IMPACT OF CREDIT SPREAD FLUCTUATIONS ON PORTFOLIO VALUE

Agil Kerimov,
Ph.D. student
Azerbaijan University,
Azerbaijan

Abstract. *Banks criticize Basel accords for potential double counting of the same risks in calculation methods of minimum required capital. These risks should be isolated from each other for accurate measurement of regulatory capital. The purpose of this paper is to isolate credit spread risk from interest rate risk and analyze the impact of pure credit spread fluctuations on portfolio value. Different scenarios are simulated by using Monte Carlo simulation method. The model is built in Excel and Visual Basic for Applications. The results show that coupon rates and credit spread deviations have an impact on the average and the standard deviation of portfolio value which makes them among the majors factors in assigning bond weights. Besides, the interest rate component that reduces the fluctuations in standard deviation should also be taken into consideration in assigning the weights.*

Key words: *Monte Carlo simulation, credit spread risk, interest rate risk, double counting.*

1. Introduction

Credit and interest rate risks are the two of the most important sources of risks faced by banks. Therefore, management of these risks is a crucial task for banks. Studies show that there is an economic relation between the two risk classes.

While analyzing credit and interest rate risks, banks must hold capital against potential expected and unexpected losses. The riskier are the assets, the more capital will be required to cover potential losses. Financial institutions have an incentive to hold as less capital as possible in order to make profitable investments. However, the chance of insolvency of banks increases as the economic capital (EC) decreases (BCBS, 2005, pp. 1-3).

Recent financial crisis of 2007-2008 showed that, banks did not hold enough capital. In order to deal with this problem, Basel Committee on Banking Supervision (BCBS) introduced Basel accords that determine regulatory capital (RC) by considering both profitability and insolvency issues of banks. However, banks criticize Basel accords for calculation methods of minimum required capital. Adding up different risk classes that have common nature during measurement of capital requirements, causes the possibility of double counting of the same risks. Double counting of risks increases minimum required capital that affects the lending business of banks (Gregory, 2012, p. 372).

This paper isolates credit spread risk from interest rate risk and analyzes the impact of pure credit spread fluctuations on portfolio value. These risks should be isolated from each other for accurate measurement of regulatory capital. Separation of these risks is done by using the studies of Letizia (2007, 2010a) on credit spread widening risk and the model is built in Excel and Visual Basic for Applications (VBA). Different scenarios are simulated by using Monte Carlo simulation method to capture the pure credit spread risk and interest rate risk effects on portfolio value.

2. Studies of Letizia

In his first working paper, Letizia (2007) measures bond value sensitivities to credit spread fluctuations. He starts by excluding current credit spread from yield in the formula of net present value (Equation 1).

$$B_{rf}(t,t_n)=\frac{1}{(1+r_i)^{t_i-t}} \qquad (1)$$

While calculating the price of a bond, interest rate risk and credit spread risk components are evaluated separately. This helps to distinguish the source of risk that leads to a change in price (Equation 2).

$$P=B_{rf}(t,t_n)+\sum_{i=1}^{n}\frac{f_i}{k}\cdot B_{rf}(t,t_i)+\frac{d-s}{k}\cdot\sum_{i=1}^{n}(t,t_i) \qquad (2)$$

where:

$\sum_{i=1}^{n}\frac{f_i}{k}\cdot B_{rf}(t,t_i)$	is the interest rate risk component;
$\frac{d-s}{k}\cdot\sum_{i=1}^{n}(t,t_i)$	is the credit spread risk component;
d	is the coupon spread (initial credit spread);
s	is the current credit spread.

As seen from the equation, credit spread component becomes zero when the coupon spread and the current credit spread are equal. Bond value changes as these factors diverge. Finally, credit spread sensitivity is derived as follows:

$$\frac{\partial P}{\partial s}=-\frac{\sum_{i=1}^{n}B_{rf}(t,t_i)}{k} \qquad (3)$$

In his another study, Letizia (2010a) refines cash flow mapping and compares the results with the outcomes of discounted cash flow (DCF) method in order to capture the price reactivity to credit spread and interest rate changes. Firstly, bond values are evaluated by using standard DCF approach. There are following assumptions for the fixed rate bond:

- The bond is with fixed annual coupons at 4% for the next 10 years;
- Flat interest rate is 3.5%;
- Credit spread is 100 basis points (bps).

$$V_{4.5\%}=\frac{4}{1+0.035+0.010}+\frac{4}{1.045^2}+\frac{4}{1.045^3}+\ldots+\frac{104}{1.045^{10}}=96.044$$

$$MD_{4.5\%}=8.036$$

In order to see how present value reacts to interest rate fluctuations on money market, discount rates are assumed to be increased by 10 bps. After this instantaneous increase, NPV of the bond reduces to 95.267. This means that the percentage loss is 0.7996% which is about eight times the discount shift. This is consistent with the result of modified duration (8.036). However, it is not possible to see whether the shift occurred on risk-free rate or credit spread side.

Letizia introduces an alternative, double-cash flow leg approach in order to measure sensitivity to credit spread and risk-free rates separately. The following are the components that determine the interest paid for bond's cash flows.

- **Floating component** is based on forward rates with no spread. Accrued interest at the evaluation date is excluded;
- **Coupon spread** is the initial credit spread determined at the issue date;

• **Credit spread** is the premium that is paid to the bond issuer at each coupon date to cover expected losses due to default of the borrower.

In this approach, the floater component is added to the credit leg, which represents CDS fees to be paid and coupons spreads to be received. Price of the bond is equal to par value, if the cost of protection against the default of borrower is perfectly equivalent to present value of the coupon-spread component. Formula of the bond value is as follows.

$$V = 1 + \sum_{i=1}^{n} \frac{(d-s)\cdot \Delta t_i \cdot (1-p_i)}{(1+r_i)^{t_i}} \tag{4}$$

where:

1 is the current value of the entire floater component;

d is the coupon spread which is constant;

s is the annual premium of the implied CDS;

Δt_i is the time interval in which the i^{th} coupon will be accrued;

$P = [p_1, p_2, \ldots p_n]$ is the stream of cumulative probabilities of default at each coupon date;

$R = [r_1, r_2, \ldots r_n]$ is the series of risk-free rates.

The following is the probability of default, derived from the par credit default swap premium:

$$p_i = 1 - e^{-s \cdot t_i} \tag{5}$$

Thus, the survival probability can be shown as:

$$1 - p_i = e^{-s \cdot t_i}$$

Finally, Equation 4 is reformulated by adding the survival probability as follows:

$$V = 1 + \sum_{i=1}^{n} (d-s)\cdot \Delta t_i \cdot \left(\frac{e^{-s}}{1+r_i}\right)^{t_i} \tag{6}$$

Price sensitivity to credit spread fluctuations can be obtained by differentiating with respect to s.

$$\frac{\partial V}{\partial s} = -\sum_{i=1}^{n} [1 + (d-s)\cdot t_i] \cdot \Delta t_i \cdot \left(\frac{e^{-s}}{1+r_i}\right)^{t_i} \tag{7}$$

Price sensitivity to a parallel shift of risk-free yield for fixed rate bonds can be calculated by the following formula:

$$\frac{\partial V}{\partial \bar{r}} = -\sum_{i=1}^{n} \left[1 + \frac{(c - \bar{r} - s)\cdot t_i}{1+\bar{r}}\right] \cdot \Delta t_i \cdot \left(\frac{e^{-s}}{1+\bar{r}}\right)^{t_i} \tag{8}$$

where:

$\bar{r}$ is the internal rate of return that risk-free rates are replaced with;

c is the nominal interest rate of the coupon.

This approach allows for using the risk-free rate for entire financial plan, because expected losses are considered to be ordinary cash outflows. Both approaches are applied to fixed rate bonds that have maturities from 1 to 10 years. Spread curve is assumed to be flat and the evaluation date is coupon date.

Evaluations show that price reactivity to credit spread and interest rate changes are almost the same while using both approaches. An insignificant effect appears when bond's maturity period increases. Therefore, using single-leg approach would be less reliable in a credit spread widening scenario.

In single-leg approach, the internal rates of return increase with the credit risk. The reason is the credit spread that is added to denominator making the discount rates increase. Eventually, the riskier bonds appear to produce greater returns. Double-leg approach solves this problem by taking the credit spread as a cash outflow.

The study also refers to VaR models. According to Letizia (2010a), traditional VaR models do not contain credit spread while measuring price reactions. Initially, he includes credit spread in the time series of interest rates and afterwards, excludes them. Observations show that, by including it is also not possible for VaR to recognize the spread risk. Excluding, on the other hand, causes underestimations in calculation of the specific risk, eventually, of the capital charge. The effect may be even bigger in case of a severe credit spread widening.

3. Modeling

The model is based on the studies of Letizia (2007; 2010a) on separating credit and interest rate risk components. Different scenarios are simulated by using Monte Carlo simulation approach. This method allows to generate an infinite number of scenarios and to test many potential outcomes which are not possible to do by historical simulation. Another advantage of this approach is that it can be easily modified to economic forecasts.

Scenarios are simulated by using random variables. There are several reasons of choosing to simulate the data instead of modeling actual data. Firstly, simulation is less complex. It is easier to see which variables have a greater impact on the outcome by simulating the data. It is also possible to fix some variables in order to see the exact relationships such as, an increase in which factor leads to a decrease in other factors. However, an actual data contain different combinations of values which makes it difficult to see different effects by modeling. On the other hand, simulation is less time consuming considering all of the stated facts above.

The model is built in Excel and Visual Basic for Applications and consists of four parts (Figure 1). Random variables are generated and formulas are entered in Excel. Monte Carlo procedure is coded in VBA. The following figure shows the steps that are taken to build the model:

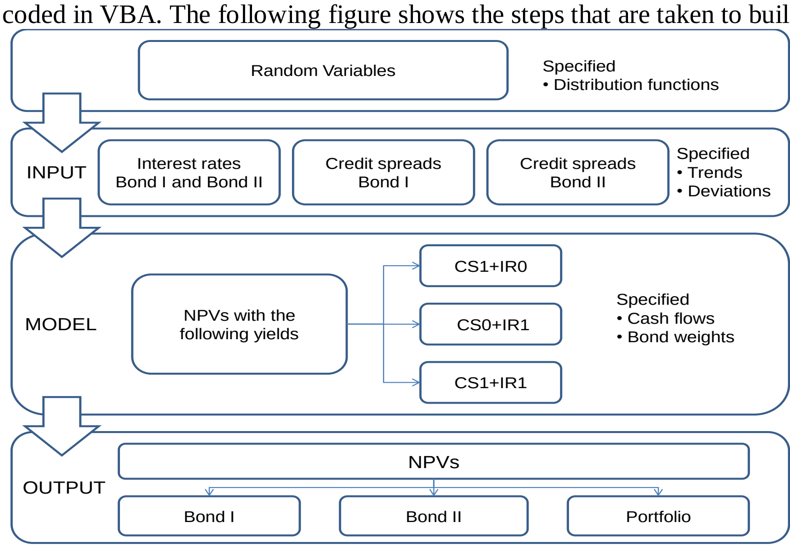

Figure 1. The steps of modeling

Random Variables

As mentioned before, random variables are used to simulate different scenarios. In order to avoid too extreme numbers, these variables are bounded with an upper (90%) and a lower (10%) borders. Once random variables between 0.1 and 0.9 are determined, they are fixed on another excel sheet. These variables are fixed, because they change after every single action in excel. Afterwards, fixed random variables are turned into variables with normal and rectangular distribution functions. This makes time series of credit spreads and interest rates to be normally and rectangularly distributed. There is an option to change the mean and the standard deviation of normal distribution function. The deviation of rectangular distribution function can also be changed.

Input:

Input database consists of yields that are separated into interest rate and credit spread components. These yields are normally/rectangularly distributed random variables with specified trends and deviations. Yields have constant initial rates for both, interest rate and credit spread components. Initial yields change during the lifetime of bonds, according to trend and deviation rates. Formula of yield is as follows:

$$y_1 = y_0 + Trend + (Random\,Variable \cdot Deviation) \tag{9}$$

Trend and deviation of yields can be adjusted in order to simulate different scenarios and analyze outcomes.

Model:

Once yields are determined, the model can be built. Bond values are determined by using a simple NPV formula. The credit spread and the interest rate components are separated in order to capture pure effects on portfolio value. The formula is as follows:

$$NPV = \frac{C_1}{(1+r_f+s)^1} + \frac{C_2}{(1+r_f+s)^2} + \ldots + \frac{P+C_{10}}{(1+r_f+s)^{10}} \tag{10}$$

where:

C	is the coupon payment;
P	is the principal;
r_f	is the credit risk-free interest rate;
s	is the pure credit spread.

The portfolio consists of two, 10-year maturity bonds. Coupon rates are assumed to be constant for the sake of simplicity. The principal is paid together with the last installment at the end of the bonds' lifetime. NPVs of the bonds are calculated by using the following yields at Period 1:

- Initial yield + credit spread;
- Initial yield + interest rate;
- Initial yield + credit spread + interest rate.

This way calculation of bond values allows to capture pure credit spread and interest rate effects on NPVs.

Output:

Running the simulation once, generates 100 micro-runs. Each micro-run gives results of NPVs for Periods 0 (initial) and 1 (with three different yields). NPVs are calculated for Bond I, Bond II and portfolio that contains Bond I and Bond II. All the micro-run results appear on output database sheet in excel after simulating the model.

Simulation consists of 7 different scenarios with 44 runs in total. Analysis of the results are done on the averages and standard deviations of portfolio values. Normally distributed random variables were sufficient to capture the desired effects. Therefore, the rectangularly distributed variables are not used.

4. Conclusion and Recommendations for Further Research

According to the results, rising coupon rates increases portfolio value even though the bonds inside portfolio have different weights or credit spread deviations. However, there is also an increase in standard deviation of portfolio value which can be explained by higher riskiness of the bonds that grant higher coupon rates.

While analyzing portfolio values with different bond weights, it is found that coupon rate and credit spread fluctuations are among the major factors in assigning weights. Even though the different coupon rates and credit spread deviations do not have a significant effect on the average portfolio value, they do have on the standard deviation of portfolio value. While analyzing the bonds with different coupon rates and constant credit spreads, it is seen that the value fluctuates less when the bonds have approximately equal weights (~50%) with a little dominance of the bond with a higher coupon rate. Small adjustment in weights is possible depending on the risk appetite. On the other hand, higher credit spread deviation increases the standard deviation of portfolio value when the coupon rates are constant. Weight of the bond with a lower credit spread deviation should have a dominant weight which leads to higher portfolio value and lower standard deviation. However, the bond with higher credit spread deviation should be included in portfolio. This leads to lower standard deviation of portfolio value that can be explained by diversification effect which reduces bond specific risk. The results also show that the credit spread trend's impact on portfolio value is trivial.

While analyzing the interest rate component, it is seen that interest rate factor reduces fluctuations in standard deviation of portfolio value in all scenarios. Besides, average portfolio value is affected more by interest rate component than credit spread component. The reason is dominant interest rate risk which can be eliminated by including more bonds in portfolio as a further research. This will also allow to see a more clear portfolio value fluctuations and assign bond weights more accurately depending on risk appetite and impact on economic capital.

During the analysis, inverse effect of standard normally distributed variables is seen. Because the mean of standard normal distribution function is 0, negative random variables change the actual trendline in another direction. Therefore, it is recommended not to use the standard normal distribution function and increase mean in a sufficient amount in order to avoid negative random variables.

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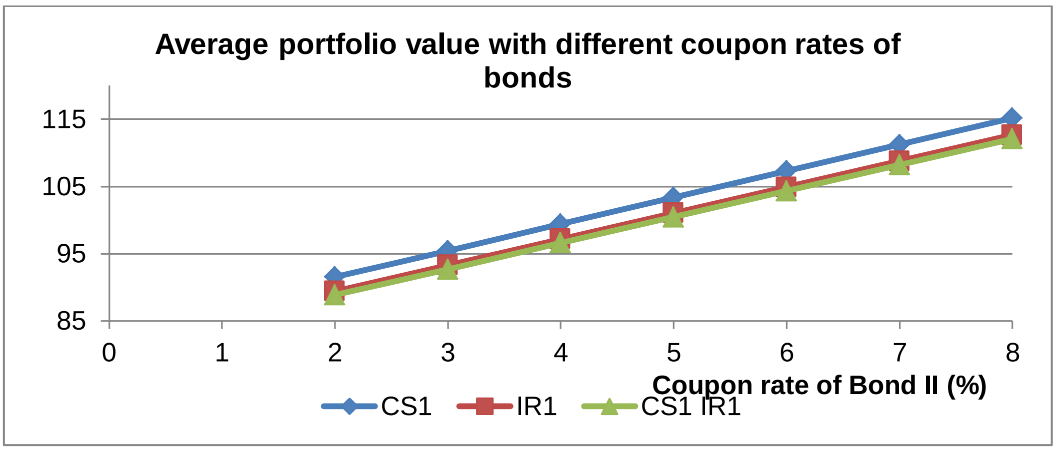
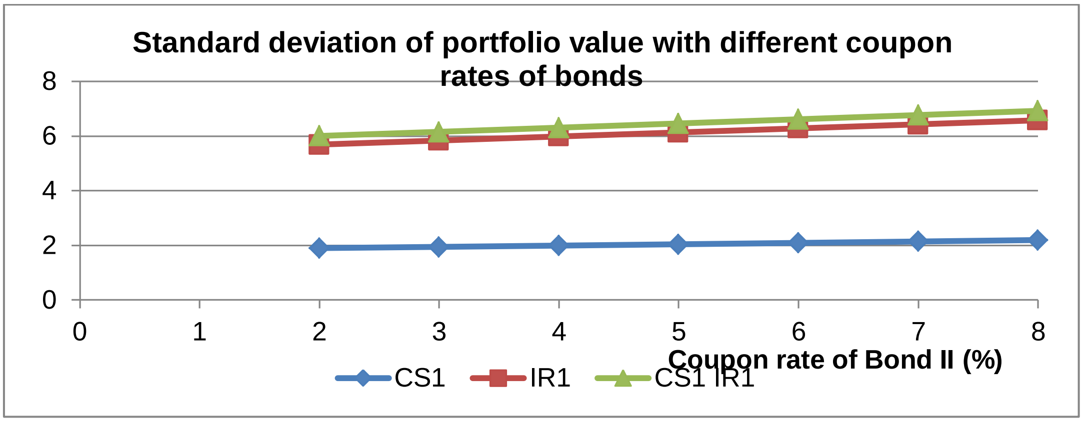
Annexes

Bond I (IR)		**Bond I (CS)**		**Bond II (CS)**	
	Trend		Trend		Trend
Initial	0,250%	Initial	0,100%	Initial	0,100%
4,00%	Deviation	0,50%	Deviation	0,50%	Deviation
	1,000%		0,500%		0,500%
	Bond I	**Bond II**		μ	0
Coupon Rate	5%	Variable		σ	1

Average			
Coupons	CS1	IR1	CS1 IR1
2	91,5351109	89,3845044	88,8567142
3	95,4073735	93,2691903	92,661756
4	99,4218327	97,1538761	96,6004899
5	103,365194	101,038562	100,472378
6	107,308554	104,923248	104,344266
7	111,251915	108,807934	108,216154
8	115,195276	112,692619	112,088041

Standard Deviation			
Coupons	CS1	IR1	CS1 IR1
2	1,90118621	5,68771022	6,00206159
3	1,94569055	5,83572399	6,1539833
4	1,99222355	5,98373823	6,30651352
5	2,04064643	6,13175292	6,45960914
6	2,09082789	6,27976801	6,6132309
7	2,14264437	6,42778348	6,76734296
8	2,19598014	6,57579931	6,92191259





Information about author

Agil Kerimov, Ph.D. student, Azerbaijan University, Yasamal r., S.Dadashov 84, General Akim Abbasov pr., Baku, AZ 1141, Azerbaijan; e-mail for correspondence: matlabm@yandex.com