NYSE Indices -
Guide to Index Mathematics

Contents

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The **NYSE Indices - Guide to Index Mathematics** is being released to provide additional information on the formulae utilized to calculate Indices. This document is intended to supplement the relevant methodology document of an Index.

1. Divisor

1.1 Definition

Indices look to measure the period to period change in the value of its components due to changes in the valuation (price) of those components in the case of a Price Return Index. For a Total Return Index, the change in value also includes any income produced by those components. Indices specifically exclude any impacts to the value of the Index due to corporate actions or changes in the composition resulting from additions, deletions, and share changes.

The Divisor is an important element in the determination of Index levels. At the inception of an Index (Base Date) the Divisor is set such that the initial Index level (Base Level) is at the desired starting point. Indices usually have a starting level of 100 or 1,000 although any number could be used. The general formula to determine an Index level is:

$$\text{Index Level} = \frac{\textit{Index Market Capitalization}}{\text{Divisor}}$$

which can be rearranged as:

$$\text{Divisor} = \frac{\textit{Index Market Capitalization}}{\text{Index Level}}$$

It is this transformed formula which allows an Index calculator to maintain the continuity of the Index in the face of changes that may occur in Index market capitalization not attributed to changes in the prices of components. For example, at the effective date of a rebalance there may be changes to the pool of components and/or the number of shares held of those components. These changes to the Index are made outside of component trading hours and as such there should be no change to the observed Index level pre- and post-rebalance. Take this simple example below:

	Current Index Market Capitalization	New Index Market Capitalization
Component #1	$1,500,000	$1,500,000
Component #2	$1,250,000	$1,250,000
Component #3	$1,250,000	$1,250,000
Component #4	$0	$1,000,000
Index Market Capitalization	$4,000,000	$5,000,000
Pre-Rebalance Index Level	1,750.00	
Pre-Rebalance Divisor	2,285.71429	
Post-Rebalance Index Level		1,750.00
Post-Rebalance Divisor		2,857.14286

In this example we see that the rebalance has added another component to the Index. This addition has increased the Index Market Capitalization from 4 to 5 million USD. If the current Divisor is used, the Index level will be calculated incorrectly (5,000,000 / 2,285.71429 = 2,187.50). Because we know that there were no component price changes, we know that the Index level pre- and post-rebalance should be the same. In order to maintain that Index level, we need to calculate a new Divisor.

2. Index Formula

2.1 Index calculation formula

The general formula for the **Price Return version [Index(PR)$_t$]** of the Index is:

$$\text{Index(PR)}_t = \frac{\sum_i P_{i,t} Q_{i,t}}{D_t}$$

Where:
t means Index Calculation Date t
D_t means the Price Return Index Divisor on Index Calculation Date t
$P_{i,t}$ means the Price (in the Index Base Currency) of Index Constituent i on Index Calculation Date t
$Q_{i,t}$ means the number of Shares of Index Constituent i on Index Calculation Date t

The Index is only calculated on Index business days, which are defined in each Index methodology guide and are generally days on which the underlying constituent exchanges and data sources are open and active.

The **Index Divisor D$_t$** will be adjusted for corporate actions and any additions, deletions, and share changes for the Index Constituents:

$$D_t = \frac{\sum_i APC_{i,t}\, Q_t}{\text{Index(PR)}_{t-1}}$$

Where:
D_t means the Index Divisor on Index Calculation Date t
Index(PR)$_{t-1}$ means the Price Return Index Level from Date t-1
$APC_{i,t}$ means the Adjusted Previous Close Price (for corporate actions, and, denominated in the Index Base Currency) of Index Constituent i on Index Calculation Date t
$Q_{i,t}$ means the number of Shares of Index Constituent i on Index Calculation Date t

The general formula for the **Gross Total Return version [Index(GTR)$_t$]** of the Index will follow that of the Price Return version:

$$\text{Index(GTR)}_t = \frac{\sum_i P_{i,t} Q_{i,t}}{D_{gtr,t}}$$

Where:
t means Index Calculation Date t
$D_{gtr,t}$ means the Gross Total Return Index Divisor on Index Calculation Date t

$P_{i,t}$ means the Price (in the Index Base Currency) of Index Constituent i on Index Calculation Date t

$Q_{i,t}$ means the number of Shares of Index Constituent i on Index Calculation Date t

The **Index Divisor** for the **Gross Total Return Index** will be adjusted as follows:

$$D_{gtr,t} = \frac{\sum_i APC_{i,t}\, Q_t}{Index(GTR)_{t-1}}$$

Where:

t   means Index Calculation Date t

$D_{gtr,t}$ means the Gross Total Return Index Divisor on Index Calculation Date t

$APC_{i,t}$ means the Adjusted Previous Close Price (for <u>gross dividends going ex-dividend on Index Calculation Date t</u> and corporate actions, and, denominated in the Index Base Currency) of Index Constituent i on Index Calculation Date t

$Q_{i,t}$ means the number of Shares of Index Constituent i on Index Calculation Date t

$Index(GTR)_{t-1}$ means the Gross Total Return Index Level from Date t-1

The general formula for the **Net Total Return version [Index(NTR)$_t$]** of the Index will follow that of the Price Return version:

$$Index(NTR)_t = \frac{\sum_i P_{i,t} Q_{i,t}}{D_{ntr,t}}$$

Where:

t   means Index Calculation Date t

$D_{ntr,t}$ means the Net Total Return Index Divisor on Index Calculation Date t

$P_{i,t}$ means the Price (in the Index Base Currency) of Index Constituent i on Index Calculation Date t

$Q_{i,t}$ means the number of Shares of Index Constituent i on Index Calculation Date t

The **Index Divisor** for the **Net Total Return Index** will be adjusted as follows:

$$D_{ntr,t} = \frac{\sum_i APC_{i,t}\, Q_t}{Index(NTR)_{t-1}}$$

Where:

t   means Index Calculation Date t

$D_{ntr,t}$ means the Net Total Return Index Divisor on Index Calculation Date t

$APC_{i,t}$ means the Adjusted Previous Close Price (for <u>net dividends going ex-dividend on Index Calculation Date t</u> and corporate actions, and, denominated in the Index Base Currency) of Index Constituent i on Index Calculation Date t

$Q_{i,t}$ means the number of shares of Index Constituent i on Index Calculation Date t

$Index(NTR)_{t-1}$ means the Net Total Return Index Level from Date t-1

The formula for the **Net Dividend** of an Index Constituent is:

$$\text{Div}_{\text{net},i,t} = \text{Div}_{\text{gross},i,t} \times (1 - \text{WTR}_{i,t})$$

Where:
$\text{Div}_{\text{net},i,t}$ means the Net Dividend for Index Constituent i on Index Calculation Date t
$\text{Div}_{\text{gross},i,t}$ means the Gross Dividend for Index Constituent i on Index Calculation Date t
$\text{WTR}_{i,t}$ means the Tax Withholding Rate being utilized for the respective country of domicile for Index Constituent (i)

The schedule of applicable tax rates can be found in the Dividend Withholding Tax Table which can be downloaded at
https://www.nyse.com/publicdocs/nyse/indices/us_index_group_tax_withholding_table.pdf.

2.2 Index Currency Variants calculation formula

The following formula is utilized to calculate additional **currency variants** of an Index:

$$\text{Index}_{t,\text{cur}} = \text{Index}_t \times \text{ForeignExchangeRate}$$

Where:
$\text{Index}_{t,\text{cur}}$ means the Index level at time t denominated in the currency of the Index currency variant
Index_t means the Index level at time t denominated in the base currency of the Index
ForeignExchangeRate means the applicable cross spot currency rate expressed as units of Index variant currency per Index base currency.

3. Leveraged Index Formula

3.1 Gross Total Return Index calculation formula

The general formula for the calculation of a **Gross Total Return version** of the Index is:

$$\text{LI}_t = \text{LI}_\text{T}\left[1 + K\left(\frac{UI_t}{UI_T}\right) - 1\right] - (K-1)LI_T\left[\frac{ONIA_T}{360}\right]D_{t,T} - a(K-1)xLI_T\left[\frac{SPR_T}{360}\right]D_{t,T}$$

LI_t = Leverage Index level at time of calculation t
LI_T = Closing Leverage Index level on the previous calculation day
UI_t = Underlying Index level (see Index summary) at time of calculation t
UI_T = Closing Underlying Index level on the previous calculation day
$ONIA_T$ = Overnight Interest Average on the previous calculation day
$D_{t,T}$, = The number of days between the day of the calculation and T the previous calculation day
$SPRT$ = Applicable interest rate spread over ONIAT
a = Applicable factor to apply spread over ONIA
K = Leverage factor

3.2 Net Total Return Index calculation formula

The general formula for the calculation of a **Net Total Return version** of the Index is:

$$\text{Index(NTR)}_t = \frac{\sum_i\left[P_{i,t}Q_{i,t}\right] - \left(\dfrac{\sum_i\left[P_{i,t}Q_{i,t}\right]}{0.5} \times BR \times \text{DT}_{t_n} + Cash\right)}{\text{D}_t}$$

Where:
t   means Index Calculation Date t
D_t means the Index divisor on Index Calculation Date t
DT_{tn} means the number of days interest is charged on any borrowing
$P_{i,t}$ means the price of Index Constituent i on Index Calculation Date t
$Q_{i,t}$ means the number of shares of Index Constituent i on Index Calculation Date t which includes shares attributed beginning of day principle, any borrowed funds and acquisition utilizing net of taxes dividends
BR   means the borrow rate applied to margined assets
Cash means the proceeds of any borrowing used to establish the full shares position and is entered as a negative number

Leverage is introduced into the above equation by including a negative cash amount equal to the amount borrowed.

Borrow rates are dependent on the trading currency of Index underlyings. Current rates are as follows:

        i)   U.S. Equities: Federal Funds Overnight Rate + 100 Basis Points (1%)
        ii)   U.K. Equities: GBP Libor Overnight Rate + 100 Basis Points (1%)
        iii)   Italian Equities: EURIBOR Overnight Rate +100 Basis Points (1%)

Index Calculation Date means a U.S., U.K. or Italian Business Day where all Constituent Exchanges are open.

Net dividends are derived using the following formula:

$$\mathrm{Div}_{nt} = \sum \left[\mathrm{Dividend}_i \times Shares_i \times \left(1 - \mathrm{W}R_i \right) \right]$$

Where:
WR_i means the Tax Withholding rate of component (i)

4. ICE FX Indices Formula

4.1 Index calculation formula

The general formula for an ICE FX Index is:

$$\text{Index Value} = C * \prod_{i=0}^{n}(Spot\ Rate_{it})^{currency\ weight\ i}$$

Where:
$Spot\ Rate_{it}$ = exchange rate of currency I at time t with all exchange rates expressed in base currency terms, i.e., units of Foreign Currency per USD/EUR/JPY.
n = number composite currencies.
$currency\ weight\ ^{i}$ = weight for currency i.
C = constant term for the Index

The constant term for each Index is as follows:

DXY: 50.14348112
ICELX: 6.07196981
ICEEX: 43.92519834
ICEJX: 2.77144629

5. Inverse (Short) Index Formula

5.1 Index calculation formula

The general formula for an Inverse Index is:

$$\text{BI}_t = \text{BI}_{\text{T}}\left[1 - K\left(\frac{UI_t}{UI_T - DIV_t} - 1\right)\right] + (K+1)BI_T\left[\frac{ONIA_T}{360}\right]D_{t,T} - axKxBI_T\left[\frac{REPO_T}{360}\right]D_{t,T}$$

Where
BI_t = Short Index level at time of calculation t
BI_T = Closing Short Index level on the previous calculation day
UI_t = Underlying Index level (see Index summary) at time of calculation t
UI_T = Closing Underlying Index level on the previous calculation day
DIV_t = Dividend Index points of Underlying Index at the time of calculation t; applied only in case the Underlying Index is a Price return Index.
$D_{t,T}$, = The number of days between the day of calculation and the previous calculation day T
$ONIA_T$ = Overnight Interest Average at the previous calculation date
$REPO_T$ = The rate reflecting the repurchase agreement embedded in the strategy and specific to
each underlying Index
a = Applicable factor to apply REPO
K = Short factor

6. U.S. Treasury Index Formula

6.1 Index Calculation formula

The formula for the real-time **Excess Return version** of the Index is:

$$Index_t = \frac{\left(NM_n * NM_p\right)}{D_t}$$

Where:

t   means Index Calculation at time t
D_t means the Index Divisor at time t (divisor is fixed at 1,000,000)
NM_n means the number of contracts of the Near Month Futures in the Index
NM_p For an intraday calculation, the last traded price of the futures contract. For a closing calculation, the Settlement Price of the futures contract.

The formula for the end of day **Total Return version** of the Index is:

$$Index(TR)_t = \left(\frac{Index(PR)_t}{Index(PR)_{t-1}} + TR_{df}\right) * Index(TR)_{t-1}$$

Where:

t   means Index Calculation at time t (current calculation day)
t-1   means Index Calculation at time t-1 (prior calculation day)
$Index(PR)_t$ means the Price Return Index level at time t
$Index(PR)_{t-1}$ means the Price Return Index level at time t-1
$Index(TR)_{t-1}$ means the Total Return Index level at time t-1

$$TR_{df} = \left(\left(\frac{1}{1 - \frac{91}{360} * USB3MTA}\right)^{\frac{t-t_{-1}}{91}}\right) - 1$$

t   means Index Calculation at time t (current calculation day)
t-1   means Index Calculation at time t-1 (prior calculation day)
UBS3MTA   means the observed rate from the most recent 13 Week Treasury Bill Auction

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