

# A GLOBAL IMPLEMENTATION OF THE FAMA- FRENCH 5-FACTOR MODEL

Model Specification

MSCI

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## **ABOUT THIS DOCUMENT**

This document describes in detail the construction of an international Fama -French five-factor model prepared for NBIM by MSCI. The implementation is based on the methodology of Fama and French (2015). The estimation universe and all input data necessary for model estimation are supplied by MSCI.

## DESCRIPTION OF INPUT DATA

All data used in model estimation is proprietary to MSCI and was chosen with the aim of approximating as closely as possible the data used by Fama and French (2015).

- 1) Investment universe. The investment universe is defined by the MSCI ACWI IMI Index, restricted to assets which (i) fall into the 23 Developed Market countries specified in Fama and French (2015), (ii) with all factor scores non-missing.
- 2) Model history & calendar. Model history spans slightly over 20 years, from July 31 1995 to December 31 2015. Model factor returns are calculated on a monthly business day calendar, i.e. dated on the last business day of each month. Similarly, all model data is end-of-month.
- 3) Returns. Factor returns are estimated from monthly USD excess returns, calculated as the difference between monthly USD returns and monthly US risk-free rate.
- 4) Market caps. In both regional and global portfolios, assets are weighted by their USD security market cap, i.e. the USD market cap of individual issues, not float adjusted.
- 5) Factor scores. Factors are constructed using MSCI descriptors, as implemented in the MSCI Global Total Market Model (cf. Morozov et al. (2015) and MSCI (2015) for further details). The non-Market factors in the Fama-French 5-factor model are mapped to MSCI descriptors as follows:
  - Small Cap (Size) → USD security market cap
  - Value (B/M) → Book-to-Price (BTOP)
  - Op. Profitability (Op) → Gross Profitability (GP)
  - Investment (Inv) → Asset Growth (AGRO)

The Market factor is the cap weighted portfolio on the investment universe.

MSCI defines Gross Profitability as:

$$GP = \frac{Sales - COGS}{TA}$$

Here, *COGS* stands for “Cost of Goods Sold” and *TA* stands for Total Assets. Fama and French (2015) subtract selling, general and administrative expenses, as well as interest, from the numerator and normalize with book equity.

MSCI defines Asset Growth as the 5 year trend growth in Total Assets by regressing *TA* against time over a period of five fiscal years. Fama and French (2015) use YoY growth of *TA*.

The factor scores B/M, Op and Inv are calculated from MSCI descriptors based on Point-in-Time (PiT) data. This means that a descriptor value with timestamp  $T$  reflects the value of that descriptor as it was known at time  $T$  and does not include subsequent restatements.

### CALCULATING B/M

Fama and French calculate B/M in June of each year by using book value from the end of the previous fiscal year, but taking market value (asset price) from the end of the previous year's December. Note that this definition introduces asynchronicity between firms' book value and market value.

Using MSCI's PiT data for Book-to-Price, we emulate this methodology by taking Book-to-Price from the end of February, and multiplying it with the ratio of asset prices in December and February:

$$B/M_{Feb} = \frac{P_{Feb}}{P_{Dec}} BTOP_{Feb}$$

In the above equation,  $P_{Feb(Dec)}$  is the USD asset price in February (December). February was chosen to capture the book value of firms which report their fiscal year-end results late.

### DEFINING THE INVESTMENT UNIVERSE

The model estimation universe is based on the MSCI ACWI IMI Index, which in MSCI's view is the broadest index universe appropriate for factor estimation and is close the estimation universe of the MSCI Global Total Market Model.

Following the methodology of Fama and French (2015), portfolios are rebalanced annually, at the end of every June. Hence, the estimation universe is also defined annually, based on information available up to the last business day of June.

To define the investment universe, the MSCI ACWI IMI Index is restricted to:

- 1) Assets with both country-of-exposure and country-of-quotations falling in the 23 Developed Market countries specified in Fama and French (2015), grouped into 4 regions as follows:
  - a. *North America*: United States, Canada
  - b. *Japan*: Japan
  - c. *Asia-Pacific (ex-Japan)*: Australia, New Zealand, Hong-Kong, Singapore
  - d. *Europe*: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Great Britain

- 2) Assets with non-missing market caps.
- 3) Assets with non-missing factor scores for B/M, Op and Inv.

## FACTOR CONSTRUCTION

Factors are constructed using the ‘2x3 double sorting’ methodology, as described in Fama and French (2015). The four non-market factors (Size, B/M, Op and Inv) are constructed in both a global- and a regional variant, as we describe below. Additionally, the three non-Size factors (B/M, Op and Inv) are calculated in a ‘Big’ and ‘Small’ versions, both globally and regionally.

All portfolios are constructed (rebalanced) annually at the end of June, from assets in the estimation universe constructed on the same day. Factor returns are calculated on each month-end throughout the year.

Only one global Market factor is constructed, which is the cap weighted portfolio on the estimation universe.

## REGIONAL PORTFOLIOS

Size, B/M, Op and Inv portfolios are constructed identically in each of the four regions, resulting in a total of  $4 \times 4 = 16$  portfolios.

In the 2x3 double-sorting methodology, each factor portfolio is a long-short combination of double-sorted portfolios. A double-sorted portfolio, in turn, is a cap-weighted portfolio sorted first by Size (into one of 2 buckets) and secondly by B/M, Op or Inv (into one of 3 buckets). The 2 Size- and 3 non Size-sorted buckets are defined by breakpoints, which are calculated as follows.

For Size, the breakpoint is the 10% percentile of cumulative market cap in the global universe. In any region, assets which fall below the breakpoint are assigned to the “Small” bucket and assets which fall above it are assigned to the “Big” bucket. We emphasize that, even though we are constructing regional portfolios, (i) the breakpoint is calculated on a global universe, and (ii) it is defined as a percentile of market cap, not number of assets. Due to large number of small caps, the lower 10% in cumulative represents a much larger fraction of assets –intended to be roughly 50%.

For B/M, Op and Inv, the breakpoints are the 30% and 70% percentile, regionally. In any region, assets falling below the 30% are assigned to the “Low” bucket, those between the 30% and 70% percentiles are assigned to the “Neutral” bucket and those above the 70%

percentile are assigned to the “High” bucket, respectively<sup>1</sup>. Note that for the three non-Size factors, the breakpoints are defined on the regional universes.

### NON-SIZE FACTORS

We first describe the construction of non-Size factors in some region which we denote  $X$ , choosing B/M as an example (the construction for Op and Inv is entirely analogous).

There are  $2 \times 3 = 6$  double-sorted regional portfolios from the intersection of 2 regional Size buckets and 3 regional B/M buckets which we denote, respectively:  $High_{Small}^X$ ,  $Neutral_{Small}^X$ ,  $Low_{Small}^X$ ,  $High_{Big}^X$ ,  $Neutral_{Big}^X$  and  $Low_{Big}^X$ . Each double-sorted portfolio is cap weighted, long-only and with weights summing to one.

The factor portfolio corresponding to the B/M factor is denoted HML (for “High Minus Low”) and is defined as:

$$HML^X = \frac{1}{2} (HML_{Small}^X + HML_{Big}^X) = \frac{1}{2} ((High_{Small}^X - Low_{Small}^X) + (High_{Big}^X - Low_{Big}^X))$$

HML is by definition dollar neutral and can be thought of as the average of the HML portfolio calculated on “Small” and “Large “ assets.

The factor portfolio corresponding to the factor Op is denoted  $RMW^X$  (for “Robust Minus Weak”). The factor portfolio corresponding to the factor Inv is denoted  $CMA^X$  (for “Conservative Minus Aggressive”). Their construction exactly mirrors the construction of  $HML^X$ .

### SIZE FACTOR

Returning to the  $2 \times 3$  double-sorted portfolios defined for the pair (Size, B/M) above, we can define a dollar neutral small-cap portfolio  $SMB_{B/M}^X$  (for “Small Minus Big”) as follows:

$$SMB_{B/M}^X = \frac{1}{3} (High_{Small}^X + Neutral_{Small}^X + Low_{Small}^X) - \frac{1}{3} (High_{Big}^X + Neutral_{Big}^X + Low_{Big}^X)$$

Similarly, from the double sorts involving (Size, Op) and (Size, Inv), respectively, we construct the factors  $SMB_{Op}^X$  and  $SMB_{Inv}^X$ . Finally, we define the Size factor portfolio  $SMB$  portfolio is defined as the average:

<sup>1</sup> In [FF5], the terms “Low”, “Neutral” and “High” are reserved for sorts performed on B/M. For Op, the low and high percentile buckets are called “Weak” and “Robust”. For Inv, the corresponding terms are “Conservative” and “Aggressive”.

$$SMB^X = \frac{1}{3}(SMB_{B/M}^X + SMB_{Op}^X + SMB_{Inv}^X)$$

There are in total 4x4=16 regional portfolios corresponding to the four factors and four regions:

- Size  $\rightarrow SMB^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$
- Value  $\rightarrow HML^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$
- Op  $\rightarrow RMW^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$
- Inv  $\rightarrow CMA^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$

Additionally, we also calculate 4x3x2=24 regional “Small” and “Big” portfolios for each non-Size factor:

- Value  $\rightarrow HML_Y^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$ ,  $Y = \{Small, Big\}$
- Op  $\rightarrow RMW_Y^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$ ,  $Y = \{Small, Big\}$
- Inv  $\rightarrow CMA_Y^X$ ,  $X = \{N. America, Japan, Asia Pac, Europe\}$ ,  $Y = \{Small, Big\}$

## GLOBAL PORTFOLIOS

Global portfolios  $SMB$ ,  $HML$ ,  $RMW$  and  $CMA$  are constructed from global double-sorted portfolios. Global double-sorted portfolios are defined with the same breakpoints that are used to calculate the regional portfolios, i.e. a global breakpoint in Size and regional breakpoints for B/M, Op and Inv.

Returning to the example of (Size, B/M), the 2x3 global double-sorted portfolios are  $High_{Small}$ ,  $Neutral_{Small}$ ,  $Low_{Small}$ ,  $High_{Big}$ ,  $Neutral_{Big}$  and  $Low_{Big}$ . The portfolio  $High_{Small}$  contains all assets, from all regions, with B/M above their respective regional breakpoint and with Size below the global breakpoint. All global double-sorted portfolios are cap weighted, with weights summing to one.

The global  $HML$  portfolio is defined as:

$$HML = \frac{1}{2}((High_{Small} - Low_{Small}) + (High_{Big} - Low_{Big}))$$

The global  $RMW$  and  $CMA$  portfolios are defined analogously.

The global Size factor portfolio is defined as:

$$SMB = \frac{1}{3}(SMB_{B/M} + SMB_{Op} + SMB_{Inv})$$

Where for example the portfolio  $SMB_{B/M}$  is defined as:

$$SMB_{B/M} = \frac{1}{3}(High_{small} + Neutral_{small} + Low_{small}) - \frac{1}{3}(High_{big} + Neutral_{big} + Low_{big})$$

There are in total 5 global portfolios:

- Market → Cap weighted estimation universe
- Size →  $SMB$
- Value →  $HML$
- Op →  $RMW$
- Inv →  $CMA$

Additionally, we calculate  $3 \times 2 = 6$  global “Small” and “Big” portfolios for each non-Size factor:

- Value →  $HML_Y$ ,  $Y = \{Small, Big\}$
- Op →  $RMW_Y$ ,  $Y = \{Small, Big\}$
- Inv →  $CMA_Y$ ,  $Y = \{Small, Big\}$

### ALTERNATIVE ESTIMATION OF GLOBAL PORTFOLIOS

The global factor portfolios contain the same assets as the regional factor portfolios taken all together. This suggests a two-step process to construct global factors:

- 1) First construct the regional factors
- 2) Average the regional factors with regions’ cap weights to arrive at the global factors

This is close to, but not the same as, the process we are following. The reason for the discrepancy is that regions’ cap weight also includes the weights of assets which are not even selected in factor construction.

## REFERENCES

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## CONTACT US

clientservice@msci.com

### AMERICAS

Americas	1 888 588 4567 *
Atlanta	+ 1 404 551 3212
Boston	+ 1 617 532 0920
Chicago	+ 1 312 675 0545
Monterrey	+ 52 81 1253 4020
New York	+ 1 212 804 3901
San Francisco	+ 1 415 836 8800
Sao Paulo	+ 55 11 3706 1360
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### EUROPE, MIDDLE EAST & AFRICA

Cape Town	+ 27 21 673 0100
Frankfurt	+ 49 69 133 859 00
Geneva	+ 41 22 817 9777
London	+ 44 20 7618 2222
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Paris	0800 91 59 17 *

### ASIA PACIFIC

China North	10800 852 1032 *
China South	10800 152 1032 *
Hong Kong	+ 852 2844 9333
Mumbai	+ 91 22 6784 9160
Seoul	00798 8521 3392 *
Singapore	800 852 3749 *
Sydney	+ 61 2 9033 9333
Taipei	008 0112 7513 *
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\* = toll free

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