

## Pengyuan International 2019 Rating Transition and Default Research

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### Summary

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This report presents the first edition of the Transition and Default Research for Pengyuan Credit Rating (Hong Kong) Company Ltd (“Pengyuan International”). It is designed to promote a greater understanding of our ratings and to introduce the approaches we use to compute statistics on the rating transition and default rates.

Statistical research on rating transition and default rates is an integral part of credit rating service. It can not only reveal the relationship between credit ratings and default rates, but also test the accuracy, stability, and consistency of credit ratings.

The key findings of our research include:

- In this report, we examine the stability of Pengyuan International's credit ratings using the rating transition matrix. 100% of Pengyuan International - rated issuers maintained their ratings through the study period. According to the sample statistics, the rating results of Pengyuan International are stable.
- During the study period, we do not observe any default for the issuers that had Pengyuan International's credit ratings.
- Pengyuan International assigned 29 public issuer ratings and 4 public issuance ratings from 11 April 2018 to 31 December 2019. The effective sample size used in this study is extremely limited. Therefore, it is difficult to reflect the relevant situation comprehensively and to draw any statistically significant conclusions. We will apply the same approach to extend the research with enhanced data.

We also provide the definition and computation methods of transition matrix and default rate in appendices.

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## Introduction

This report is the first edition of Pengyuan International's rating transition and default research. It is prepared to help market participants better understand our credit ratings through a study of default events and rating transitions within Pengyuan International's rating universe. The data used for this research include all Pengyuan International's global scale long-term issuer credit ratings (LTICR) issued before 31 December 2019. Due to the limited number of ratings published by Pengyuan International, some of the research results may not be statistically significant and conclusive. As a result, while it is still informative to share the results, some findings based on the limited samples should be interpreted with caution. We will extend the study period and update the research results annually in the future. With enhanced data, the research results will be a more informative reflection of the rating stability and the historical relationship between ratings and default risk.

## Ratings Issued by Pengyuan International

Pengyuan International assigned 29 public issuer ratings and 6 public issuance ratings from 11 April 2018 to 31 December 2019. The issuer ratings are distributed from BB- to AA (see Exhibit 1 and 2). While the performance history is limited, the rating performance is in line with expectations. During the study period, we do not observe any default for rated entities.

**Exhibit 1: Public Issuer Ratings of Pengyuan International until 31 December 2019**

No.	Name	Publishing Date in 2018	Publishing Date in 2019	Ratings
1	China Hongqiao Group Limited	11-Apr-18	30-Aug-19	FC LTICR BB- / LC LTICR BB- / Outlook Negative
2	CMB International Capital Corporation Ltd	17-Jul-18	21-Jun-19	FC LTICR A- / LC LTICR A- / WR
3	China Sovereign Rating	7-Sep-18	28-Aug-19	FC LTICR AA / LC LTICR AA+ / Outlook Stable
4	Shanghai Construction Group Company Limited	5-Dec-18	5-Dec-19	FC LTICR BBB / LC LTICR BBB / Outlook Stable
5	Shimao Property Holdings Limited (Shimao)		31-Jan-19	FC LTICR BBB- / LC LTICR BBB- / Outlook Stable
6	GoHo AMC		18-Feb-19	FC LTICR BB / LC LTICR BB / WR
7	Central China Real Estate Limited		25-Mar-19	FC LTICR BB / LC LTICR BB / Outlook Stable
8	Huai'an Water Conservatory Holding Group Company Limited		10-Apr-19	FC LTICR BBB- / LC LTICR BBB- / Outlook Stable
9	Aluminum Corporation of China Limited (CHALCO)		26-Apr-19	FC LTICR BBB+ / LC LTICR BBB+ / Outlook Stable
10	Maoye International Holdings Ltd		14-May-19	FC LTICR B+ / LC LTICR B+ / Outlook Stable
11	Yangzhou Economic and Technological Development Zone Development Corporation		14-Jun-19	FC LTICR BBB / LC LTICR BBB / Outlook Stable
12	Ronshine China Holdings Limited	-	7-Aug-19	FC LTICR BB / LC LTICR BB / Outlook Stable
13	Shanghai Municipal Government Rating		3-Sep-19	FC LTICR AA- / LC LTICR AA / Outlook Stable
14	Jiangsu Provincial Government Rating		3-Sep-19	FC LTICR A+ / LC LTICR AA- / Outlook Stable
15	Jilin Provincial Government Rating		3-Sep-19	FC LTICR A / LC LTICR A+ / Outlook Stable
16	Shandong Provincial Government Rating		3-Sep-19	FC LTICR A+ / LC LTICR AA- / Outlook Stable
17	Henan Provincial Government Rating		3-Sep-19	FC LTICR A / LC LTICR A+ / Outlook Stable
18	China Vanke Co., Ltd.		10-Sep-19	FC LTICR BBB+ / LC LTICR BBB+ / Outlook Stable
19	Guangdong Provincial Government Rating		24-Oct-19	FC LTICR AA- / LC LTICR AA / Outlook Stable
20	Zhejiang Provincial Government Rating		24-Oct-19	FC LTICR AA- / LC LTICR AA / Outlook Stable
21	Sichuan Provincial Government Rating		24-Oct-19	FC LTICR A+ / LC LTICR AA- / Outlook Stable
22	Shanxi Provincial Government Rating		24-Oct-19	FC LTICR A+ / LC LTICR AA- / Outlook Stable
23	Guizhou Provincial Government Rating		24-Oct-19	FC LTICR A / LC LTICR A+ / Outlook Stable
24	Tianjin Provincial Government Rating		5-Dec-19	FC LTICR A / LC LTICR A+ / Outlook Stable
25	Guangxi Provincial Government Rating		5-Dec-19	FC LTICR A / LC LTICR A+ / Outlook Stable
26	Jiangxi Provincial Government Rating		5-Dec-19	FC LTICR A+ / LC LTICR AA- / Outlook Stable
27	Hunan Provincial Government Rating		5-Dec-19	FC LTICR A / LC LTICR A+ / Outlook Stable
28	Fujian Provincial Government Rating		5-Dec-19	FC LTICR A+ / LC LTICR AA- / Outlook Stable
29	Bank of China (BOC)		20-Dec-19	FC LTICR A+ / LC LTICR A+ / Outlook Stable

**Exhibit 2: Public Issuance Ratings of Pengyuan International until 31 December 2019**

No	Name	Publishing Date in 2018	Publishing Date in 2019	Ratings	ISIN	Due Date
1	China Central Government USD Bonds- 5-year bond with issue size of US\$ 1.5 billion	12-Oct-18	28-Aug-19	AA	XS1891571348	19-Oct-23
2	China Central Government USD Bonds- 10-year bond with issue size of US\$ 1 billion	12-Oct-18	28-Aug-19	AA	XS1891574441	19-Oct-28
3	China Central Government USD Bonds- 30-year bond with issue size of US\$ 500 million	12-Oct-18	28-Aug-19	AA	XS1891577030	19-Oct-48
4	Notes issued by Huai'an Water Conservancy Holding Group Co., Ltd.	-	10-Apr-19	BBB-	XS1972568858	24-Apr-22
5	Notes issued by Yangzhou Economic and Technological Development Zone Development Corporation	-	14-Jun-19	BBB	XS2012941774	27-Jun-22
6	Notes issued by Ronshine China Holdings Limited	-	9-Oct-19	BB	XS1976760782	25-Oct-22

## Rating Transitions

Rating transition matrix shows the rates of a given rating migrating to other rating categories. It illustrates the transition volatility and default risk of each rating category. The rating transition rates are computed as by comparing the ratings of issuers at the beginning of the study period to the end of the study period (See Appendix for I for details on constructing the rating transition matrix).

Exhibit 3 provides the one-year rating transition rates of Pengyuan International's long-term foreign currency issuer credit ratings. The transition matrices are constructed at the rating modifier level. As we can see from the exhibit, other than one withdrawn rating, all of Pengyuan International's rated issuers maintained their long-term foreign currency issuer credit ratings over the study period. The same pattern holds for Pengyuan International's long-term local currency issuer credit ratings (see Exhibit 4).

**Exhibit 3: One-Year Rating Transition 2018 – 2019: Foreign Currency**

Credit Rating as of 20190101	Number of Ratings	Credit Ratings as of 20191231 (%)																			
		AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC to CC	RS	D/SD	WR
AAA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA	1	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
BBB+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BBB	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BBB-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CCC to CC		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D/SD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>4</b>																				

WR – Withdrawn

Source: Pengyuan International

**Exhibit 4: One-Year Rating Transition 2018 – 2019: Local Currency**

Credit Rating as of 20190101		Credit Ratings as of 20191231 (%)																			
Credit Rating	Number of Ratings	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC to CC	RS	D/SD	WR
AAA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA+	1	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AA-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
BBB+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BBB	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BBB-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BB-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B+		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B-		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CCC to CC		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D/SD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>4</b>																				

WR – Withdrawn

Source: Pengyuan International

Theoretically, the rating transition matrices show a good rating stability. However, the current statistical observation period is not long enough and the number of samples is very limited. In the future, with the increase of the observation period and sample number, the rating transition matrices will provide a more informative and conclusive indication of the rating stability and default risk.

## Default Rates

Issuers within Pengyuan International's rating universe experience no defaults over the study period. The methodologies described in Appendix III and IV are not applicable until there are observed defaults.

## Conclusions

In this report, we compute statistics on the rating transitions and defaults of the issuers rated by Pengyuan International from 2018 to 2019. We did not observe any defaults over the study period. Due to the short study period and small sample size, it is difficult to reflect the relevant situation comprehensively and make statistically significant conclusion. We will take the same method for further research next year with extended rating samples.

## Appendix I

### Definition of Credit Rating Transition Matrix

The credit rating transition matrix is one of the test criteria for the stability of rating results. Rating stability refers to the degree to which credit ratings remain unchanged over a particular period. The credit rating transition matrix is the statistics of credit rating transition paths of the rating agency's rating objects within a particular time period, calculating transition rates of each rating category to form a transition matrix. It can measure the stability of the rating results by observing the transition of credit ratings from the beginning to the end of a time period.

The credit rating transition matrix is briefly described as follows: assume the credit rating of the rating object at the beginning of the period is  $i$ , and its credit rating at the end of the period is adjusted to  $j$ , then the credit rating transition rate of the rating object is  $P_{ij}$  and the following matrix is called the transition matrix.

$$P = \begin{pmatrix} P_{11} & P_{12} & P_{13} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ P_{i1} & P_{i2} & P_{i3} & \cdots \\ \vdots & \vdots & \vdots & \vdots \end{pmatrix} \quad P_{ij} \geq 0, \quad i, j = 1, 2, 3, \dots$$

Obviously,  $\sum_{j=1}^{\infty} P_{ij} = 1, i = 1, 2, 3, \dots$

### The Statistical Sample of the Credit Rating Transition Matrix

Pengyuan International adopts the internationally prevailing static pool approach to estimate the transition matrix. The static pool approach can be understood from two aspects. Firstly, in terms of sample selection, it only examines the rating objects whose ratings are active and outstanding from the beginning to the end of the observation period. Secondly, when counting the ratings for each rating category, this approach only considers the ratings of the rating objects at the beginning and end of the period, and the trajectory of the ratings within the period are not considered.

### Measurement and Estimation of Credit Rating Transition Matrix

Different measurements of credit rating transition matrix illustrate the properties and characteristics of the "rating transition" using different methods and from different perspectives. Pengyuan International employs three different statistical methods to estimate three different measurements of credit rating transition matrix.

#### 1. One-year transition matrix

The statistical method of the one-year transition matrix is called the cohort method, which is the most commonly used and basic method to calculate the credit rating transition matrix. The cohort method is to record credit ratings of all qualified obligors or obligations at the beginning of the year. For example, let  $n_i$  indicate that there are  $n_i$  rating objects with credit rating  $i$  at the beginning of year  $y$  and it will be compared with the credit records at the end of the year. If there are  $n_{ij}$  rating objects that are transitioned from rating  $i$  to rating  $j$  at the end of the year, the formula  $P_{ij} = \frac{n_{ij}}{n_i}$  calculates the transition rate from rating  $i$  to rating  $j$  during that period. The matrix created after the complete calculation of the transition rates of all migration paths with all rating levels at the beginning of the period is the one-year credit rating transition matrix, which is called the one-year transition matrix of year  $y$ . In this way, the transition matrix of other time spans can be obtained, such as the two-year transition matrix of year  $y$  and the five-year transition matrix of year  $y$ .

#### 2. Average transition matrix

Taking the one-year average transition matrix as an example, the average transition matrix is obtained by the weighted average of one-year transition matrix for multiple years. For instance, let  $P_1(i, j)$  denote the transition rate from rating  $i$  to rating  $j$  of year  $y_1$  and  $P_2(i, j)$  denote the transition rate from rating  $i$  to rating  $j$  of year  $y_2$ .  $P_3(i, j), P_4(i, j), \dots, P_k(i, j)$  are the transition rates for year  $y_3, y_4, \dots, y_k$ .  $\bar{P}_{ij}$  denotes the average one-year transition rate from year  $y_1$  to year  $y_k$ , which is calculated as

$$\bar{P}_{ij} = P_1(i, j)w_1(i) + P_2(i, j)w_2(i) + \cdots + P_k(i, j)w_k(i),$$

where  $w_1(i)$  is the weight of  $p_1(i, j)$  and is calculated as follows:

$$w_1(i) = \frac{n_1(i)}{n_1(i) + n_2(i) + \dots + n_k(i)}$$

where  $n_1(i)$  denotes the number of rating objects with rating  $i$  at the beginning of the year  $y_1$ ,  $n_2(i)$  denotes the number of rating objects with rating  $i$  at the beginning of the year  $y_2$  and so on.

## Appendix II

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### Default rate indicators

The default rate indicators are built by various methods or defined from different perspectives, with an aim to describe the nature and characteristics of the number of defaults. We will start from introducing three rank-classified indicators that are of the most concerned in default studies.

#### 1. Annual default rate

Annual default rate is usually associated with a specific sample and a time horizon, which refers to the annual default rate of different rating entities within the time horizon of the sample (usually 1 year).

Normally, the credit rating of a defaulting entity is its rating level at the beginning of the default year, i.e., as of January 1. For instance, the default rate of a AA rated entity in 2001 is the default rate of the rated entity whose rating is AA at the beginning of 2001.

#### 2. Cumulative default rate

Cumulative default rate refers to the cumulative default rate of a sample over multiple years, which equals the total number of defaults during the period divided by the total number of the sample at the beginning of the time period. The rate is the accumulation of annual default rate in a particular time horizon (usually 2 years and above), and it is also targeted at a specific sample.

#### 3. Average cumulative default rate

Average cumulative default rate refers to the average of the cumulative default rates of various time horizons and multiple sample groups. The time horizon of this indicator is usually 2 years and above, and it has a concept of multiple samples.

## Appendix III

### Default rate calculation

#### 1. Cohorts

The calculation of most indicators is based on the concept of cohorts. Specifically, a cohort is formed on the basis of the rating held by the rated entity at the beginning of a certain year. Normally, a  $n(R, Y)$  denotes the size of the cohort composed of rating entities holding rating R at the beginning of Y year. For instance, a  $n(AA, 2001)$  denotes the size of the cohort of companies holding AA rating at the beginning of 2001..

#### 2. Annual default rate

Annual default rate equals to the number of defaults from the cohort that occur in the cohort formation year divided by the total number of entities in the cohort. For a cohort holding rating R at the beginning of year Y, let  $d(R, Y)$  be the number of defaults of the cohort over the year Y,  $n(R, Y)$  denotes the size of the cohort, and  $D(R, Y)$  denotes the annual default rate of the cohort. Then  $D(R, Y) = d(R, Y) / n(R, Y)$ .

#### 3. Marginal default rate

Denote  $d(R, Y, t)$  as the number of defaults in the t-th year of the cohort formed at the beginning of year Y,  $n(R, Y, t)$  as the number of non-defaults of the cohort until the start of the t-th year, and the marginal default rate  $MD(R, Y, t)$  as the probability of a default in the t-th year of an entity that has no default record before the t-th year. Then the marginal default rate equals the number of defaults in the t-th year divided by the number of remaining non-defaults at the beginning of the t-th year, that is  $MD(R, Y, t) = d(R, Y, t) / n(R, Y, t)$ .

#### 4. Cumulative default rate

Denote  $d(R, Y, t)$  as the number of defaults of the cohort in the t-th year after being rated. Then T-year cumulative default rate  $CD(R, Y, T)$  equals the total number of defaults from the year of cohort formation up to the T-th year divided by the total number of rated entities of the cohort at the start of the period, that is:

$$CD(R, Y, T) = \sum_{t=1}^T d(R, Y, t) / n(R, Y)$$

which is

$$CD(R, Y, T) = 1 - \prod_{t=1}^T [1 - MD(R, Y, t)]$$

Where  $1 - MD(R, Y, t)$  denotes the marginal survival rate of the t-th year.

For instance,  $d(AA, 2001, 1)$  denotes the number of defaults of the cohort in 2001 (same with  $d(AA, 2001)$ ),  $d(AA, 2001, 2)$  denotes the number of defaults of the cohort in 2002, ..., then  $\sum_{t=1}^5 d(AA, 2001, t)$  is the cumulative number of defaults of the rated entities holding AA rating between 2001 and 2005.  $CD(AA, 2001, 5)$  represents the cumulative default rate of the cohort from 2001 and 2005, which is a 5-year indicator.

When  $T = 1$ , the cumulative default rate equals the annual default rate.

#### 5. Average marginal default rate

The indicators above all use the concept of a single cohort, that is, only one sample cohort is concerned. However, the average marginal default rate and the following average cumulative default rate use the concept of multiple cohorts and examine a set of cohorts. Those are weighted averages, which are weighted by the relative size of the cohort. The average marginal default rate aims at computing average cumulative default rate.

Denote  $d(R, Y_0, t)$  as the number of defaults of the cohort formed at the beginning of year  $Y_0$  in the t-th year,  $d(R, Y_i, t)$  as the number defaults of the cohort formed at the beginning of year  $Y_i$  in the t-th year; denote  $n(R, Y_0, t)$  as the number of non-defaults of the cohort formed at the beginning of  $Y_0$  until the start of the t-th year,  $n(R, Y_i, t)$  as the number of non-defaults of the cohort formed at the beginning of year  $Y_i$  until the start of the t-th year. The average marginal default rate  $\overline{MD}(R, T, t)$  represents the weighted average default rates of the rated entities in  $i_t$  cohorts in the t-th year that have no default records before the t-th year, which can be calculated by

$$\overline{MD}(R, Y, t) = \frac{d(R, Y_0, t) + d(R, Y_1, t) + \dots + d(R, Y_i, t)}{n(R, Y_0, t) + n(R, Y_1, t) + \dots + n(R, Y_i, t)} = \sum_{Y=Y_0}^{Y_i} d(R, Y, t) / \sum_{Y=Y_0}^{Y_i} n(R, Y, t)$$



where the time span of samples is between the beginning of  $Y_0$  and the beginning of  $Y_{i+t}$ , and there are total  $(i + t)$  years.

For instance, in order to calculate the average marginal default rate of the AA-level entities in the third year, the time span should be from the beginning of 2001 to the beginning of 2005 (or the end of 2004). The formula is as follows:

$$\overline{MD}(AA, 2001, 3) = \sum_{Y=2001}^{2003} d(AA, Y, 3) / \sum_{Y=2001}^{2003} n(AA, Y, 3)$$

The numerator of the RHS of the equation is a sum of three numbers, which are 1) the number of AA-level defaulting entities that are rated at the start of 2001 and default in 2003, 2) the number of AA-level defaulting entities that are rated at the start of 2002 and default in 2004 and 3) the number of AA-level defaulting entities that are rated in 2003 and default in 2005; the denominator is also a sum of three numbers, which are 1) the number of AA-level non-defaulting entities that are rated at the start of 2001 and have no default record until 2003, 2) the number of AA-level non-defaulting entities that are rated at the start of 2002 and have no default record until 2004 and 3) the number of AA-level non-defaulting entities that are rated in 2003 and have no default record until 2005.

## 6. Average cumulative default rate

Denote  $\overline{CD}(R, Y, T)$  as the T-year weighted average cumulative default rate. Then

$$\overline{CD}(R, Y, T) = 1 - \prod_{t=1}^T [1 - \overline{MD}(R, Y, t)]$$

Obviously,  $\overline{CD}(R, Y, 1) = \overline{MD}(R, Y, 1)$ , i.e., 1-year average cumulative default rate equals to 1-year average marginal default rate.

In this case, the sample time horizon is  $(i_T + T)$  years, hence it also represents the T-year average cumulative default rate in  $(i_T + T)$  years, where  $i_T$  denotes the number of cohorts used for computing the average marginal default rate of the T-th year.

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