Morningstar Fixed-Income Style Box™

Morningstar Methodology
Effective 31 October 2016

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Introduction

The Morningstar Style Box was introduced in 1992 to help investors and advisors determine the investment style of a fund. Different investment styles often have different levels of risk and lead to differences in returns. Therefore, it is crucial that investors understand style and have a tool to measure their style exposure. The updated Morningstar Style Box provides an intuitive visual representation of style that helps investors build better portfolios and monitor them more accurately.

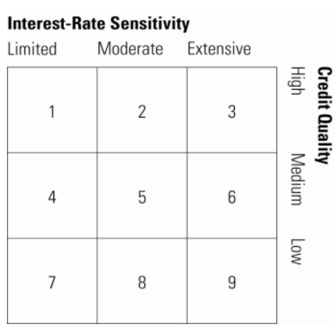
Morningstar classifies bond funds in its style box according to interest-rate sensitivity and average credit quality. The interest-sensitivity groups are limited, moderate, and extensive as measured by the average effective duration of a fund's holdings, and the credit-quality groups are high, medium, and low based on letter (or alphanumeric) credit ratings of bond holdings by third-party credit-rating agencies. The nine possible combinations of these characteristics correspond to the nine squares of the Morningstar Style Box—quality is displayed along the vertical axis and interest-rate sensitivity along the horizontal axis.

Fixed-Income Style Box

Overview

The model for the fixed-income style box is based on the two pillars of fixed-income performance: interest-rate sensitivity and credit quality. As depicted in the image below, the three interest-sensitivity groups are limited, moderate, and extensive, and the three credit-quality groups are high, medium, and low. These groupings display a portfolio's effective duration and third-party credit ratings to provide an overall representation of the fund's risk orientation given the interest-rate sensitivity and credit ratings of bonds in the portfolio.

Exhibit 1 The Fixed-income Style Box



Source: Morningstar Direct. Data as of dd/mm/yyyy.

Horizontal Axis: Interest-Rate Sensitivity

Prior to October 2009, taxable-bond funds domiciled in the United States with durations of 3.5 years or less were considered short-term (having limited sensitivity to interest-rate change); durations of more than 3.5 years but less than 6.0 years were considered intermediate-term (having moderate sensitivity to interest-rate change); and durations of more than 6.0 years were considered long-term (having extensive sensitivity to interest-rate change). In October 2009, Morningstar moved from the aforementioned static breakpoints to dynamic breakpoints.

On a monthly basis, Morningstar calculates duration breakpoints based around the effective duration of the Morningstar Core Bond Index (MCBI).

Limited: 25% to 75% of MCBI
Moderate: 75% to 125% of MCBI
Extensive: 125% of MCBI (no upper limit on long-term durations)

By using the MCBI as the duration benchmark, Morningstar lets the effective duration bands fluctuate in lock step with the market, which will minimize market-driven style-box changes.

Non-U.S. taxable-bond funds domiciled in the U.S. use static duration breakpoints. These include U.S.-domiciled funds in the world-bond and emerging-markets bond Morningstar Categories. These thresholds are:

Limited: <= 3.5 years
Moderate: > 3.5 and <= 6.0 years
Extensive: > 6.0 years

Municipal-bond funds domiciled in the U.S. use static duration breakpoints. These thresholds are:

Limited: <= 4.5 years
Moderate: > 4.5 and <= 7.0 years
Extensive: > 7.0 years

All non-U.S.-domiciled funds use static duration breakpoints. These thresholds are:

Limited: <= 3.5 years
Moderate: > 3.5 and <= 6.0 years
Extensive: > 6.0 years

Vertical Axis: Credit Quality

Historically, Morningstar followed the industry practice of reporting the average credit rating of a bond portfolio by taking a weighted average of ratings based on data provided by fund companies. However, because default rates tend to rise at a nearly geometric pace between the lowest grades (a mathematical property called convexity), this method systematically understated the average default rate of a bond portfolio. For example, for U.S. corporate bonds (as of the date of this document), the spread in default rates between CCC and BBB rated bonds was more than 21 times that of the default-rate spread between BBB and AAA bonds. Yet, the conventional averaging method assumes that these spreads are equal.

To see the impact of this, consider a portfolio of 90% AAA bonds and 10% CCC bonds. According to the conventional method, the average credit rating of this portfolio is AA. However, the average default rate for this portfolio is that of BB bonds.

To correct this bias, Morningstar takes the convexity of default-rate curves into account when calculating the average credit rating of a portfolio. The first step is to map the grades of a portfolio's constituents into relative default rates using a convex curve. The next step is to average the resulting default rates on a weighted basis (rather than the grades) to come up with an average default rate for the portfolio. Finally, using the same convex curve, Morningstar maps the resulting average default rate back into a grade. For example, a portfolio of 90% AAA bonds and 10% CCC bonds will have an average credit rating of BB under this new methodology.

Independent research confirms that the arithmetic average credit rating of a bond portfolio systematically understates the credit risk. Research also confirms that a more meaningful measure would be to average the default probabilities associated with each letter grade, and then use the convex curve that relates the numerical representation of the letter grades to default probability in order to assign a letter or alphanumeric rating to the portfolio. This procedure is detailed in Appendix A.

Based on the following breakpoints, Morningstar maps the calculated average asset-weighted letter credit rating (see Appendix A) for all portfolios on the vertical axis of the style box:

1. Low credit quality–asset-weighted average credit rating is less than BBB.
2. Medium credit quality–asset-weighted average credit rating is less than AA, but greater or equal to BBB.
3. High credit quality–asset-weighted average credit rating is AA and higher.

Source of Data

The data that drives the fixed-income style box is surveyed from fund companies. Morningstar asks fund companies to send the following information on a monthly or quarterly basis for each of their fixed-income or allocation funds.

Credit Quality

Each fixed-income security and cash instrument in a fund is assigned to one of the following eight categories for the credit-quality calculations. The percentage of assets for each letter rating is presented as a percentage of all fixed-income and cash assets.

Example credit-quality breakdown:

AAA	AA	A	BBB	BB	B	Below B	Not Rated	Total
71.72	3.91	7.08	9.49	1.44	0.98	0.00	5.38	100.00

Letter-rating data provided to Morningstar in one of the first seven categories (AAA through Below B) only reflects letter ratings assigned by one of the Nationally Recognized Statistical Rating Organizations. So-called internal or manager-derived alphanumeric credit ratings are not included in those categories; rather, bonds not rated by an NRSRO are included in the Not Rated category.

Morningstar is sensitive to the reality that some vendors use Moody's Investor Services alphanumeric ratings rather than or in addition to S&P letter ratings. Below is a chart showing the equivalent Moody's alphanumeric-rating class for each S&P letter-rating class.

S&P[1]	AAA	AA	A	BBB	BB	B	Below B
Moody's	Aaa	Aa2	A2	Baa2	Ba2	B2	Below B2

Morningstar prefers that bonds be classified according to the Barclays Capital Global Family of Indices ratings rules when ratings are available from all three agencies (that is, use the middle rating of Moody's, S&P, and Fitch after dropping the highest and lowest available ratings); if only two rating agencies rate a security, then the lowest rating should be used; if only one agency rates a security, then that rating can be used; if there is a security with no rating, then that security should go into Not Rated.

Average Effective Duration

Morningstar asks fund companies to calculate and send average effective duration (also known as "option-adjusted duration") for each of their fixed-income or allocation funds. We ask for effective duration because that measure typically gives the best estimation of how the prices of bonds with embedded options, which are common in many mutual funds, will change as a result of changes in interest rates.

Effective duration takes into account expected mortgage prepayments or the likelihood that embedded options will be exercised. If a fund holds futures, other derivative securities, or other funds as assets, the aggregate effective duration should include the weighted impact of those exposures. Standard practice for calculating this data point requires the determination of a security's option-adjusted spread,

1 A more specific breakdown of S&P and Moody's letter grades can be found in Table 1 on Page 15 of this methodology.

including the use of option models or Monte Carlo simulations, as well as the testing of interest-rate scenarios. Morningstar requests that funds only report data in this field that has been specifically labeled as effective (or option-adjusted) duration or that the fund is certain has been calculated in the fashion described.

Morningstar categorizes any fixed instrument with less than 92 days to maturity as cash for the purposes of calculating a fund’s asset-allocation breakdown. These short-term fixed securities and other cash instruments are included in the calculation of effective duration.

Morningstar accepts surveys returned with modified duration (and no effective duration provided) for funds in the municipal and high-yield categories. Surveys for all other U.S. bond categories that lack a submission for effective duration will not be accepted.

However, Morningstar accepts surveys returned with modified duration (and no effective duration provided) for non-U.S.-domiciled fixed-income funds not in a convertible-bond category.

Modified duration is generally defined as the approximate percentage change in a bond price for a 100-basis-point change in yield, assuming that the bond's expected cash flows do not change when the yield changes. Modified duration works well as an estimator for modest interest-rate shifts that occur over a short period of time for bonds without embedded options.

The problem, particularly in the U.S., is that bonds with embedded options are quite common. Even the simplest callable bond may present a roadblock to using modified duration. In Europe, such concerns are much less of an issue; therefore, Morningstar will accept modified duration when effective duration is not provided.

Morningstar will not accept modified duration for funds in convertible-bond categories, as the interest-rate sensitivity of a convertible bond depends on the value of its embedded option. If convertibles trade at distressed prices (its option is said to be deep out of the money), the price of the convertible bond will be driven mainly by the probability of default of the company and therefore will be minimally sensitive to change in interest rates. If the option is slightly out of the money or at the money, the convertible bond will trade like a corporate bond and may be highly sensitive to changes in interest rates. If the option is in the money or deep in the money, the bond will trade more like issuer's underlying equity, such that its value will be almost equal to the underlying equity plus the time value of the embedded option. In this case, the bond becomes nearly insensitive to interest-rate changes. Modified durations assume that an instrument's sensitivity to interest rates depends exclusively on the schedule of coupon payments. Because the sensitivity to interest rates for a convertible bond depends on whether its option is in the money or out of the money, as well as the price of the underlying stock, Morningstar cannot rely on modified duration as a reasonable measure of convertible-bond interest-rate risk.

Appendix A

The first column of Table 1 on Page 15 represents the credit-quality data requested in Morningstar's credit-quality survey. The next two columns are the equivalent credit-quality ratings for Moody's and S&P. The fourth column is the numerical representations used in this methodology.

Morningstar has found that a good model of default rates for a number of rated bond universes is as follows:

$$d(x) = d_{AAA} + \left(d_{CCC} - d_{AAA}\right) f\left(x, \Theta\right) \quad [1]$$

Where

x	=	the numerical representation of the bond's rating
$d(x)$	=	the default rate of the bond
d_{AAA}	=	the default rate of AAA bonds (Aaa on Moody's scale)
d_{CCC}	=	the default rate of CCC bonds (Caa2 on Moody's scale)
$f(.;\Theta)$	=	the relative default rates This is a convex two-segment quadratic spline with $f(1;.) = f'(1;.) = 0;\ f(19;.) = 1;\ f(10,\Theta) = \frac{1}{2}(1-\Theta)$
Θ	=	the convexity parameter; 1/3 ≤ Θ ≤ 1 (This guarantees that $f(.;\Theta)$ is increasing and convex)

The convexity parameter measures the change in the slope from the AAA to BBB range to the BBB to CCC range, relative to the overall slope of the default-rate curve:

$$\Theta = \frac{\left(d_{CCC} - d_{BBB}\right) - \left(d_{BBB} - d_{AAA}\right)}{d_{CCC} - d_{AAA}} \quad [2]$$

Where d_{BBB} is the default rate for BBB bonds (Baa2 on Moody's scale).

Morningstar calculated Θ for a number of bond universes using equation [2] and found that 0.9 is a fair representation. Because the methodology requires one convex scale for all bond universes, Morningstar set Θ = 0.9 globally. However, because Morningstar will periodically review the data and could choose another value in the future, Θ is programmed as a parameter that can be readily changed.

The fifth column of Table 1 (refer to Page 15) shows the relative default rates using Θ = 0.9, and the sixth column shows the resulting fitted default rates using the values of d_{AAA} and d_{CCC} for the corporate-bond universe. The seventh column shows the empirical default rates for the corporate universe. Figure 1 (refer to Page 16) graphs these empirical default rates and the default-rate spline, showing that the spline is a good representation of the default-rate curve.

Let y=f(x) denote the value of a quadratic spline at x. Morningstar divides the domain of f(.) into intervals of the form [x_{s-1}, x_s], [y_{s-1}, y_s]. The values of the endpoints are:

s	xs	ys
0	1	0
1	10	½ (1- Θ)
2	19	1

If x falls within the interval [x_{s-1}, x_s], the following occurs:

$$f(x) = a_{0s} + a_{1s}x + a_{2s}x^2 \qquad [3]$$

Where a_{0s}, a_{1s} and a_{2s} are parameters to be determined.

To determine the three parameters , and for segment s, three equations are needed. Two of the equations follow from the condition that segment s connect the points (x_{s-1}, y_{s-1}) and (x_s, y_s).

Hence:

$$y_{s-1} = a_{0s} + a_{1s}x_{s-1} + a_{2s}x_{s-1}^2 \qquad [4]$$

and

$$y_s = a_{0s} + a_{1s}y_s + a_{2s}y_s^2 \qquad [5]$$

The third condition follows from the condition that the f(.) be differentiable everywhere on the interval [x_{s-1}, x_s]. Suppose for the moment that the value of $y'_{s-1} = f'(x_{s-1})$ is known. Hence,

$$y'_{s-1} = a_{1s} + 2a_{2s}x_{s-1} \qquad [6]$$

Solving equations [4], [5], and [6] for a_{0s}, a_{1s} and a_{2s}, we have:

$$a_{0s} = y_{s-1} - \frac{1}{2}\left(y'_{s-1} + a_{1s}\right)x_{s-1} \qquad [7]$$

$$a_{1s} = \frac{y_s - y_{s-1} + \frac{1}{2}\left(x_{s-1} - \frac{x_s^2}{x_{s-1}}\right)y'_{s-1}}{x_s - \frac{1}{2}\left(x_{s-1} + \frac{x_s^2}{x_{s-1}}\right)} \qquad [8]$$

$$a_{2s} = \frac{y'_{s-1} - a_{1s}}{2x_{s-1}} \qquad [9]$$

We can then calculate

$$y_s^{'} = a_{1s} + 2a_{2s}x_s \quad [10]$$

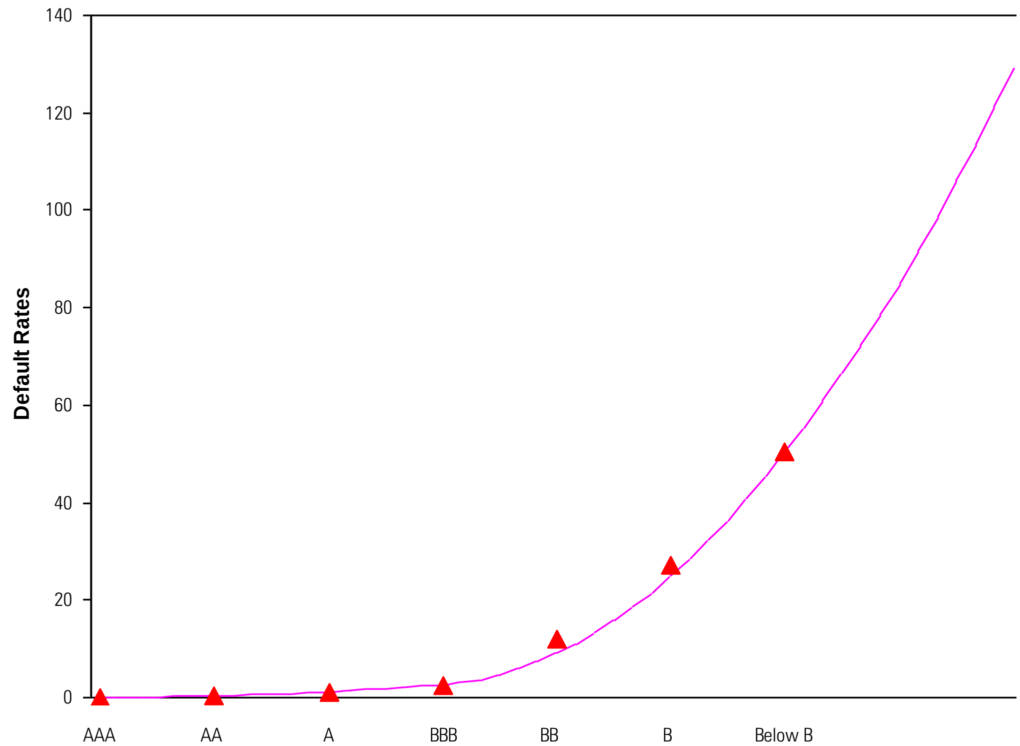
Let the numerical representation of a letter grade be x and the default probability be y. The two intervals for x are [1, 10] and [10, 19], representing AAA to BBB and BBB to CCC, respectively. Because the default probability curve is flat near AAA, set $y_0^{'} = 0.$ With s=1, use equations [7], [8], and [9] to find a_{0s}, a_{1s}, and a_{2s}, and equation [10] to calculate $y_s^{'}$. This process is then repeated for s=2.

Exhibit 1 Credit Grades and Default Rates

Morningstar	Moody's	S&P	Numerical Representation (x)	Relative Default Rate (y') %	Fitted Default Rate	Empirical Default Rates
AAA	Aaa	AAA	1	0.00%	0.1041	0.1041
AA	Aa1 Aa2 Aa3	AA+ AA AA-	4	0.56%	0.3829	0.2330
A	A1 A2 A3	A+ A A-	7	2.22%	1.2192	0.9911
BBB	Baa1 Baa2 Baa3	BBB+ BBB BBB-	10	5.00%	2.6131	2.361
BB	Ba1 Ba2 Ba3	BB+ BB BB-	13	17.78%	9.0251	11.8464
B	B1 B2 B3	B+ B B-	16	49.44%	24.9158	27.0871
Below B	Caa1 Caa2 Caa3 Ca	CCC+ CCC CCC- / CC CC / C	19	100.00%	50.2850	50.2850
		NR	16	49.44%	24.92	
		NR Muni	13	17.78%	9.03	

Source: Morningstar.

Exhibit 2 Default Probability Curves



Source: Morningstar Direct. Data as of 27/07/2016.

Bond Portfolios

Given a portfolio of fixed-income securities, let

x_i = the i[th] numerical security credit grade representation ($x_2 = x_{21} = x_{23} = x_{24} = 0$)

w_i = the portfolio weight of bonds with grade $\sum_{i=1}^{27} w_i = 1$

The average default probability of the portfolio is

$$y_p = \sum_{i=1}^{27} w_i f(x_i) \qquad [11]$$

To assign a portfolio letter grade, first calculate $f^{1}(y_p)$. To do this, first identify which segment of the spline falls into (s= 1 for [ ] or s=2 for [ ]). Then calculate as follows:

$$x_p = \frac{-a_{1s} + \sqrt{a_{1s}^2 - 4a_{2s}(a_{0s} - y_p)}}{2a_{2s}} \qquad [12]$$

Round to x_p the nearest integer and assign letter grades as follows:

Exhibit 3 Letter Grades

Non-Linear Score Mapping	Grade
1 <= Average Credit Quality <= 2	AAA
3 <= Average Credit Quality <= 5	AA
6 <= Average Credit Quality <= 8	A
9 <= Average Credit Quality <= 11	BBB
12 <= Average Credit Quality <= 14	BB
15 <= Average Credit Quality <= 17	B
18 <= Average Credit Quality	Below B

Source: Morningstar.

In terms of x_p, the vertical axis of the style box are:

A. Low credit quality $x_p > 11$

B. Medium credit quality $5 < x_p \leq 11$

C. High credit quality $x_p \leq 5$

The average default probability of the portfolio (formula 11) can also be mapped to letter grades by using the following table:

Exhibit 4 Letter Grades

Linear Score Mapping	Grade	Style Box Position
<0.13889	AAA	High Quality
>=0.13889 and < 1.2500	AA	High Quality
>=1.2500 and < 3.47223	A	Medium Quality
>=3.47223 and < 9.02778	BBB	Medium Quality
>=9.02778 and < 31.25000	BB	Low Quality
>=31.25000 and < 72.36112	B	Low Quality
≥ 72.36112	Below B	Low Quality

Source: Morningstar.

The quadratic spline interpolation allows Morningstar to make changes to the average default rates without having to change the mapping for Table 2. When average default rates are changed the mappings for Table 3 will also change.

Recent Changes

Effective Oct. 31, 2016, Morningstar changed the definition of cash and equivalents from instruments with less than one year to maturity to instruments with less than 92 days.