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METHODOLOGY FOR THE MANAGEMENT OF THE FTSE EDHEC-RISK EFFICIENT INDEX SERIES

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SECTION 1

1.0 Introduction

1.1 This document contains the rules for the management and calculation of the FTSE EDHEC-Risk Efficient Index Series (EIS). The Index Series is calculated by FTSE based on a portfolio optimisation approach developed by EDHEC-Risk. FTSE and EDHEC-Risk developed this Index Series to create a more efficient way to capture the equity market total returns. In particular, the Index Series seeks to avoid the inefficiency in terms of risk and return of market capitalisation weighted indices. By weighting securities in an optimal way, taking into account their correlation, risk and return properties, the index series aims at obtaining the portfolio of securities with the highest reward-to-risk ratio.

1.2 The aim of the index series is to construct portfolios of constituents that achieve the highest possible Sharpe ratio. In order to maximise the Sharpe ratio, two essential inputs will need to be estimated for this portfolio optimisation: the expected returns of each stock and the covariance matrix of returns of all stocks.

To estimate the covariance matrix, the latest in the field of academic research suggests using factor models that describe the comovement of stocks through their exposure to common risk factors. A statistical factor model will be used which is described in detail in Rule 8.1.

On the other hand expected stock returns are harder to estimate. In particular, using the past realised returns to estimate expected returns is known to lead to poor results because observed returns are extremely noisy and do not carry much information on the true expected returns. However expected returns are linked to a stock's riskiness as investors want to be compensated for higher risk by higher returns. The estimate for expected returns is therefore based on the risk of each stock. The computation of expected returns is further described in Rule 8.2.

In a nutshell, the aim of the method is to construct indices that have higher Sharpe ratios than cap-weighted indices, by focussing on the reliable estimation of the above input parameters.

1.3 The FTSE EDHEC-Risk EIS is based on all constituent securities in the FTSE All-World Index Series. Constituents receive weights which result from EDHEC-Risk´s portfolio optimisation and which reflect their ability to maximise the reward-to-risk ratio for a broad market index. This "efficiency" can be measured by an improvement in the achieved Sharpe Ratio, a measure of the excess return (or risk premium) per unit of risk (or index volatility). The FTSE EDHEC-Risk EIS index weights thus correspond to the constituents' efficient weights. For more explanation of the Sharpe ratio calculation used in this context, see Appendix A.

1.4 The FTSE EDHEC-Risk EIS are calculated for the following regions:

- **US Index** (based on the constituents of the FTSE All-World US Index);
- **UK Index** (based on the constituents of the FTSE All-World UK Index);
- **Eurobloc Index** (based on the constituents of the FTSE All-World Eurobloc Index);
- **Japan Index** (based on the constituents of the FTSE All-World Japan Index); and,
- **Developed Asia Pacific ex Japan Index** (based on the constituents of the FTSE All-World Developed Asia Pacific ex Japan Index).

SECTION 1

1.5 The FTSE EDHEC-Risk EIS Price Index Values are calculated on a real time basis every 15 seconds with the following currencies:

- FTSE EDHEC-Risk Efficient USA Index calculated in US Dollar
- FTSE EDHEC-Risk Efficient UK Index calculated in UK Pound Sterling
- FTSE EDHEC-Risk Efficient Eurobloc Index calculated in Euro
- FTSE EDHEC-Risk Efficient Japan Index calculated in Japanese Yen
- FTSE EDHEC-Risk Efficient Developed Asia Pacific ex Japan Index calculated in US Dollar

1.6 Price and Total Return Indices are published in their calculated currencies at the end of each working day. The Total Return Indices are based on ex-dividend adjustments. Currencies provided for all indices will also include US Dollar, Euro, UK Pound Sterling and Japanese Yen on an end of day basis.

1.7 Unless specifically detailed in this document, the methodology and management of the FTSE EDHEC-Risk EIS is based on the FTSE Global Equity Index Series Ground Rules. The FTSE EDHEC-Risk EIS methodology should therefore be read in conjunction with these Ground Rules, which are available on FTSE's website (www.ftse.com).

SECTION 2

2.0 Status of Index Series

2.1 The FTSE EDHEC-Risk EIS is calculated in the specified currency (see Rule 1.5) on a real time basis and may exist in the following states.

a) Firm

i. The Index Series is being calculated during Official Market Hours (see Appendix D). No message will be displayed against the index value.

ii. The Official Closing Price for FTSE EDHEC-Risk EIS will be the Exchange Official Closing Price for the Index.

b) Closed

The Index Series has ceased all calculations for the day. The message 'CLOSE' will be displayed against the index value calculated by FTSE.

c) Held

During Official Market Hours, the Index Series has exceeded pre-set operating parameters and the calculation has been suspended pending resolution of the problem. The message 'HELD' will be displayed against the last index value calculated by FTSE.

d) Indicative

If there is a system problem or situation in the market that is judged to affect the quality of the constituent prices at any time when the Index Series is being calculated, the index will be declared indicative (e.g. normally where a 'fast market' exists in the equity market). The message 'IND' will be displayed against the index value calculated by FTSE.

e) Part

If the Index Series is being calculated during the normal Official Index Period hours, but there are less than 75% of the constituents by capitalisation available with firm prices, then the index will be displayed with the message 'PART' to indicate that only a proportion of the securities prices are included. With the exception of the message 'PART', the index will continue to be calculated and displayed as if it were firm.

2.2 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.

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

SECTION 3

3.0 Index Management

3.1 FTSE International Limited (FTSE)

3.1.1 FTSE is responsible for the operation of the FTSE EDHEC-Risk EIS. FTSE will maintain records of the market capitalisation of all constituents and will make changes to the constituents and their weightings in accordance with the Ground Rules. FTSE will carry out reviews and implement the resulting constituent changes as required by the Ground Rules.

3.1.2 Changes to constituent weightings will be made by FTSE in accordance with the Ground Rules. FTSE is responsible for publicising and keeping a record of all changes to constituent weightings. The weightings of constituents in the real time indices shall be used in the calculation of the end of day indices.

3.1.3 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, Indicative or Part (see Rule 2.1).

3.2 EDHEC-Risk Institute (EDHEC-Risk)

3.2.1 EDHEC-Risk is responsible for the calculation of the efficient weights. EDHEC-Risk will provide an efficient factor for every stock in the FTSE EDHEC-Risk EIS at each periodic review. FTSE will then use these factors for the calculation of the FTSE EDHEC-Risk EIS.

3.3 Re-calculations

3.3.1 The FTSE EDHEC-Risk EIS is recalculated whenever errors or distortions occur that are deemed to be significant. Users of the FTSE EDHEC-Risk EIS are notified through appropriate media.

3.4 Status of these Ground Rules

3.4.1 These Ground Rules are a guide to the policies and procedures applying at the date of publication to the operation and maintenance to the FTSE EDHEC-Risk EIS. They have been prepared and approved by FTSE and EDHEC-Risk. However, these policies and procedures, and their precise application, are subject to variation and periodic review.

3.4.2 The purpose of publishing this guide is to provide information about the general basis on which decisions relating to the calculation and publication of the FTSE EDHEC-Risk EIS are currently made.

3.4.3 In light of the intended purpose of this guide, and the likely variation and periodic review of the policies and procedures it contains, no liability whether as a result of negligence or otherwise is accepted by FTSE and EDHEC-Risk (or any person concerned with the preparation or publication of this guide) for any losses, damages, claims and expenses suffered by any person as a result of:

a) any reliance on this guide, and/or
b) any errors or inaccuracies in this guide, and/or
c) any non-application or misapplication of the policies or procedures described in this guide, and/or
d) any errors or inaccuracies in the compilation or any constituent data.

SECTION 3

3.5 Amendments and Exceptions

3.5.1 In the event that the FTSE and EDHEC-Risk or any of those responsible for the operation and administration of the FTSE EDHEC-Risk EIS consider that an exception should be made to any of the Ground Rules, the issue must be brought to the attention of FTSE and EDHEC-Risk, who will normally put the matter to decision.

3.5.2 Where an exception is granted to the Ground Rules under Rule 3.4.1, it shall not be deemed to create a precedent for future decisions of FTSE and EDHEC-Risk.

3.5.3 Changes to the Ground Rules can only be made by FTSE and EDHEC-Risk.

3.5.4 Material changes to the Ground Rules are announced after being approved by FTSE and EDHEC-Risk.

SECTION 4

4.0 Eligible Securities

4.1 Companies in the FTSE All-World Index Series will be eligible to be included in the FTSE EDHEC-Risk EIS. Please refer to the FTSE Global Equity Index Series Ground Rules on the FTSE website for information on the construction of the FTSE All-World Index Series.

4.2 Constituents from the following indices will be included in the FTSE EDHEC-Risk EIS.

- FTSE All-World US Index
- FTSE All-World UK Index
- FTSE All-World Eurobloc Index
- FTSE All-World Japan Index
- FTSE All-World Developed Asia Pacific ex Japan Index

4.3 Convertible preference shares and loan stocks are excluded until converted.

4.4 Companies whose business is that of holding equity and other investments (e.g. Investment Trusts) which are assumed by the Industry Classification Benchmark as Subsector equity investment instruments (8985) and Non-equity investment instruments which are assumed by the Industry Classification Benchmark as Subsector non-equity investment instruments (8995) will not be eligible for inclusion. For further details on the Industry Classification Benchmark (ICB), please visit the FTSE website.

SECTION 5

5.0 Periodic Review of Constituents

5.1 The FTSE EDHEC-Risk EIS applies an efficient weighting scheme to the constituents of an underlying FTSE index. Rather than using the free-float adjusted market capitalisation that is used in the underlying index, the FTSE EDHEC-Risk EIS uses efficient weights determined in an optimisation procedure.

5.2 The FTSE EDHEC-Risk EIS will be reviewed quarterly based on the constituents of the underlying FTSE All-World Index available after the close of business on the third Friday of March, June, September and December.

5.3 The quarterly review will be implemented and rebalanced on the next working day after the close of business on the third Friday of March, June, September and December.

5.4 The cut-off date for the calibration data (see Rule 6.2.1) is two weeks prior to the implementation date of each periodic review, hence after the close of business on the third Friday of March, June, September and December.

SECTION 6

6.0 Efficient Weighting Method

6.1 Objective

6.1.1 EDHEC-Risk computes security weights in an optimised portfolio which creates the maximum Sharpe ratio. This efficient index weights are obtained from an estimated covariance matrix Σ and expected excess return estimates μ for constituent securities in an index. (See Section 8 for a more detailed discussion of the risk and return inputs).

6.1.2 EDHEC-Risk finds the efficient weights as the set of weights that allow an investor to obtain the highest Sharpe ratio, given the risk and return inputs and the weight constraints. The constituent weights that solve this optimisation are the efficient weights *w** that will be used in the FTSE EDHEC-Risk EIS, obtained according to the following formula:

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

where μ is the vector of expected returns in excess of the risk free rate and Σ is the covariance matrix for returns of these constituents. The efficient weights lead to the highest expected returns per unit of risk, given the expected excess returns and given the covariance matrix for the index constituents in question.

6.1.3 Our approach is to compute the portfolio weights that solve the optimisation problem. These weights

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

where *m* is a scalar that insures that the weights sum up to one (or equivalently, that the investment in the riskless asset, which is the (*Z+1*)*th* asset in the portfolio choice problem, is zero). This optimal weight determines the final weight that the constituents will have in the FTSE EDHEC-Risk EIS. It is the relevant weighting criterion used in the FTSE EDHEC-Risk EIS just like other indices use the company's market cap or accounting characteristics as a weighting criterion.

6.1.4 Appendix B contains a simple example with two stocks that shows how the weighting criterion is computed.

6.2 Data

6.2.1 Total return data including reinvested dividends is obtained for all index constituents over the past 2 years up to the quarterly review (see Section 5). Weekly returns data are computed from the previous week's Friday's close to the current week's Friday close. This data is referred to as the calibration data and the corresponding time period as the calibration period.

6.2.2 Returns in local currency are used in the optimisation. For index constituents that are traded in markets with different currencies, local currency returns are converted into US Dollars returns using the Reuters/WM spot exchange rate.

6.2.3 Constituents are classified into those that do or do not have sufficient returns data. EDHEC-Risk calculate efficient weights for securities with sufficient data; those with insufficient data are *de facto* given a minimum weight.

SECTION 6

6.2.4 Constituent securities which have either missing price data or an unchanged price (typically illiquid stocks) for more than ten weeks within the calibration period are classified as having insufficient returns data and will see their weight set to the minimum weight. In effect, no more than 10 data points are missing or zero is required within the calibration period to be classified as having sufficient returns. The minimum weight is defined as the lower bound weighting used for stocks which have sufficient data and enter the optimisation (see Rule 6.3 below).

6.3 Weighting Constraints

6.3.1 In the optimisation process, an upper bound u_i and a lower bound l_i will be imposed on the weight of each constituent security, where i = 1,…*N*. These bounds ensure that all securities are included in the FTSE EDHEC-Risk EIS, but that no security is given a dominant weighting.

6.3.2 Once the weighting criterion have been obtained according to Rule 6.1, to respect the constraints that each security's weight lies between the upper bound u_i and a lower bound l_i, an adjustment will be made.

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

The following steps will be implemented to make sure this is the case:

a) All negative weights will be set to zero. The remaining positive weight will be normalised so that they sum to 1-1/λ.

b) The lower bound 1/λ*N* will be added to all weights. The weights now sum to one.

c) If the weights exceed the upper bound, these will be set equal to the upper bound and then reallocate the amount to all stocks that are below the upper bound but above the lower bound, pro-rated by the part of their weight that exceeds the lower bound.

d) If this procedure leads to further stocks exceeding the upper bound, Rule 6.3.2(c) will be repeated until the upper bound is respected by all securities.

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

6.3.4 For each index in the FTSE EDHEC-Risk EIS, the lower bound will be equal to 1/(λ*N*) and the upper bound will be equal to λ/*N*, where *N* is the number of constituents. To avoid liquidity problems and concentration, we set λ=2.

6.4 Optimal Control Approach

6.4.1 Weightings obtained from the quarterly optimisation may or may not be applied to the FTSE EDHEC-Risk EIS. This choice is intended to limit index turnover and to avoid creating turnover when the changes in index weights are below a threshold. EDHEC-Risk will only want to incur the turnover from updating the optimal weights if the impact of the weight changes is substantial, i.e. if a significant amount of new information has arrived since the last rebalancing.

SECTION 6

This approach is consistent with insights obtained from optimal portfolio control techniques as evidenced in the literature on dynamic portfolio optimisation in the presence of transaction costs. At each review date, EDHEC-Risk can decide to apply the new weights obtained from the optimisation *w** or to leave weights unchanged. Constituent changes in the underlying index is still taken into account, even if "efficient" weights are left unchanged, by adding new entries in the underlying index to the FTSE EDHEC-Risk EIS.

6.4.2 In order to control the decision to rebalance or not, the potential weight changes are assessed due to the updating of efficient weights. Therefore, at each review date whether the decision to implement the new optimal weights would lead to reaching the threshold or not will be assessed. At each review date *D*, optimised weights *w** and minimum weights for stocks with insufficient data are obtained. From these weights, the full set of weights $w^{(D2)}$ at the review date are constructed which would be applied on the next rebalancing date, and compare them to the actual weights $w^{(D1)}$ at the close of business on the review date. The sum of absolute weight changes δ_D are then computed based on all constituents that were present at the close of day *D* and/or in the new constitution to be applied going forward as:

$$\delta_D = \sum_i \left| w_i^{(D2)} - w_i^{(D1)} \right|$$

6.4.3 Comparisons between the value obtained for δ_D and the threshold value $\bar{\delta}_D$ are defined for the corresponding index. If the value obtained is greater than or equal to the threshold, the new weights are used from the re-optimisation and proceed as described in 6.1, 6.2 and 6.3. If the obtained value is lower, the constitution is updated only without applying the re-optimised weights. This procedure is described in Rule 6.4.4 below.

6.4.4 The threshold which is used to determine whether re-optimised weights should be used is obtained from back-tests for long term U.S. data, as well as from the track record of the FTSE EDHEC-Risk EIS. From these tests, the threshold is set at 50% for all 5 indices. This produced between 24% to 33% annual one way turnover in our backtests. A threshold of 50% means that only the re-optimised weights are applied if at least half the portfolio wealth would be traded to implement the new weighting. If the required weight changes are below this threshold, the constitution is only updated. These thresholds may be adjusted over time.

6.4.5 When the decision is made to only update the constitution at date *D,* EDHEC-Risk will look at the constituent list at date *D2* that will be applied after the review and the constituent list at date *D1*, the close of the review date. The following notation is used:

C	Set of current constituents at date *D2*
P	Set of past constituents, i.e. constituents at *D1*
C ∩ P	Set of "surviving stocks": stocks that are in both current and past constitution
C ∩ P^C^	Set of "new entries": stocks that have entered the current constitution but where not on the past constitution. (Note that **P^C^** refers to the complement of **P,** i.e. the set of stocks that is not in **P**.)
E = Card(C ∩ P^C^)	Number of new entries at *D2.* (Note that **Card(C ∩ P^C^)** refers to the number of constituents that are either in **C** or not in **P**)

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6.4.6 When the decision is made to only update the constitution, the procedure is as follows:

a) The fixed minimum weight 1/λ*N* is attributed to all entering stocks, as doing so takes these new constituents into account without including them in the optimisation.

b) EDHEC-Risk will compute the weights of surviving stocks after rebalancing by simply adjusting the weights prior to rebalancing. In this adjustment, the fact that entries and exits occur due to changes in constitution is taken into account. The principle is to leave the relative weights of surviving stocks unchanged while taking onto account the changes in the constitution of the underlying index. In particular, the weights of the surviving stocks after rebalancing as w_i^{D2} is computed as:

$$w_i^{D2} = \frac{w_i^{(D1)}}{\sum_{i=1} w_i^{(D1)}} \times (1-\sum_{j=1}^{E} l_j) \quad \text{for all } i \text{ in } (C \cap P)$$

This means that EDHEC-Risk will first readjust the weights of surviving stocks so that they sum to one. This is the part to the left of the multiplication sign. This step is necessary because if there are exits of some stocks, the weights of surviving stocks prior to rebalancing do not sum. The second step is to adjust for the fact that new entries with their minimum weight are included. There will be room for the new entries by reducing the weights of surviving stocks by multiplying them with the term to the right of the multiplication sign.

c) EDHEC-Risk will delete all existing constituents and normalise the weights of surviving stocks so that they sum to one after deletion of exits. The portfolio of surviving stocks is combined with eligible new entries.

6.5 Efficiency Adjustment Factor

6.5.1 At the review date the efficient weights applied to the constituents correspond to the weights obtained by following steps 6.1 to 6.4.

6.5.2 FTSE computes an Efficiency Adjustment Factor for each constituent at the review date. This factor is computed by dividing the FTSE EDHEC-Risk Efficient Weights by the weight the constituent has in the original market capitalisation weighted index. Thus multiplication of the free-float adjusted capitalisation weight of the constituent in the underlying index will lead to the weight in the FTSE EDHEC-Risk EIS.

6.5.3 The efficiency adjustment factor is constant between rebalancing dates of the index. FTSE uses this adjustment factor when making changes to the FTSE EDHEC-Risk EIS Efficient Weights due to corporate actions (see Section 5).

6.6 Index Calculation Formula

6.6.1 The efficiency adjustment factor x_i is given by $x_i = w_i / c_i$, where w_i is the 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 index with: $c_i = c_i / \sum_{j=1}^{N} c_j$

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

The index calculation formula is:

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

where:

- i = 1,2,….,N;
- N is the number of constituents in the FTSE EDHEC-Risk Efficient Index;
- p_i is the price of the *i-th* security;
- e denotes the relevant exchange rate;
- s 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;
- x_i denotes the efficiency adjustment factor which is further detailed above in this document.
- All other variables are further detailed in the FTSE Global Equity Index Series Ground Rules.

SECTION 7

7.0 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, the constituent will be included in the corresponding FTSE EDHEC-Risk EIS at the next quarterly review. New Issues 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.

7.2.2. A stock will be deleted from the relevant FTSE EDHEC-Risk Efficient Index when the constituent is delisted from its stock exchange or becomes bankrupt, insolvent or is liquidated.

7.2.3 Constituents will be deleted from the indices when confirmation is received that acceptance levels have reached a minimum of 85% and that any new shares of the bidding company (if applicable) are listed (exceptionally, for constituents of the UK Index, the qualifying announcement is that the offer has been declared wholly unconditional). A company deleted following a takeover, with a remaining free float of 15% or less, will not be re-considered for index inclusion until completion of a one year trading record.

7.3 Mergers and Takeovers

7.3.1 Mergers and Takeovers between constituents

If a merger takes place between two index constituents, and the created entity remains in the underlying FTSE All-World Index, this entity will remain in the FTSE EDHEC-Risk EIS and its weight will be equal to the sum of the weights prior to the merger. If an index constituent acquires another index constituent, this will be treated like a merger. Hence the acquiring entity's weight will be equal to the sum of the weights prior to the acquisition.

7.3.2 Mergers and Takeovers between a constituent and a non-constituent

If a constituent is acquired by a non-constituent, the company will be removed from the FTSE EDHEC-Risk EIS, concurrent with the removal from the underlying FTSE All-World Index. This is treated like any deletion on Rule 7.2. If the non-constituent as a result of a stock merger or acquisition is subsequently added to the underlying FTSE All-World Index, it will be included in the FTSE EDHEC-Risk EIS at the weight of the acquired constituent.

7.4 Splits / Demergers

7.4.1 If an index constituent has a de-merger, and if the entity that has been spun-off remains in the underlying FTSE All-World Index, the same adjustment factor as for the parent company will be applied to this entity. If the spun-off entity will not be a constituent of the underlying FTSE All-World Index, it will also not be eligible for inclusion in the FTSE EDHEC-Risk EIS.

SECTION 7

7.5 Suspension of Dealing

7.5.1 THE FTSE EDHEC-Risk EIS will treat suspension of dealing in line with the FTSE All-World Index Series.

7.5.2 Where a constituent is suspended it may remain in the FTSE EDHEC-Risk EIS, at the price at which it is suspended for up to 10 business days. During this time on advice from FTSE may agree to delete the constituent immediately either at its suspension price or at a value of zero. This change will be effected after the close of the index calculation and prior to the start of the index calculation on the following day. Removing a constituent at zero indicates that the stock is believed to be valueless.

7.5.3 When a suspension of a constituent lasts beyond noon on the tenth business day (and the option to remove the constituent has not been exercised), the constituent will normally be deleted from the index on the eleventh trading day, either at its suspension price or at zero.

7.6 Relisting of Suspended Constituents

7.6.1 If a company relists then it will be eligible for inclusion in the FTSE EDHEC-Risk EIS at the next quarterly review providing it meets the eligibility criteria as defined in Rule 4.

SECTION 8

8.0 Definition of Optimisation Inputs

In order to compute the efficient weighting criterion according to the formula in Rule 6.1.3, two inputs are needed: the covariance matrix of returns of index constituents and the vector of their expected excess returns. The following two subsections describe in turn how each of these inputs is estimated from the returns data of index constituents.

8.1 Covariance Matrix

8.1.1 Introduction: An estimate of the covariance matrix for securities in the underlying FTSE All-World indices is necessary to describe the interdependence of constituent returns. While this interdependence is irrelevant for the expected return of the efficient index, the covariance is important for computing the volatility of the efficient index. Simply computing the covariance matrix from past return observations leads to estimation error. It is therefore important to impose some structure on the covariance matrix to reduce the dimensionality of the estimation problem. Below, the steps necessary to implement our approach of modelling the covariance matrix are described.

8.1.2 Factor Model: The key problem in covariance matrix estimation is the curse of dimensionality; when a large number of stocks are considered, the number of parameters to estimate grows exponentially, where the majority of them are pairwise correlations. Therefore at the estimation stage, the challenge is to reduce the number of factors that come into play. In general, a multifactor model decomposes the returns of an asset into its expected rewards for exposition to risk factors. Such a factor of the following form is used:

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

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

8.1.3 Covariance Matrix: Given the factors and the loadings of the stocks on these factors, the covariance matrix can be estimated as:

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

where Σ_F is the $K \times K$ matrix of covariance between the factors and Σ_ε is the $Z \times Z$ covariance matrix of the error terms. Modelling the covariance this way allows to avoid the noise in the estimation of individual covariance terms. The covariance between two stocks can be assumed as entirely driven by the exposure to the common risk factors.

8.1.4 Estimation of the Factor Model: To construct the covariance matrix, the factors and estimate factor loadings are needed to be specified. A statistical factor model is chosen to be used. Each factor is modelled as a linear combination of returns of index constituents. Next, extract the first K principal components. These principal components yield the best K-dimensional summary of the information contained in the dataset of Z constituents. They can be interpreted as the common factors that drive the variation on the data. Ex post, our statistical factors can be interpreted as providing proxies for factors like investment styles or industry sectors.

SECTION 8

8.1.5 The exact procedure to extract principal components and construct the covariance matrix is described in Appendix C. The method of extracting principal components is standard in quantitative financial analysis. Standard textbooks provide a comprehensive description of the approach (see in particular Ruey Tsay, Analysis of Financial Time Series, Wiley, 2002, 1st ed., Chapter 8.7 and 8.8).

8.2 Expected Returns

8.2.1 Introduction: Expected returns are notoriously hard to estimate and present a problem in any portfolio optimisation. An insight from financial theory says investors will be averse to holding securities with high total risk. Our total risk estimate is the downside risk or semi-deviation of the returns of each constituent. This total risk estimate provides the means to estimate expected returns. The idea behind this is that, since investors want to avoid holding stocks with high semi-deviation, these stocks will have a relatively low price and thus a high expected return.

8.2.2 Total risk measure: The semi-deviation is a downside risk measure. Compared to volatility, the semi-deviation is a more meaningful definition of risk since it only takes into account deviations below the mean. Over the calibration period, EDHEC-Risk will compute the semi-deviation of the returns of each constituent SEM_i with respect to the average return μ_i of the *i-th* stock as

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

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*.

8.2.3 Portfolio sorting: Rather than using the value of semi-deviation for each stock, stocks will be grouped into portfolios and use the median semi-deviation of stocks in the portfolio as an estimate for the expected return for each stock in this portfolio. More precisely, the stocks will be sorted into deciles[1] portfolios based on their semi-deviation. That is, the 10% of stocks is grouped with the highest semi-deviations into one portfolio, then the 10% of stocks with the next highest semi-deviations and so forth. Within each of these portfolios, the median semi-deviation for stocks is computed in the portfolio.

8.2.4 Setting expected returns: EDHEC-Risk will then set the expected return of a stock to the median semi-deviation of all stocks in the portfolio the stock belongs to. The idea is that expected returns of a stock should be linked to the typical semi-deviation of stocks in the group that the stock belongs to. EDHEC-Risk do not use each stock's semi-deviation directly to avoid estimation error. In fact, financial research commonly identifies differences in expected returns between different groups of stocks but rarely develops predictions about individual stocks. Thus EDHEC-Risk will use a robust relation between the average semi-deviation of a group of stocks and their expected return. More precisely, the stock's weighting will be computed by setting the expected excess return of the stock in the formula in section 5.3.4 equal to the median semi-deviation of stocks in the same portfolio as described above in Rules 8.2.1, 8.2.2 and 8.2.3. This is based on the insight that stocks with high semi-deviation have high expected returns.

[1] 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 Sharpe ratio of a portfolio is defined as the expected return in excess of a risk free investment of a portfolio divided by the risk of the same portfolio, where the 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 of the expected portfolio return and the risk free interest rate. Given a vector w that contains the weights of all portfolio constituents, the numerator of the Sharpe ratio can be computed from the vector μ that contains the expected excess returns of all constituents and the denominator of the Sharpe ratio can be computed from the covariance matrix for returns of these constituents 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 with the 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 that multiply the rest of the equation, they are not relevant for the relative weightings of the two stocks. The only thing of interest is the multiplication of the matrix with the vector of expected returns.

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

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 $Var_1\mu_2 - Cov\,\mu_1$.

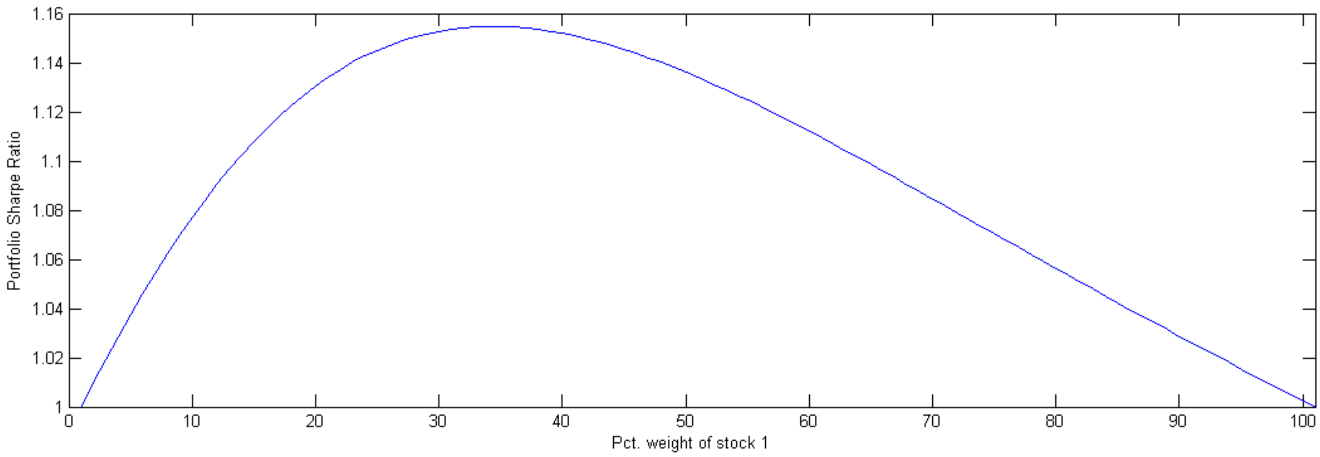
Consider the following two stocks:

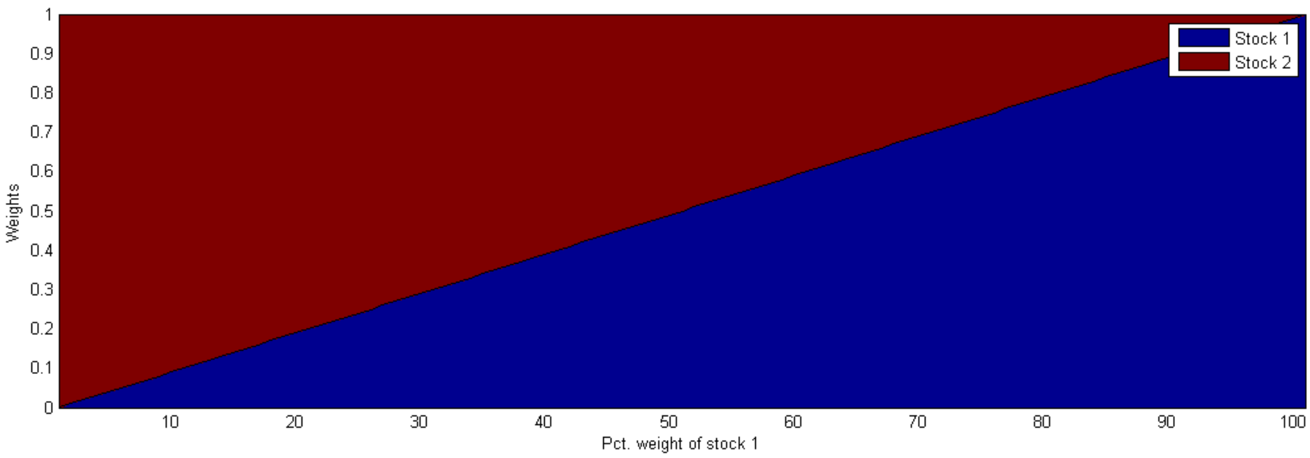
The expected excess return of stock 1 is 20%, for stock 2 it is 10%. The volatility (standard deviation) of returns of stock 1 is 20% and that of stock 2 is 10%. The correlation between the two stocks' returns is 0.5. Then our input parameters are

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

The weight of the first stock 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, as can be seen below.

APPENDIX B





The upper plot of this figure shows how the Sharpe ratio of a portfolio of stock 1 and stock 2 evolves as the weight of stock 1 increase. It can be seen that a maximum is reached at 33.3%.

In the EDHEC-Risk Efficient Indexing approach, these efficient weights computed to maximise the Sharpe ratio are the relative weighting criterion. To respect weight constraints and to take into account stocks with insufficient data, these weights are adjusted. These adjustments achieve that weights are bound below, capped above and that stocks without data are included with a minimal weight. However, the relevant criterion for the weight of a stock is the efficient weight computed in the Sharpe ratio maximisation. The efficient weights, in the example 1/3 for stock 1 and 2/3 for stock 2 are the relevant weighting criterion. The efficiency weight is used as a weighting criterion, just like other indices use the company's market cap or accounting characteristics.

Cap-weighted indices weight stocks by the footprint they leave on the stock market. Characteristics-based indices weight stocks by their footprint in the economy. Investors probably don't care much about the footprint a company leaves in the economy or the footprint it leaves on the stock market. Our approach weights stocks by the "risk/return footprint" they leave in the investor's portfolio. Obviously, investors want to have a high weight in stocks that contribute positively to the portfolios Sharpe ratio and a low weight in stocks that contribute less to increasing the Sharpe ratio.

APPENDIX C

Principal Component Analysis

1.0 First, the returns are standardised, so that all returns have the same scale and differences of scale, due to for instance differences in leverage of different companies are neutralised.

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

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

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.

2.0 Next, the common factors are extracted that drive correlations between the returns of different constituents. Three common factors are extracted through a statistical procedure. The interpretation of such implicit factors is similar to the identification of industry or style factors. EDHEC-Risk will conduct Principle Component Analysis (PCA) on the sample correlation matrix S. The following factor model will be 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* by factor *j* and *F* is a vector with the unobservable underlying factors.

3.0 *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:

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

For which variances and covariance are:

$$Var[f_i] = l_i^T S\, l_i = \lambda_i \qquad i = 1, 2, \ldots Z$$
$$Cov[f_i, f_j] = l_i^T S\, l_j \qquad i \neq j$$

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

4.0 Select number of factors retained for the factor model. Then, select the number of factors by using only those *K* factors associated with an eigenvalue greater or equal to:

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

APPENDIX C

5.0 Construct correlation matrix P based on the factor model:
Now focus on the first *K* factors, that is $f_{1,....}f_K$ obtained in step 2.0.
Taking the eigenvalues-eigenvector pairs:

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

$$
\begin{aligned}
\mathrm{P} &= \lambda_1 e_1 e_1^T + \lambda_2 e_2 e_2^T + \ldots + \lambda_{K_1} e_{K_1} e_{K_1}^T \\
&= \begin{bmatrix} e_1 & e_2 & \ldots & e_{K_1} \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \lambda_{K_1} \end{bmatrix} \begin{bmatrix} e_1^T \\ e_2^T \\ \vdots \\ e_{K_1}^T \end{bmatrix} = L\Lambda L^T
\end{aligned}
$$

Where L is a $N \times K$ matrix with *K<N* and where *K* had been chosen in step 2.0. Now enforce that the diagonal elements of P will be equal to one.

6.0 Construct Covariance matrix. Finally, for each element in P(i,j), compute 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 USA Index	14:30	21:10
FTSE EDHEC-Risk Efficient UK Index	08:00	16:30
FTSE EDHEC-Risk Efficient Eurobloc Index	08:00	16:30
FTSE EDHEC-Risk Efficient Japan Index	00:00	06:20
FTSE EDHEC-Risk Efficient Developed Asia Pacific ex Japan Index	00:00	09:00

Notes:

1. Timings are GMT Hours.

APPENDIX E

Contacts Details

FTSE

Further information on the FTSE EDHEC-Risk Efficient Index Series are available from FTSE on www.ftse.com, who will also welcome comments on these Ground Rules. 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.

TK 30/10/2009