Government Pension Fund Global (GFPG) ("The Oil Fund") - using the data

Bernt Arne Ødegaard

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Introduction

The Norwegian *Government Pension Fund Global* is currently the world's largest Sovereign Wealth Fund, with Assets Under Management (AUM) of 12 billion NOK.

In these notes we show how to use the data provided by NBIM to do various calculations.

The calculations are shown using `R`.

1 NBIM Data

NBIM provides downloadable data that can be used to do your own evaluation of the funds investments.

Of primary interest is the spreadseheet containtin monthly returns broken down by

- Asset class (equity/fixed income/total)
- Reference currency (NOK/USD/Currency Index)

But there is lots of additional data

- NBIM portfolio compositions
- ...

A key routine for working with this data is one that pulls the relevant time series of returns: The routine below builds `xts` series by pulling the data from that excel spreadsheet. This example collects the data for returns in USD. These routines are sourced everywhere, look for the "`source`" statement at the top of most of the following examples.

file:`read_nbim_USD_returns_from_excel.R`

```
library(xts)                        # time series library
library(readxl)                     # reading excel files library
datadir <- "/home/bernt/data/2023/nbim/" # set datadir to where the file lives
filename <- paste0(datadir,"monthly-returns-1h2022.xlsx")

DataEquityReturnsUSD <- read_xlsx(filename, sheet="Equity - USD",skip=2)
dates <- as.yearmon(as.Date(as.character(na.omit(DataEquityReturnsUSD$Month)),
                    format="%Y-%m-%d"))
n <- length(dates)
dates <- dates[2:n]                 # cut the first date, as this is empty
Equity_Rets_USD <- xts(na.omit(DataEquityReturnsUSD$`Actual portfolio`),
                    order.by=dates)
names(Equity_Rets_USD) <- "Equity_Rets_USD"
```

```
Equity_Benchmark_Rets_USD <- xts(na.omit(DataEquityReturnsUSD$`Benchmark index`),
                                 order.by=dates)
names(Equity_Benchmark_Rets_USD) <- "Equity_Benchmark_Rets_USD"

DataFixedIncomeReturnsUSD <- read_xlsx(filename, sheet="Fixed income - USD",skip=2)
dates <- as.yearmon(as.Date(as.character(na.omit(DataFixedIncomeReturnsUSD$Month)),
                            format="%Y-%m-%d"))
Fixed_Income_Rets_USD <- xts(na.omit(DataFixedIncomeReturnsUSD$`Actual portfolio`),
                             order.by=dates)
names(Fixed_Income_Rets_USD) <- "Fixed_Income_Rets_USD"
Fixed_Income_Benchmark_Rets_USD <- xts(na.omit(DataFixedIncomeReturnsUSD$`Benchmark index`),
                                       order.by=dates)
names(Fixed_Income_Benchmark_Rets_USD) <- "Fixed_Income_Benchmark_Rets_USD"

DataTotalReturnsUSD <- read_xlsx(filename, sheet="Fund combined - USD",skip=2)
dates <- as.yearmon(as.Date(as.character(na.omit(DataTotalReturnsUSD$Month)),
                            format="%Y-%m-%d"))
Total_Rets_USD <- xts(na.omit(DataTotalReturnsUSD$Fund), order.by=dates)
names(Total_Rets_USD) <- "Total_Rets_USD"
Total_Benchmark_Rets_USD <- xts(na.omit(DataTotalReturnsUSD$`Benchmark index`),
                                order.by=dates)
names(Total_Benchmark_Rets_USD) <- "Total_Benchmark_Rets_USD"
```

2 Plotting wealth evololution

Looking at the financial investments.

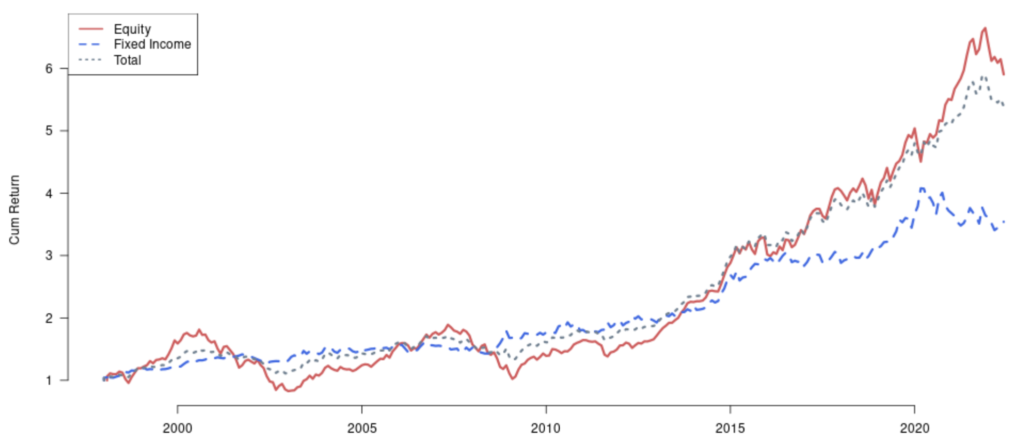
Evaluating: What *return* do one earn on an investment, without counting for in and outflow from the fund?

The *wealth relative* implied in the asset returns

$$W_T = \prod_{t=1}^{T} (1 + r_t)$$

Or, how much will one NOK invested in 1998 have grown to?

Figure 1 Aggregate wealth, Total, Equity and Fixed income, in NOK



Show the R code that produces such a picture, for equity only
file: `cum_wealth_plot_NOK_equity_only.R`

```
source ("../2023_01_read_current/read_nbim_NOK_returns_from_excel.R")
outdir <- "../../results/2023_01_cumulative_wealth_plots/"

Equity_Rets_NOK <- na.omit(Equity_Rets_NOK)
Equity_Benchmark_Rets_NOK <- na.omit(Equity_Benchmark_Rets_NOK)
Rp <- as.matrix(Equity_Rets_NOK)
Rb <- as.matrix(Equity_Benchmark_Rets_NOK)
Rdiff <- Rp-Rb
wp  <- 1.0
WealthP <- c(wp)
wb  <- 1.0
WealthB <- c(wb)
wd <- 1.0
WealthDiff <- c(wd)
for ( i in 1:length(Rp)) {
    wp <- wp*(1+Rp[i])
    WealthP <- c(WealthP,wp)
    wb <- wb*(1+Rb[i])
    WealthB <- c(WealthB,wb)
    wd <- wd*(1+Rdiff[i])
    WealthDiff <- c(WealthDiff,wd)
}

dates <- c(as.yearmon("1998-02"),index(Equity_Rets_NOK))
WealthP <- xts(WealthP,order.by=dates)
WealthB <- xts(WealthB,order.by=dates)
WealthDiff <- xts(WealthDiff,order.by=dates)

filename <- paste0(outdir,"wealth_evolution_equity_portfolios_NOK.png")
png(filename,width=1000,heigh=500)
plot.zoo(merge(WealthP,WealthB),
         screen=c(1,1), lty=c(1,2),
         main="", ylab="Cum Return",
         xlab="",
         las=1,
         lwd=3,
         bty="n",
         col=c("indianred","royalblue"))
legend("topleft",
       c("Portfolio","Benchmark"),
       lty=c(1,2),
       col=c("indianred","royalblue"),
       lwd=c(2,2))
dev.off()
```

Figure 2 Aggregate wealth, Equity portfolio, in NOK

3 The Sharpe Ratio

A Sharpe ratio is

$$S = \frac{r_p - r_f}{\sigma(r_p - r_f)}$$

Calculate this for the fund's equity portfolio using Ken French's market portfolio as a benchmark. That means we use the fund's returns in USD.

Table 1 Sharpe ratios - Equity portfolios

Sharpe ratios - 1998–2022

	Mean (%)	Sharpe
fund portfolio	7.6	0.102
benchmark	7.2	0.096
RMRF	7.8	0.111

The table shows Sharpe ratios for the fund's equity portfolio. Returns in USD. Using the French risk free rate. The fund and the benchmark are international portolioe. RMRF is the excess return for Ken French's US market portfolio.

File: `calculate_sharpe.R`

```
library(xtable)
source ("~/data/2023/french_global_data/read_global_5_pricing_factors.R")
source ("../2023_01_read_current/read_nbim_USD_returns_from_excel.R")
outdir <- "../../results/2023_02_describe_returns/"
data <- merge(Equity_Rets_USD, Equity_Benchmark_Rets_USD,
              RF, RM, RMRF,all=FALSE)
eRp <- data$Equity_Rets_USD      - data$RF
eRb <- data$Equity_Benchmark_Rets_USD - data$RF
RMRF <- data$RMRF

sharpe_p <- mean(eRp)/sd(eRp)
sharpe_b <- mean(eRb)/sd(eRb)
sharpe_m <- mean(RMRF)/sd(RMRF)

tab <- matrix(nrow=3,ncol=2)
tab[1,1] <- 1200 * mean(data$Equity_Rets_USD)
tab[1,2] <- sharpe_p
tab[2,1] <- 1200 * mean(data$Equity_Benchmark_Rets_USD)
tab[2,2] <- sharpe_b
tab[3,1] <- 1200 * mean(data$RM)
tab[3,2] <- sharpe_m

rownames(tab) <- c("fund portfolio","benchmark", "RMRF")
colnames(tab) <- c("Mean (%)", "Sharpe")

filename <- paste0(outdir,"sharpe_equity_estimates_98_22.tex")
xtab <- xtable(tab,digits=c(0,1,3))
print(xtab,
      file=filename,
      floating=FALSE)
```

4 The Treynor measure

$$T = \frac{r_p - r_f}{\beta_p}$$

Calculate this for the fund's equity portfolio using Ken French's market portfolio as a benchmark. That means we use the fund's returns in USD.

Table 2 Treynor measure - Equity portfolios

Treynor measures - 1998–2022

	Beta	Treynor
fund portfolio	1.05	0.0047
benchmark	1.05	0.0044
RMRF	1.00	0.0051

The table shows Treynor measures for the fund's equity portfolio. Returns in USD. Using the French risk free rate. The fund and the benchmark are international portolios. RMRF is the excess return for Ken French's US market portfolio.

File: `calculate_treynor.R`

```
library(xtable)
source ("~/data/2023/french_global_data/read_global_5_pricing_factors.R")
source ("../2023_01_read_current/read_nbim_USD_returns_from_excel.R")
outdir <- "../../results/2023_02_describe_returns/"
data <- merge(Equity_Rets_USD, Equity_Benchmark_Rets_USD,
              RF, RM, RMRF,all=FALSE)
eRp <- data$Equity_Rets_USD - data$RF
eRb <- data$Equity_Benchmark_Rets_USD - data$RF
RMRF <- data$RMRF

beta_p <- cov(eRp,RMRF)/var(RMRF)
treynor_p <- mean(eRp)/beta_p
beta_b <- cov(eRb,RMRF)/var(RMRF)
treynor_b <- mean(eRb)/beta_b
treynor_m <- mean(RMRF)/1

tabT <- matrix(nrow=3,ncol=2)
colnames(tabT) <- c("Beta","Treynor")
rownames(tabT) <- c("fund portfolio","benchmark", "RMRF")

tabT[1,1] <- beta_p
tabT[1,2] <- treynor_p
tabT[2,1] <- beta_p
tabT[2,2] <- treynor_b
tabT[3,1] <- 1
tabT[3,2] <- treynor_m
filename <- paste0(outdir,"treynor_equity_estimates_98_22.tex")
xtab     <- xtable(tabT,digits=c(0,2,4))
print(xtab,
      file=filename,
      floating=FALSE)
```

5 Alpha estimation

Alpha is an attempt to answer the question: Does the return on a portfolio/asset exceed its *required* return?

Jensens alpha is the difference between actual performance and required return

$$\alpha_p = r_p - \text{reqiured return} = r_p - \hat{r}_p$$

To find an estimate of requred return an asset pricing model is required.

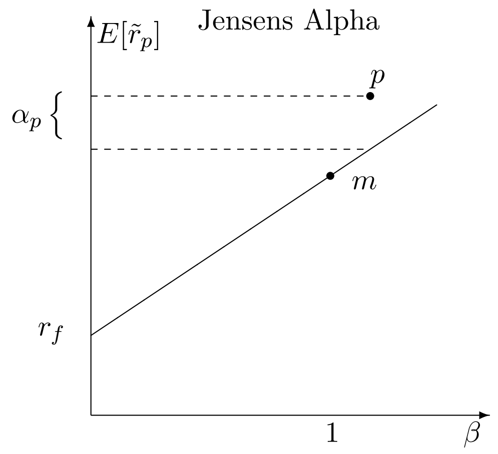
The classical such asset pricing model is the CAPM, which is what Jensen used

$$\hat{r}_p = (r_f + \beta_p(r_m - r_f))$$

Alpha is then

$$\alpha_p = r_p - (r_f + \beta_p(r_m - r_f))$$

Graphically:



The CAPM is not the only possible asset pricing model. Models such as the Fama-French three and five factor models are common alternatives.

If $\alpha_p > 0$, this is interpreted as positive performance.

5.1 Alpha estimation for the fund

Estimate the "alpha" of the equity portfolio, using the global Fama French factors.

$$r_{pt} - r_{ft} = \alpha + \beta(r_{mt} - r_{ft}) + \varepsilon_t$$

$$r_{pt} - r_{ft} = \alpha + \beta(r_{mt} - r_{ft}) + b^{SMB}SMB_t + b^{HML}HML_t + \varepsilon_t$$

$$r_{pt} - r_{ft} = \alpha + \beta(r_{mt} - r_{ft}) + b^{SMB}SMB_t + b^{HML}HML_t + b^{RMW}RMW_t + +b^{CMA}CMA_t + \varepsilon_t$$

Here r_{pt} is the portfolio return, r_{ft} the risk free rate, and r_{mt} the return on a market portfolio. Here SMB_t and HML_t are the two Fama French factors on market size and book to market, and then the two additional Fama French factors RMW and CMA. All of these are the global (developed) factors.

This is the estimation one would grab for without thinking too hard.

But the NBIM portfolio should be evaluated by asking whether it "outperforms" the benchmark b, and we should investigate the models of type

$$r_{pt} - r_{bt} = r_{diff,t} = \alpha + \beta(r_{mt} - r_{ft}) + \varepsilon_t$$

Table 3 Alpha estimation

Alpha estimation using NBIM portfolio *p*. Returns in USD.

	Dependent variable:		
	eRp		
	One Factor	Three Factors	Five Factors
Constant	−0.0004	−0.001	−0.001**
	(0.0004)	(0.0003)	(0.0004)
RMRF	1.048***	1.054***	1.056***
	(0.008)	(0.008)	(0.009)
SMB		−0.037**	−0.028
		(0.018)	(0.019)
HML		0.068***	0.082***
		(0.012)	(0.020)
RMW			0.054**
			(0.024)
CMA			−0.028
			(0.029)
Observations	293	293	293
Adjusted R^2	0.984	0.985	0.986
Note:			*p<0.1; **p<0.05; ***p<0.01

This is asking whether the *difference portfolio* has positive alpha.

File: `alpha_estimation_USD.R`

```
library(stargazer)
source ("~/data/2023/french_global_data/read_global_5_pricing_factors.R")
source ("../2023_01_read_current/read_nbim_USD_returns_from_excel.R")
outdir <- "../../results/2023_01_alpha_estimation/"

data <- merge(Equity_Rets_USD,
              Equity_Benchmark_Rets_USD,
              RF,RMRF,SMB,HML,RMW,CMA,all=FALSE)
Rp  <- data$Equity_Rets_USD
eRp <- Rp-data$RF
RMRF <- data$RMRF
SMB <- data$SMB
HML <- data$HML
RMW <- data$RMW
CMA <- data$CMA

regr9822_1 <- lm(eRp~RMRF)
regr9822_3 <- lm(eRp~RMRF+SMB+HML)
regr9822_5 <- lm(eRp~RMRF+SMB+HML+RMW+CMA)

filename <- paste0(outdir,
                 "alpha_estimation_equity_USD_whole_period_one_three_five_factor_model.tex")
stargazer(regr9822_1,
         regr9822_3,
         regr9822_5,
```

Table 4 Alpha estimation

Alpha estimation using difference NBIM portfolio p and benchmark b. Returns in USD.

	Dependent variable:		
	diffRp		
	One Factor	Three Factors	Five Factors
Constant	0.0003**	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)
RMRF	0.017***	0.016***	0.012***
	(0.002)	(0.002)	(0.003)
SMB		0.040***	0.038***
		(0.005)	(0.006)
HML		−0.015***	−0.002
		(0.004)	(0.006)
RMW			−0.002
			(0.007)
CMA			−0.025***
			(0.009)
Observations	293	293	293
Adjusted R^2	0.141	0.299	0.313
Note:			*p<0.1; **p<0.05; ***p<0.01

```r
          column.labels=c("One Factor","Three Factors","Five Factors"),
          no.space=TRUE,
          model.numbers=FALSE,
          float=FALSE,
          align=TRUE,
          digits=3,
          intercept.top=TRUE,
          intercept.bottom=FALSE,
          out=filename,
          omit.stat=c("rsq","f","ser")
          )

data <- merge(Equity_Rets_USD,
              Equity_Benchmark_Rets_USD,
              RF,RMRF,SMB,HML,RMW,CMA,
              all=FALSE)
diffRp   <- data$Equity_Rets_USD-data$Equity_Benchmark_Rets_USD
RMRF <- data$RMRF
SMB <- data$SMB
HML <- data$HML
RMW <- data$RMW
CMA <- data$CMA

regr9822_1 <- lm(diffRp~RMRF)
regr9822_3 <- lm(diffRp~RMRF+SMB+HML)
regr9822_5 <- lm(diffRp~RMRF+SMB+HML+RMW+CMA)

filename <- paste0(outdir,
```

```
                "alpha_estimation_diff_equity_USD_whole_period_one_three_five_factor_model.tex")
stargazer(regr9822_1,
        regr9822_3,
        regr9822_5,
        column.labels=c("One Factor","Three Factors","Five Factors"),
        no.space=TRUE,
        model.numbers=FALSE,
        float=FALSE,
        align=TRUE,
        digits=3,
        intercept.top=TRUE,
        intercept.bottom=FALSE,
        out=filename,
        omit.stat=c("rsq","f","ser")
        )
```

See **?**