FTSE EDHEC-Risk Efficient Index Series

v3.0

Contents

Section 1
Introduction

1. Introduction

1.1 This document contains the Ground Rules for the construction and management of the FTSE EDHEC-Risk Efficient Index Series (FTSE EDHEC-Risk EIS). The index series is calculated by FTSE International Limited (FTSE) using an optimisation approach developed by EDHEC-Risk Institute (EDHEC-Risk) referred to in these Ground Rules as the efficient weight method. The index series aims to reflect equity market performance of securities weighted in an optimal manner.

1.2 Optimal security weightings result from maximisation of the expected Sharpe ratio. Sharpe ratio maximisation requires two inputs: the expected return of each stock (in excess of a risk-free rate) and the covariance matrix of stock returns.

1.3 The FTSE EDHEC-Risk EIS is based on the eligible constituent securities of the FTSE All-World Index Series (see section 4 for eligible securities). Constituent weightings result from the application of an optimisation process to maximise the reward-to-risk ratio of a broad market index. The efficiency of the resulting index may be measured by improvements in the Sharpe ratio (relative to capitalisation weighted index). More detail of the Sharpe ratio calculation used in this context can be found in Appendix A.

1.4 The FTSE EDHEC-Risk EIS does not take account of ESG factors in its index design.

1.5 FTSE EDHEC-Risk Efficient Index Series (EIS) is composed of the following reference indices:

FTSE EDHEC Index	Universe	Currency	Reference indices
FTSE EDHEC-Risk Efficient All-World Index	FTSE All-World Index	US Dollar	USA, Canada, Developed Asia Pacific ex Japan, Japan, Emerging Asia Pacific, Developed Eurozone, Developed Europe ex Eurozone ex UK, UK, Emerging Europe, Latin America, Israel, Middle East and Africa ex Israel
FTSE EDHEC-Risk Efficient All-World ex US Index	FTSE All-World ex US Index	US Dollar	Canada, Developed Asia Pacific ex Japan, Japan, Emerging Asia Pacific, Developed Eurozone, Developed Europe ex Eurozone ex UK, UK, Emerging Europe, Latin America, Israel, Middle East and Africa ex Israel
FTSE EDHEC-Risk Efficient All-World ex Japan Index	FTSE All-World ex Japan Index	US Dollar	USA, Canada, Developed Asia Pacific ex Japan, Emerging Asia Pacific, Developed Eurozone, Developed Europe ex Eurozone ex UK, UK, Emerging Europe, Latin America, Israel, Middle East and Africa ex Israel
FTSE EDHEC-Risk Efficient All-World ex UK Index	FTSE All-World ex UK Index	US Dollar	USA, Canada, Developed Asia Pacific ex Japan, Japan, Emerging Asia Pacific, Developed Eurozone, Developed Europe ex Eurozone ex UK, Emerging Europe, Latin America, Israel, Middle East and Africa ex Israel
FTSE EDHEC-Risk Efficient Developed Index	FTSE Developed Index	US Dollar	USA, Canada, Developed Asia Pacific ex Japan, Japan, Developed Eurozone, Developed Europe ex Eurozone ex UK, UK, Israel

FTSE EDHEC Index	Universe	Currency	Reference indices
FTSE EDHEC-Risk Efficient Emerging Index	FTSE Emerging Index	US Dollar	Emerging Asia Pacific, Emerging Europe, Latin America, Middle East and Africa ex Israel
FTSE EDHEC-Risk Efficient Developed Europe Index	FTSE Developed Europe Index	US Dollar	Developed Eurozone, Developed Europe ex Eurozone ex UK, UK
FTSE EDHEC-Risk Efficient Developed Europe ex UK Index	FTSE Developed Europe ex UK Index	US Dollar	Developed Eurozone, Developed Europe ex Eurozone ex UK
FTSE EDHEC-Risk Efficient Developed Eurozone Index	FTSE Developed Eurozone Index	Euro	Developed Eurozone
FTSE EDHEC-Risk Efficient Asia Pacific Index	FTSE Asia Pacific Index	US Dollar	Developed Asia Pacific ex Japan, Japan, Emerging Asia Pacific
FTSE EDHEC-Risk Efficient Asia Pacific ex Japan Index	FTSE Asia Pacific ex Japan Index	US Dollar	Developed Asia Pacific ex Japan, Emerging Asia Pacific
FTSE EDHEC-Risk Efficient Developed Asia Pacific ex Japan Index	FTSE Developed Asia Pacific ex Japan Index	US Dollar	Developed Asia Pacific ex Japan
FTSE EDHEC-Risk Efficient Developed Asia Pacific ex Japan ex Korea Index	FTSE Developed Asia Pacific ex Japan ex Korea Index	US Dollar	Developed Asia Pacific ex Japan ex Korea
FTSE EDHEC-Risk Efficient USA Index	FTSE US Index	US Dollar	USA
FTSE EDHEC-Risk Efficient UK Index	FTSE UK Index	UK Pound Sterling	UK
FTSE EDHEC-Risk Efficient Japan Index	FTSE Japan Index	Japanese Yen	Japan

1.6 Each FTSE EDHEC-Risk Efficient Index comprises a set of reference indices. Eligible securities within each reference index are weighted using an efficient weighting method. Reference indices are used as the building blocks to create each aggregate index by weighting each component reference index by investable market capitalisation. This approach permits the efficient weighting method (see section 6) to be applied within countries and regions (i.e. at the reference index level), whilst ensuring that in aggregate each index reflects the regional and currency structure of the comparable market capitalisation weighted index.

1.7 These Ground Rules should be read in conjunction with the FTSE Global Equity Index Series Ground Rules and the Corporate Actions and Events Guide for Non Market Capitalisation Weighted Indices, which are available at www.lseg.com/en/ftse-russell/. Unless stated in these Ground Rules, the FTSE EDHEC-Risk EIS will
follow the same process as the FTSE Global Equity Index Series.

1.8 Price and total return indices will be calculated on an end-of-day basis. The total return indices include income based on ex-dividend adjustments.

1.9 The indices may be calculated in real time (see Appendix E).

1.10 The base currency of the benchmark is USD. Index values may also be published in other currencies.

1.11 FTSE Russell hereby notifies users of the index series that it is possible that circumstances, including external events beyond the control of FTSE Russell, may necessitate changes to, or the cessation of, the index series and therefore, any financial contracts or other financial instruments that reference the index series should be able to withstand, or otherwise address the possibility of changes to, or cessation of, the index series.

1.12   FTSE Russell

FTSE Russell is a trading name of FTSE International Limited, Frank Russell Company, FTSE Global Debt Capital Markets Limited (and its subsidiaries FTSE Global Debt Capital Markets Inc. and FTSE Fixed

Income Europe Limited), FTSE Fixed Income LLC, FTSE (Beijing) Consulting Limited, Refinitiv Benchmark Services (UK) Limited, Refinitiv Limited and Beyond Ratings.

1.13   Index users who choose to follow this index or to buy products that claim to follow this index should assess the merits of the index's rules-based methodology and take independent investment advice before investing their own or client funds. No liability whether as a result of negligence or otherwise is accepted by FTSE Russell or EDHEC-Risk for any losses, damages, claims and expenses suffered by any person as a result of:

– any reliance on these Ground Rules;

– any inaccuracies in these Ground Rules;

– any non-application or misapplication of the policies or procedures described in these Ground Rules; and/or

– any inaccuracies in the compilation of the index or any constituent data.

Section 2
Management responsibilities

2. Management responsibilities

2.1 FTSE International Limited (FTSE)

2.1.1 FTSE is the benchmark administrator of the index series.

2.1.2 FTSE is responsible for the daily calculation, production and operation of the FTSE EDHEC-Risk EIS, and will:

– maintain records of the index weightings of all constituents;

– make changes to the constituents and their weightings in accordance with the Ground Rules;

– carry out the periodic index reviews of the index series and apply the changes resulting from the reviews as required by the Ground Rules;

– publicise changes to the constituent weightings resulting from their ongoing maintenance and the periodic reviews; and

– disseminate the indices.

2.1.3 The weightings of constituents in the real-time indices shall be used in the calculation of the end-of-day indices.

2.1.4 FTSE is also responsible for monitoring the performance of the FTSE EDHEC-Risk EIS throughout the day and will determine whether the status of the indices should be firm, held or indicative (see Appendix E).

2.2 EDHEC-Risk Institute

2.2.1 EDHEC-Risk is responsible for the calculation of the efficient weights. EDHEC-Risk will provide the efficient weighting for each stock in the FTSE EDHEC-Risk EIS at each periodic review.

2.3 Status of these Ground Rules

2.3.1 These Ground Rules set out the methodology and provide information about the publication of the FTSE EDHEC-Risk EIS.

2.4 Amendments to these Ground Rules

2.4.1 These Ground Rules shall be subject to regular review (at least once a year) by FTSE Russell to ensure that they best reflect the aims of the index series. Any proposals for significant amendments to these Ground Rules will be subject to consultation with FTSE Russell advisory committees and other stakeholders if appropriate. The feedback from these consultations will be considered by the FTSE Russell Index Governance Board before approval is granted.

2.4.2　　Where FTSE Russell determines that the Ground Rules are silent or do not specifically and unambiguously apply to the subject matter of any decision, any decision shall be based as far as practical on the Statement of Principles. After making any such determination, FTSE Russell shall advise the market of its decision at the earliest opportunity. Any such treatment will not be considered as an exception or change to the Ground Rules, or to set a precedent for future action, but FTSE Russell will consider whether the rules should subsequently be updated to provide greater clarity.

Section 3
FTSE Russell index policies

3. FTSE Russell index policies

These Ground Rules should be read in conjunction with the following policy documents, which can be accessed using the links below:

3.1 Queries and Complaints

FTSE Russell's complaints procedure can be accessed using the following link:

Benchmark_Determination_Complaints_Handling_Policy.pdf

3.2 Recalculation Policy and Guidelines

3.2.1 Where an inaccuracy is identified, FTSE Russell will follow the steps set out in the FTSE Russell Index Recalculation Guidelines when determining whether an index or index series should be recalculated and/or associated data products reissued. Users of the FTSE EDHEC-Risk EIS will be notified through appropriate media.

For further information please refer to the FTSE Russell Recalculation Policy and Guidelines document, which is available from the FTSE Russell website using the link below or by contacting info@ftserussell.com.

Equity_Index_Recalculation_Policy_and_Guidelines.pdf

3.3 FTSE Russell Policy for Benchmark Methodology Changes

3.3.1 Details of FTSE Russell's policy for making benchmark methodology changes can be accessed using the following link:

Policy_for_Benchmark_Methodology_Changes.pdf

3.4 FTSE Russell Governance Framework

3.4.1 To oversee its indices, FTSE Russell employs a governance framework that encompasses product, service and technology governance. The framework incorporates the London Stock Exchange Group's three lines of defence risk management framework and is designed to meet the requirements of the IOSCO Principles for Financial Benchmarks[1], the European benchmark regulation[2] and the UK benchmark regulation[3]. The FTSE Russell governance framework can be accessed using the following link:

FTSE_Russell_Governance_Framework.pdf

3.5 Real Time Status Definitions

3.5.1 Please refer to the following guide for details of real time status definitions for indices which are calculated in real time.

Real_Time_Status_Definitions.pdf

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[1] IOSCO Principles for Financial Benchmarks Final Report, FR07/13 July 2013.
[2] Regulation (EU) 2016/1011 of the European Parliament and of the Council of 8 June 2016 on indices used as benchmarks in financial instruments and financial contracts or to measure the performance of investment funds.
[3] The Benchmarks (Amendment and Transitional Provision) (EU Exit) Regulations 2019.

Section 4
Eligible securities

4. Eligible securities

4.1 Constituents of the FTSE All-World Index Series will be eligible for inclusion in the FTSE EDHEC-Risk EIS. Please refer to the FTSE Global Equity Index Series Ground Rules at www.lseg.com/en/ftse-russell/ for information on the construction of the FTSE All-World Index Series.

4.2 Ineligible securities

4.2.1 China A shares included in the FTSE Global Equity Index Series are ineligible for inclusion in the FTSE EDHEC Risk Efficient Index Series.

4.2.2 Companies whose business is that of holding equity and other investments (e.g. investment trusts) classified by the Industry Classification Benchmark (ICB)[4] as closed end investments (30204000) will not be eligible for inclusion. For further details on the ICB, please visit the ICB website:

Industry Classification Benchmark

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[4] FTSE indices migrated to the new ICB classification system in March 2021.

Section 5
Periodic review of constituents

5. Periodic review of constituents

5.1   The FTSE EDHEC-Risk EIS applies the weighting method described in section 6 to the constituents of each reference index.

5.2   The FTSE EDHEC-Risk EIS will be reviewed quarterly using eligible constituents of the relevant reference indices on the Monday following the third Friday of March, June, September and December.

5.3   The cut-off date for the calibration data (see rule 5.2.1) is the close of business on the first Friday of March, June, September and December i.e. two weeks prior to the implementation date of each review.

5.4   The quarterly review will be implemented after the close of business on the third Friday (i.e. effective the following Monday) in March, June, September and December.

Section 6
Efficient weighting method

6. Efficient weighting method

6.1 Objective

6.1.1 The determination of the efficient index weights that maximise the expected Sharpe ratio of each reference index requires estimates of the stock return covariance matrix Σ and expected stock excess returns μ for each constituent of the reference index (see section 8 for a definition of the risk and return inputs).

6.1.2 The FTSE EDHEC-Risk EIS index weights are the set of weights that maximise the expected Sharpe ratio, given the risk and return inputs and the constraints described in 6.3. These are the efficient weights w*, obtained according to:

$$w^* = \arg\max_w \frac{w'\mu}{\sqrt{w'\Sigma w}}$$

where μ is the vector of expected returns in excess of the risk-free rate and Σ is the stock return covariance matrix.

6.1.3 The solution to this optimisation problem results in weights w^*:

$$w^* = m\,\Sigma^{-1}\mu$$

where *m* is a scalar that ensures that weights sum to one. These optimal weights determine the final weight of constituents of the FTSE EDHEC-Risk EIS.

6.1.4 Appendix B contains a two-stock example that details the determination of index weights.

6.2 Data

6.2.1 Weekly (Friday close to close) local total return data over the two-year period to the data cut-off of each quarterly review (see section 5) is used. This data is referred to as the calibration data and the time period as the calibration period.

6.2.2 Local currency returns are used in the optimisation. Securities that trade in currencies other than the local currency are converted to US Dollar returns using the WM/Refinitiv official closing spot exchange rate.

6.2.3 Efficient weights are determined only for securities with sufficient data; securities with insufficient data are allocated a minimum weight.

6.2.4 Securities with more than 10 missing data points or an unchanged price (typically illiquid stocks) over more than 10 weeks during the calibration period are classified as having insufficient return data and their weights are set to the minimum weight. This minimum weight is defined as the lower weighting bound applied to securities that have sufficient data (see rule 6.3).

6.3 Weighting constraints

6.3.1 An upper and lower bound, u_i and l_i respectively, are imposed on the weight of each constituent security, where i = 1,…N.

6.3.2 The following process is applied to the weightings derived according to rule 6.1 to ensure that each security's weight lies between the upper and lower bounds ui and li.

$$l_i \le w_i^* \le u_i$$

a. All negative weights are set to zero. The remaining positive weights are normalised such that they sum to 1-1/λ, where λ is a constant (see rule 6.3.4).

b. The lower bound 1/(λN) is added to all weights, such that the sum of all weights is one.

c. Security weightings in excess of the upper bound are set equal to the upper bound and the excess weight is reallocated to all stocks that have weightings below the upper and above the lower bounds in proportion to the degree to which the weight exceeds the lower bound.

d. If this procedure leads to additional breaches of the upper bound, rule 6.3.2(c) will be repeatedly applied until the upper bound is respected by all securities.

6.3.3 By construction, the aggregate weight of all N constituent weights equals one. This is achieved by setting the aggregate weight of the Z securities forming part of the optimisation equal to the proportion of total index weight that is not taken up by the M stocks with insufficient data. More precisely, the sum of efficient weights obtained from the optimisation is set equal to $1 - \sum_{j=1}^{M} l_j$, where M is the number of stocks with insufficient data.

6.3.4 The lower bound of each index in the FTSE EDHEC-Risk EIS is equal to 1/(λN) and the upper bound is equal to λ/N, where N is the number of constituents. λ is set equal to three.

6.4 Optimal control approach

6.4.1 To limit turnover, the weightings obtained from the quarterly optimisation are only applied to the FTSE EDHEC-Risk EIS if the change in index weights is above a specific threshold. Turnover arising from an update to the optimal weights is applied only if the impact of such weight changes is substantial, i.e. if sufficient new information has arrived since the last index review.

Consequently, the new weights obtained from the optimisation w* at each quarterly review may not be applied.

6.4.2 Let D be the effective date of the quarterly review. The optimised weights w^* and minimum weights for stocks with insufficient data determine the set of optimal weights $w^{Optimal}$ to be applied. The weights $w^{Optimal}$ are compared to the current index weights $w^{Current}$ at the close of business of the cut-off date. The sum of the prospective absolute weight changes δ_D is calculated as:

$$\delta_D = \sum_i \left| w_i^{Optimal} - w_i^{Current} \right|$$

6.4.3 If δ_D is greater than or equal to the threshold value $\bar{\delta}_D$,the new weights from the re-optimisation are applied following the procedure described in rules 5.1, 5.2 and 5.3. If the threshold value is not breached, only index constituents are updated following the procedure described in rules 6.4.6 and 6.4.7.

6.4.4 The threshold used to determine whether the re-optimised weights are applied is set at 70% for developed indices and 90% for emerging indices. For example, a threshold of 70% implies that re-optimised weights are only applied if at least 35% one-way turnover is required.

6.4.5   Re-optimised weights are applied at the quarterly review if the index has not been rebalanced optimally for seven consecutive quarters, irrespective of whether or not the threshold described in rule 6.4.4 is breached. Consequently, the application of optimised weights will occur at least every two years.

6.4.6   If only the index constituents are to be updated at quarterly review date, *D* then this set constituents C is compared to the constituents as of the cut-off date.

6.4.7   The procedure for updating constituents only is as follows:

a.   The minimum weight 1/(λ*N)* is applied to all new stocks entering the reference indices. This permits new constituents to be taken into account without including them in the optimisation. Let the number of new entrants be *E.*

b.   Deleted stocks have their weights set to zero according to:

$$w_i^{Current} = 0 \text{ if stock i is not in C.}$$

c.   The rebalance weights wiD of constituents as of the cut-off date are now calculated as:

$$w_i^D = \frac{w_i^{Current}}{\sum_{i=1} w_i^{Current}} \times [1 - E * 1/(\lambda N)]$$

6.5   Liquidity rules

6.5.1   To facilitate replication of the index, two capping rules are applied to the index weights determined through the application of rules 6.1 to 6.4.

6.5.2   The maximum multiple of the free-float market capitalisation weight is set at 10x. Note that the re-normalisation of index weights may result in some securities breaching the 10x market capitalisation weight.

6.5.3   The change in index weight at each quarterly review is limited to a security's market capitalisation weight in the case of developed markets and to 50% of the market capitalisation weight emerging markets.

6.6   Weight adjustment factor

6.6.1   At the review date, the efficient weights applied to constituents correspond to the weights obtained by the application of rules 6.1 to 6.5.

6.6.2   FTSE computes a weight adjustment factor for each constituent at the review date. This factor is computed by dividing the FTSE EDHEC-Risk Efficient Weight by the market capitalisation weight in the relevant reference index. Multiplication of the free-float adjusted capitalisation weight of each constituent in the reference index by the weight adjustment factor results in the FTSE EDHEC-Risk efficient index weight.

6.7   Index calculation formula

6.7.1   The weight adjustment factor x_i is given by $x_i = w_i / c_i$, where w_i is the FTSE EDHEC-Risk Efficient Weight obtained for the *i-th* constituent (*i*= 1,…,*N*) and c_i is its (free-float adjusted market capitalisation) weight in the underlying FTSE Reference Index.

6.7.2   The FTSE EDHEC-Risk EIS is calculated by adjusting the free float adjusted capitalisation weight in the underlying index using the weight adjustment factor, i.e. $w_i = x_i c_i$.

The index calculation formula is:

$$\sum_{i=1}^{N} \frac{\left(p_i \times e_i \times s_i \times f_i \times x_i \right)}{d}$$

where:

– $i = 1, 2, \dots, N$;

– N is the number of securities in the FTSE EDHEC-Risk Efficient Index;

– p_i is the price of the *i-th* security;

– e_i denotes the relevant exchange rate;

– s_i denotes the number of shares in issue;

– f_i denotes the investability weight computed by FTSE based on the free float;

– d is the index divisor, which represents the index-wide capitalisation at the initial date; and

– x_i denotes the weight adjustment factor.

Section 7
Changes to constituent companies

7.   Changes to constituent companies

7.1   New issues

7.1.1   The FTSE EDHEC-Risk EIS will not have intra-review additions.

7.1.2   When a constituent is added to an underlying FTSE All-World Index, if eligible, the constituent will be included in the corresponding FTSE EDHEC-Risk EIS at the next quarterly review. New issues if eligible are considered as additions.

7.2   Deletions

7.2.1   If a constituent is removed from the underlying FTSE All-World Index, the constituent will also be removed from the relevant FTSE EDHEC-Risk Efficient Index. The deletion will be concurrent with its deletion from the FTSE All-World Index.

Section 8
Corporate actions and events

8. Corporate actions and events

8.1   If a constituent in the underlying index has a stock split, stock consolidation, rights issue, bonus issue, a change in the number of shares in issue or a change in free float (with the exception of tender offers), the constituent's weighting in the FTSE EDHEC-Risk EIS Index will remain unchanged pre and post such an event.

8.2   Full details of changes to constituent companies due to corporate actions and events can be accessed in the Corporate Actions and Events Guide for Non Market Cap Weighted Indices using the following link:

Corporate_Actions_and_Events_Guide_for_Non_Market_Cap_Weighted_Indices.pdf

A corporate action is an action on shareholders with a prescribed ex-date. The share price will be subject to an adjustment on the ex-date. The index will be adjusted in line with the ex-date.

These include the following:

– capital repayments;

– rights issues/entitlement offers;

– stock conversion;

– splits (sub-division)/reverse splits (consolidation); and

– scrip issues (capitalisation or bonus issue).

A corporate event is a reaction to company news (event) that may impact the index depending on the index rules. For example, a company announces a strategic shareholder is offering to sell their shares (secondary share offer) – this could result in a free float weighting change in the index. Where an index adjustment is required, FTSE will provide notice advising of the timing of the change.

8.3   Suspension of dealing

Suspension of dealing rules can be found within the Corporate Actions and Events Guide for Non Market Cap Weighted Indices.

8.4   Takeovers, mergers and demergers

The treatment of takeovers, mergers and demergers can be found within the Corporate Actions and Events Guide for Non Market Cap Weighted Indices.

Section 9
Definition of optimisation inputs

9. Definition of optimisation inputs

To compute the efficient index weights according to the formula in rule 6.1.3, two inputs are required: the covariance matrix of returns of index constituents and the vector of expected excess returns. The following two subsections describe the estimation of each of these inputs.

9.1   Covariance matrix

9.1.1   An estimate of the covariance matrix of securities in the underlying FTSE All-World Indices is necessary to describe the interdependence of constituent returns. This interdependence is irrelevant in determining the expected return of the efficient index; however, covariance is important for computing the volatility of the efficient index. Calculating the covariance matrix from past return observations leads to estimation error. Therefore, some structure is imposed on the covariance matrix to reduce the dimensionality of the estimation problem. The approach to modelling the covariance matrix in the FTSE EDHEC-Risk EIS is described below.

9.1.2   A large number of stocks results in fast growth in the number of parameters to be estimated; the majority of them pairwise correlations. To reduce the number of dimensions, a multifactor model is used to decompose the returns of an asset into the expected rewards from exposure to common risk factors. A factor model of the following form is used:

$$r = \alpha + \beta F + \varepsilon$$

where r is column vector that contains the returns for the $Z = N\text{-}M$ stocks that enter the optimisation. N is the number of constituents and M is the number of stocks with insufficient data. r depends linearly on F, a K column vector. The matrix β contains the loadings of the Z stocks on the K factors. α is a vector of constants and ε is a vector of random error terms.

9.1.3   Given the factors and the loadings of each stock on these factors, the covariance matrix may be estimated as:

$$\Sigma = \beta \Sigma_F \beta' + \Sigma_\varepsilon$$

where Σ_F is the $K \times K$ factor covariance matrix and Σ_ε is the $Z \times Z$ covariance matrix of error terms.

Modelling covariance in this way avoids the noise in the estimation of individual covariance terms. The covariance between two stocks is entirely driven by exposure to common risk factors.

9.1.4   To construct the covariance matrix, factors and factor loadings are required. A statistical factor model is used. Each factor is modelled as a linear combination of returns of individual index constituents. The first K principal components are extracted. These principal components yield the best K-dimensional summary of the information contained in stock returns.

9.1.5   The exact procedure used to extract principal components and construct the covariance matrix is described in Appendix C. A comprehensive description of the approach can be found in Ruey Tsay, *Analysis of Financial Time Series*, Wiley, 2002, 1st ed., chapter 8.7 and 8.8.

9.2   Expected returns

9.2.1   Expected returns are difficult to estimate and present a problem in any portfolio optimisation problem. Financial theory indicates investors will be averse to holding securities with high total risk. Downside risk or semi-deviation of returns is used to estimate total risk. The total risk estimate provides a means to estimate expected returns; since *ceteris paribus* investors wish to avoid holding high total risk stocks, these stocks will have a relatively low prices and thus relatively high expected returns.

9.2.2   Semi-deviation is a downside risk measure and a more meaningful definition of risk compared to volatility, since only deviations below the mean are considered. The semi-deviation of the returns of each constituent

SEM$_i$ with respect to the average return μ_i is calculated as:

$$SEM_i = \sqrt{E\left\{\min\left[r_{i,t} - \mu_i\right], 0\right\}^2}$$

where E(.) denotes the expectation operator computed as the arithmetic average, min(x,y) denotes the minimum of x and y, and $r_{i,t}$ is the return of stock *i* in week *t*.

9.2.3   Individual semi-deviation values of each stock are not used. Rather stocks are grouped by semi-deviation and the median semi-deviation of stocks within each group forms the expected return estimate for each stock in that group. More precisely, stocks are sorted into deciles[5] based on semi-deviation. That is, the 10% of stocks with the highest semi-deviation form one group; the 10% of stocks with the next highest semi-deviations the next group and so forth. Within each group, the median semi-deviation of all stocks within the group forms the expected return of all stocks within that group.

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[5] If the index has less than 100 constituents, quintiles are used instead. If the index has less than 50 constituents, quartiles are used.

Appendix A
Sharpe ratio definition

The (estimated) Sharpe ratio of a portfolio is defined as the expected portfolio return in excess of the risk-free rate divided by the risk of the same portfolio. Risk is measured in terms of the volatility or standard deviation of portfolio returns:

$$S_P = \frac{\mu_P}{\sigma_P}$$

Where $\mu_P = E(R_P) - R_f$ i.e. the expected excess return is computed as the difference between the expected portfolio return and the risk-free interest rate.

Given a vector of portfolio weights, the numerator of the Sharpe ratio may be calculated from the vector μ of constituent expected excess returns. The denominator of the Sharpe ratio can be computed from the constituent return covariance matrix Σ.

$$\mu_P = \mu w \qquad \sigma_P = \sqrt{w'\Sigma w}$$

Appendix B
Example of calculations

The weights of the maximum Sharpe ratio portfolio are given by:

$$w^* = m \Sigma^{-1} \mu$$

With two stocks:

$$\Sigma = \begin{pmatrix} Var_1 & Cov \\ Cov & Var_2 \end{pmatrix} ; \quad \mu = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}$$

The optimal weights are obtained by inverting the covariance matrix and multiplying it by the vector of expected returns:

$$w^* = m \frac{1}{Var_1 Var_2 - Cov^2} \begin{pmatrix} Var_2 & -Cov \\ -Cov & Var_1 \end{pmatrix} \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}$$

Since the first two terms are scalars, they are not relevant for the relative weightings of the two stocks. Only the multiplication of the matrix with the vector of expected returns is pertinent.

$$\begin{pmatrix} Var_2 & -Cov \\ -Cov & Var_1 \end{pmatrix} \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} = \begin{pmatrix} Var_2 \mu_1 - Cov \mu_2 \\ Var_1 \mu_2 - Cov \mu_1 \end{pmatrix}$$

Hence the weight of the first stock is proportional to $Var_2 \mu_1 - Cov \mu_2$ and the weight of the second stock is proportional to $Var_1 \mu_2 - Cov \mu_1$.

Consider the following two stocks:

The expected excess return of stock one and two are 20% and 10% respectively. The volatilities (standard deviation) of returns are 20% and 10% respectively. The correlation between the two stocks' returns is 0.5. Then the input parameters are:

$$\Sigma = \begin{pmatrix} 0.04 & 0.01 \\ 0.01 & 0.01 \end{pmatrix} ; \quad \mu = \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix}$$

The weight of stock one is proportional to 0.01×0.2 - 0.01×0.1 = 0.001 and the weight of the second stock is proportional to 0.04×0.1 - 0.01×0.2 = 0.002. Normalising 0.001 and 0.002 yields weights of 1/3 and 2/3. This weighting yields the highest Sharpe ratio for these two stocks.

Appendix C
Principal component analysis

1. Returns are standardised to have the same scale.

   For each stock i, compute the time series of weekly standardised returns:

   $r_{i,t} = (R_{i,t} - \mu_i)/\sigma_i$ with i = 1,…., Z and t = 1,…., 104.

   where Z is the number of stocks that enter the optimisation, R_{it} is the return of stock i in week t, μ_i is the average return of stock i, and σ_i is its standard deviation.

2. Common factors are extracted through the application of a statistical procedure, principle component analysis (PCA) on the sample correlation matrix S. The following factor model is used in matrix form for the 104 x Z matrix r of the time series of standardised returns over the calibration period:

$$r = LF + \varepsilon$$

   Where the coefficients l_{ij} of L correspond to the loading on variable i of factor j and F is the vector of unobserved factors.

3. S denotes the sample covariance matrix of standardised returns, which is equivalent to the sample correlation matrix. The Z principal components are computed. The i-th principal component is given by:

$$f_i = l_i^T r = \sum l_{ni} r_n \qquad i = 1, 2, \dots Z$$

   For which variances and covariance are:

$$Var[f_i] = l_i^T S\, l_i = \lambda_i \qquad i = 1, 2, \dots Z$$

$$Cov[f_i, f_j] = l_i^T S\, l_j \qquad i \neq j$$

   and $l_i^T l_i = 1, i = 1, 2, \dots Z$ the loadings are determined by the eigenvectors of S and their variances are equal to the corresponding eigenvalues λ_i.

4. The number of factors selected for retention in the factor model is determined by using only those K factors associated with an eigenvalue greater or equal to:

$$\lambda^{max} = 1 + \frac{N}{T} + 2\sqrt{\frac{N}{T}}$$

5. Construct the correlation matrix P based on the factor model focusing on the first K factors, that is $f_{1,\dots,}f_K$ obtained in step four.

   Taking the eigenvalue-eigenvector pairs:

   $(e_1, \lambda_1), (e_2, \lambda_2), \dots (e_K, \lambda_k)$ where $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_K \geq 0$ and $e_j = [e_{1,j}, e_{2,j}, \dots, e_{K,j}]^T$ of the correlation matrix P, the correlation matrix can be written as:

$$P = \lambda_1 e_1 e_1^T + \lambda_2 e_2 e_2^T + \dots + \lambda_{K_1} e_{K_1} e_{K_1}^T$$

$$= \begin{bmatrix} e_1 & e_2 & \dots & e_{K_1} \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \lambda_{K_1} \end{bmatrix} \begin{bmatrix} e_1^T \\ e_2^T \\ \vdots \\ e_{K_1}^T \end{bmatrix} = L\Lambda L^T$$

   Where L is a $N \times K$ matrix with $K<N$, where K is chosen in step four and enforcing the requirement that the diagonal elements of P equal one.

6. Construct covariance matrix. For each element in P(i,j), compute the corresponding covariance term:

$$\Sigma(i, j) = \sigma_i \sigma_j P(i, j)$$

Appendix D
Index opening and closing hours

Index	Open	Close
FTSE EDHEC-Risk Efficient Index Series		
FTSE EDHEC-Risk Efficient All-World Index	00:30	21:10
FTSE EDHEC-Risk Efficient All-World ex US Index	00:30	21:10
FTSE EDHEC-Risk Efficient All-World ex UK Index	00:30	21:10
FTSE EDHEC-Risk Efficient Developed Index	00:30	21:10
FTSE EDHEC-Risk Efficient Emerging Index	00:30	21:10
FTSE EDHEC-Risk Efficient Developed Europe Index	08:00	16:30
FTSE EDHEC-Risk Efficient Developed Europe ex UK Index	08:00	16:30
FTSE EDHEC-Risk Efficient Developed Eurozone Index	08:00	16:30
FTSE EDHEC-Risk Efficient Asia Pacific Index	00:30	13:30
FTSE EDHEC-Risk Efficient Asia Pacific ex Japan Index	00:30	13:30
FTSE EDHEC-Risk Efficient Developed ex Japan Index	00:30	21:10
FTSE EDHEC-Risk Efficient Developed ex US Index	00:30	21:10
FTSE EDHEC-Risk Efficient Developed Asia Pacific ex Japan Index	00:30	09:00
FTSE EDHEC-Risk Efficient USA Index	14:30	21:10
FTSE EDHEC-Risk Efficient UK Index	08:00	16:30
FTSE EDHEC-Risk Efficient Japan Index	00:30	06:45

Notes:

Closing values at 21:10 will be disseminated at 21:30.

Timings are UK hours.

Appendix E
Status of index series

The FTSE EDHEC-Risk EIS is calculated in the specified currency (see rule 1.7) on a real-time basis.

For further details of real time definitions please refer to the following guide:

Real_Time_Status_Definitions.pdf

The official opening and closing hours of the FTSE EDHEC-Risk EIS are set out in Appendix D. Variations to the official hours of the index will be published by FTSE Russell.

US Dollar, Euro, UK Pound Sterling and Japanese Yen values will be calculated on an end-of-day basis.

Appendix F
Further information

A Glossary of Terms used in FTSE Russell's ground rule documents can be found using the following link:

Glossary.pdf

FTSE

For further information on the FTSE EDHEC-Risk Efficient Index Series, visit www.lseg.com/en/ftse-russell/ or e-mail info@ftserussell.com. Contact details can also be found on this website.

EDHEC-Risk Institute

Further Information on EDHEC-Risk Institute is available on www.edhec-risk.com. Contact details can also be found on this website.

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