to verify our theory on concentration effect, we constructed a fine-grained portfolio with one PD grade only, and added in a large loan with the same PD but different weights, and tried to compare the corresponding resulting unexpected losses from the simulation. Here PD effect doesn't exist as PDs are the same for all the loans, so any change in unexpected loss is purely caused by the concentration effect.

The parameters of the original single grade portfolio are defined in appendix A. And the table below compares simulated unexpected loss with regulatory capital charge after a large loan is added to the original portfolio.

Table 3.2.1 Results of pure concentration effect under single PD portfolio

Relative weight (percentage)	Basel Capital (percentage of EAD)	Simulated Unexpected Loss (percentage of EAD)
0	0.092738	0.0878
2	0.092738	0.0867
4	0.092738	0.0981
6	0.092738	0.1039
8	0.092738	0.1156
10	0.092738	0.1481
15	0.092738	0.1743
20	0.092738	0.2146
30	0.092738	0.3171

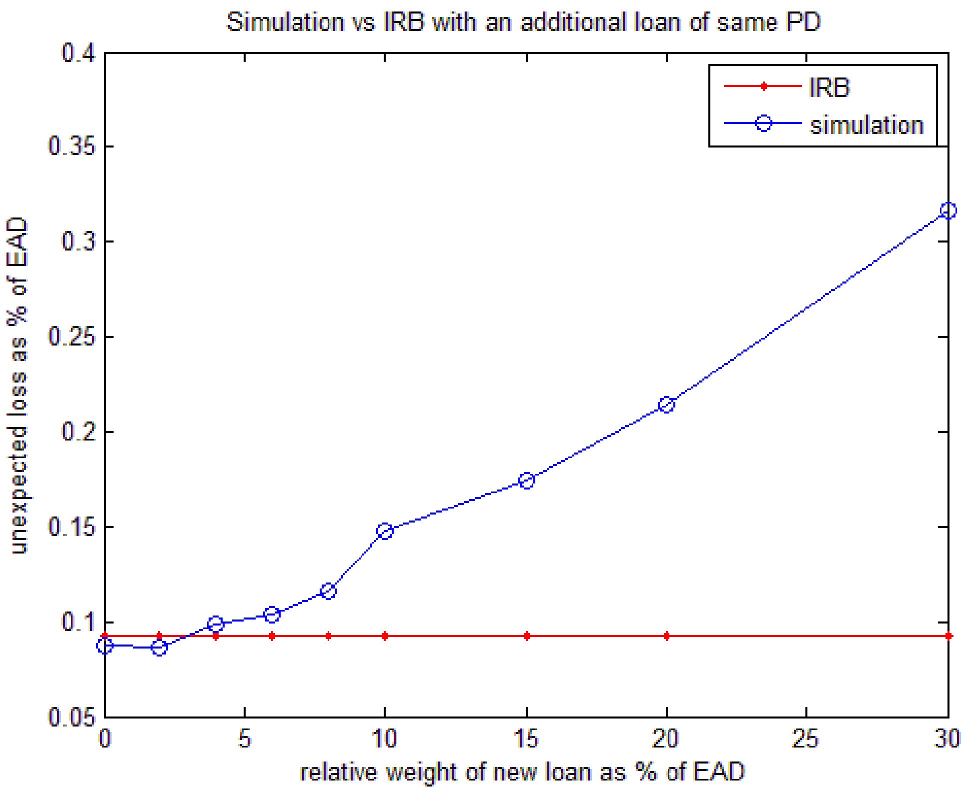

Figure 3.2.3 Illustration of pure concentration effect

This result confirms our discussion before that Basel doesn't incorporate concentration effect, which would increase the true unexpected loss demonstrated by simulations, and this effect grows as the level of concentration increases.

Now that we understand how PD effect and concentration effect work independently, wetook another step by examining the combined effects. Theoretically, when the new loan has a higher PD than that of the original portfolio, both effects work in the same direction, which increase the unexpected loss. However, when the added loan has a lower PD, concentration effect and PD effect tend to offset each other, and it depends on the strength of each effect to decide the combined result. Figure 3.2.4 and 3.2.5 illustrate this point by looking at two cases, respectively when PD dominates or concentration dominates as the added loan has a lower PD.

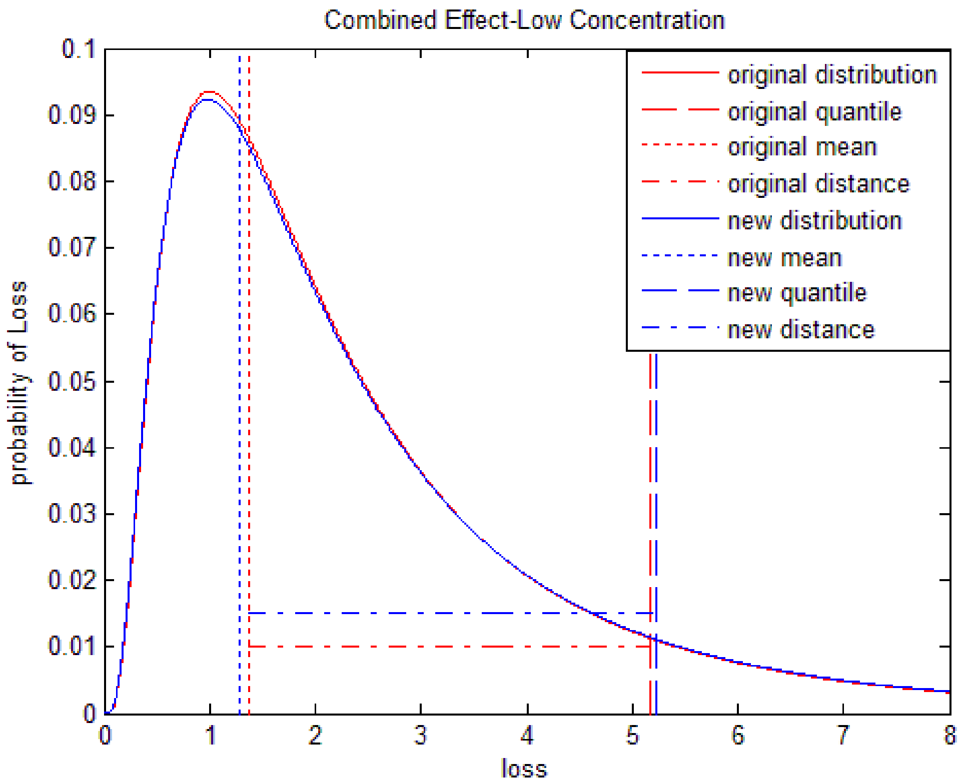

Figure 3.2.4 Illustration of combined effect (a)–low PD low concentration

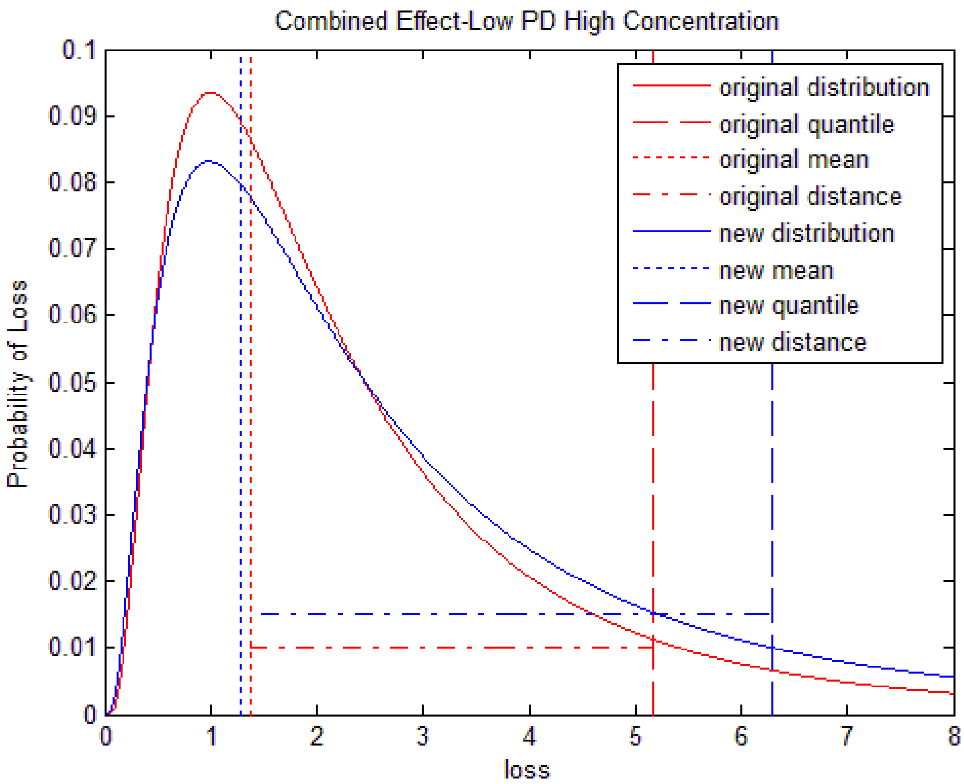

Figure 3.2.5 Illustration of combined effect (b)-low PD high concentration

To illustrate this, we used the Fitch and added a loan of significantly larger exposure into one of the 15 grades. The addition of such a loan increased the total EAD of the portfolio and the weight of the corresponding PD grade, thus impacted the portfolio PD. This resulted in a change in the regulatory capital charge calculated by the IRB formula, and we investigated the accuracy of this marginal capital by comparing it with the change of unexpected loss obtained from simulations. In this situation, both PD effect and concentration effect come into play.

The relative weight of the additional loan and its PD influenced the result significantly. To demonstrate this point, we assigned a range of different weights to the additional loan and placed it into a high PD grade first, and then into a low PD grade. We chose a set of relative weights of the additional loan, and a low PD grade of 0.13% and a high PD grade of 0.98%.

And to ensure that the outcome is reliable, we ran each scenario for 20,000 simulations. The result we obtained is as follows:

Table 3.2.2 Add a loan to PD grade of 0.13%

Relative weight (percentage)	Basel Capital (percentage of EAD)	Simulated Unexpected Loss (percentage of EAD)
0	0.027841	0.0284
1	0.027706	0.0248
2	0.027514	0.0288
3	0.027437	0.0288
4	0.027302	0.0333
6	0.027033	0.0281
8	0.026763	0.0333
10	0.026494	0.0397
20	0.025147	0.0747
30	0.0238	0.1083

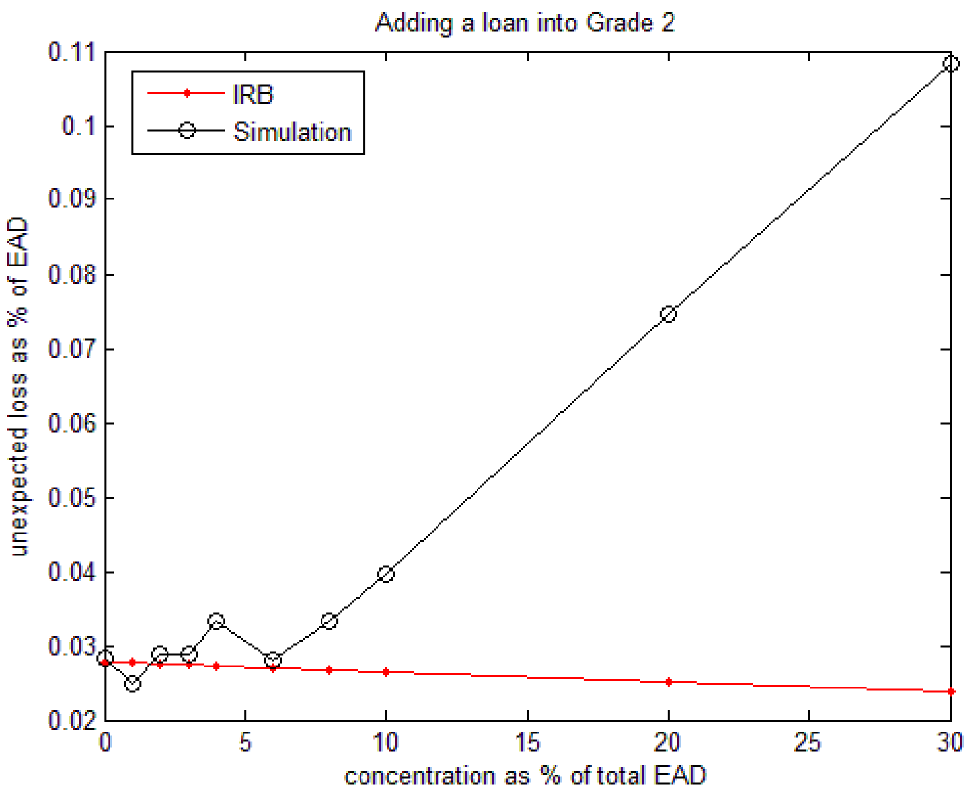

Figure 3.2.6 Combined effect under Fitch portfolio (a)-Grade 2

We could observe that when PD of the additional loan is low, Basel capital charge decreases as the new loan takes on more weight, influenced by PD effect. However, the simulation doesn't have a clear pattern when concentration is below 6%. This is intuitively correct since PD effect and concentration effect tend to cancel out in this situation, but when concentration grows, concentration effect clearly dominates PD effect as the simulated unexpected loss increases dramatically. In this case, Basel II curve yields the misleading impression that a high exposure to the additional loan still improves the risk of portfolio, when in fact it is quite risky to have such a high concentration, which is captured by the simulation.

In the case that PD of the additional loan is high at 0.98%, the result is as follows:

Table 3.2.3 Add a loan to PD grade of 0.98%

Relative weight (percentage)	Basel Capital (percentage of EAD)	Simulated Unexpected Loss (percentage of EAD)
0	0.027841	0.0284
1	0.028027	0.0289
2	0.028214	0.0303
4	0.028587	0.0326
6	0.028773	0.0349
8	0.029332	0.0409
10	0.029705	0.0466
15	0.030638	0.064
20	0.03157	0.0797
30	0.033434	0.1146

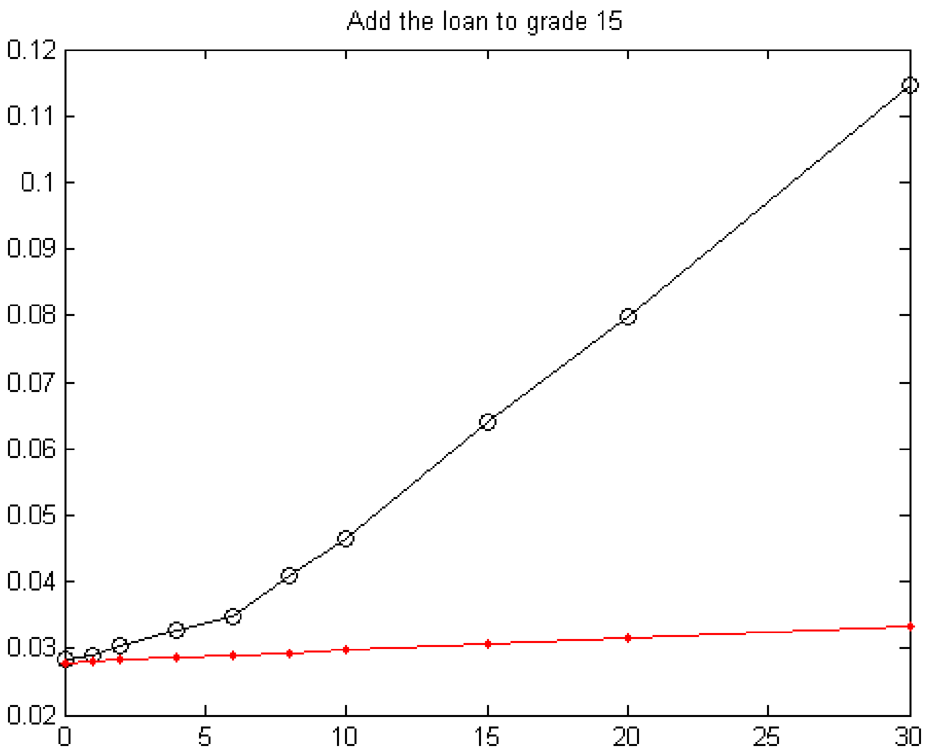

Figure 3.2.7 Combined effect under Fitch portfolio (b) – grade 15

In this case, both PD effect and concentration effect move the loss quantile to the right, so unexpected loss would increase unambiguously. This is verified by the graph above, where both Basel and simulated capital charge increase as the additional loan takes on more weight. The difference could be explained as concentration effect. As a result, although more capital is required under IRB formula when there is more concentration, the marginal capital charge is still inadequate. The difference becomes significant as the weight of the new loan goes beyond 5%.

To sum up, both two cases illustrated that marginal capital charge under Basel II is insufficient because of its inability to account for concentration effect, this would give banks incentives to add large loans in their portfolios, which contradicts Basel's intention to pursue better risk management, by encouraging banks to take more risk.

3.3. Proposition 3: Marginal impact of adding an extremely low-risk loan will not be fully captured by any VaR approach.

In this section, we examined the special case in proposition 2 when we assigned the special loan into grade 1 with PD of .0006. The result is not consistent with the proposition demonstrated previously.

The PD in grade one is 0.06% and it is noteworthy that it is less than the significance level of the downturn condition.

$$0.0006 < 1 - \ 0.999 = 0.001$$

As we proved in Proposition 2, Basel's IRB framework does not incorporate concentration. Thus PD effect will be the only factor driving the shift of the loss distribution and causing the percentage risk cushion to decrease with increasing concentration. The following graph shows that Basel capital charge declines linearly as new loan grows.

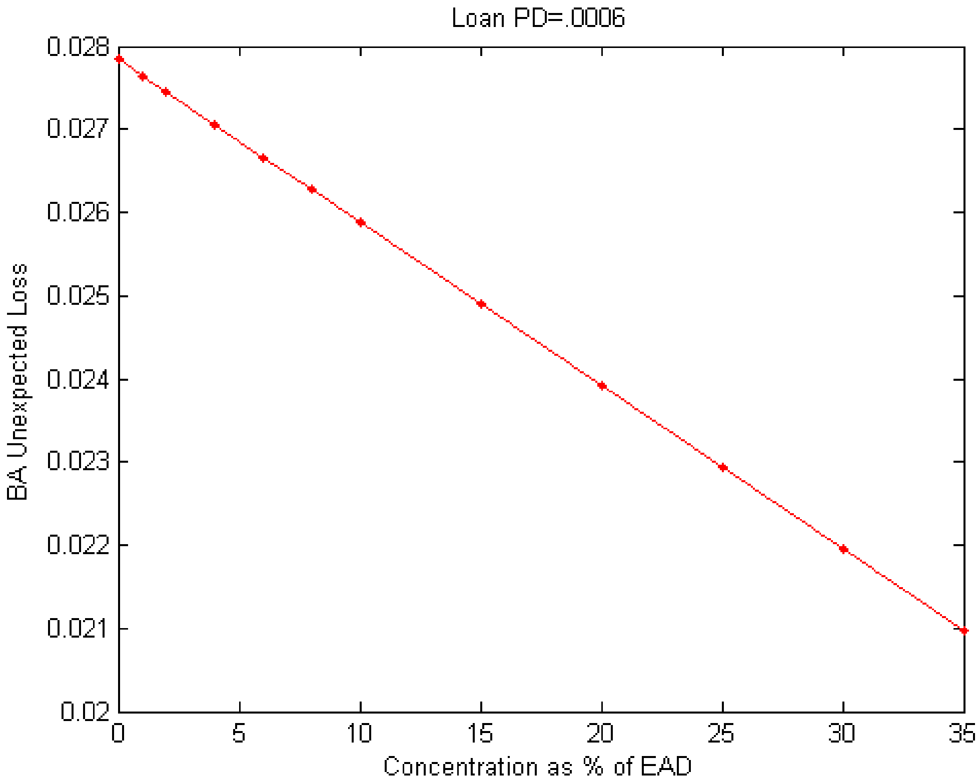

Figure 3.3.1 IRB under special case-grade 1

The simulation however showed inconsistent results compared to conclusions derived in Proposition 2. In order to analyze this point in particular, again we used the one-band simplified portfolio mentioned before, and added in a loan with PD of 0.0006 and different weight. Based on the simulation results, we have the following unexpected loss as a percentage of EAD.

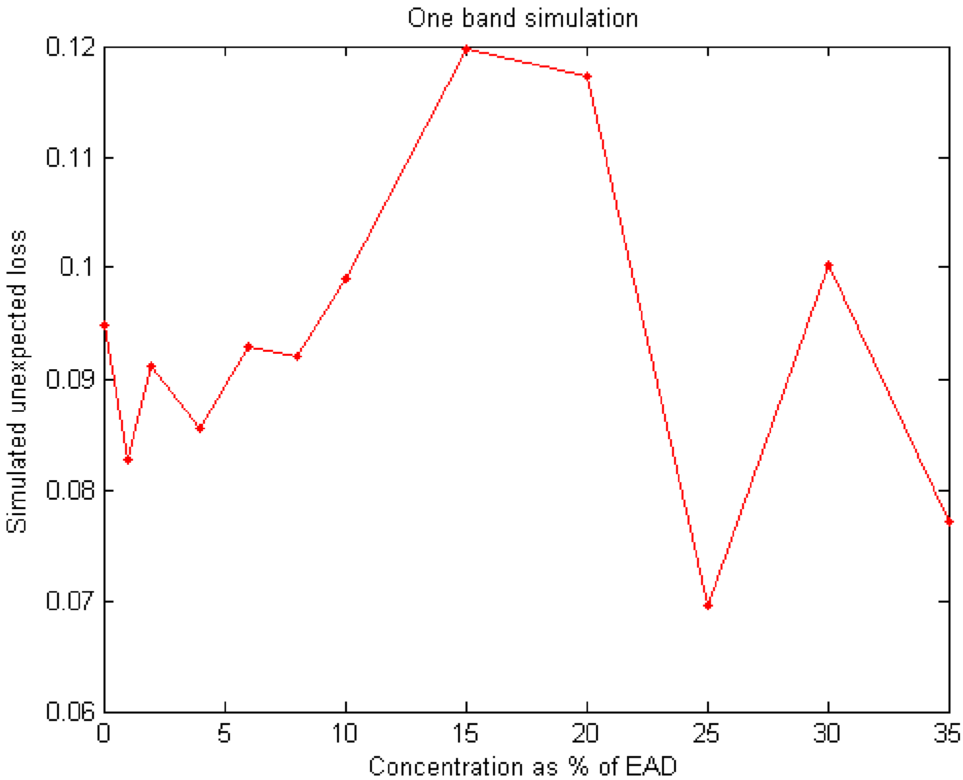

Figure 3.3.2 Illustration of special case under single band portfolio

Since PD of new loan was set to be extremely small, as we derived in proposition 2, the entire distribution will shift to the less risky side and cause the quantile to decrease as well. However, the concentration effect illustrated earlier does not dominate the PD effect even with 35% concentration.

One possible explanation deals with the deficiency of the quantile measurement. VaR approach simply ignores the losses beyond the quantile. However if the PD is smaller than α, the increasing tail density gained from concentration effect will not have as much impact as in proposition 2.

We proposed two ways to account for the deficiency of VaR by either employing another risk measurement or increasing the degree of confidence.

3.3.1. Expected Shortfall (ES)

Tasche (2001) demonstrated that ES better describes the expected loss conditional on the worst scenario occurring than VaR. We computed ES to compare with Basel's and simulated VaR approach.

In this test, we carefully examined the simulated results to make sure that the controlled loan defaults certain times within 20000 simulations such that it complies with Basel's assumption. In short we ensured the loss at the 0 .1% quantile, the minimum loss of the worst scenario, does not include a loss in the controlled loan. The following graph compares two VaR approaches with expected shortfall when a significantly large loan is added to grade 1.

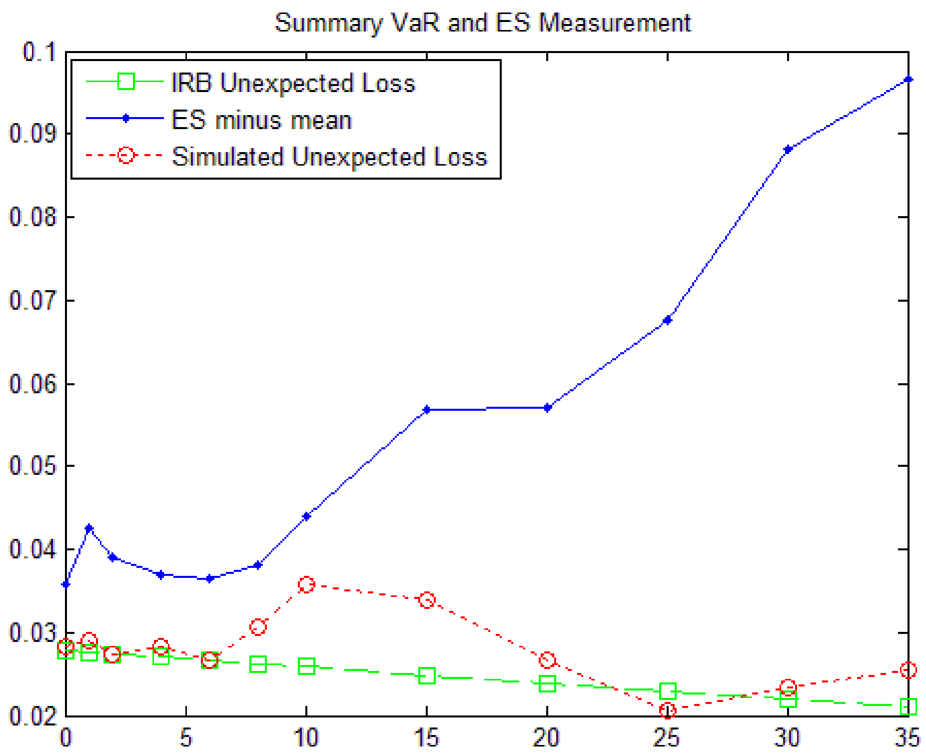

Figure 3.3.3 VaR and ES

Table 3.3.1 Results of UL under three approaches

PD grade 1	Basel	Simulation	ES minus mean loss	def time of new loan
0	0.027841	0.0282	0.0358	0
1	0.027645	0.0291	0.0426	8.5
2	0.027449	0.0274	0.0391	11
4	0.027056	0.0284	0.037	14
6	0.026664	0.0267	0.0365	11
8	0.026272	0.0306	0.0381	15
10	0.02588	0.0357	0.044	14
15	0.024899	0.034	0.0569	15
20	0.023919	0.02673	0.057046	10
25	0.022938	0.0205	0.0677	11
30	0.021958	0.0233	0.0881	12
35	0.020977	0.0255	0.0967	14

We included the default time to show that across all cases in our simulation, the concentrated loan does not default more than 20 times, which is derived from .1% of 20000 simulations.

We can see from the graph that the two VaR approaches all demonstrated that the by adding such a portfolio we can enjoy some level of risk reduction. This is intuitively incorrect since such a loan with concentration would add more risk, captured by the ES measurements.

3.3.2. Confidence Level

Another way to bypass this obstacle is to change the level of significance such that the new threshold is lower than the PD of the concentrated loan. In our case, we can choose any number lower than 0.94%=1- 0.06%. Basel will automatically assume such loan to default, which leaves the only remaining concern to be concentration impact. Thus when the level of significance is set lower than 0.94%, the situation is identical to the case illustrated above with concentrated loan is placed into PD grade 2, as the PD of grade 2 is 0.13% which is higher than 1-99.9%=0.1%. The following table compares two VaR approaches with expected shortfall when a large loan is added to PD grade 2.

Table 3.3.2 Results of UL after changing alpha

concentration weight	Basel	Simulation	ES	ES-SimVaR
0	0.027841	0.0284	0.0358	0.0074
1	0.027706	0.0274	0.0378	0.0104
2	0.027514	0.0284	0.0404	0.012
4	0.027302	0.0333	0.0409	0.0076
6	0.027033	0.0281	0.0347	0.0066
8	0.026763	0.0333	0.0405	0.0072
10	0.026494	0.0397	0.0458	0.0061
20	0.025147	0.0747	0.0798	0.0051
30	0.0238	0.1083	0.1134	0.0051

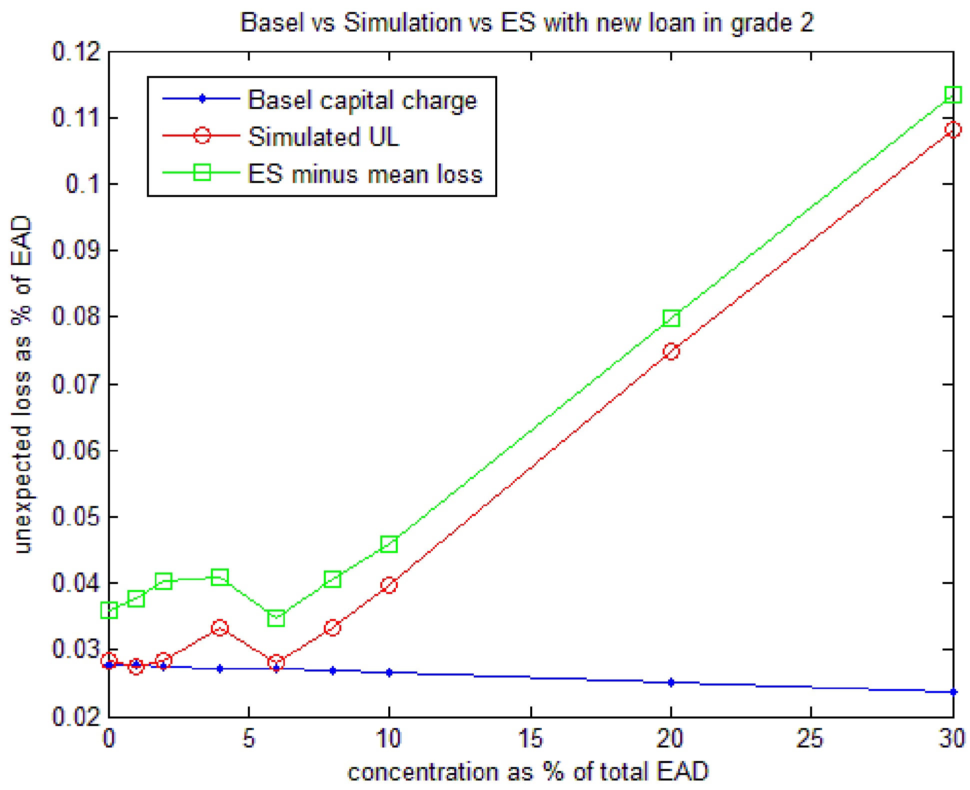

Figure 3.3.4 Changing the significance level

We can easily tell that the difference between ES and Simulated VaR would not widen as concentration increases, as seen in the previous case. So in this situation VaR is a reliable risk measure as it captures the loss of the big loan. This is equally valid when we decrease the level of significance in case that the large loan's PD is too low.

4. Conclusion

In this paper, we focused on the deficiency of Basel IRB due to its granularity assumption. We constructed a scenario violating such assumption and quantified the potential calculation error by comparing IRB's results to our simulated unexpected losses. We found that such difference could be substantial given that the concentration is moderately high, which is consistent with empirical studies (Tasche and Emmer, 2005).

Therefore banking practitioners and industrial supervisors should be aware of such flaw. Banks with medium or small portfolio size acquiring additional loans could run into the risk of misunderstanding the marginal risk contribution of the loan by computing the risk capital under IRB's framework.

Moreover, the VaR approach underpinning the IRB model has its own limitations in providing accurate information of portfolio loss under distressed situation. We have proven in proposition 3 that when a significantly low-risk loan is added to the portfolio, the percentage risk capital computed under VaR measurement will decrease regardless of the level of concentration. This could generate unintended incentives for banks to load up risky loans and balance the added risk by acquiring a highly concentrated low-risk loan. Under such case, the risk cushion computed will be far from sufficient to cover the potential loss if occurred. Supervisors should be alarmed of such new types of "regulatory arbitrage" in the era of Basel II.

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Appendices

Appendix A: Base Portfolio Parameters

	Fitch Portfolio	One-grade Portfolio
Asset Category	Corporate loans	Corporate loans
Number of loans	6000	6000
Notional amount of each loan	1	1
PD	Defined below	0.5%
LGD	0.36	1
Maturity	1	1
PD Grades	15	1
Confidence level	99.9%	99.9%
Correlation	Calculated as Basel's formula	Calculated as Basel's formula

PD Bands & Exposure for Fitch Portfolio

PD band	PD (%)	% of total exposure
1	0.06	4.6
2	0.13	5.7
3	0.15	6.1
4	0.18	10.2
5	0.2	10.9
6	0.23	10.7
7	0.44	9.5
8	0.49	7.4
9	0.54	7.3
10	0.63	6.7
11	0.68	5.6
12	0.84	4.9
13	0.89	4.7
14	0.95	3.9
15	0.98	1.8