

METHODOLOGY FOR ASSIGNMENT OF CREDIT RISK PROFILES TO DEBENTURES

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EXECUTIVE SUMMARY

The number of debentures deposited with B3 totaled 1,451 on November 30, 2018. They were issued by 665 companies in dozens of sectors of the Brazilian economy. In aggregate, they were worth approximately BRL 425 billion.

The liquidity of the secondary market for debentures was limited, however. Daily trading in debentures averaged only 80. Two were traded in all the trading sessions held in the 12 months prior to our survey. Average daily trading value was about BRL 250 million. Leaving aside debentures held in treasury and those issued by leasing companies, the secondary market has the potential to trade BRL 334 billion, yet annualized daily turnover averages only 18%.

With all due caveats regarding comparability, turnover on the Brazilian cash equity market is 160%.

To develop the primary and secondary markets for debentures, B3 will now calculate daily reference prices for publicly placed debentures governed by CVM Instructions 400 and 476. Prices will not be calculated for the following: perpetual and convertible debentures that incorporate interest into the principal; debentures issued by leasing companies; debentures issued by companies that do not disclose accounting information to the public or do not do so on a timely basis; and debentures issued by holding companies whose holdings in the equity of other companies are not identified. In this version, we will calculate prices only for projects at a pre-operational stage or under development and guaranteed by shareholders.

Considering empirical evidence from around the world, we expect publication of reference prices to be useful for price formation and to bolster investor confidence accordingly, as well as helping to fuel trading volume.

B3's methodology for calculating the reference prices of debentures is based on trading in the primary and secondary markets and on the credit risk profiles assigned to the debentures concerned. It takes both marking to market and marking to model into account.

This document describes **B3's methodology for assigning credit risk profiles to debentures**.

CVM Instruction 521 establishes that credit risk rating, defined as assessing the credit quality of an issuer of equity or debt securities, structured transactions, and any financial assets admitted for trading in the securities market, must be done by rating agencies registered with CVM, in the case of agencies domiciled in Brazil. Rating

agencies are defined as entities that perform the activity professionally in the context of the securities market.

The Instruction applies only to ratings produced for publication, diffusion or distribution to third parties, even if the parties concerned are limited to clients.

B3 is not a rating agency, and its pricing appraisals should not be construed as credit ratings, particularly for the purposes of compliance with CVM Instruction 521. They serve for internal consumption in the context of debenture pricing. B3's credit profiles will therefore not be published. However, B3 is willing to discuss with market participants specific cases in which credit risk profiles are assigned immediately in accordance with the methodology described in this document and information in the public domain, as in the case of debentures in default or issued by companies undergoing court-supervised reorganization.

1. INTRODUCTION

The starting point for B3's pricing methodology is a breakdown of debenture cash flow discount rates into two components:

- The risk-free interest rate relative to the index, extracted from daily adjustments to futures contracts referenced to the index and basically corresponding to a mark-to-market rate;
- The spread corresponding to its credit risk: an interest rate that is added to the risk-free rate to give the premium required by investors to accept the credit risk.¹ To calculate this spread, a credit risk profile must be assigned to every debenture. B3 uses a proprietary methodology for this purpose.

After calculating credit risks, all debentures are grouped in accordance with this variable, and debentures with similar levels of credit risk are given the same risk profile.

Daily yield curves are estimated for credit risk profiles on the basis of actual trading in the debentures concerned. The difference between a yield curve and the curve for the interest rate used is the spread for the profile.

Credit risk is also calculated for debentures not traded on any given day, and the credit risk profile spread is associated with each of these using the spread for the day as if it were the issue date.

The discount rate is obtained by adding the spread to the risk-free interest rate for the index. The reference price is the result of the cash flow discounted at this rate.

The credit risk profile is associated with the **probability of debenture default**. More specifically, it is the risk of failure by the issuer to **honor payments in Brazilian currency for the 12 months following** the appraisal. The profile therefore refers to the comparability of companies and debenture issues in Brazil; there is no international comparability.

The methodology considers three groups of variables: the first two are associated with the issuer and the third with the characteristics of the debenture.

The first group consists of variables that capture (i) the **issuer's risk profile**, such as jurisdiction, economic sector, market positioning, regulatory risk, the structure of the business group to which the company belongs (if any), governance, and business strategy.

¹ This component may also contain other risk premiums. The most common is for liquidity risk.

The second group comprises variables that capture (ii) the issuer's **financial risk profile**, such as cash flow, profitability, and financial structure and flexibility.

The third group covers variables that capture (iii) the **characteristics of the debenture issue**, such as creditor protection (cross-default clause, financial covenants, guarantees etc.), seniority and subordination.

Because of the large number of issuers, whenever possible B3 uses quantitative methods to appraise credit risk. The methodology has four sequential components. Three are quantitative, and the fourth is a final adjustment:

- (i) a statistical model for estimating the default probability;
- (ii) a statistical model for adjusting the default probability based on macro-sectoral factors;
- (iii) assignment of credit risk profiles grouped according to similar default probabilities;
- (iv) qualitative adjustments to profiles.

Initially, the probability of default (i) was estimated by logistic regression, used to predict binary events (non-default or default) according to the three variables above.

In November 2022, B3 began using a new statistical model with updated parameters for predicting default and a more refined appraisal of credit risk.

The model estimates the probability of default based on variables referring to periods prior to the period in which default may materialize. It resembles the scoring models used internally by institutions with credit portfolios that comprise large numbers of issuers, and is described in section 3 below, "Estimating default probability".²

The time lag pertaining to the variables in the model described in section 3 tends to reduce the accuracy of the estimated default probabilities. One way to mitigate this effect is to adjust the probabilities so that they take into account the expected conditions in the period in which default may occur. This forward-looking adjustment, deployed for issuers in similar sectors, is item (ii) above (statistical model for adjusting the probability of default by macro-sectoral factors). For each macro-sector, the default probabilities are adjusted by forecasts for macroeconomic variables that effect

² If the number of issuers were substantially smaller, it would be possible to construct explanatory variables for the period in which default could occur. For example, balance-sheet variables could be predictions for the 12 months ahead.

all issuers in the period during which default may occur. This adjustment is described in section 4, "Macro-sectoral adjustment of the probability of default".

The third quantitative component of the methodology is (iii) assignment of credit risk profiles in groups of similar default probabilities. Risk scores are ranked from lowest to highest and grouped according to the level of risk. Each group is given a credit risk profile – a letter indicating credit quality. Section 5, "Assigning credit risk profiles", describes how the risk scale works.

To address situations in which the quantitative approach is not sufficient, credit risk profiles can be shifted up or down a level by qualitative factors, the fourth component of the methodology. To control the risk of subjective decisions, they are subjected to strict governance. The qualitative adjustment process and its governance are described in section 6, "Qualitative adjustments".

B3 uses the methodology summarized above and described in more detail below to assign daily credit risk profiles to publicly placed debentures in accordance with the scope defined here.

2. ELIGIBILITY

The universe of debenture issuers encompasses a wide range of companies from publicly traded corporations to small privately held firms for which little information is available, and issues are both privately and publicly placed.

There are two main pre-requisites for assignment of a credit risk profile:

- The company must have issued at least one debenture publicly – our methodology includes an appraisal of coupon payment, which is possible only for publicly placed issues;
- It must have published financial statements, which contain valuable information for the purposes of appraising creditworthiness.

Given the quantitative model developed for the methodology, the following additional eligibility pre-requisites were needed:

- Not being greenfield projects (construction or ramp-up), as the quantitative model is anchored in financial statements, which are not representative for greenfield projects;
- Not being in securitization, leasing or any business relating to the financial system, as these have different dynamics from the standpoint of credit risk profile appraisal.

Whenever B3 concludes that the issuer of a debenture is not aligned with the proposed solution, it will not be eligible for a credit risk rating. In cases that are representative of the market but with many securities that are not eligible, B3 uses an override to assign a credit risk profile, as described below.

3. ESTIMATING DEFAULT PROBABILITY AND SCORING RISK

The estimation technique starts by inferring a risk ranking based on the national scale used by rating agencies, combined with the spread captured from eligible debenture trades³. To validate this rule, default probability ranking was checked against the spread captured from debenture trades considered valid for the purposes of inferring credit risk spread. This validation is illustrated in Table 2.

Table 2 – Illustrative ranking of national rating scale and spread levels

NON-INCENTIVIZED		INCENTIVIZED	
Agency rating	Spread curve level	Agency rating	Spread curve level
AAA	4.0	AAA	3.4
AA+	4.58	AA+	4.3
AA	4.64	AA	4.4
AA*-	5		
AA-	5.38		
A+	6.21	A+	6.3
A-	8.33		
		BBB-	9.5
BB	10	BB	11
		B	11

This ranking variable was observed for between 50% and 60% of the eligible universe for modeling and considered a representative sample.

The inferred grid is scalable to include more levels of risk so as to show more accurately the process of deterioration or recovery in the eligible universe.

Thus, the dependent variable Y is defined as a grid with 12 levels of credit risk, and X is the set of explanatory variables.

Each explanatory variable selected undergoes identification of the distribution of values and normalization. The values are ranked from highest to lowest, and ten equidistant centroids are obtained. Scores are assigned to the centroids, ranging from

³ Extra-group trades, in addition to the other eligibility criteria established in the Debenture Pricing Manual.

0 for the worst to 100 for the best. This treatment is designed to create a common scale for all explanatory variables.

Equation (1) explains each issuer's position on the 12-level grid, defined by a score from 0 for the worst level to 100 for the best.

$$y_{(x)} = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \dots (1)$$

where:

- Y is the categorical variable ranked into 12 levels
- β_i is the linear coefficient for each explanatory variable

Equation (1) is estimated by maximizing the Spearman correlation as the objective function, using global optimization approach with contour conditions.

With each estimate by the model, the sample expands to include the most recent period possible. The period used for this latest estimation was January-December 2019.

The next topic comprises two sub-items. The first defines a default event. The second describes the variable selection process.

3.1 Definition of default event and concept of default

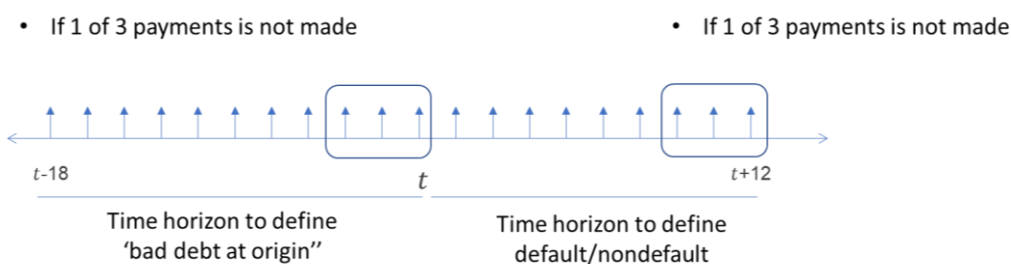
A debenture issuer is held to be in default when it fails to pay principal or interest during the last three events in a 12-month window on the date of the appraisal.

At time t , the issuer should not be held to be in default as in this case it would not be necessary to estimate the probability of default.

An issuer is considered "original bad debt" when it fails to make at least one payment of principal or interest on any of the latest three due dates in the past 18 months, considering all debentures with due dates in the period.

The 18-month window is relevant because some debentures pay out annually and non-payment can become evident only with a considerable lag.

All debentures linked to the same issuer must be considered because the credit risk profile is assigned to the issuer. The following figure attempts to clarify the difference between "original bad debt" and default.



3.2 Selection of variables ($X_{i,d,t}$)

The initial set of variables that are candidates for deployment in the model should be designed to capture the debenture issuer's business and financial risks.

Because the number of available variables is large, a well-defined selection process must be used.

The selection process is sequential and comprises three stages: (i) univariate, (ii) bivariate and (iii) multivariate.

Stage (i) is univariate and aims to select explanatory variables that:

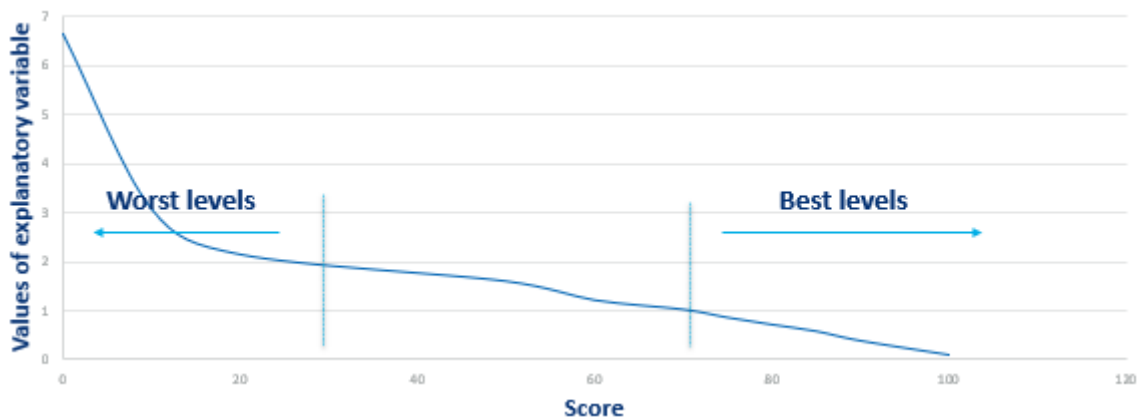
- Have a correlation with the dependent variable that is statistically significant and makes economic sense
- Have a small number of null values
- Remain stable over time
- Are available when the model is being estimated
- Have significant discriminatory power

The variables selected in the univariate stage go through to the bivariate stage (ii), which analyzes the behavior of one explanatory variable in the presence of another to avoid problems of collinearity in the model. Correlations between the variables and between them and the dependent variable are calculated. If two variables correlate at an absolute value above a certain threshold, the variable with the lower absolute correlation with the dependent variable is discarded.

At the end of the second stage, the selected variables have been processed so as to create a common scale. This treatment entails the application of continuous scoring on a scale of 0 to 100, representing the worst and best in the universe of each variable. This treatment comprises three steps:

1. Identification of the central element: ranking of observations and selection of 10 equidistant centroids.
2. Normalization: assignment of scores to the centroids on a scale from 0 for worst to 100 for best.
3. Linearization: each variable has its universe of values converted into scores based on a linear function constructed from the scores of neighboring centroids.

The next figure illustrates the process.



Finally, the multivariate process (iii) consists of estimating the values of β_i by optimization. In this stage, the process of estimating by optimization defines weights considering the aggregate impact of the significance of each variable. Thus, we have the universe of explanatory variables determining an equation equivalent to (1).

The process of constructing the model includes the creation of possible models based on equation (1), each with its own set of explanatory variables. Selection among the possible models entails evaluating:

- Metrics that estimate which solution has the most discriminatory power, i.e. can best separate individuals, or the best level of Spearman correlation with the categorical response variable.
- The final rank order proposed by the equation, in terms of performance indicators such as the observed valid trading spread.
- Out-of-sample performance: part of the available data is excluded from the estimation of values of β_i . For this universe, the estimated models are used to appraise discrimination metrics in order to find which equation has good separating power in the development sample and is also capable of

discriminating in external samples, displaying the most robustness as a predictive model.

4. MACRO-SECTORAL ADJUSTMENT OF THE DEFAULT PROPABILITY

Considering that a large proportion of the information in the model is based on past events, there is clearly a possibility of improving the quality of risk classification estimations.

One way of doing so is to adjust the risk score so that it takes into account the expected conditions in the future period when deterioration may occur and also so that these affect groups of sectors similarly. The number of issuers is again an important element of decision making in constructing the credit risk profile methodology. While on one hand the large number of issuers means that forward-looking adjustments must be sectoral, on the other hand the limited number of issuers in certain sectors means that forward-looking adjustments must be applied to groups of sectors. To preserve the objective nature of B3's credit risk profile assignment methodology, forward-looking adjustments are made in two quantitative stages.

To minimize the subjective nature of this methodology, the source of the forecasts for macroeconomic variables is the Central Bank of Brazil's Market Expectation System (Focus). [Click here to visit Focus](#).

In the second stage, each issuer's score is corrected in accordance with the estimated macro-sectoral model and a Bayesian transformation distributes the macro-sectoral adjustment in proportion to each issuer's risk.

5. ASSIGNING CREDIT RISK PROFILES

The third component of the methodology is (iii) assignment of credit risk profiles. To this end, debentures are ranked by their scores in ascending order and grouped by similarity of these values. Each group is given a letter that represents its credit profile: the closer the letter is to the beginning of the alphabet, the more creditworthy the group and the lower the probability of default. The credit profiles represent a discretization of default probabilities or credit scores.

From the credit standpoint, the groups should have the following characteristics over time:

- Good stability;
- Average default probability for upper credit profile groups should always be lower than for groups with lower credit profiles and vice-versa;

- Smooth migration between groups.

Because the methodology for assigning credit risk profiles is part of the methodology for pricing debentures, the latter affects the former as far as choosing the number of credit profiles is concerned. Each profile must be associated with a yield curve estimated on a daily basis, and the limited liquidity of debentures on the secondary market limits the number of credit profiles.

Taking all the above factors together, seven credit profiles were chosen. Besides the four profiles presented in Table 2 below (A, B, C and C-), the credit risk rating scale also includes D, E and F.

Profile D is assigned to issuers in severe default (“original bad debt”) at time *t* or issuers undergoing court-supervised reorganization; profile E to issuers under court-supervised reorganization but whose recovery plans were not approved within the legal timeframe or are not being implemented in the terms approved by their creditors; and profile F to issuers that are being liquidated or ceasing to operate.

Table 2 – Credit risk profiles in the first version of the methodology

Profile	Average default – period in which model was developed
A	3%
B	7%
C	22%
C-	43%

6. QUALITATIVE ADJUSTMENTS

Qualitative adjustment consists of upgrading or downgrading the credit risk profiles assigned by quantitative methods in cases where they did not capture relevant information at the right time.

These adjustments are effected in compliance with strict governance, since they directly reflect subjective appraisal. The first governance element is (i) collegiate decision making. Decisions on qualitative adjustment are made by **B3’s Working**

Group on Corporate Bond Pricing. The second element is (ii) the **Rules on Qualitative Adjustment of Credit Risk Profiles**, which contains the guidelines to be followed when making appraisals.

The qualitative adjustment rules are detailed below.

6.1 Pre-defined qualitative adjustments

a. Court-supervised reorganization

If a company files for court-supervised reorganization but has not defaulted on any debentures, its credit risk profile is rated D by qualitative adjustment.

b. Greenfield projects with irrevocable real guarantees

Many projects in the initial stage have debentures guaranteed by shareholders, and the credit risk or default risk is therefore directly linked to the guarantor's credit risk. This information is typically available in the debenture deed and is not structured so as to be captured quantitatively by the methodology. Thus, after confirmation of the presence of an enforceable guarantee that transfers credit risk to the guarantor, the guarantor's credit risk profile is assigned to the debenture. If there are several joint guarantors, the profile assigned to the debenture is that of the guarantor with the highest risk.

6.2 Additional qualitative adjustments

Even when the model is structured and displays excellent adherence by predicting the observed average probability, there are subjective factors that are not captured quantitatively and can help produce a more accurate credit risk profile, such as:

- Shareholders may be both excellent credit risk mitigators and factors that increase the default probability;
- Market positioning – a sector with more competition or more dependence on factors external to the company's numbers can increase the company's credit risk;
- The issue has an excessive number of supplements and a risk profile that resembles that of "forced restructuring";
- Reports in news media outlets.

In some cases, an in-depth appraisal of the issuer is performed to see if it is necessary to adjust the quantitatively assigned credit risk profile.

6.3 Application

The application of pre-defined qualitative adjustments is part of the methodology but must be approved by B3's Pricing Department (as methodological overrides).

The additional qualitative adjustments require approval by a multidisciplinary working group and an appraisal forum.

Any alteration in the qualitative stage is considered an override, typically with an assignment date and valid for six months.

A return to the credit risk profile assigned in the quantitative stage can be effected before the override expires, provided the conditions that led to the qualitative adjustment have ceased to exist.

CONTROL INFORMATION

Effective: from April 8, 2019

1st version: April 8, 2019

2nd version: April 20, 2020

3rd version: April 29, 2020

4th version: July 20, 2022

Responsibility for the document

Activity	Area responsible
Drafting	Credit Risk Analytics
Revision	Pricing
Approval	Risk Management

Change log

Version	Changes	Rationale	Date
1	Original version	N/A	N/A
2	Adjustments to text of all sections. Change to item 5 of Table 2 in light of new equation. Additional details in section 6.	New version of model (August 2019). Refinement to application of qualitative adjustments.	April 20, 2020
3	Adjustments to section 6	Revision of text	April 29, 2020
4	Changes to sections 3 (3.1 and 3.2), 4, 5 and 6 (6.3)	New version of model and structural changes to Risk Management Department.	July 20, 2022