Morningstar Calculated Fixed-Income Analytic Measures
Calculation of cash flow analytic measures--price, yield, and duration.

Introduction
Fixed-income analysis is inherently an exercise in the measurement of future cash flows. Payments of interest on principal invested constitute the primary means of return to fixed-income investors with the expectation that the principal will be repaid upon maturity. Therefore, measuring the expected rate of return and potential risks to these payments is of paramount importance.

Morningstar calculates portfolio-level analytics for two commonly accepted measures of fixed-income investing, one of expected returns—yield—and of interest-rate risk—duration—to provide investors with tools to assess relative value and risk between fixed-income portfolio investment choices. These are presented as portfolio average values, which provide a straightforward single measure upon which to compare investment alternatives. Like all Morningstar calculated fixed-income analytic measures, yield and duration are first calculated at holding level and then aggregated to portfolio-level measures.

Introduction to Prices and Yields
For fixed-income securities, price and yield are two sides of the same coin, but yield is the measure of return that is of true interest. The price of a bond should be considered a derivative of yield, although price is most often the input used to calculate fixed-income analytic measures. The price of a bond is the net present value of the series of future payments of interest and principal to which a “rate of discount” has been applied. The rate of discount is critical to determining the current value, the price, of a bond at any given time. The discount rate is called the “yield” of the security. With sufficient knowledge of the timing and amounts of future interest and principal payments, a price can be deduced from yield and yield from price. While there are several ways to measure yields, Morningstar calculates the yield to maturity.

Price and Yield Inversely Related
Price and yield move inversely. The underlying basis for valuation is a series of predetermined payments (with exceptions for some types of securities), so, as the rate of discounting (yield) increases, the present value of the payment (price) falls. If the discount rate being demanded in the market increases, the present value of the payments decreases; if discount rate decreases, the present value of the payments increases.

Bond Price Quotation
Bond prices are almost always quoted as percentages of face value. The price that represents the face value is referred to as “par” and quoted as 100.00, meaning 100% of face value at maturity. By quoting...
price as a percentage, things like differing denominations or currencies are much easier to handle in a consistent manner. A price below par is called a discount while a price above par is a premium.

**Price Treatment of Accrued Interest**

Another aspect of bond price is whether or not the quoted price is inclusive of accrued interest. Although interest is paid periodically over the life of a bond, the interest accrues on a daily basis between payments. The value on a date between payments must incorporate the amount of interest accrued. When the price quote is inclusive of the accrued interest, it is known as dirty price; if the accrued interest is separated and not included in the quote, it is known as a clean price.

Bond prices and yields change subject to the influence of the factors, which need to be measured by analytics—changes in the overall level of interest rates, changes in the credit of the issuer, relative changes in how risks are compensated, and so on.

**Introduction to Duration**

Because changes in interest rates can introduce adverse consequences for fixed-income investors, it is important to quantify the impact of the change. The inverse relationship between price and yield means that a rise in interest rates will cause the value of a fixed income investment to decrease, just as falling rates will result in an increase in value. Of critical importance to fixed-income investors is the extent of the expected effect.

Duration is a measure of the expected impact a change on interest rates, in the form of yield, will have on a fixed-income instrument’s value. The larger the duration, the greater the potential impact in price will be for a given change in interest rates, both good and bad.

Like yields, there are differing ways to measure duration. Morningstar calculates two types of duration, but both are measures of sensitivity to changes in interest rates, modified duration and effective duration.

Taken together, prices, yields, and durations are highly informative measures for fixed-income investors.

**Derivation of Prices From Holdings Data**

Morningstar receives holdings data from managed investment providers as an input to the calculation of portfolio analytics. While the value of each holding and the face value of each holding are provided, the price of the holding is not a data element received. Because price is used as a key input value to calculation of yield and duration, the price must be derived from holding value and par value as reported. As holding value is assumed to contain accrued interest, the derived price is a dirty price equivalent.

**Definitions:**

*Dirty Price*—the price of a bond including the amount of accrued interest earned

*Clean Price*—the price of a bond excluding the amount of accrued interest earned
Calculation of Holding Derived Price
Holding Derived Price = Holding Value/Par Value

Identification of Outliers
After price derivation, Morningstar benchmarks the derived prices using pricing data, which is licensed from third-party sources. Logic is employed to identify prices that appear to be statistical outliers. Outlier identification is accomplished by examining the entire sample set of prices and comparing each individual variance to the median variance of the sample. Those that fall outside 2.5 standard deviations are determined to be outliers. Outlier prices are then subjected to two additional conversion techniques.

Currency Conversion
Morningstar collects two currency values, one for the portfolio and one for a holding within a portfolio. If the holding currency is different from the portfolio currency, a currency conversion factor is applied.

Decimal Factor Logic
In other cases, the denominator may be supplied using a nonstandard factor resulting in the improper location of the decimal point for the derived price. Morningstar applies logic to identify and correct these prices prior to their use in downstream analytics.

After application of conversion strategies, the derived prices are again benchmarked to identify remaining outliers. Such prices are then segregated for further analysis and may be suppressed from downstream analytics calculations.

Holding-Level Calculations
Morningstar uses the derived price as an input to three measures, which are calculated at a holding level before aggregation to portfolio level:

- Yield to Maturity
- Modified Duration
- Effective Duration

To be able to calculate modified duration, a fourth measure, Macaulay duration, must first be calculated to use as an input.

Yield to Maturity
Yield captures the expected future return for a holding. Calculating yield to the stated maturity of a holding assumes that the holding will be owned for the entire life until redemption and all payments will be received on a timely basis. Morningstar calculates yield to the stated maturity of the holding, the date of an eligible put feature (yield to put), a prerefunded date, or the estimated average life of a pass-through mortgage-backed security. Morningstar assumes a standard prepayment rate of 100% prepayment speed assumption, 6% annually for seasoned issues, for MBS calculations.
Definition:
Yield to Maturity—the rate of return of a fixed-income instrument for a given price, assuming it is held to maturity and all interest and principal payments are made in a timely manner as specified in the offering terms and conditions.

Duration and Interest-Rate Risk
Duration is a primary measure of interest-rate risk for fixed-income analysis. As such, it quantifies the exposure of a holding to a rise in interest rates. Morningstar considers three types of duration that are commonly accepted by market participants:

- Macaulay duration
- Modified duration
- Effective duration

Macaulay Duration
Macaulay duration, named after its inventor, Frederick Macaulay, is a measure of the future cash flows of a fixed-income instrument. Macaulay duration measures the weighted average life of the present value of future cash flows to calculate a term that is generally reported in number of years. The present value is derived using the yield to maturity, which is an input value. As a measure of term, it indicates the relative length of time an investor will be exposed to interest-rate risk.

Macaulay duration is used as an input to modified duration, and Morningstar does not currently publish Macaulay Duration as a data point.

Calculation of Macaulay Duration
\[ Macaulay \text{ Duration} = \frac{\sum (\text{Present Value} \times \text{Time})}{\text{Price of the Bond}} \]

Example: Macaulay Duration
- Coupon—5%
- Yield to maturity—4%
- Maturity—10 Years
Modified Duration

Modified duration is derived from Macaulay duration and measures the price sensitivity of a fixed-income holding to a change in interest rates. It is expressed as a percentage change value. Modified duration accounts for the frequency of interest calculations of the instrument.

Definition:

*Modified Duration*—The sensitivity of price to changes in interest rates, generally 100 basis points (1%), expressed as a percentage value

Calculation of Modified Duration

\[
Modified \ Duration = \frac{Macaulay \ Duration}{\left(1 + \frac{\text{Yield to Maturity}}{\text{Interest Compounding Frequency}}\right)}
\]

Example: Modified Duration

- Coupon--5%
- Yield to Maturity--4%
- Maturity--10 Years

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<thead>
<tr>
<th>Payment</th>
<th>Amount</th>
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<tbody>
<tr>
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<tr>
<td>Coupon 2</td>
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<tr>
<td>Principal</td>
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</tbody>
</table>

Macaulay Duration (in Years) > 8.19

Source: Morningstar.
Effective Duration

Effective duration is a variant of modified duration in that it is also a measure of sensitivity to changes in interest rates. The difference is that effective duration considers the impact of option features such as calls or prepayments. Therefore, the calculation of effective duration involves the use of an option pricing model. The effective duration value is the change value, or delta of the model output.

Initially, Morningstar will calculate effective duration only for pass-through mortgage-backed securities and for all other holdings without option features. This will result in an effective duration value that is the same as the modified duration value for holdings that are not MBS. In the future, Morningstar will calculate effective duration (also called OAS duration) using a Black-Karasinski model.

Definition:
Effective Duration -- The estimated change in price for a given change in interest rates taking into account the impact of option features

Calculation of Effective Duration

Effective Duration = (Price Given Decrease in Interest Rates) - (Price Given Increase in Interest Rates) / \[(2 \times \text{Current Price}) \times \text{Change in Interest Rates}\]

Alternatively:

Effective Duration = \((P(1) - P(2)) / (2 \times P(0) \times Y)\)
Where:
- \( P(0) \) = the bond's original price per $100 worth of par value
- \( P(1) \) = the price of the bond if the yield were to decrease by Y percent
- \( P(2) \) = the price of the bond if the yield were to increase by Y percent
- \( Y \) = the estimated change in yield used to calculate \( P(1) \) and \( P(2) \)

**Calculation of Portfolio Averages for Yield to Maturity, Modified Duration, and Effective Duration**

For a portfolio that holds multiple fixed-income instruments, the portfolio measure is the average of the weighted values of applicable holdings. Morningstar calculates portfolio average measures for both long holdings and short holdings separately.

**Calculation of Portfolio Average Values for Yield and Duration**

The portfolio average of yield and duration measures is an aggregation of the holding-weighted analytic measures divided by the portfolio value.

\[
\text{Average Portfolio Analytic Measure} = \frac{(\text{Holding Value 1} \times \text{Analytic Measure 1}) + (\text{Holding Value 2} \times \text{Analytic Measure 2}) + \ldots + (\text{Holding Value n} \times \text{Analytic Measure n})}{\text{Portfolio Value}}
\]

Alternatively:

\[
\text{Average Portfolio Analytic Measure} = (\text{Holding 1 Weight} \times \text{Analytic Measure 1}) + (\text{Holding 2 Weight} \times \text{Analytic Measure 2}) + \ldots + (\text{Holding n Weight} \times \text{Analytic Measure n})
\]

Where Analytic Measure Is:
- Yield to maturity
- modified duration
- effective duration

**Summary**

Understanding potential return and risk in a fixed-income portfolio is critical to achieving successful investment outcomes. Morningstar calculates measures of expected return and interest-rate risk based on analysis of cash flow payments according to commonly accepted methodologies. Yield to maturity is a measure of the expected future returns of an investment. Holding-level yield values are aggregated into portfolio averages according to Morningstar portfolio aggregation methodologies. Both modified duration and effective duration are measures of sensitivity to interest-rate changes that inform investors about potential risks. By calculating portfolio average measures for these key fixed-income metrics, Morningstar provides valuable information so that investors can better assess the potential risks and returns between investment alternatives.