



# *Module #4*

# Investment replica

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# Portfolio replication in short

We want to track a given portfolio («target portfolio») without knowing its holdings

We do not know either which securities the portfolio contains or what weight each security has

We can only observe reported returns: for us, the target portfolio is a complete black box

We want to crack this black box and see how it is made inside



# Why do it???

## PORTFOLIO

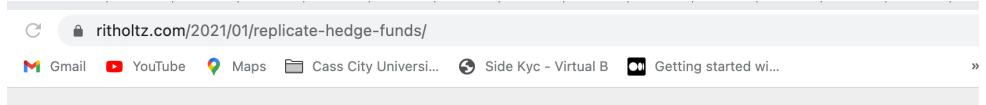


Julie Segal

# Hedge Fund Replication Worked in January. Here's Why.

Replication passed a significant test in the volatile month of January when retail investors sent the stock of GameStop soaring and some equity long-short funds reeling.

February 12, 2021



The screenshot shows a search results page for "5 hedge fund replication strategy etfs" on the ETFdb website. The top navigation bar includes links for App, Gmail, YouTube, Maps, Cass City Universi..., Side Kyc - Virtual B, and Ge... Below the search bar, there are categories for ETF DATABASE, Channels, Database, Tools, Research, and Webcasts. The main content area features a large image of a hand holding a magnifying glass over a pile of coins, with a red box highlighting the word "Hedge Fund". The title "BEYOND BASIC BETA CHANNEL" is above the main headline "5 Hedge Fund Replication Strategy ETFs to Consider".



BEYOND BASIC BETA CHANNEL

## 5 Hedge Fund Replication Strategy ETFs to Consider

Ben Hernandez Apr 18, 2019

Most might consider 13 to be an unlucky number, but for **hedge funds**, it marks the best first quarter its had in as many years. According to the Hedge Fund Research index, which tracks the performance of hedge funds, it rose 5.7 percent in Q1 of 2019—its highest since 2006.

## MiB: How to Replicate Hedge Funds in an ETF

January 26, 2021 10:00am by Barry Ritholtz

The screenshot shows a podcast episode from Bloomberg Opinion's Masters in Business series. The episode is titled "Andrew Beer on the Hedge Fund Industry (Podcast)" and was published on January 22, 2021. It is described as being 1 ora 14 min long. The host is Andrew Beer. The interface includes a "Riproduci" (Play) button and a "Vedi altro" (View more) button.

# Motivation 1

## – Alternative Investments Clones

YOU WANT TO BE EXPOSED TO THE SAME KIND OF FINANCIAL RISK AND RETURN WHILE AVOIDING HIGH FEES AND LIQUIDITY RESTRICTIONS TYPICAL OF ALTERNATIVE INVESTMENTS (EG HEDGE FUNDS)

YOU HAVE A LONG POSITION IN AN ALTERNATIVE INVESTMENT FUND, OR IN A PORTFOLIO OF ALTERNATIVES (FUND OF FUNDS), AND YOU MAY WISH TO HEDGE THE RISK OF A DOWNTURN

FOR RISK ANALYSIS PURPOSES YOU WANT TO UNDERSTAND WHICH RISK FACTORS DRIVE THE ALTERNATIVE FUND





# Motivation 2 – Index Tracking

You may want to track a very illiquid index - which is very costly if not impossible from the execution point of view

You may want to track a very big index - which means having huge Assets under Management (AuM): many funds have less than 100 million euros/US dollars, and you typically need billions, in order to physically replicate an index

1-BLOOMBERG

Tabs are here! Options X

GO F1 F2 F3 F4 PRINT HELP MEMO SEARCH QUOTE QUOTE MONIT NEWS MSG MENU PG BAC PG FW GOV CORP MTGE MUNI PFD EQUITY M-Mkt CMDTY INDEX CURNC CLIENT CMND index

< > | ISH JP \$EM BD \$D Equity ▾ | DES ▾ | Related Functions Menu ▾

MSG: +1 ★ ?

**IEMB IM € ↓ 91.35 -0.20** M91.36 / 91.43M 704x2355  
 At 17:08 d Vol 31,891 0 91.55M H 91.55M L 91.15M Val 2.912M

**IEMB IM Equity** Export ▾ Page 1/5 Security Description: ETF

1) Profile 2) Performance 3) Holdings 4) Allocations 5) Organizational

ISHARES JPM USD EM BND USD D FIGI BBG0018QCZ55

Objective Fixed Income Emerging Market

iShares J.P. Morgan USD EM Bond UCITS ETF is an exchange-traded fund incorporated in Ireland. The Fund aims to track the performance of the J.P. Morgan Emerging Markets Bond Index Global Core Index. Settlement: ICSD.

6) Comparative Returns   COMP »	Bloomberg Classification	Appropriations
	Fund Type: ETF Asset Class: Fixed Income Economic ...: Emerging Markets Strategy: Government Geo. Focus...: Global	Leverage: No Actively Managed: No Swap Based: No Derivatives Based: No Currency Hedged: No Replication Strategy: Optimized Securities Lending: Yes
7) Price	Trading Data	Characteristics
8) NAV 05/07/21	Bid Ask Spread: 0.050	11) Und. Index: JPEICORE
INAV	90D Avg Agg Vol: 667.5k	Index Weight: Market Cap
Fund Percent Premium	Implied Liquidity: N.A.	1Y Px Track. Err.: 2.433
52 Wk H 07/03/20	Market Cap: EUR 6.71B	1Y NAV Track. Err.: 1.380
52 Wk L 02/25/21	Shares Out: 73.5M	Inception Date: 11/09/10
Options	Total Assets: USD 11.29B	Expense Ratio: .450%

1-BLOOMBERG

GO F1 F2 F3 F4 PRINT HELP MEMO SEARCH QUOTE QUOTE MONIT NEWS MSG MENU PG BA PG FW GOV CORP MTGE MUNI PFD EQUITY M-Mkt CMDTY INDEX CURNC CLIENT CMND index

< > | ISHR WRLD €-H Equity ▾ | DES ▾ | Related Functions Menu ▾ NEWS ALERT ★ ?

**IWDE IM** € **↑ 70.58** -0.20 M70.62 / 70.65M 4259 x 12768  
 At 16:59 d Vol 44,600 0 70.77M H 70.85M L 70.53M Val 3.154M

**IWDE IM Equity** Export ▾ Page 1/5 Security Description: ETF

1) Profile 2) Performance 3) Holdings 4) Allocations 5) Organizational

ISHARES MSCI WORLD EUR-H FIGI BBG001M0XDQ9  
 Objective Global

iShares MSCI World EUR Hedged UCITS ETF Acc is an exchange-traded fund incorporated in Ireland. The Fund aims to track the performance of the MSCI World 100% Hedged to EUR Index Net. The fund reinvests income received back into the fund. Settlement: ICSD.

6) Comparative Returns   COMP »	Bloomberg Classification	Appropriations
 <p>1 yr Tot Ret vs Index          MXWOHEUR Index 40.5996          IWDE IM Equity 40.1788</p>	<b>Fund Type</b> ETF <b>Asset Class</b> Equity <b>Market Cap</b> Large-cap <b>Strategy</b> Blend <b>Geo. Focus...</b> Global	<b>Leverage</b> No <b>Actively Managed</b> No <b>Swap Based</b> No <b>Derivatives Based</b> No <b>Currency Hedged</b> Yes <b>Replication Strategy</b> Full <b>Securities Lending</b> Yes
7) Price	Trading Data	Characteristics
8) NAV 05/07/21	<b>Bid Ask Spread</b> 0.040	11) Und. Index MXWOHEUR
INAV	<b>90D Avg Agg Vol</b> 509.8k	Index Weight Market Cap
Fund Percent Premium	<b>10) Implied Liquidity</b> 120.2M	1Y Px Track. Err... 4.778
52 Wk H 05/10/21	<b>Market Cap</b> EUR 3.18B	1Y NAV Track. E... .062
52 Wk L 05/14/20	<b>Shares Out</b> 45.0M	Inception Date 04/04/11
Options	<b>No Total Assets</b> EUR 3.18B	Expense Ratio .550%

# Motivation 3 – UCITS clones

Say that the company has an alternative fund for institutional investors, which invests in instruments that are not UCITS, that is, not eligible by the MIFID regulation (e.g. private debt, other alternative funds, etc.)

The company wants to create a retail products, that is, a UCITS vehicle (ie mutual fund) with similar financial characteristics, but made up of liquid instruments, e.g. Futures, ETFs, etc.,

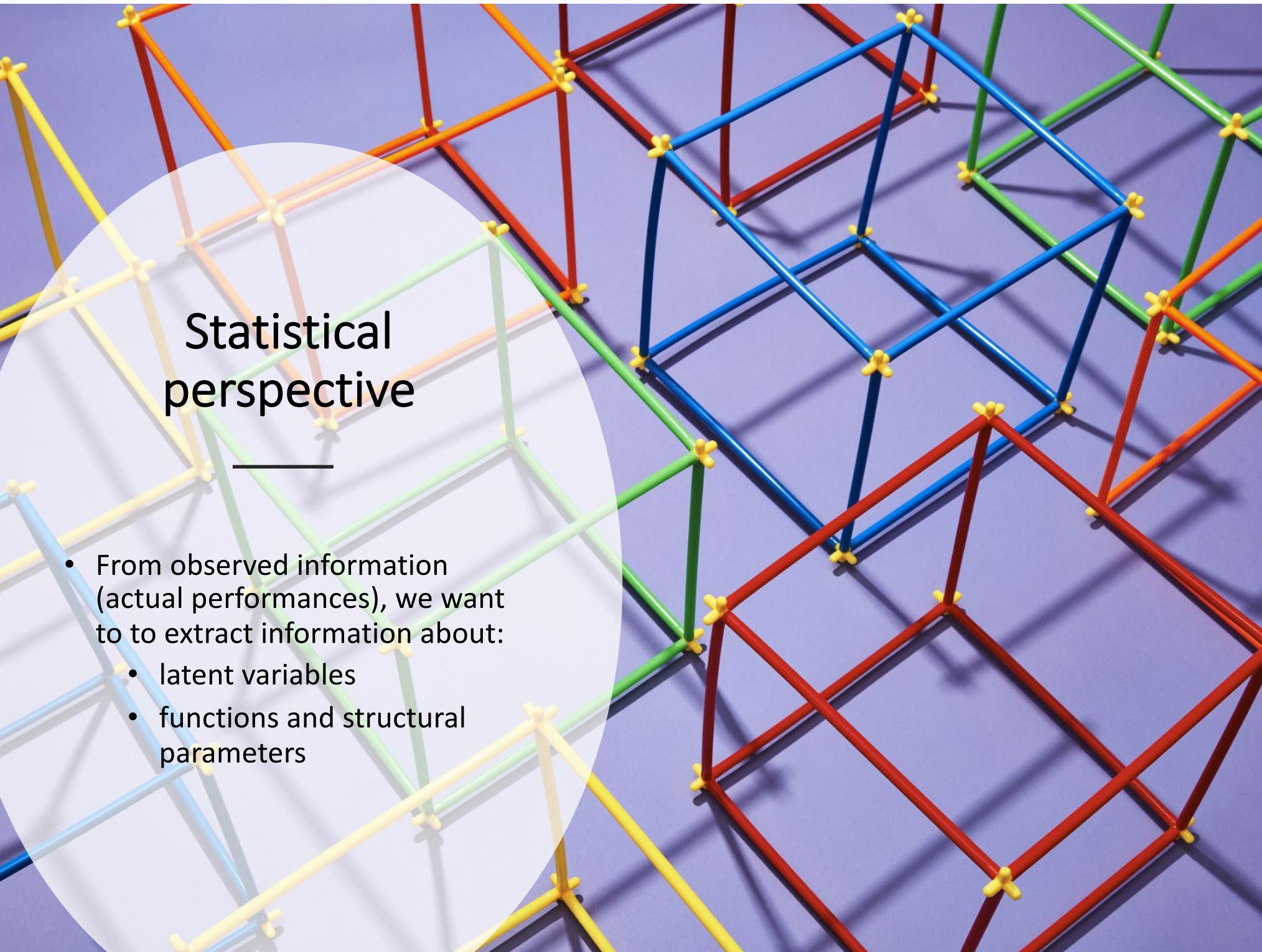
# Motivation 4 – Risk Management

You want a standard tool that finds the key liquid financial factors behind any investment, even if the underlying assets are not disclosed

It can be used as an alternative to standard factor models

Useful during due diligences, or litigations

Useful for simple scenario simulation (instead of using thousands of securities, you simulate just a few factors)



## Statistical perspective

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- From observed information (actual performances), we want to extract information about:
  - latent variables
  - functions and structural parameters



# Linear clones

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- Portfolio return is a linear combination of asset returns
- So we need a linear model, a linear clone
- A linear clone is constructed by.
  - estimating some regression model using a time series of prior index and factor returns
  - using the resulting coefficient estimates as portfolio weights (ie investment positions in the underlying factors)
- Although index tracking is driven from the financial industry, it is in fact a pure signal processing problem: a regression of the (historical) data subject to some portfolio constraints with some caveats and particularities
- «**Sparse portfolio tracking**»: we use a small number of assets to (approximately) replicate a portfolio or an index



# Using Futures, in short

- You have 100 millions EUR (normal mutual fund)
- Buy Futures contracts exposing yourself to 100 millions of S&P 500: only the money corresponding to the margins is paid
- Futures margin are typically 3-12% of the notional value of the contract
- The rest is invested in short-term "collateral" bonds that hopefully yield something and can easily sold in case of margin call
- So your financial exposure is (say): 90 short term bonds + 100 S&P 500 + 10 cash (margins) = 200% exposure
- Using Futures, you can financially expose yourself far beyond your capital: welcome to the LEVERAGE world

You can do  
that  
according to  
UCITS/MIFID

Max leverage =

- 200%

*Or*

- Max 1M VaR(99%)  
= 20%

Let's look at  
the data

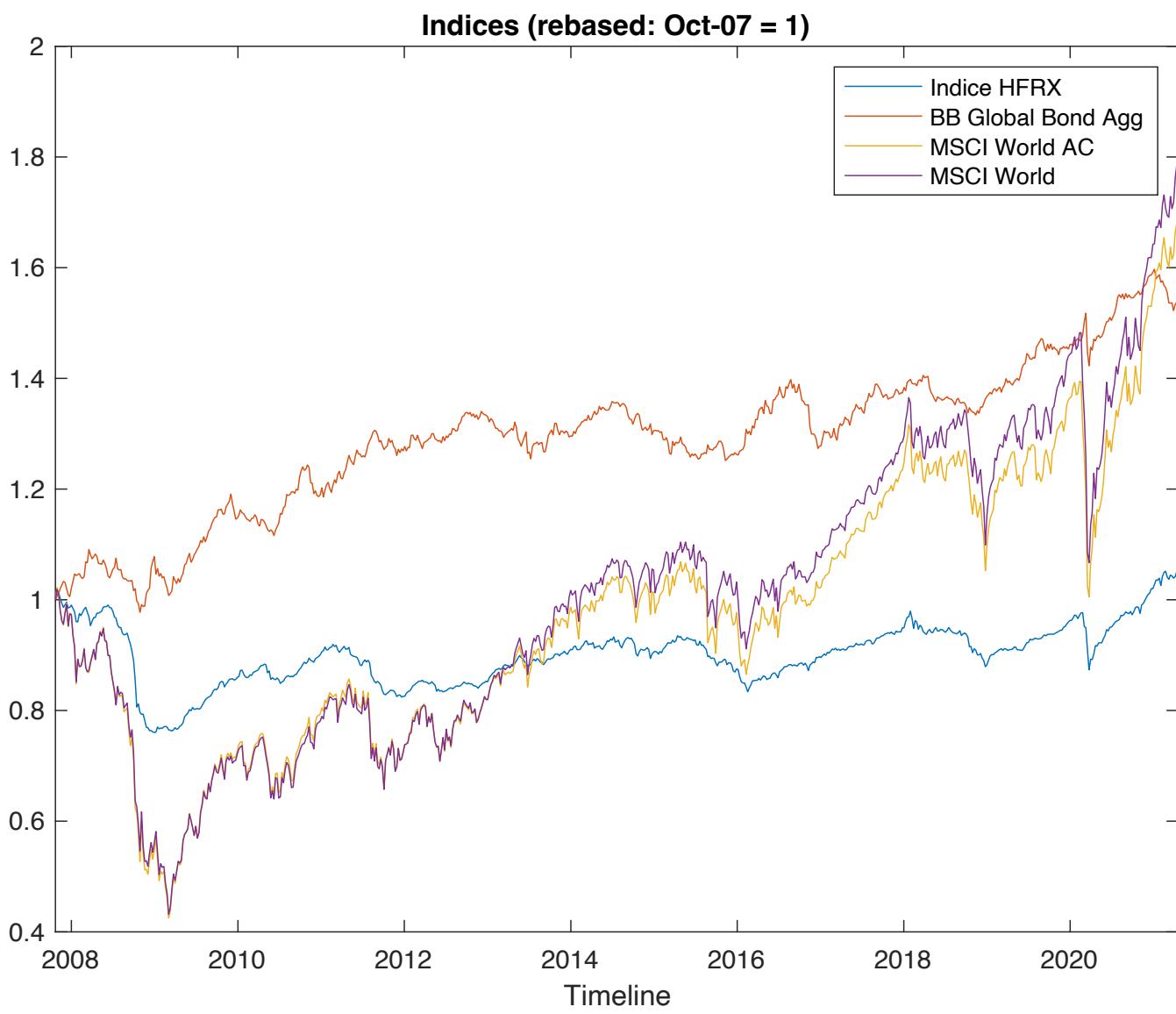
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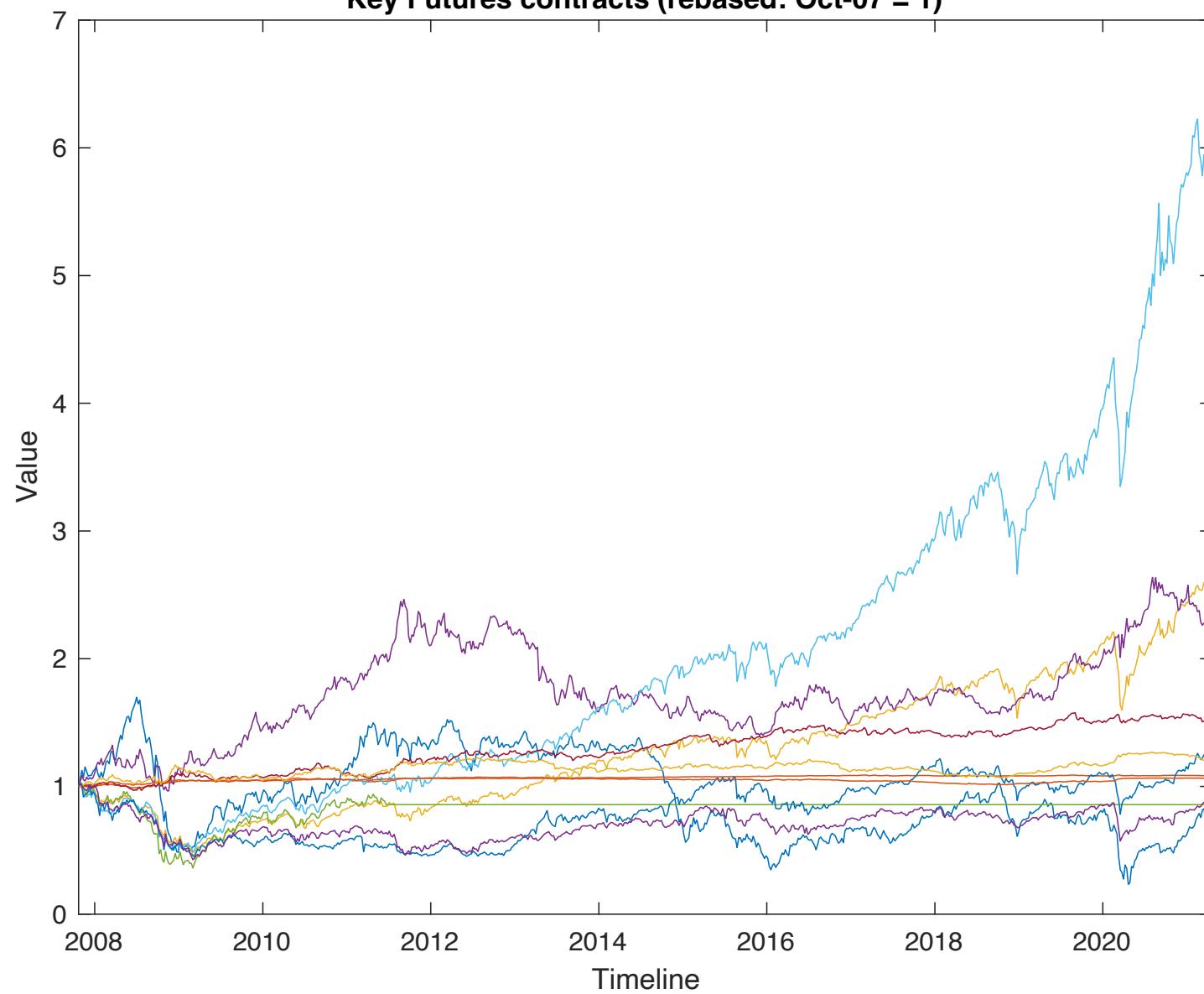
# Data overview

Weekly data from  
Bloomberg  
(Oct-2007/Apr-2021)

- A global Hedge Fund Index
- Global indices (bond/equity)
- Key Futures contracts

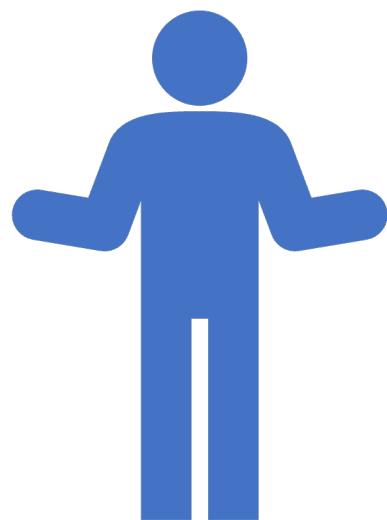


### Key Futures contracts (rebased: Oct-07 = 1)



Brainstorming

*(don't be shy)*



Ideas?



Coding session starts |

## Some practical considerations

- We focus on the algorithm (after all, this is a Machine Learning lab for Fintech - we cannot go much farther in the territory of portfolio construction and trading)

### ***However***

- Anyone wishing to make the project-work on investment replication, and has a financial background, might go deeper
- In particular, with regard to:
  - Trading and transaction costs/revenues
  - Rebalancing times and methods
  - Tricks for minimizing execution costs

# Trading costs

- Futures contracts are the most liquid and least expensive financial instruments to trade, on average
- Assuming that we are a mutual fund (or any other «UCI», Undertakings in Collective Investment product) of decent size – say >50 millions EUR – using automated program trading, direct trading costs can be 2-4 bps = 0.02%-0.04%



# Rebalancing



- It can be weekly, monthly, quarterly, or event –based
- The change in the composition of the holding portfolio during rebalancing can be controlled by including a turnover penalty
  - we already take this into account if we use Machine Learning techniques with Regularization, such as LASSO ( $\ell_1$  shrinkage of the weights towards 0)
  - eliminate very small trades and eventually normalize the weights (preserve proportions among assets)
  - avoid trading if the distance between the vector of the "old" weights and the new ones is less than a certain threshold

# Rollover effects

- To maintain a constant exposure to the Futures cointract, an expiring contract needs to be rolled into a new contract
- You face rollover effects when you switch from the contract that is close to expiration to another contract in a further-out month
- It can be positive or negative
- When you close the contract that expires soon, it is priced close to Spot, but the new contract that you enter into may be priced above or below Spot
- It has to do with contango and backwardation:
  - Contango = the forward price of a contract is higher than the spot price
  - Backwardation = the spot price is higher than future price

# Useful Python classes

Scikit-learn nicely provides separate classes with built-in cross-validation:

- [https://scikit-learn.org/stable/modules/generated/sklearn.linear\\_model.LassoCV.html?highlight=lasso#sklearn.linear\\_model.LassoCV](https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LassoCV.html?highlight=lasso#sklearn.linear_model.LassoCV)
- [https://scikit-learn.org/stable/modules/generated/sklearn.linear\\_model.RidgeCV.html#sklearn.linear\\_model.RidgeCV](https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.RidgeCV.html#sklearn.linear_model.RidgeCV)
- [https://scikit-learn.org/stable/modules/generated/sklearn.linear\\_model.ElasticNetCV.html#sklearn.linear\\_model.ElasticNetCV](https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.ElasticNetCV.html#sklearn.linear_model.ElasticNetCV)

# Some useful references

- Lan Wu, Yuehan Yang, Hanzhong Liu, (2014) «Nonnegative-lasso and application in index tracking», Computational Statistics & Data Analysis, Volume 70, <https://doi.org/10.1016/j.csda.2013.08.012>
- Tibshirani, R. (1996). Regression shrinkage and selection via the lasso J. R. Statist. Soc. B (2011) 73, Part 3, pp. 273–282 <https://tibshirani.su.domains/ftp/lasso-retro.pdf>
- Ali N. Akansu, Sanjeev R. Kulkarni, Dmitry M. Malioutov, (2016), «Financial Signal Processing and Machine Learning», Wiley-IEEE Press
- Roncalli, Thierry and Weisang, Guillaume, (2009) «Tracking Problems, Hedge Fund Replication and Alternative Beta». Available at SSRN: <https://ssrn.com/abstract=1325190> or <http://dx.doi.org/10.2139/ssrn.1325190>

# Take home on investment replication

- Investment strategy replication can be done, to some extent using Machine Learning methods
- You might use:
  - Linear regression methods
  - Latent variable models like State-Space models
  - Whatever...
- Replication strategies are less than perfect, however they bring value
- Think that: you can create an index of some very expensive funds (commissions between 2% and 3% are not uncommon), sometimes closed to new investors, and replicate it, albeit imperfectly, without the lock-ups and the costs of a typical hedge fund

## Now YOU

**It's your turn: same story as the other times...**