THOMSON REUTERS INDICES
COUNTRY & REGION INDEX METHODOLOGY

Updated September 2011

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INTRODUCTION

Thomson Reuters Indices

Thomson Reuters is the world's leading source of intelligent information for businesses and professionals. We combine industry expertise with innovative technology to deliver critical information to leading decision makers in the financial, legal, tax and accounting, scientific, healthcare and media markets, powered by the world's most trusted news organization.

Thomson Reuters provides trusted and innovative indices and index-related services to the investment community. Our index business leverages Thomson Reuters global footprint and unparalleled depth and breadth of the financial markets to provide our clients with:

- **Beta-generating indices**
- **Alpha-creating indices**
- **Custom index services**
- **Outsourced index calculation services**

Whether you require indices for benchmarking, or for the development of investment vehicles, Thomson Reuters offers a range of index solutions to satisfy your requirements. Delivered via Thomson Reuters platforms and data feeds, Thomson Reuters Indices leverage the latest technologies for ease of use and convenient delivery.

Thomson Reuters Indices are used by investors such as plan consultants, investment managers, mutual fund providers, ETF providers, financial advisors, investment banks, stock exchanges, and the media. Thomson Reuters does not provide financial advice to clients, which allows for the provision of truly objective market information.

Each index is constructed employing content sets with the highest data integrity. They are transparent and designed to provide unbiased and neutral measures of the markets. Our rigorous financial models, analytics and classifications provide insight needed to make better investment decisions.

Index Family

The Thomson Reuters Country & Region Indices serve as a group of comprehensive, standalone indices as well as a foundation for a number of other indices, including Thomson Reuters Sector Indices.

The Thomson Reuters Country & Region Indices cover 51 countries and 26 regions, including countries with as few constituents as approximately 10 and as many as approximately several thousand. The indices are designed to serve as liquid, broad-based and comprehensive tools for investment professionals and analysts to benchmark and invest in common stock on a local, regional or global basis.

These indices are unique and advantageous in several ways: First, is the liquidity test. The liquidity test takes advantage of the latest research among the economic and mathematical communities regarding what a liquid security is. Next, is the comprehensive nature of the indices: They comprise 97.68% of the market capitalization of the liquid securities in a market. This rule exists in order to limit the number of micro-cap stocks that appear in any Thomson Reuters Broad Market Indices (BMI). It also means the related Thomson Reuters Sector Indices can support the increased level of granularity the Thomson Reuters Business Classification (TRBC) schema gives. Finally, with the combined global security coverage that the Thomson Reuters databases give, the depth of coverage – in the number of securities and in their attributes – is difficult to match.

Index Types

Thomson Reuters currently offers market capitalization weighted domestic indices for countries, regions and sectors.

In the sections below, we will detail the country level market capitalization methodology as the regional indices are rollups of the country indices. The methodology for the Thomson Reuters Sector Indices is available upon request.

CONSTRUCTION

This section describes the underlying Thomson Reuters data and methodology used to construct Thomson Reuters Indices.

Data

Thomson Reuters index data is sourced from Datastream. For individual securities – which in these indices are limited to common stocks - the following data points are collected on a daily basis: A variety of security IDs (CUSIP, SEDOL and RIC primarily and IDs secondarily); both the adjusted and total return prices for the securities; shares outstanding for the primary share classes (if not available or known; the largest share class is used) and each security's float factor. All of these data points are collected at the individual country level.

Other country level data that is collected includes two years of daily price history and the primary and subsidiary exchanges on which the security trades. Additional data is collected on a as-needed basis and is referenced in the sections below. Lists of countries for which Thomson Reuters collects data (as well as the regional roll-ups) can be found at the link provided in Appendix B.

For each country, data is collected for securities headquartered in that country as well as securities headquartered elsewhere but traded on the local exchange(s).

The data is then reviewed by the Thomson Reuters Indices team to assure the quality of the data used in the index construction. In addition, content user acceptance tests (UATs) are performed during the index construction process to further verify the quality of the data.

Liquidity Test

Once the securities for an individual country are identified, (i.e. sufficient price history is available as well as shares outstanding, IDs, etc), the liquidity test is performed on each security. The purpose of this test is to make sure that the necessary liquidity is present for any security included in any Thomson Reuters index.

This is followed by some common definitions of liquidity:

- Ability to buy or sell significant quantities of a security quickly, anonymously, and with minimal or no price impact
- Market-makers: provide liquidity by taking the opposite side of a transaction. If an investor wants to buy, the market- maker sells and vice versa
- In exchange for this service, market-makers buy at a low bid price and sell at a higher ask price
- This ability to buy low and sell high insures that the market-makers will make some profits

Some related concepts are:

- Depth: The quantity available for sale or purchase away from the current market price
- Breadth: The market has many participants
- Resilience: Price impacts caused by the trading are small and quickly die out

Liquidity has no truly common definition: From a computational or statistical standpoint it is considered unobservable. Unobservable entities generally have corresponding error. A quick mathematical example demonstrates this:

- Unobservable variables create measurement error. (The problem with measurement error is in the X's [liquidity in this case], not with the Y's [security return].)
- Basic measurement error framework:

  - We are interested in estimating the effect of the unobservable x* on a dependent variable y

$$y = \beta x^* + \varepsilon$$

  - Let x be observable, with a relation to x* given by:

$$x = x^* + \upsilon$$

- If we regress y on x, $\text{plim } b=\beta \text{ var}(x^*)/(\text{var}(x^*)+\sigma 2\upsilon)\neq\beta$
- Our results will be inconsistent and biased
- Note: as $\sigma 2\upsilon$ increases, the regression estimates becomes even more unreliable

There are other statistical means of working with this measurement error, such as through instrumental variables, commonly referred to as proxies. Proxies need to correlate well with x*. Some common proxies are:

- ***Trading volume***: Indirect but widely used measure. It is simple and available. (Fact: more active markets tend to be more liquid.) But trading volume is correlated to volatility, which can impede market liquidity.
- ***Trading frequency***: Number of trades executed within a specified interval, without regard to trade size. High trading frequency may also indicate a more liquid market, but it, too, can be associated with volatility and hence lower liquidity.
- ***The bid-ask spread (Level or %):*** It measures the cost of executing a small trade. Usually calculated as the difference between the bid or offer price and the bid-ask midpoint. It can be calculated quickly, with data widely available in real time. But bid andoffer quotes are good only for limited quantities and time periods; the spread just measures the cost of executing a single trade ofa certain size.
- ***Quote size:*** Quantity of securities tradable at the bid and offer prices. It accounts for market depth and complements the bid-ask spread. Market makers often do not reveal the full quantities they will transact at a given price so the measured depth underestimates the true depth.
- ***Trade size***: Quantity of securities traded at the bid and offer prices, reflecting any negotiation over quantity. Alternative depth measure. Trade size also underestimates market depth, because the quantity traded is often less than the quantity that could have been traded at a given price.
- ***Price impact coefficient (Temporary or Permanent)***: It considers the rise (fall) in price that typically occurs with a buyer- initiated (seller-initiated) trade. Useful for large trades or a series of trades.

Much of the academic research in the past 15 years has shown that price, together with the bid-ask spread and depth measures, provides a good picture of liquidity. When depth measures are not available, a measure of volume can be used in its place.

The same academic studies noted above show that the largest weight is regularly given to price impact. Because of this, Thomson Reuters breaks away from traditional computations of liquidity – via volume – and uses price.

This liquidity filter is based on the PhD thesis of Dr. Mark Labovitz[1]. The liquidity measure Labovitz proposes exploits the fact that stocks whose liquidities are the most sensitive to market liquidity, are not necessarily those whose prices are the most sensitive to market liquidity. In short, the price movement of an illiquid security is sticky and not regularized, and the response of the security to the market factor (or factors in a multi-factor model) is much more likely to be idiosyncratic. What this means for Thomson Reuters Indices is that for every security included in any Thomson Reuters index, the necessary liquidity is present to make that security truly investable.

[1] M. Labovitz "Using Return Level as a Dependence Function in a Statistical Model for the Joint Distribution of the Extreme Values of Equities," PhD Thesis (in progress), Department of Mathematical Sciences, University of Colorado Denver. Readers interested in reading about the exact calculation method Thomson Reuters uses are referred to Appendix C.

Market Capitalization Rule

Once all of the securities in a country that pass the liquidity test are known, a market capitalization rule is applied by country. The rule states that each country index should be composed of 97.68% of the total market value of the exchange or exchanges used. This rule is in place to limit the number of micro-cap stocks that enter any country index. While it does not eliminate all micro-cap stocks, it does significantly reduce their presence.

Methodology

Thomson Reuters market capitalization weighted (market cap) indices are free float. They are calculated using standard industry compilation and pricing methods in combination with Thomson Reuters unique liquidity filter. Eligible securities are those common stocks for which the data requirements are met *and* that have passed the liquidity test.

A float adjusted market capitalization is computed for each stock (this is sometimes referred to the stock's market value) and the market values are arranged in descending order. The stock that is nearest to 97.68% of the total market value of all the stocks is the last stock included in the index. This rule exists in order to limit the number of micro-cap stocks that appear in any Thomson Reuters Broad Market Indices (BMI). Once weights are computed, the constituents and weights for the market-cap index are known.

Pricing

The market capitalization (cap) weighted index uses the market cap of the constituent (*price X free float shares*) as a weighting factor. Consequently, in this construction, we divide the sum of the market caps of all the stocks in the index at a given time by a quantity which is the sum of the market caps at some initial time divided by an initial index value (e.g., 100). The process must include an initial step to compute an adjustment factor defined as the total market cap at time *0, divided by100.*   With respect to the mathematical manipulations (not the quantities), the computation is:

$$\text{Index Price}_t = \frac{\sum_{i=1}^{n}\left(p_{i,t} \times q_{i,t} \times r_{i,t}\right)}{\sum_{i=1}^{n}\left(p_{i,0} \times q_{i,0} \times r_{i,0}\right) / 100}$$

$$= 100 \times \frac{\sum_{i=1}^{n}\left(p_{i,t} \times q_{i,t} \times r_{i,t}\right)}{\sum_{i=1}^{n}\left(p_{i,0} \times q_{i,0} \times r_{i,0}\right)}$$

where: $p_{i,t}$ = price of equity *i=1,2,…,n, at* time *t=0,1,2,…,T* and *t=0* means the initial time period,

n = the number of equities in the index,

$q_{i,t}$ = float adjusted shares outstanding for equity *i* at time *t*

$$r_{i,t} = \begin{cases} 1, \text{ if a country index} \\ \text{exchange rate from local currency to USD at time (t), if a regional index} \end{cases}$$

100 = the initial value of the index defined as the initial total market cap $a_0 \; / f$

The result present in the above equation is generalized in the chain pricing equation:

$$\text{Index Price}_t = \frac{\sum_{i=1}^{n}\left(p_{i,t} \times q_{i,t} \times r_{i,t}\right)}{\sum_{i=1}^{n}\left(p_{i,t-1} \times q_{i,t-1} \times r_{i,t-1}\right) / \left(a_{t-1} / f\right)}$$

$$= \frac{a_{t-1}}{f} \times \frac{\sum_{i=1}^{n}\left(p_{i,t} \times q_{i,t} \times r_{i,t}\right)}{\sum_{i=1}^{n}\left(p_{i,t-1} \times q_{i,t-1} \times r_{i,t-1}\right)}$$

where: *t=1,2,…,T .*

Adjustment for Liquidation

Adjustments are as follows:

(1) Keep the liquidated constituent in the index, use the last closing price prior to liquidation to yield a constituent value which results in a constant constituent value that will be included in the index computations until the next rebalance, or

(2) Adjust as follows:

$$Index\ Price_t = \frac{\sum_{i=1}^{n-1}\left(p_{i,t} \times q_{i,t} \times r_{i,t}\right)}{\sum_{i=1}^{n-1}\left(p_{i,t-1} \times q_{i,t-1} \times r_{i,t-1}\right) / \left(a_{t-1} / f\right)}$$

$$= \frac{a_{t-1}}{f} \times \frac{\sum_{i=1}^{n-1}\left(p_{i,t} \times q_{i,t} \times r_{i,t}\right)}{\sum_{i=1}^{n-1}\left(p_{i,t-1} \times q_{i,t-1} \times r_{i,t-1}\right)}$$

where: the index has been re-ordered so that the deleted constituent has been removed, and; the numerator of the divisor is the previous day's (prior to liquidation) market cap computed as if the constituent had already been deleted and the denominator is the index price for the previous day as computed.

Whether (1) or (2) is followed is determined by the Index Action Committee (IAC) every month.

The pricing calculations for regional indices are essentially the same; the only difference is that, when multiple currencies are involved, prices are converted to USD. In such cases, when currency conversions have been applied, the daily index price change will also reflect the daily change(s) in the exchange rates(s). Consequently, index values may change based on the common currency in which they are calculated, i.e., calculating an index value for Hungary in U.S. Dollars will likely not produce the same value as calculating the same index value in Hungarian Forints, since the index would also reflect the change in HUF->USD exchange rates.

To snap the rates, Thomson Reuters stops the official index value at the time of the westerly-most country, yet continues to calculate the index value internally (using an internal symbol) until 22:00 GMT (FX closing time). The next day, instead of using the previous day's official index value published for the calculation, Thomson Reuters uses the internal index value as of 22:00 GMT previous day.

Total Return

The total return is a quantity which adjusts the price for issuance of dividends. When a company issues a dividend, the price of the equity drops in the exact amount of the per share dividend amount. Leaving aside subsequent market movements of the equity price, the impact of a constituent equity dividend upon an index is a drop in the price of the index. A companion index which is based on the total return adjusts the price-only index for the issuance of dividends by its constituents. The total return index is computed as follows:

$$TRIndexPrice_t = TRIndexPrice_{t-1} \times \frac{\sum_{i=1}^{n}\left[\left(p_{i,t} \times h_{i,t} \times r_{i,t}\right) + \left(div_{i,t} \times h_{i,t} \times r_{i,t}\right)\right]}{\sum_{i=1}^{n}\left(p_{i,t-1} \times h_{i,t-1} \times r_{i,t-1}\right)}$$

Where: $p_{i,t}$ = price of equity $i=1,2,\ldots,n$, *at* time $t=0,1,2,\ldots,T$ and $t=0$ means the initial time period

n = the number of equities in the index

$h_{i,t}$ = the number of shares in equity i at time t == $q_{i,t}$ or $s_{i,t}$ depending on whether MC or EQ weighting is used respectively,

$$r_{i,t} = \begin{cases} 1, \text{ if a country index} \\ \text{exchange rate from local currency to USD at time (t), if a regional index} \end{cases}$$

$div_{i,t}$ = per share dividend on ex-date

All quantities in the equation above are end-of-day quantities. The numerator is computed as per the ex-date for any dividends. A key point for this approach comes via the observation that the dividend is adjusted for solely on the ex-date and does not enter the computations (implicitly) after that date. To accomplish this on the day following the ex-date, a price-only version of the index's ex-date total value enters in the denominator (divisor) of the equation.

The set-up of the total return index, including initial value, is identical to the price-only indices.

MAITENANCE

Daily Index Maintenance

Thomson Reuters Indices are maintained on a daily basis by a dedicated support team. This team, with direct collaboration from the Thomson Reuters Data Operations Global Corporate Actions teams, identifies all corporate action events that affect the capital structure of a constituent in the index including stock splits, delistings, and symbol changes and ensure these changes are implemented into the applicable index. The team also monitors divisor movements and performs constituent pricing comparisons between independent constituent price sources to ensure the accuracy of the index return values.

Index Rebalance

The indices are rebalanced on a semi-annual basis starting in the first quarter of 2010 with subsequent quarterly reviews. This rebalance is the major source of additions and deletions to Thomson Reuters Indices.

The rebalancing process starts with all eligible common stock with the necessary data. The liquidity test is applied to this set of stocks and those stocks that pass this test are now eligible for possible inclusion in the index. The 97.68% capitalization filter is applied at this stage in order to arrive at the final set of stocks that will actually be in the index.

After these steps, the following reviews are executed:

- Stocks with 2 years of price data that fail the liquidity filter will be examined against a bid-ask measure to see if they belong to the index.
- Those stocks that have less than 2 years of price data but more than 6 months will have their liquidity determined by a bid-ask measure.
- Stocks with less than 6 months of price data will have their entry decided by the IAC.
- The 20% cap rule: When one or more stock(s) is (are) a significant part of the market cap and is (are) pushing out stocks that belong to the index, Thomson Reuters screens all indices for stocks that comprise/make up more than 20% of the total local market capitalization (market cap). Thomson Reuters caps those stocks at 20% and re-computes market cap coverage. At the discretion of the IAC, the presence of too many micro-cap stocks may mean a trimming of the results of the 20% cap rule.
- Turnover: When stocks are pushed out of the index for reasons other than the 2 given above, turnover is typically occurring at the margin, i.e., among the smallest stocks. Thomson Reuters limits the semi-annual turnover percentage to the smallest value possible without distorting the constituent list. Turnover bands based on numbers of constituents in an index and in some cases individual country turnover percentage will or could be used.
- Historically low constituent numbers - This is related to indices that "consistently" (to be defined by country) have less than the requisite number of constituents. In this situation, the Thomson Reuters IAC reviews each potential index that is deficient and determines whether it should continue as an index.

Corporate Actions

For details on the corporate action treatment for the indices, please see the separate Corporate Actions Methodology.

GOVERNANCE

Index Action Committee

There are two index action committees (IAC) at Thomson Reuters Indices. The first is an internal IAC for reviewing country and region indices. It is composed of the Thomson Reuters Indices Head of Product Management, the Chief Index Strategist, Thomson Reuters Head of Data Operations and the Head of Technology.

The main activity of this Index Action Committee is to insure that the attributes the index claims to possess – the necessary liquidity, capitalization assignment (large, mid or small-cap) or style considerations – are indeed present. These reviews take place at each rebalance and at each quarterly review. The Index Action Committee also deals with unusual corporate actions which are not handled by the pricing methodology or by the internal data management team that makes hand- adjustments to the index for items such as mergers and delistings. These reviews take place on a monthly or more frquent basis. Finally, as each index needs a minimum number of constituents in order for its price to be computed, the Index Committee decides if an index should be discontinued or possibly resurrected. This decision will normally be made during the rebalance period but could happen more often.

The external IAC is composed of external (to Thomson Reuters) members with the exception of the Thomson Reuters' Chief Index Strategist.

The purpose of this committee is to review and approve the changes to the country and region indices at each rebalance and quarterly review. The information provided to the external IAC will come primarily from the internal IAC though the external IAC reserves the right to ask for more information from other Thomson Reuters sources. External IAC decisions are the final word on country and regions rebalancing and quarterly reviews.

Business Rules

Selecting candidates for a country level index

Thomson Reuters uses the country of incorporation to determine the headquarters of a firm. There are instances where the country of incorporation is not where the headquarters of a firm is. In those cases where the headquarters of a firm are known to be different from the country of incorporation, Thomson Reuters uses the company stated headquarters of a firm to determine membership in a particular country's domestic index.

As an example, companies incorporated in the Marshall Islands but with a primary listing in the United States will be treated as US companies. The country of the headquarters of a company is derived through a set of rules using security identifiers in conjunction with ISO standardized data. This might differ in some cases from the formally declared headquarters of a given company, as could be the case in the example above. If concerns with the rule based derivation of the company/country mapping arise, decisions can be reviewed on a case by case basis by the index committee.

- For rebalance purposes, start and end dates are determined when selecting equities. Dates occur at a minimum of 6 months and a maximum of 2 years
- Prices reflected in the rebalance are based on trading days determined according to the prior year calendar
- Stocks considered suspended or dead are considered 'dead' as of the "last traded date"
- Only equities with a current status of "active" are included
- Equities with a current status of "dead" or "suspended" are included if the "last traded date" occurs after the rebalance end date

- Equity end date status is determined as follows:
  - If the stock is currently suspended or dead and the “last traded date” is less than or equal to the end date for this rebalance, then the status on the end date is “dead”.
  - If the stock is currently active then the status is “active”.

Selecting candidates for a region or global index

- Candidates for regional and global indices include all constituents within the countries that comprise the index. All rules for country level indices apply to regional and global indices.
- A constituent may exist in more than one country index. Equities are considered equal if they possess the same ISIN:
  - If only one of the set of duplicates is the primary equity, we use that equity and exclude secondaries
  - If all duplicates are secondaries, one of the equities is randomly selected and the others are excluded
  - If all duplicates are primaries, both equities are included

Determining prices, shares, and FX rates for rebalancing for each equity in the list of candidates

- Thomson Reuters supplies price, USD price, share count, free float percentage and free float adjusted share count for each trading date that falls within the range of the dates covered by the rebalance (two years)
- If USD price, or share count is not available, the value is considered zero
- If free float percentage is not available, the value is considered 50%. Free float adjusted share count is considered equal to share count

Finding prices, shares and FX rates for pricing

- For daily pricing, data is supplied for each of the equities that are constituents on that day
- If an FX rate, price or share count is not available on a requested date, Thomson Reuters selects the next best date with available data
- The next best date for pricing is the first date, working backward from the requested date, for which there is non-zero pricing
- The next best date for share count is the first date, working backward from the requested date, for which there is non- zero share count
- The next best date for an FX rate is the first date, working backward from the requested date, for which there is a non- zero FX rate – the rate is used to convert equity price to USD
- If a dividend was paid on the requested date, it is included. The FX rate used for the dividend is the first date, going backward from the requested date, for which there is a non-zero FX rate. This FX rate is used to convert the dividend to USD

APPENDIX

A: Exchanges Used in Thomson Reuters Equity Indices

TR INDEX COUNTRY	EXCHANGE	TR INDEX COUNTRY	EXCHANGE
*Argentina	• Buenos Aires Stock Exchange (MERVAL)	Malaysia	• Bursa Malaysia
Australia	• Australian Securities Exchange (ASX)	Mexico	• Mexico Stock Exchange
Austria	• Vienna Stock Exchange (Wiener Börse)	Morocco	• Casablanca Stock Exchange
Bahrain	• Bahrain Stock Exchange	Netherlands	• Euronext Amsterdam
Belgium	• Euronext Brussels	New Zealand	• New Zealand Stock Exchange
Brazil	• Sao Paulo Stock Exchange (BM&F BOVESPA)	Norway	• Oslo Stock Exchange
Canada	• Toronto Stock Exchange (TSX)	Oman	• Muscat Securities Market
Chile	• Santiago Stock Exchange	Pakistan	• Karachi Stock Exchange
China	• Shanghai Stock Exchange	Philippines	• Philippine Stock Exchange
Czech Republic	• Prague Stock Exchange	Poland	• Warsaw Stock Exchange
Denmark	• Copenhagen Stock Exchange	Portugal	• Euronext Lisbon
Egypt	• Egyptian Exchange	Qatar	• Qatar Exchange
Finland	• Helsinki Stock Exchange	Russian	• MICEX
France	• Euronext Paris	Singapore	• Singapore Exchange (SGX)
Germany	• XETRA (Deutsche Börse)	South Africa	• Johannesburg Stock Exchange
Greece	• Athens Stock Exchange	Spain	• Madrid Stock Exchange (Mercado Continuo)
Hong Kong	• Hong Kong Stock Exchange	Sweden	• Stockholm Stock Exchange
Hungary	• Budapest Stock Exchange	Switzerland	• SIX Swiss Exchange
India	• National Stock Exchange of India • Bombay Stock Exchange	Taiwan	• Taiwan Stock Exchange
Indonesia	• Indonesia Stock Exchange	Thailand	• Thailand Stock Exchange (SET)
Ireland	• Irish Stock Exchange	*Turkey	• Istanbul Stock Exchange
Israel	• Tel Aviv Stock Exchange	UAE	• Abu Dhabi Securities Exchange • Dubai Financial Market
Italy	• Milan Stock Exchange	United Kingdom	• London Stock Exchange
Japan	• Tokyo Stock Exchange • Osaka Stock Exchange	United States	• New York Stock Exchange • NASDAQ Stock Market • NYSE AMEX
Korea	• Korea Stock Exchange (Koscom) • KOSDAQ	Vietnam	• Ho Chi Minh Exchange
Kuwait	• Kuwait Stock Exchange		

***** Represents End of Day (EOD) Data

B: Equity Indices Country and Region List

For a list the Equity Indices Country and Region List, click here.

C: Liquidity Test

Context for Reproduced Research: This methodology focuses upon an alternative means to build dependence functions and factor models describing the joint distribution of equity returns. The model makes use of extreme value theory (EVT) which is one of the central technologies used herein. In this and the sections immediately preceding it, the investigator is performing quality adjustments to the initial data set which included daily performance measures on nearly 80,000 publicly traded securities over a period of eight years. The impact of missing data, incomplete sets of observations and time series deemed too short is greatly reduced the number of equity series under consideration by the investigator. A guiding principle in making these data reductions is that the investigator is looking for general results (results applicable across many equities series) rather than results which are idiosyncratic to a few equity series. It is in this context which investigator conducted the research described below.

In the initial fit of parameters for non-time varying generalized extreme value distributions (GEV), the investigator observed a substantial number of instances in which the maximum likelihood estimation of the block maximum[2] extreme series failed to converge in accordance with model fitting diagnostics. It is in search of an explanation to describe this behavior that the investigator pursued the research described below.

Liquidity

Examination of the return series shows that a value of 0 for the daily return was not uncommon. According to FactSet (Pers. Comm. [2007]), these are accurate observations and are not indicative of missing or poor-quality observations. What does a 0 value for a daily return mean? Well, since a daily return is defined as:

$$R_t = \frac{(P_t - P_{t-1})}{P_{t-1}} \qquad (3.1)$$

Where: R_t is the total return for time t

P_t is the price adjusted for corporate action at time t

Therefore, a return value of 0 suggests $P_t = P_{t-1}$

It is most likely in the event of substantial numbers of the daily values being 0 that little or no trading of the security had taken place. Such a circumstance is known as illiquidity. In the event of illiquidity “an asset or security cannot be converted into cash very quickly (or near prevailing market prices)” (Financial.Dictionary [2008]). A market-clearing price for a trade is not easily or typically as rapidly found for an illiquid equity as for a liquid one. The price movement of the illiquid equity is “sticky” and not as regularized; also, the response of the return to the market factor is likely to be much more idiosyncratic. In the context of this research a major consequence of such a result would be that the fitting of a generalized extreme-value (GEV) model would be problematic because, as is described in the next chapter, the method of parameter-fitting used in this research is a highly nonlinear, iterative search. The manifestation of this lack of liquidity would be the failure to converge to reasonable maximum-likelihood estimator (MLE) GEV parameters (as defined by Smith [1985] and reported in Chapter 1) or to converge at all.

The GEV model-fitting activity will be developed in detail in Chapter 4. However, to look at the relationship between the distribution of zeros in the extreme-value series (liquidity) and the ability to estimate MLE-property-confirming estimates, the investigator ran non-time-varying estimates (once again discussed in Chapter 4) of the GEV location, scale, and shape parameters for weekly and monthly extreme-value series, constructed using the block-maxima model for all 15,528 equities resulting from the filtering detailed in Table 3.3.

[2] A block maximum methodology groups the observations (in this case return) by say time period and then takes the maximum or minimum value in the group to represent the extreme for the group. In this research block minimums using a weekly or monthly block were studied.

If the equities did not converge or did converge but did not meet the criteria laid out by Smith (1985), reproduced here for convenience, then a random variable ascribing the successful fit of the equity was assigned the value of 0. On the other hand, a successful convergence meeting the Smith criteria was assigned a 1:

- If ξ >-0.5, MLE_{GEV} estimators possess common asymptotic properties.
- If -1<ξ <-0.5, MLE_{GEV} estimators may be computed, but they do not have regular or standard asymptotic properties.
- If ξ <-1, MLE_{GEV} estimators may not be obtained.

Additionally, the investigator created a number of independent variables from the analysis of the extreme weekly and monthly series. These were:

- Largest number of consecutive zeros (Max.Gap)
- The percentage of zeros in the extreme-values series (Portion.Zero)
- The number of "zero gaps," namely, the number of sets of consecutive zeros separated by sets of one or more non- zeros (Num.Gaps)

The dependent random variable describing GEV model quality was modeled as a function of the functions of the sets of zeros, using a logistic regression model (Neter *et al*. [1996]).

Table 3.5 Analysis of deviance table from stepwise logistic regression for weekly extreme-value series

Source	DF	Deviance	Resid.Df	Resid.Dev	P(Q>=q)
Intercept	NA	NA	15,527	13,889.15	NA
Portion.Zero	1	7,747.07	15,526	6,142.08	0
Num.Gaps	1	458.05	15,525	5,684.03	0
Portion.Zero X Num.Gaps	1	125.55	15,524	5,558.48	0
Max.Gap	1	60.02	15,523	5,498.46	9.44E-15
Portion.Zero X Max.Gap	1	82.96	15,522	5,415.50	0

Table 3.6 Analysis of deviance table from stepwise logistic regression for monthly extreme-value series

Source	DF	Deviance	Resid.Df	Resid.Dev	P(Q>=q)
Intercept	NA	NA	15,527	10,349.14	NA
Portion.Zero	1	9,170.26	15,526	1,178.88	0
Max.Gap	1	61.59	15,525	1,117.29	4.21885E-15

Table 3.7 Cross-tabs from the assignment of weekly extreme-value series to classes

	Pred.Failed	Pred.Converged	Total Row
Obs.Failed	2,014	599	2,613
Obs.Converged	730	12,185	12,915
Total Column	2,744	12,784	15,528

Table 3.8 Cross-tabs from the assignment of monthly extreme-value series to classes

	Pred.Failed	Pred.Converged	Total Row
Obs.Failed	1,487	117	1,604
Obs.Converged	69	13,855	13,924
Total Column	1,556	13,972	15,528

The predictor selection method was a stepwise process using both forward and backward steps. The results (not shown here) exhibited a strong inverse relationship.

CONTACTS

RESEARCH
Andrew Clark
Chief Index Strategist
Thomson Reuters Indices
Andrew.Clark@thomsonreuters.com
Phone: +1 303.941.6017

PRODUCT MANAGEMENT
Lucas Garland
Global Head of Product Management
Thomson Reuters Indices
Lucas.Garland@thomsonreuters.com
Phone: +1 303.357.0564

COMMERCIAL STRATEGY & BUSINESS DEVELOPMENT
Jamie Robinson
Head of Commercial Strategy & Business Development
Thomson Reuters Indices
James.Robinson@thomsonreuters.com
Phone: +41 (0)79 933.2655

DATA OPERATIONS
Ray Koscinski
Global Head of Data Operations
Thomson Reuters Indices
Ray.Koscinski@thomsonreuters.com
Phone: +1 646.223.5618