Morningstar Indexes Calculation Methodology

Morningstar Indexes
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Introduction

This document contains the calculation methodology for the Morningstar Global Equity Indexes. In order to replicate the indexes for investment activities, it is imperative to understand how they are calculated and how different component factors influence their performance. An index level can be calculated using various methods where the central theme remains the same—capture the composite performance of underlying securities while taking into account the impact of corporate events. Because there are different types of index weighting schemes, these calculations differ depending on how such events influence the price and shares of underlying securities. The Morningstar Global Equity Indexes are calculated using a modified version of Laspeyres index—also known as a base-weighted index, since constituents' price change is weighted by the quantities (i.e., index shares) in the base period. This document examines the formulas used for such indexes to help users understand various concepts of index calculations.

Index Divisor

Morningstar Indexes uses the concept of an "index divisor" to calculate daily index levels. The performance of the index is linked to change in the market value of its constituents. The portfolio market value of the index—which is actually the sum of its constituents' index market value—is adjusted by changing the index divisor to calculate the index levels. The index divisor for a given day (t) is defined as:

$$D(t) = \frac{Initial\ MV(t)}{I(t-1)} \quad (1)$$

Where:

T	=	Time the index is calculated
D(t)	=	Divisor at time (t)
Initial M(t)	=	Initial market value of the index at time (t)
I(t-1)	=	Index level at the close of day (t-1)

The index divisor remains unchanged unless there is a change in index composition, which can be due to corporate actions, changes in shares outstanding and the float factor, or the addition or deletion of securities from the index. In such cases, the divisor is adjusted to avoid distortions caused by such events and to keep the index level from changing because of factors that are not the result of stock market price action.

Market-Capitalization- and Float Market-Capitalization-Weighted Indexes

One of the most common types of indexes is the market-cap-weighted index, where the weight of each constituent is determined by dividing its market capitalization by the total market capitalization of the index. Another variant is the float market-cap-weighted index, where float market capitalization is taken instead. In these indexes, the price movement of a larger security will therefore have a larger impact than that of a small security.

The following formula is used to calculate the index level:

$$Index\ Level = \frac{\sum_i^n P_i * Q_i}{Index\ Divisor} \qquad (2)$$

Where:

P_i	=	Share price of security i in index currency
Q_i	=	Total shares outstanding of security i (adjusted for float if float market-cap weighted)
N	=	Number of securities in the index

If the number of stocks in the index changes because of the addition or deletion of securities, the total market value of the index changes, but the index level should not change on such occasions. This is achieved by adjusting the divisor for the next day. Following similar terminology as stated in the Index Divisor section, we can write the following equation:

$$I(t) = \frac{Closing\ MV(t)}{D(t)} \qquad (3)$$

Suppose there are n securities in the index out of which k securities will be deleted and replaced by an equal number of securities the next day. Then Equation (2) can be expanded to the following:

$$I(t) = \frac{(\sum_i^{n-k} P_i * Q_i) + (\sum_d^k P_d * Q_d)}{D(t)} \qquad (4)$$

Now, this index should still open at I(t-1) on the next day (t). Assuming no corporate event and constant float and shares outstanding on the current constituents, the equation can be written as:

$$\frac{(\sum_i^{n-k} P_i * Q_i) + (\sum_d^k P_d * Q_d)}{D(t-1)} = I(t-1) = \frac{(\sum_i^{n-k} P_i * Q_i) + (\sum_a^k P_a * Q_a)}{D(t)} \qquad (5)$$

Where P_d and Q_d represent security price and shares of deleted securities, while P_a and Q_a represent security price and shares of added securities.

The index divisor for the day (t) can, thus, be written as:

$$D(t+1) = D(t) * \frac{(\sum_i^n P_i(t)*Q_i(t)) + \Delta MV(t+1)}{(\sum_i^n P_i(t)*Q_i(t))} \quad (6)$$

Or:

$$D(t+1) = D(t) + \frac{\Delta MV(t+1)}{I(t)} \quad (7)$$

Where:

D(t+1)	=	Divisor at time (t+1)
D(t)	=	Divisor at time (t)
$P_i(t)$	=	Share price of security i in index currency at time (t)
$Q_i(t)$	=	Total shares outstanding of security i (adjusted for float if float market-cap weighted) at time (t)
N	=	Number of securities in the index
ΔMV(t+1)	=	Aggregate change in market value resulting from additions and deletions

The above equation can be generalized where ΔMV(t+1) can be computed for every stock in the index along with other corporate action adjustments, and the resulting sum can be used to calculate the index divisor for the next day. These adjustments are made after the market is closed for trading where aggregate market value change is calculated using the portfolios at the market close and the next market opening. As the calculation suggests, this divisor doesn't change as a result of any market-neutral event, such as a stock split.

Equal-Weighted Indexes

Another index weighting method is equal weighting, where equal weight is assigned to each constituent at reconstitution. The weights drift from their original assigned weights as the price of underlying stocks changes until the next index rebalance, when it is reset to equal weight.

Index weight in an equal-weighted index is determined by the following formula:

$$IW_i = \frac{1}{n} \quad (8)$$

And the constructed shares for each constituent in the index can be calculated as:

$$S_i(t) = \frac{\sum_j^n (P_j(t)*Q_j(t))*IW_i*C}{P_i(t)} \quad (9)$$

This can be further written in terms of the security's float-adjusted outstanding shares:

$$S_i(t) = Q_i(t) * \frac{\sum_j^n Float\ Mcap_j(t) * IW_i * C}{Float\ Mcap_i(t)} \quad (10)$$

Or:

$$S_i(t) = Q_i(t) * AF_i \quad (11)$$

Where:

$S_i(t)$	=	Constructed shares of company i at time (t)
$Q_i(t)$	=	Float-adjusted total outstanding shares of company i at time (t)
n	=	Number of stocks in the index
t	=	Time the index is calculated
P_i	=	Share price of security i in index currency at time (t)
IW_i	=	Company weight in index i at rebalancing time
C	=	Index-specific constant used to limit index shares beyond its outstanding shares
Float $Mcap_i(t)$	=	Float market cap of security i at time (t)
AF_i	=	Adjustment factor of security i

It is important to note that the shares Si(t) for the index constituents are artificial constructs used for calculation purposes. Consequently, the constructed shares are linked to the actual shares of the company in terms of the total dividends paid by the company. Hence, the index-specific constant C can be assigned to normalize the index shares.

Dividend Dollar-Weighted Indexes

Dividend dollar-weighted indexes are those where the constituents are weighted according to the total dividends paid by the company to investors. Consequently, the available dividend dollar value is the product of the security's shares outstanding, free float factor, and annualized dividend per share.

Index weight in a dividend dollar-weighted index is determined by the following formula:

$$IW_i(t) = \frac{d_i(t) * Q_i(t)}{\sum_{i=1}^n d_i(t) * Q_i(t)} \quad (12)$$

Where $d_i(t)$ is the dividend per share of the company (i) at time (t).

And the constructed shares $S_i(t)$ for each constituent in the index calculation formula can be calculated using the equations 9, 10, and 11:

$$S_i(t) = \frac{\sum_j^n (P_j(t) * Q_j(t)) * IW_i * C}{P_i(t)} \quad (9)$$

Or:

$$S_i(t) = Q_i(t) * \frac{\sum_j^n Float\ Mcap_j(t) * IW_i * C}{Float\ Mcap_i(t)} \quad (10)$$

Or:

$$S_i(t) = Q_i(t) * AF_i \quad (11)$$

The adjustment factor for each security on the rebalancing date (t) can be calculated by:

$$AF_i = \frac{IW_i(t)}{W_i(t)} \quad (13)$$

Where:

$IW_i(t)$ = Capped weight of security i in index at rebalancing time (t)

$W_i(t)$ = Uncapped weight of security i in index at rebalancing time (t) based on float market cap

Capped Weighted Indexes

Capped-weighted indexes are those where the weight of a single constituent and/or the sum of the weights of all securities representing a defined group are constrained to a maximum weight. The group can be defined on the basis of parameters like: supersectors, sectors, industries, countries, securities having weight constraints, etc. Such indexes are mostly designed to take into account the constraints imposed by the UCITS or the U.S. Internal Revenue Code in order to provide asset diversification to the investors.

In such instances, the excess weight is distributed among the remaining constituents with an objective to preserve relative weights for a maximum number of stocks within the index. These weights will drift from their earlier assigned weights as the price of underlying stocks changes. Hence, adjustment is required at rebalancing to assign appropriate weights to index constituents according to the capping algorithm.

The index calculation methodology for the capped indexes remains same as in the float market-capitalization indexes, except that weights of individual stocks differ from those assigned by their float market cap.

The equations 9, 10, 11, and 13 can be used again from the previous section to calculate index shares:

$$S_i(t) = \frac{\sum_j^n (P_j(t) * Q_j(t)) * IW_i * C}{P_i(t)} \quad (9)$$

Or:

$$S_i(t) = Q_i(t) * \frac{\sum_j^n Float\ Mcap_j(t) * IW_i * C}{Float\ Mcap_i(t)} \quad (10)$$

This can be further written in terms of the adjustment factor as:

$$S_i(t) = Q_i(t) * AF_i \quad (11)$$

Where:

$$AF_i = \frac{IW_i(t)}{W_i(t)} \quad (13)$$

Capped Weighting Adjustments

The capped-weight IW_i is calculated on the basis of different capping methods, which can be further segregated into the following techniques:

Single Constituent Capping

This method is applied when a single constituent exceeds the maximum weight allowed.

Single Constituent and Group Capping

This method is applied to restrict the weight of a single constituent to a predefined weight, as well as weights of all constituents with a combined weight greater than a certain amount to a predefined group weight.

Any such capping can be written in terms of B-A-C capping (e.g., 5-20-50 capping rule).

The procedure to cap weights is explained below.

The first step is to assign a weight to each security, which is generally based on its float market cap. Other ways to assign weights includes total dividends paid, value score, growth score, etc.

For a given set of weights, $w_1, w_2, \ldots, w_N$, with $w_1 \geq w_2 \geq \ldots \geq w_N$, and $\sum_{i=1}^{N} w_i = 1$, we test to see if the B-C rule holds as follows:

Let:

$$w_i^* = \begin{cases} w_i, & x \geq B \\ 0, & x < B \end{cases}$$

If $\sum_{i=1}^{N} w_i^* \leq C$, the B-C rule holds.

Let:

N	=	Number of stocks in the portfolio
Cap/A	=	A (i.e., maximum weight allowed for any stock)
x_i	=	Original weight of the i^{th} largest stock in the portfolio, $x_1 \geq x_2 \ldots \geq x_N$ $\sum_{i=1}^{N} x_i = 1$

If $x_1 \leq$cap and the B-C rule holds for $x_1, x_2, \ldots, x_N$,, we do not need any reweighting. If the B-C rule does not hold, the cap should be set to a value less than x1and the following algorithm should be tried. If we start with x_1>cap, we try the algorithm described below.

Morningstar reweights using a two-part linear function as follows:

$$y_i = \begin{cases} y_K + \beta_1 (x_i - x_K), & \text{if } i \leq K \\ \beta_2 x_i, & \text{if } i \geq K \end{cases} \quad (14)$$

Where K is the index of the stock at which the function is kinked. Note that this reweighting preserves the relative weights of all stocks beginning from the Kth stock.

Given K, we need to set à1 and à2. From equation (13), it follows that:

$$\beta_1 = \frac{y_1 - y_K}{x_1 - x_K} \quad (15)$$

And:

$$\beta_2 = \frac{y_K}{x_k} \quad (16)$$

We set:

$$y_1 = \text{cap} \quad (17)$$

We need to set y_K so $\sum_{i=1}^{N} y_i = 1$. Some algebra shows that this occurs when:

$$y_K = \frac{1-\gamma y_1}{(K-1)-\gamma+\frac{1-z}{x_K}} \tag{18}$$

Where:

$$z = \sum_{i=1}^{K-1} x_i \tag{19}$$

And:

$$\gamma = \frac{z-(K-1)x_K}{x_1-x_K} \tag{20}$$

We chose K to maximize the number of stocks for which relative weights are preserved. This occurs at the lowest value of K for which yK≤y1. Hence, our reweighting algorithm is as follows:

1. Set z=0, y1=cap, and K=1
2. If K<N, set K=K+1; otherwise go to step 8
3. Set $z=z+x_K-1$
4. Set γ and y_K using equations (7) and (5) respectively
5. If $y_K>y_1$, go back to step 2
6. Set β_1 and β_2 using equations (2) and (3) respectively
7. For i = 1,…, N, set y_i using equation (1)
8. If the B-C rule holds for y1, y2, ,…, yN, this is the solution, so stop
9. Otherwise go back to step 2
10. There is no solution that meets the B-C rule with this cap

Target Volatility Indexes

Morningstar Target Volatility Indexes are calculated to provide flexible exposure to the base index that achieves a certain volatility target. The target exposure to the base index is based on the ratio of the target volatility to the measured historic volatility of the base index. The target exposure is monitored daily and is subject to both an exposure tolerance and a maximum exposure.

The target exposure is calculated by the following formula:

If $w_{t-1} \leq 100\%$ then:

$$ER_t = ER_{t-1} \times \left[2 - \left(\frac{L3M_t}{L3M_{t-1}}\right)\right] \times \left[w_{t-1} \cdot \left(\frac{B_t}{B_{t-1}}\right) + (1 - w_{t-1}) \cdot \left(\frac{FFE_t}{FFE_{t-1}}\right)\right] \tag{21}$$

Else:

$$ER_t = ER_{t-1} \times \left[2 - \left(\frac{L3M_t}{L3M_{t-1}}\right)\right] \times \left[w_{t-1} \cdot \left(\frac{B_t}{B_{t-1}}\right) + (1 - w_{t-1}) \cdot \left(\frac{L3M_t}{L3M_{t-1}}\right)\right] \tag{22}$$

where:

I_t	=	Index level on date t
w_{t-1}	=	Realized exposure of the index on date t-1
B_t	=	Base index level on date t
FFE_t	=	Index capitalizing at the federal-funds effective rate on date t with a base value of 1 on the inception date of the base index, calculated daily using value from date t-1, on an (actual/360) day count basis. The underlying fed-funds rates follow the U.S. Fed calendar
$L3M_t$	=	Index capitalizing at the 3-month Libor rate on date t with a base value of 1 on the inception date of the base index, calculated daily using value from date t-3, on an (actual/360) day count basis. The underlying Libor rates follow the Libor fixing calendar

Measuring Volatility

The measured volatility of the base index is taken as either the trailing 20-business-day historic volatility or the trailing 60-business-day historic volatility, whichever is greater.

$$measured\_volatility = \max(Vol20_t, Vol60_t) \tag{23}$$

Where:

$$\mathrm{Vol20_t} = \sqrt{252 \times \frac{20}{19} \times \left[\frac{1}{20}\sum_{k=1}^{20} \mathrm{Ln}^2\left(\frac{B_{t-k}}{B_{t-k-1}}\right) - \left(\frac{1}{20}\sum_{k=1}^{20} \mathrm{Ln}\left(\frac{B_{t-k}}{B_{t-k-1}}\right)\right)^2\right]} \tag{24}$$

And:

$$\mathrm{Vol60_t} = \sqrt{252 \times \frac{60}{59} \times \left[\frac{1}{60}\sum_{k=1}^{60} \mathrm{Ln}^2\left(\frac{B_{t-k}}{B_{t-k-1}}\right) - \left(\frac{1}{60}\sum_{k=1}^{60} \mathrm{Ln}\left(\frac{B_{t-k}}{B_{t-k-1}}\right)\right)^2\right]} \tag{25}$$

Determining the Target Exposure

The target exposure of the Morningstar Ultimate Stock-Pickers Target Volatility Index to the base index is determined by the formula below, with the aim of maintaining a target volatility. It is based on the ratio between the target volatility and the measured historic volatility of the base index, and will vary between zero and the maximum allowable exposure.

$$w_{Target(t)} = \min\left(max\_exposure, \frac{target\_volatility}{measured\_volatility} \right) \quad (26)$$

Where:
max exposure = 150%
target volatility = Target volatility chosen for the index

To discourage daily rebalancing of Target Volatility Indexes, the target exposure is updated only when there is a change that is greater than the exposure tolerance percentage. The current exposure of the index on the inception date shall be equal to the target exposure on the inception date.

$$w_0 = w_{Target(0)} \quad (27)$$

On any subsequent date t, the current exposure shall be determined as follows:

$$w_t = \left\{ \begin{array}{l} w_{Target(t)} \ if \ w_{t-1} > (1+tolerance) \cdot w_{Target(t)} \\ w_{Target(t)} \ if \ w_{t-1} < (1-tolerance) \cdot w_{Target(t)} \\ w_{t-1} \ otherwise \end{array} \right\} \quad (28)$$

Where tolerance = 10%
w_t = Realized exposure of the index on date t
$w_{Target}(t)$ = Target exposure of the index on date t

Trading Cost Adjustment Factor, or TCAF

To account for higher transaction and portfolio management costs associated with the target volatility strategy, a flat adjustment factor is applied to the calculated index level to arrive at the final, published index level for volatility indexes.

On any index business day, the final adjusted index level I_t, shall be calculated as follows:

$$I_t = I_{t-1} \times \left(\frac{ER_t}{ER_{t-1}} \right) \times \left[1 - TCAF \times \left(\frac{n}{360} \right) \right]$$

Where:
ER_t = Unadjusted index level on day t
n = Number of days between t and (t-1)

Currency-Hedged Indexes

The Currency Hedge Index is long the benchmark index and short currency forwards whose notional amount is based on market capitalization of foreign currencies in the benchmark index. In other words, the hedge ratio, i.e., the proportion of the portfolio's currency exposure that is hedged, is set to 100%.

The index is rebalanced monthly, usually on the last trading day of the month,[1] using foreign currency weights and corresponding notional amounts determined as of one business day before the last business day of the month. This approach ensures that index calculation closely resembles the actual implementation lag seen in real-world portfolios.[2]

To account for the difference in the rebalance date and the date on which the notional amounts are determined, a monthly adjustment factor is applied on the hedge ratio. The notional amounts hedged remain constant throughout the month and are not modified on account of price movement, corporate action, or rebalance and reconstitution of the underlying index. The daily index calculation marks to market the one-month forward contracts using a linear interpolation of spot and forward prices based on the one-month forwards.

Please note that the historical index levels are based on the currency weights and the corresponding notional amounts determined on the last business day of the month and are computed only on a monthly basis.

Monthly Currency Hedge Index Calculations

The monthly hedge ratio is calculated as follows:

$$HR = MAF * \sum_i^n \{W_{i1-1d} * FXRate_{i1-1d} * (\frac{1}{FFRate_{i1}} - \frac{1}{FFRate_{i2}})\}$$

$$MAF = HedgedIndex_{1\text{-}1d} / HedgedIndex_1$$

$$HedgedIndex_2 = HedgedIndex_1 * (\frac{UnhedgedIndex_2}{UnhedgedIndex_1} + HR)$$

Where:

HR	=	Adjusted hedge ratio
n	=	Number of currencies underlying the index
$W_{i1\text{-}1d}$	=	Weight of currency i in the index as of one business day before the previous rebalance date
$FXRate_{i1\text{-}1d}$	=	Spot rate of currency i as of one business day before the previous rebalance date
$FFRate_{i1}$	=	Forward rate of currency i as of the previous rebalance date
$FFRate_{i2}$	=	Forward rate of currency I as of the current rebalance date

1 Morningstar Developed Markets ex-US and Emerging Markets Factor Tilt Hedge Indexes rebalance at the close of the third Friday of the month, coinciding with the rebalance schedule of the underlying indexes.

2 For the purposes of showing back-tested performance, no lag is assumed.

MAF	=	Monthly adjustment factor to take into account the one-day lag between the rebalance date and the date on which notional amounts are determined
$HedgedIndex_{1\text{-}1d}$	=	Hedged index level as of one business day before the previous rebalance date
$HedgedIndex_1$	=	Hedged index level as of the previous rebalance date
$HedgedIndex_2$	=	Hedged index level as of the current rebalance date
$UnhedgedIndex_1$	=	Unhedged index level as of the previous rebalance date
$UnhedgedIndex_2$	=	Unhedged index level as of the current rebalance date

The daily hedge impact is calculated as follows:

$$HR_d = MAF * \sum_i^n \{W_{i1-1d} * FXRate_{i1-1d} * (\frac{1}{FFRate_{i1}} - \frac{1}{FFRate_{interpolated}})$$

$$FFRate_{interpolated} = FXRate_1 + ((D-d)/D * (FFRate_d - FXRate_d))$$

$$MAF = HedgedIndex_{1\text{-}1d}/HedgedIndex_1$$

$$HedgedIndex_d = HedgeIndex_1 * (\frac{UnhedgedIndex_d}{UnhedgedIndex_1} + HR_d)$$

Where:

d	=	Current day of the month
D	=	Number of calendar days in the month
HR_d	=	Adjusted hedge ratio as of the current day
$FFRate_{interpolated}$	=	Forward rate interpolated for intramonth performance of the hedge
$FFRate_d$	=	One-month forward rate at day d
$FXRate_d$	=	Spot rate at day d
$HedgedIndex_d$	=	Hedged index level as of the current day
$UnhedgedIndex_d$	=	Unhedged index level as of the current day

Other notations are the same as above.

Total Return and Net Return Calculation

While price-return indexes gauge the change in prices of index constituents as explained in the previous sections, total-return indexes, on the other hand, reflect the changes in both prices and reinvestment of dividends paid by the index constituents. The dividends distributed are reinvested in the index based on the weights of constituents as of the ex-date. Only cash dividends and regular capital repayments are included while calculating the total returns. Other dividends, including special dividends and extraordinary capital repayments, are already considered in the calculation of price-return index variants.

$$TR\ Return_t = \left(\frac{Index\ Level_t + TR\ Index\ Dividend_t}{Index\ Level_{t-1}} - 1\right) \quad (29)$$

Where:

$$TR\ Index\ Dividends_t = \frac{\sum_i^n Dividend_i * \ Shares_i}{D(t)} \quad (30)$$

Further, the TR index level can be calculated by the formula below:

$$TR\ Index\ Level_t = \ TR\ Index\ Level_{t-1} * (1 + TR\ Return_t) \quad (31)$$

The above approach is also used to calculate the net total return (NR) indexes where dividends distributed are adjusted for the withholding tax rate (WTR) applicable to nondomestic investors who do not benefit from double taxation treaties.

Morningstar Withholding Tax Rates is available on the corporate website.

$$NR\ Index\ Dividends_t = \frac{\sum_i^n Dividend_i * \ (1 - \ WTR_i) * \ Shares_i}{D(t)} \quad (32)$$

$$NR\ Return_t = \left(\frac{Index\ Level_t + \ NR\ Index\ Dividend_t}{Index\ Level_{t-1}} - 1\right) \quad (33)$$

And:

$$NR\ Index\ Level_t = \ NR\ Index\ Level_{t-1} * (1 + NR\ Return_t) \quad (34)$$

Index Conversion Into Another Currency

Any index can be calculated into another currency by using the formula below:

$$Index\ Level\ in\ Curr_t = Index\ Level\ in\ Curr_{t-1} * \frac{Index\ Level\ in\ USD_t \ * \ FXRate_t}{Index\ Level\ in\ USD_{t-1} * \ FXRate_{t-1}} \quad (35)$$

The base value for indexes is often chosen to be 1,000. This may be different for others where one can choose values like 100 or 1,000. If the currency start date falls after the index start date, the index calculation starts from the currency start date.

Local-Currency Return Calculation

The local-currency return calculation involves calculation of the weighted percentage change in the price of each constituent, which is further used to compute the index levels. This approach yields the same results as our divisor-based methodology. However, because of its simplicity, the local-currency return approach is preferred over divisor-based methodology when multiple currencies are involved in the calculation.

$$IW_{i,t-1} = \frac{P_i(t-1) * S_i(t-1) * FXRate_i(t-1)}{\sum_i^n P_i(t-1) * S_i(t-1) * FXRate_i(t-1)} \qquad (36)$$

$$I(t) = I(t-1) * \sum_i^n \frac{P_i(t)}{P_i(t-1)} * IW_i(t-1) \qquad (37)$$

Where:

I(t)	=	Index level at the close of day (t)
I(t-1)	=	Index level at the close of day (t-1)
$P_i(t)$	=	Price of security i in index at the close of day (t)
$P_i(t-1)$	=	Price of security i in index at the close of day (t-1)
$S_i(t-1)$	=	Shares of security i in index at the close of day (t-1)
$FXRate_i(t-1)$	=	Exchange rate of security i
$IW_i(t-1)$	=	Weight of security i in index at the close of day (t-1)

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