

Assignment 7

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```
library('tidyverse')

## Warning: package 'tidyverse' was built under R version 3.6.3

## -- Attaching packages -----

## v ggplot2 3.3.2      v purrr  0.3.4
## v tibble  3.0.3      v dplyr  1.0.2
## v tidyr   1.1.2      v stringr 1.4.0
## v readr   1.4.0      v forcats 0.5.0

## Warning: package 'ggplot2' was built under R version 3.6.3
## Warning: package 'tibble' was built under R version 3.6.3
## Warning: package 'tidyr' was built under R version 3.6.3
## Warning: package 'readr' was built under R version 3.6.3
## Warning: package 'purrr' was built under R version 3.6.3
## Warning: package 'dplyr' was built under R version 3.6.3
## Warning: package 'forcats' was built under R version 3.6.3

## -- Conflicts -----
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()     masks stats::lag()

library("lubridate")

## Warning: package 'lubridate' was built under R version 3.6.3

##
## Attaching package: 'lubridate'

## The following objects are masked from 'package:base':
##
##   date, intersect, setdiff, union

library("readxl")
library("zoo")

## Warning: package 'zoo' was built under R version 3.6.3
```

```

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##      as.Date, as.Date.numeric

setwd('C:/Users/Zhongyun Zhang/Desktop/')
dataset <- read.csv('dataset.csv')
dataset$CUSIP = substr(dataset$CUSIP,1,6)
dataset$Year = dataset$FYEAR + 2

#add investment (IV) based on format codes
dataset$IV <- ifelse(dataset$SCF<4,
dataset$CAPX+dataset$IVCH+dataset$AQC+dataset$FUSEO-dataset$SPPE-dataset$SIV,
  ifelse(dataset$SCF==7,
dataset$CAPX+dataset$IVCH+dataset$AQC-dataset$SPPE-dataset$SIV-
dataset$IVSTCH-dataset$IVACO, NA))
#add Internal cash flow (ICF) based on format codes
dataset$ICF <- ifelse(dataset$SCF<4,
dataset$IBC+dataset$XIDOC+dataset$DPC+dataset$TXDC+dataset$ESUBC+dataset$SPPI
V+dataset$FOPO+dataset$FSRCO, ifelse(dataset$SCF==7,
dataset$IBC+dataset$XIDOC+dataset$DPC+dataset$TXDC+dataset$ESUBC+dataset$SPPI
V+dataset$FOPO+dataset$EXRE, NA))

fundamentals <- dataset %>% group_by(CUSIP) %>% mutate(Book = AT,
  Cash_Flow = rollmean(ICF, 5, partial=TRUE, fill = NA),
  Revenue = rollmean(SALE+NOPI+SPI, 5, partial=TRUE, fill =
NA),

  Sales = rollmean(SALE, 5, partial=TRUE, fill = NA),
  Dividends = rollmean(DV, 5, partial=TRUE, fill = NA),
  Investment = rollmean(IV, 5, partial=TRUE, fill = NA),
  Profitability = rollmean(NI/AT, 5, fill = NA),
  Asset_turnover = SALE/((AT + lag(AT))/2),
  Altman_Z = 1.2*(ACT-LCT)/AT + 1.4*(RE/AT) + 3.3*(OIADP/AT)
+
  0.6*(PRCC_F*CSHO)/LT + 0.99*SALE/AT,
  Ohlson_0 = -1.32 -0.407*log(AT) + 6.03*LT/AT - 1.43*(ACT-
LCT)/AT +
  0.0757*LCT/ACT - 2.37*NI/AT - 1.83*(PI+DP)/LT -
  1.72*ifelse(LT>AT, 1, 0) +
  0.285*ifelse(lag(NI)<0 & lag(NI, k=2)<0, 1, 0) -
  (NI-lag(NI))/(abs(NI) + abs(lag(NI)))) %>%
  select(CUSIP, Year, Book: Ohlson_0)

setwd('C:/Users/Zhongyun Zhang/Desktop/')
msf <- read.csv('msf.csv')
colnames(msf)[2] <- "Date"
msf$Date <- msf$Date %>% as.Date(format = "%m/%d/%Y") %>% as.yearmon()
msf$RET <- msf$RET %>% as.character %>% as.numeric()

```

```

## Warning in function_list[[k]](value): NAs introduced by coercion

library(devtools)

## Warning: package 'devtools' was built under R version 3.6.3

## Loading required package: usethis

## Warning: package 'usethis' was built under R version 3.6.3

install_github("antshi/ffData")

## WARNING: Rtools is required to build R packages, but is not currently
installed.
##
## Please download and install Rtools 3.5 from https://cran.r-
project.org/bin/windows/Rtools/.

## Skipping install of 'ffData' from a github remote, the SHA1 (766c050f) has
not changed since last install.
## Use `force = TRUE` to force installation

#library(devtools)
#install_github("antshi/ffData")
#library(ffData)
#devtools::install_github("sstoeckl/ffdownload")

#download the FF data and import
#ffDataDownload(type = "USResearch", number_factors = 3, freq = "m",
#start = "192607", end = "202006")
setwd("C:/Users/Zhongyun Zhang/Desktop/")

FF <- read.csv('F-F_Research_Data_Factors.csv')
library(readr)
FF_mom <- read_table2("C:/Users/Zhongyun Zhang/Desktop/F-
F_Momentum_Factor.TXT", col_names = FALSE)

##
## -- Column specification -----
## cols(
##   X1 = col_double(),
##   X2 = col_double()
## )

## Warning: 6 parsing failures.
## row col expected          actual
file
## 1125 X1 a double Annual      'C:/Users/Zhongyun Zhang/Desktop/F-
F_Momentum_Factor.TXT'
## 1125 X2 a double Factors:    'C:/Users/Zhongyun Zhang/Desktop/F-
F_Momentum_Factor.TXT'
## 1126 X1 a double January-December 'C:/Users/Zhongyun Zhang/Desktop/F-

```

```

F_Momentum_Factor.TXT'
## 1127 X1 a double Mom 'C:/Users/Zhongyun Zhang/Desktop/F-
F_Momentum_Factor.TXT'
## 1221 X1 a double Copyright 'C:/Users/Zhongyun Zhang/Desktop/F-
F_Momentum_Factor.TXT'
## ....
.....
## See problems(...) for more details.

colnames(FF_mom)[1] <- "Date"
colnames(FF_mom)[2] <- "Momentum"

FF_mom$Date <- FF_mom$Date %>% as.character %>% paste("01") %>%
as.Date("%Y%m%d") %>% as.yearmon()
FF$Date <- FF$Date %>% as.character %>% paste("01") %>% as.Date("%Y%m%d")
%>% as.yearmon()

FF <- left_join(FF, FF_mom)

## Joining, by = "Date"

FF$Date <- FF$Date + 1/12

msf_lagged <- msf %>% group_by(PERMNO) %>% mutate(PRC_lagged = lag(PRC)) %>%
mutate(RET_lagged = lag(RET)) %>% mutate(SHROUT_lagged = lag(SHROUT)) %>%
mutate(VWRETD_lagged = lag(VWRETD))

msf_lagged$Year <- msf_lagged$Date %>% year

```

To get the Stock's Betas for the past 12 months

```

beta_finder <- function(m) {
y = m/12

list <- msf_lagged %>% filter(Year < 1927 & Year >= 1926) %>%
group_by(PERMNO) %>%
summarize(beta = cov(RET_lagged, VWRETD_lagged)/var(VWRETD_lagged, na.rm =
T))

names(list)[2] <- "1927"

for (years in 1928:2019) {
list_beta <- msf_lagged %>% filter(Year < years &
Year >= years - y) %>% group_by(PERMNO) %>%
summarize(beta = cov(RET_lagged, VWRETD_lagged)/var(VWRETD_lagged, na.rm
= T))

names(list_beta)[2] <- as.character(years)

list <- list %>% full_join(list_beta, by = "PERMNO")
}

```

```

}

list <- list[order(list$PERMNO),]

return(list)
}

betadata <- beta_finder(12)
print(betadata)

## # A tibble: 33,018 x 94
##   PERMNO `1927` `1928` `1929` `1930` `1931` `1932` `1933` `1934` `1935`
##   <int> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1 10000      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 2 10001      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 3 10002      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 4 10003      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 5 10005      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 6 10006      NA  1.01  0.517  0.309  0.198  1.68  2.12  2.09  2.05
3.52
## 7 10007      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 8 10008      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 9 10009      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## 10 10010      NA  NA    NA    NA    NA    NA    NA    NA    NA
NA
## # ... with 33,008 more rows, and 83 more variables: `1937` <dbl>, `1938`
<dbl>,
## # `1939` <dbl>, `1940` <dbl>, `1941` <dbl>, `1942` <dbl>, `1943` <dbl>,
## # `1944` <dbl>, `1945` <dbl>, `1946` <dbl>, `1947` <dbl>, `1948` <dbl>,
## # `1949` <dbl>, `1950` <dbl>, `1951` <dbl>, `1952` <dbl>, `1953` <dbl>,
## # `1954` <dbl>, `1955` <dbl>, `1956` <dbl>, `1957` <dbl>, `1958` <dbl>,
## # `1959` <dbl>, `1960` <dbl>, `1961` <dbl>, `1962` <dbl>, `1963` <dbl>,
## # `1964` <dbl>, `1965` <dbl>, `1966` <dbl>, `1967` <dbl>, `1968` <dbl>,
## # `1969` <dbl>, `1970` <dbl>, `1971` <dbl>, `1972` <dbl>, `1973` <dbl>,
## # `1974` <dbl>, `1975` <dbl>, `1976` <dbl>, `1977` <dbl>, `1978` <dbl>,
## # `1979` <dbl>, `1980` <dbl>, `1981` <dbl>, `1982` <dbl>, `1983` <dbl>,
## # `1984` <dbl>, `1985` <dbl>, `1986` <dbl>, `1987` <dbl>, `1988` <dbl>,
## # `1989` <dbl>, `1990` <dbl>, `1991` <dbl>, `1992` <dbl>, `1993` <dbl>,
## # `1994` <dbl>, `1995` <dbl>, `1996` <dbl>, `1997` <dbl>, `1998` <dbl>,
## # `1999` <dbl>, `2000` <dbl>, `2001` <dbl>, `2002` <dbl>, `2003` <dbl>,

```

```
## # `2004` <dbl>, `2005` <dbl>, `2006` <dbl>, `2007` <dbl>, `2008` <dbl>,
## # `2009` <dbl>, `2010` <dbl>, `2011` <dbl>, `2012` <dbl>, `2013` <dbl>,
## # `2014` <dbl>, `2015` <dbl>, `2016` <dbl>, `2017` <dbl>, `2018` <dbl>,
## # `2019` <dbl>
```

To get the Stock's Volatility for each year

```
total_volatility_1 <- msf_lagged %>% group_by(PERMNO, Year) %>%
  summarize(volatility1 = 100 * (((sum ((RET_lagged - mean(RET_lagged, na.rm =
T))^2, na.rm = T) /
                                (n() - sum(is.na(RET_lagged)) -
1)))^0.5) * (12^0.5))
```

```
## `summarise()` regrouping output by 'PERMNO' (override with `.groups`
argument)
```

```
print(total_volatility_1)
```

```
## # A tibble: 412,894 x 3
## # Groups:   PERMNO [33,556]
##   PERMNO Year volatility1
##   <int> <dbl>      <dbl>
## 1 10000 1985         0
## 2 10000 1986      87.7
## 3 10000 1987      58.1
## 4 10001 1985         0
## 5 10001 1986      10.3
## 6 10001 1987      17.0
## 7 10001 1988      15.0
## 8 10001 1989      28.2
## 9 10001 1990       8.89
## 10 10001 1991      21.2
## # ... with 412,884 more rows
```

To get the Stock's Volatility for each year using another measure

```
total_volatility_2 <- msf_lagged %>% group_by(PERMNO, Year) %>%
  summarize(volatility2 = 100 * (((sum ((RET_lagged)^2, na.rm = T) /
                                (n() - sum(is.na(RET_lagged))))^0.5) * (12^0.5))
```

```
## `summarise()` regrouping output by 'PERMNO' (override with `.groups`
argument)
```

```
print(total_volatility_2)
```

```
## # A tibble: 412,894 x 3
## # Groups:   PERMNO [33,556]
##   PERMNO Year volatility2
##   <int> <dbl>      <dbl>
## 1 10000 1985        NaN
## 2 10000 1986      92.3
## 3 10000 1987      82.9
```

```
## 4 10001 1985      NaN
## 5 10001 1986      11.7
## 6 10001 1987      16.4
## 7 10001 1988      15.0
## 8 10001 1989      30.7
## 9 10001 1990       8.56
## 10 10001 1991     25.1
## # ... with 412,884 more rows
```

To compute the idiosyncratic volatility

```
#library('broom')
```

The function to calculate the volatility using 1 factor regression

```
vol_by_regression <- function() {
  dt <- NA
  for (stocks in unique(msf_lagged$PERMNO)) {
    df_t <- NA
    for (years in 1926:2019) {
      ld <- msf_lagged %>% filter(PERMNO == stocks &
                                Year == years)

      cont_check <- dim(ld)[1]
      na_check <- ld$RET_lagged %>% is.na() %>% sum
      if (cont_check > 0 & na_check < 12) {
        fit <- lm(data = ld, RET_lagged ~ Mkt.RF)
        RSE <- sqrt(deviance(fit)/df.residual(fit))
      } else {
        RSE <- NA
      }
      RSE <- data.frame(RSE)
      names(RSE) <- as.character(years)
      df_t <- cbind(df_t, RSE)
    }
    row.names(df_t) <- as.character(stocks)
    df_t <- df_t[-1]
    dt <- rbind(dt, df_t)
  }
}
```

To merge MSF and F-F datasets

```
msf_lagged_FF <- left_join(msf_lagged, FF, by = "Date")
```

To calculate Beta and Alpha and errors manually, this saves a lot of calculation time and avoid using too many loops of regression models

```
idiosync_vol1 <- msf_lagged %>% group_by(PERMNO, Year) %>%
  mutate(beta = cov(RET_lagged, VWRETD_lagged,
                    use = "pairwise.complete.obs")/var(VWRETD_lagged, na.rm =
```

```

T),
  alpha = mean(RET_lagged, na.rm = T) - beta*mean(VWRETD_lagged, na.rm
= T),
  error = RET_lagged - (alpha + beta*VWRETD_lagged)) %>%
group_by(PERMNO, Year) %>%
summarize(RSE = sqrt(sum(error^2, na.rm = T) / (n()-sum(is.na(error))-2) ),
  m = n()-sum(is.na(error))) %>%
mutate(Idiosyncratic_vol1 = 100*ifelse((RSE!=Inf), RSE, NA)*sqrt(m))
print(idiosync_vol1)

## # A tibble: 412,894 x 5
## # Groups:   PERMNO [33,556]
##   PERMNO  Year    RSE      m Idiosyncratic_vol1
##   <int> <dbl> <dbl> <int>          <dbl>
## 1  10000  1985  0         0            0
## 2  10000  1986 0.259      10          82.0
## 3  10000  1987 0.187       6          45.8
## 4  10001  1985  0         0            0
## 5  10001  1986 0.0273     10           8.63
## 6  10001  1987 0.0515     12          17.8
## 7  10001  1988 0.0453     12          15.7
## 8  10001  1989 0.0853     12          29.6
## 9  10001  1990 0.0262     12           9.07
## 10 10001  1991 0.0549     12          19.0
## # ... with 412,884 more rows

```

To calculate the RSEs and idiosyncratic volatility using F-F 3-factor model

```

idiosync_vol2 <- msf_lagged_FF %>% group_by(PERMNO, Year) %>%
  mutate(beta1 = cov(RET_lagged, Mkt.RF,
    use = "pairwise.complete.obs")/var(Mkt.RF, na.rm = T),
    beta2 = cov(RET_lagged, SMB,
    use = "pairwise.complete.obs")/var(SMB, na.rm = T),
    beta3 = cov(RET_lagged, HML,
    use = "pairwise.complete.obs")/var(HML, na.rm = T),
    alpha = mean(RET_lagged, na.rm = T) -
      (beta1*mean(Mkt.RF, na.rm = T) +
        beta2*mean(SMB, na.rm = T) +
        beta3*mean(HML, na.rm = T)),

    error = RET_lagged - (alpha + beta1*Mkt.RF +
      beta2*SMB + beta3*HML)) %>%
  group_by(PERMNO, Year) %>%
  summarize(RSE = sqrt(sum(error^2, na.rm = T) / (n()-sum(is.na(error))-4)),
    m = n()- sum(is.na(error))) %>%
  mutate(Idiosyncratic_vol2 = 100*ifelse((RSE!=Inf), RSE, NA)*sqrt(m))

print(idiosync_vol2)

## # A tibble: 412,894 x 5
## # Groups:   PERMNO [33,556]

```



```
##      PERMNO  Year    RSE      m Idiosyncratic_vol2
##      <int> <dbl>  <dbl> <int>          <dbl>
##  1  10000  1985  0        0          0
##  2  10000  1986 0.287     10        90.9
##  3  10000  1987 0.234      6        57.4
##  4  10001  1985  0        0          0
##  5  10001  1986 0.0325    10        10.3
##  6  10001  1987 0.0548    12        19.0
##  7  10001  1988 0.0432    12        15.0
##  8  10001  1989 0.0928    12        32.1
##  9  10001  1990 0.0299    12        10.4
## 10  10001  1991 0.0657    12        22.8
## # ... with 412,884 more rows
```

To calculate the RSEs and idiosyncratic volatility using F-F 3-factor model and Carhart Momentum factor

```
idiosync_vol3 <- msf_lagged_FF %>% group_by(PERMNO, Year) %>%
  mutate(beta1 = cov(RET_lagged, Mkt.RF,
    use = "pairwise.complete.obs")/var(Mkt.RF, na.rm = T),
    beta2 = cov(RET_lagged, SMB,
    use = "pairwise.complete.obs")/var(SMB, na.rm = T),
    beta3 = cov(RET_lagged, HML,
    use = "pairwise.complete.obs")/var(HML, na.rm = T),
    beta4 = cov(RET_lagged, Momentum,
    use = "pairwise.complete.obs")/var(Momentum, na.rm = T),
    alpha = mean(RET_lagged, na.rm = T) -
      (beta1*mean(Mkt.RF, na.rm = T) +
        beta2*mean(SMB, na.rm = T) +
        beta3*mean(HML, na.rm = T) +
        beta4*mean(Momentum, na.rm = T)),
    error = RET_lagged - (alpha + beta1*Mkt.RF +
      beta2*SMB + beta3*HML + beta4*Momentum)) %>%
  group_by(PERMNO, Year) %>%
  summarize(RSE = sqrt(sum(error^2, na.rm = T) / (n()-sum(is.na(error))-5)),
    m = n()-sum(is.na(error))) %>%
  mutate(Idiosyncratic_vol3 = 100*ifelse((RSE!=Inf), RSE, NA)*sqrt(m))

print(idiosync_vol3)

## # A tibble: 412,894 x 5
## # Groups:   PERMNO [33,556]
##      PERMNO  Year    RSE      m Idiosyncratic_vol3
##      <int> <dbl>  <dbl> <int>          <dbl>
##  1  10000  1985  0        0          0
##  2  10000  1986 0.275     10        87.1
##  3  10000  1987 0.351      6        85.9
##  4  10001  1985  0        0          0
##  5  10001  1986 0.0246    10         7.77
```

```
## 6 10001 1987 0.0585 12 20.3
## 7 10001 1988 0.0467 12 16.2
## 8 10001 1989 0.0985 12 34.1
## 9 10001 1990 0.0288 12 9.99
## 10 10001 1991 0.0729 12 25.3
## # ... with 412,884 more rows
```

To restrict stocks with market capitalization of \$100 million

```
msf_restricted <- msf_lagged_FF %>% filter(abs(PRC_lagged)*SHROUT_lagged >=
100000 &
                                abs(PRC_lagged) > 5 & Date>= 1970)
msf_restricted$CUSIP <- substr(msf_restricted$CUSIP, 1, 6)
```

To calculate the annual returns of each stock

```
msf_annual_return <- msf_restricted %>% group_by(Year, PERMNO) %>%
  mutate(annual_return = cumprod(ifelse(is.na(RET_lagged), 1,
(RET_lagged+1)))-1,
        annual_VWRETD = cumprod(ifelse(is.na(VWRETD_lagged), 1,
(VWRETD_lagged+1)))-1,
        annual_Mkt.RF = cumprod(ifelse(is.na(Mkt.RF), 1, (Mkt.RF+1)))-1,
        annual_SMB = cumprod(ifelse(is.na(SMB), 1, (SMB+1)))-1,
        annual_HML = cumprod(ifelse(is.na(HML), 1, (HML+1)))-1,
        annual_RF = cumprod(ifelse(is.na(RF), 1, (RF+1)))-1) %>%
  group_by(Year, PERMNO) %>% top_n(1, Date)
```

To merge the COMPUSTAT data and CRSP data:

```
merged <- inner_join(msf_annual_return, fundamentals, by = c("Year",
"CUSIP"))

library("readxl")
library("lubridate")
USREC <- read_excel(paste("C:/Users/Zhongyun Zhang/Desktop/USREC.xls"), skip =
10)
colnames(USREC)[1] <- "Date"
USREC$Year <- USREC$Date %>% as.numeric() %>% as.Date(origin="1899-12-30")
%>% year

## Warning in function_list[[i]](value): NAs introduced by coercion
USREC <- USREC %>% group_by(Year) %>% summarize(recession = max(USREC))
## `summarise()` ungrouping output (override with `.groups` argument)
```

To get the recession data and make them with start and end dates

```
library(quantmod)

## Warning: package 'quantmod' was built under R version 3.6.3
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 3.6.3
##
## Attaching package: 'xts'
##
## The following objects are masked from 'package:dplyr':
##
##     first, last
##
## Loading required package: TTR
##
## Warning: package 'TTR' was built under R version 3.6.3
##
## Registered S3 method overwritten by 'quantmod':
##   method             from
##   as.zoo.data.frame zoo
##
## Version 0.4-0 included new data defaults. See ?getSymbols.

getSymbols("USREC",src="FRED")

## 'getSymbols' currently uses auto.assign=TRUE by default, but will
## use auto.assign=FALSE in 0.5-0. You will still be able to use
## 'loadSymbols' to automatically load data. getOption("getSymbols.env")
## and getOption("getSymbols.auto.assign") will still be checked for
## alternate defaults.
##
## This message is shown once per session and may be disabled by setting
## options("getSymbols.warning4.0"=FALSE). See ?getSymbols for details.

## [1] "USREC"

start <- index(USREC[which(diff(USREC$USREC)==1)])
end   <- index(USREC[which(diff(USREC$USREC)==-1)-1])
start <- year(start)
end   <- year(end)
recession <- cbind(start=start[-34], end=end[-1])
recession <- as.data.frame(recession)
```

The function to calculate portfolio return based on fundamental values and plot the results together with VWRETD returns

```
funda_indexing <- function(funda_value, y1, y2){
funda <- as.name(funda_value)
recession_data <- recession %>% filter(start>=y1 & end <= y2)
output <- merged %>% filter(Year>=y1 & Year<=y2) %>% group_by(Year) %>%
  mutate(weight = eval(funda)/sum(eval(funda), na.rm = T),
          weighted_return = annual_return*weight) %>% group_by(Year) %>%
  summarize(portfolio_return = sum(weighted_return, na.rm = T),
            annual_VWRETD = median(annual_VWRETD)) %>%
  mutate(cum_port_return = cumprod((portfolio_return + 1)),
         cum_VWRETD = cumprod(annual_VWRETD + 1))
```

```

print(output)

plt <- output %>% ggplot(aes(x = Year)) +
  geom_line(aes(y = cum_port_return,
                color = "Cum Portfolio Return")) +
  geom_line(aes(y = cum_VWRETD,
                color = "Cum VWRETD Return")) +
  scale_y_continuous(name = "Cum VWRETD Return",
                     sec.axis = sec_axis(~ ., name = "Cum VWRETD Return")) +
  labs(title = paste("Fundamental Indexing based on:",
                    as.character(funda_value)), color =
"Data") +
  geom_rect(data=recession_data,
            aes(xmin=start,xmax=end, ymin=-Inf,ymax=Inf),
            inherit.aes = FALSE, fill="blue", alpha=0.2) +
  labs(caption = "Recession Shown in Shaded Area") + theme_bw() +
  theme(legend.position = "bottom")

print(plt)
}

```

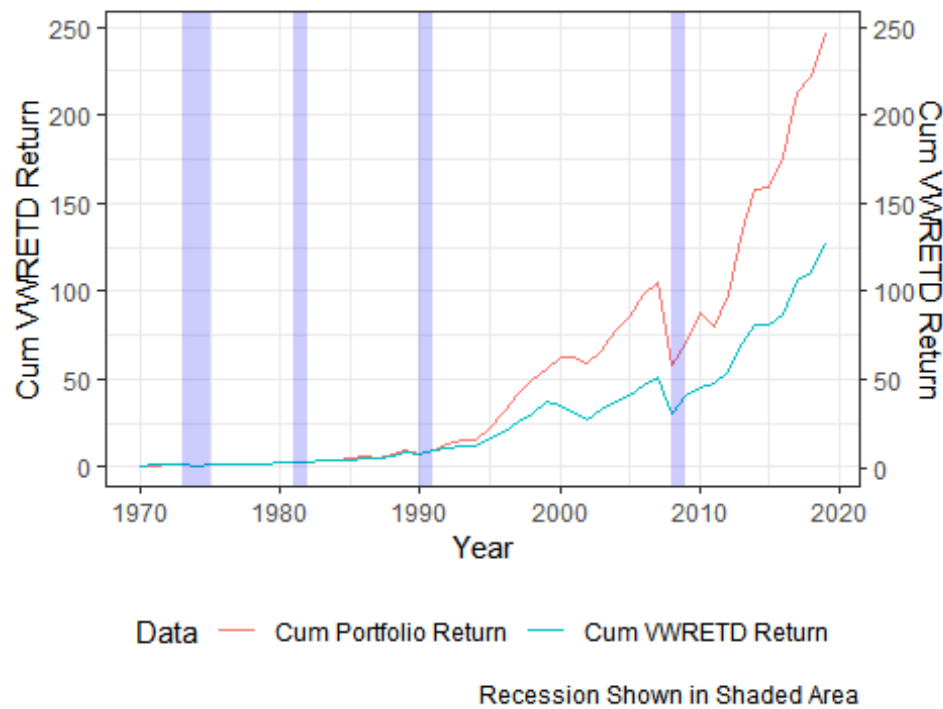
```
funda_indexing("Book", 1970, 2019)
```

```

## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.0864         -0.0751         0.914         0.925
## 2 1971          0.0600          0.129         0.968         1.04
## 3 1972          0.287          0.266         1.25          1.32
## 4 1973         -0.0999         -0.188         1.12          1.07
## 5 1974         -0.148         -0.251         0.956         0.805
## 6 1975          0.256          0.351         1.20          1.09
## 7 1976          0.268          0.181         1.52          1.28
## 8 1977          0.0515         0.0217         1.60          1.31
## 9 1978          0.0969         0.0753         1.76          1.41
## 10 1979         0.210          0.231         2.13          1.74
## # ... with 40 more rows

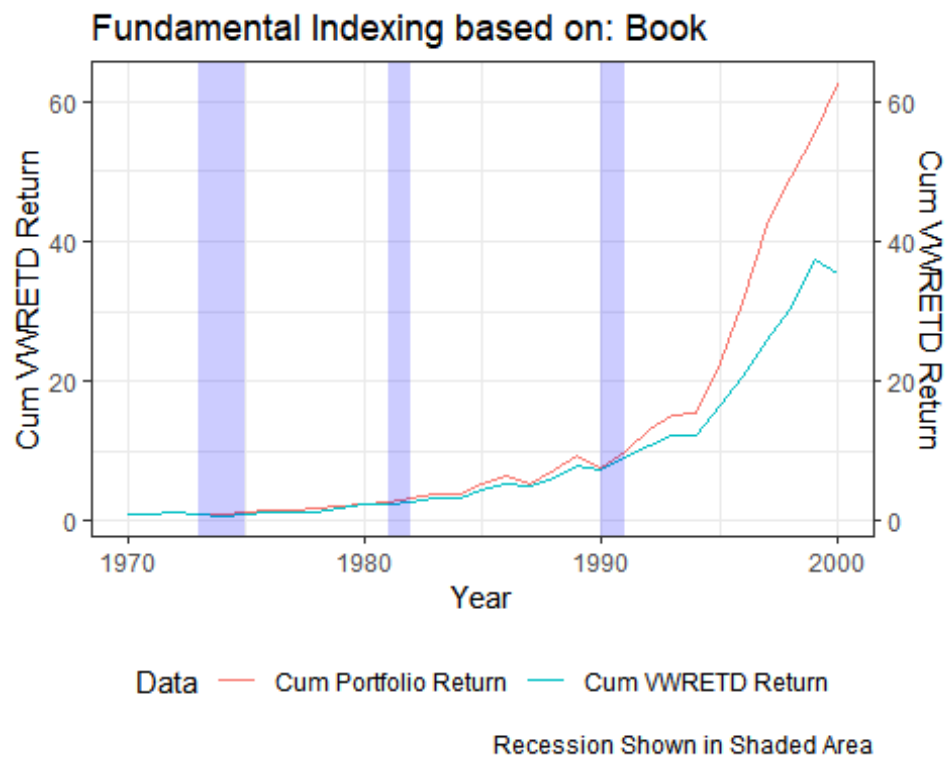
```

Fundamental Indexing based on: Book



```
funda_indexing("Book", 1970, 2000)
```

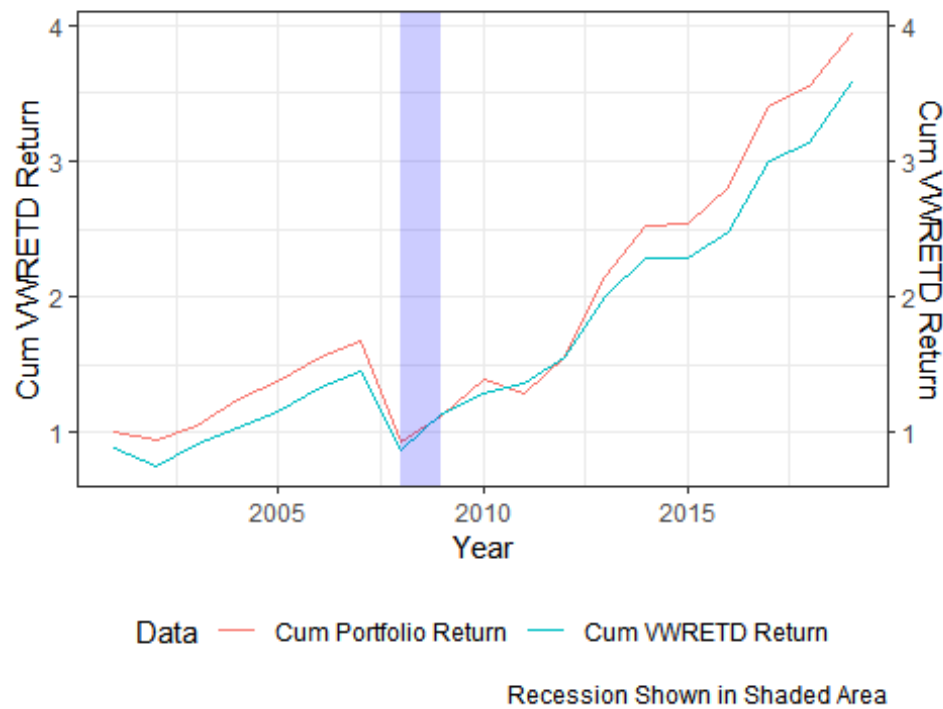
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0864      -0.0751         0.914         0.925
## 2 1971       0.0600       0.129          0.968         1.04
## 3 1972       0.287       0.266          1.25          1.32
## 4 1973      -0.0999      -0.188          1.12          1.07
## 5 1974      -0.148      -0.251          0.956         0.805
## 6 1975       0.256       0.351          1.20          1.09
## 7 1976       0.268       0.181          1.52          1.28
## 8 1977       0.0515      0.0217          1.60          1.31
## 9 1978       0.0969      0.0753          1.76          1.41
## 10 1979       0.210       0.231          2.13          1.74
## # ... with 21 more rows
```



```
funda_indexing("Book", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001         0.00158        -0.110         1.00         0.890
## 2 2002        -0.0571         -0.149         0.944         0.757
## 3 2003         0.116         0.205         1.05         0.913
## 4 2004         0.175         0.141         1.24         1.04
## 5 2005         0.110         0.107         1.37         1.15
## 6 2006         0.136         0.154         1.56         1.33
## 7 2007         0.0704         0.0891        1.67         1.45
## 8 2008        -0.445         -0.398         0.927         0.872
## 9 2009         0.216         0.305         1.13         1.14
##10 2010         0.240         0.134         1.40         1.29
##11 2011        -0.0818         0.0519        1.28         1.36
##12 2012         0.218         0.148         1.56         1.56
##13 2013         0.378         0.287         2.15         2.01
##14 2014         0.169         0.138         2.52         2.28
##15 2015         0.00672        0.00194        2.53         2.29
##16 2016         0.108         0.0814        2.81         2.47
##17 2017         0.209         0.214         3.39         3.00
##18 2018         0.0474         0.0422        3.56         3.13
##19 2019         0.108         0.144         3.94         3.58
```

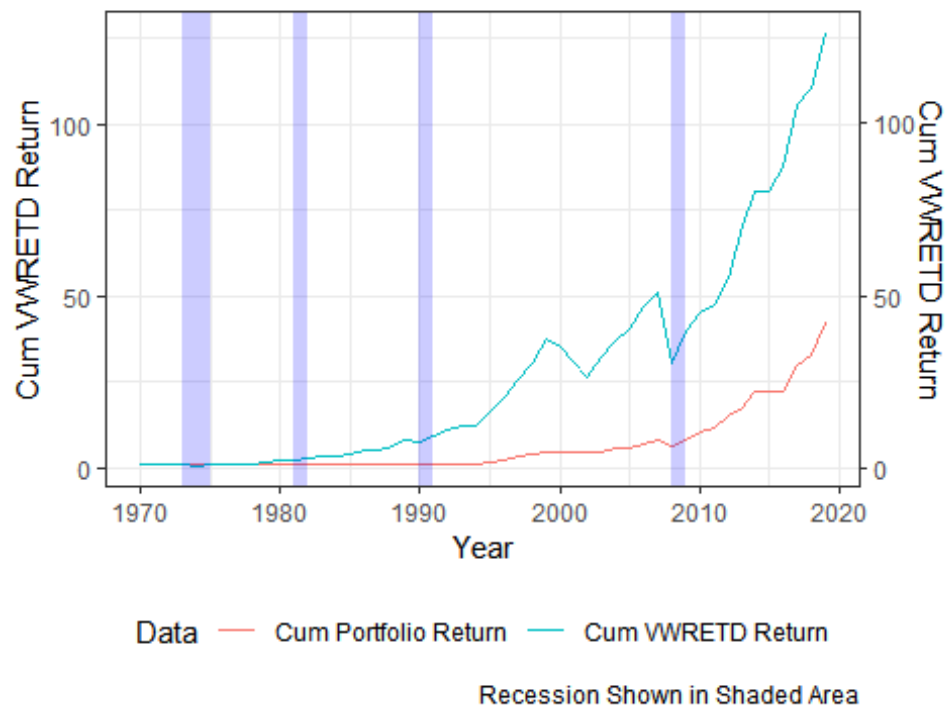
Fundamental Indexing based on: Book



```
funda_indexing("Cash_Flow", 1970, 2019)
```

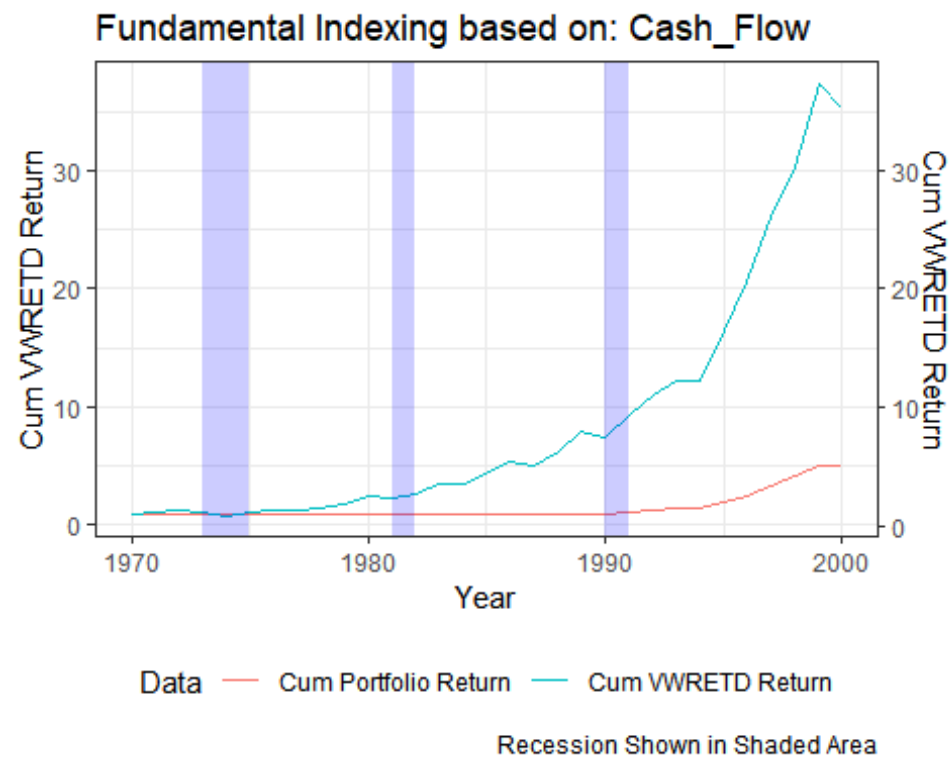
```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970             0      -0.0751             1      0.925
## 2 1971             0       0.129             1      1.04
## 3 1972             0       0.266             1      1.32
## 4 1973             0      -0.188             1      1.07
## 5 1974             0      -0.251             1      0.805
## 6 1975             0       0.351             1      1.09
## 7 1976             0       0.181             1      1.28
## 8 1977             0       0.0217            1      1.31
## 9 1978             0       0.0753            1      1.41
## 10 1979            0       0.231             1      1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: Cash_Flow



```
funda_indexing("Cash_Flow", 1970, 2000)
```

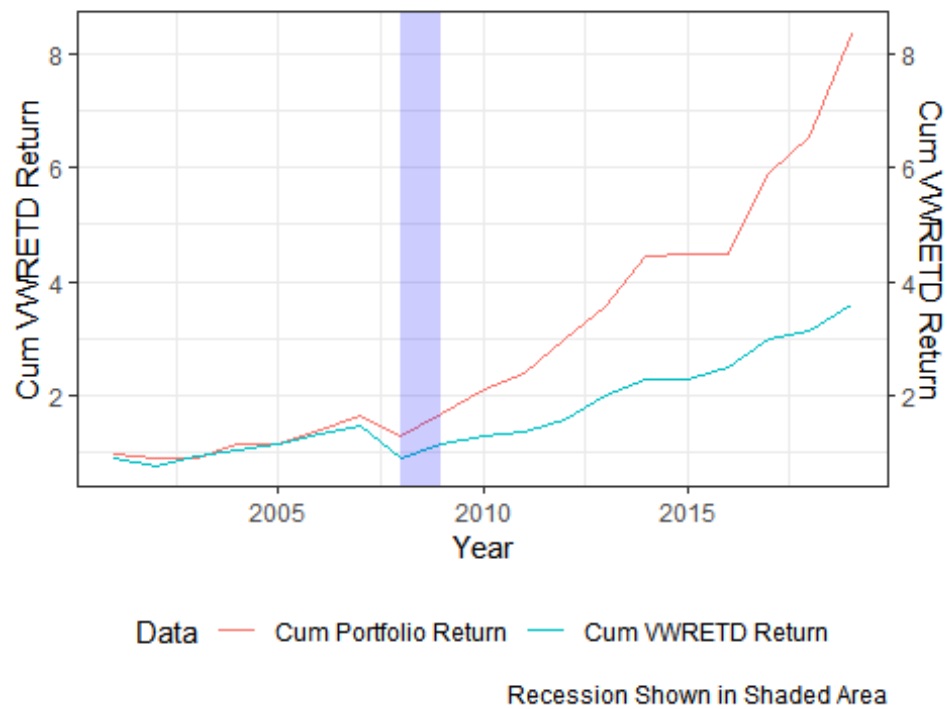
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970             0      -0.0751             1      0.925
## 2 1971             0       0.129             1      1.04
## 3 1972             0       0.266             1      1.32
## 4 1973             0      -0.188             1      1.07
## 5 1974             0      -0.251             1      0.805
## 6 1975             0       0.351             1      1.09
## 7 1976             0       0.181             1      1.28
## 8 1977             0       0.0217            1      1.31
## 9 1978             0       0.0753            1      1.41
## 10 1979            0       0.231             1      1.74
## # ... with 21 more rows
```

```
funda_indexing("Cash_Flow", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001      -0.0393      -0.110         0.961         0.890
## 2 2002      -0.0738      -0.149         0.890         0.757
## 3 2003     -0.00361      0.205         0.887         0.913
## 4 2004       0.288       0.141         1.14         1.04
## 5 2005       0.00939      0.107         1.15         1.15
## 6 2006       0.197       0.154         1.38         1.33
## 7 2007       0.193       0.0891        1.65         1.45
## 8 2008      -0.214      -0.398         1.29         0.872
## 9 2009       0.283       0.305         1.66         1.14
##10 2010       0.260       0.134         2.09         1.29
##11 2011       0.139       0.0519        2.38         1.36
##12 2012       0.260       0.148         3.00         1.56
##13 2013       0.184       0.287         3.55         2.01
##14 2014       0.250       0.138         4.44         2.28
##15 2015       0.00621      0.00194        4.47         2.29
##16 2016       0.00359      0.0814        4.48         2.47
##17 2017       0.318       0.214         5.91         3.00
##18 2018       0.107       0.0422        6.54         3.13
##19 2019       0.279       0.144         8.37         3.58
```

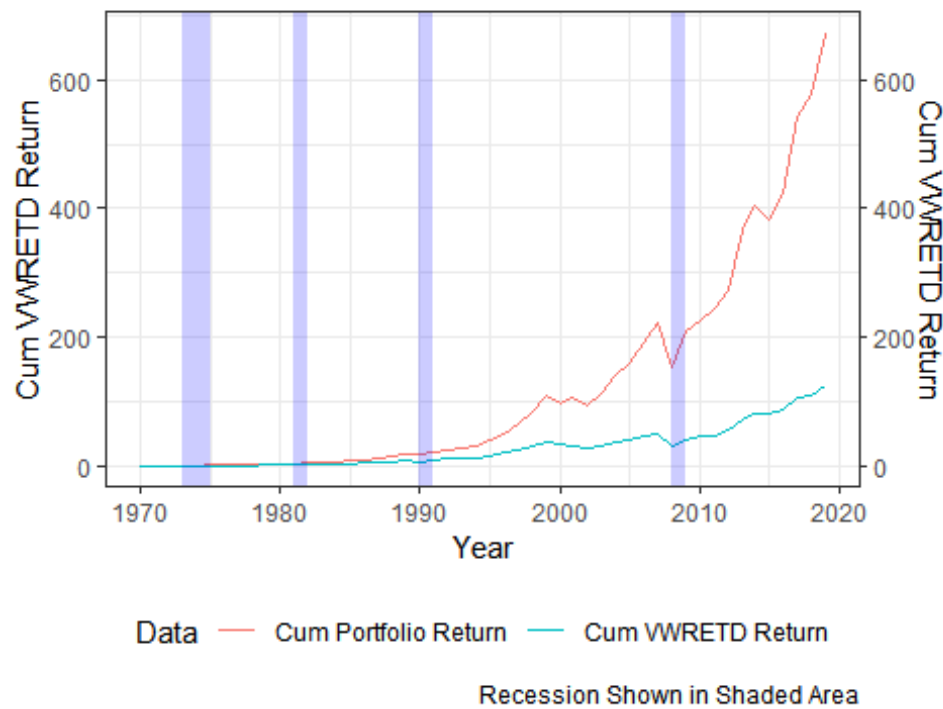
Fundamental Indexing based on: Cash_Flow



```
funda_indexing("Revenue", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.137         -0.0751         0.863         0.925
## 2 1971          0.152          0.129         0.994         1.04
## 3 1972          0.265          0.266         1.26         1.32
## 4 1973        -0.0634        -0.188         1.18         1.07
## 5 1974        -0.120        -0.251         1.04         0.805
## 6 1975          0.461          0.351         1.51         1.09
## 7 1976          0.244          0.181         1.88         1.28
## 8 1977          0.0613         0.0217         2.00         1.31
## 9 1978          0.171          0.0753         2.34         1.41
## 10 1979         0.322          0.231         3.09         1.74
## # ... with 40 more rows
```

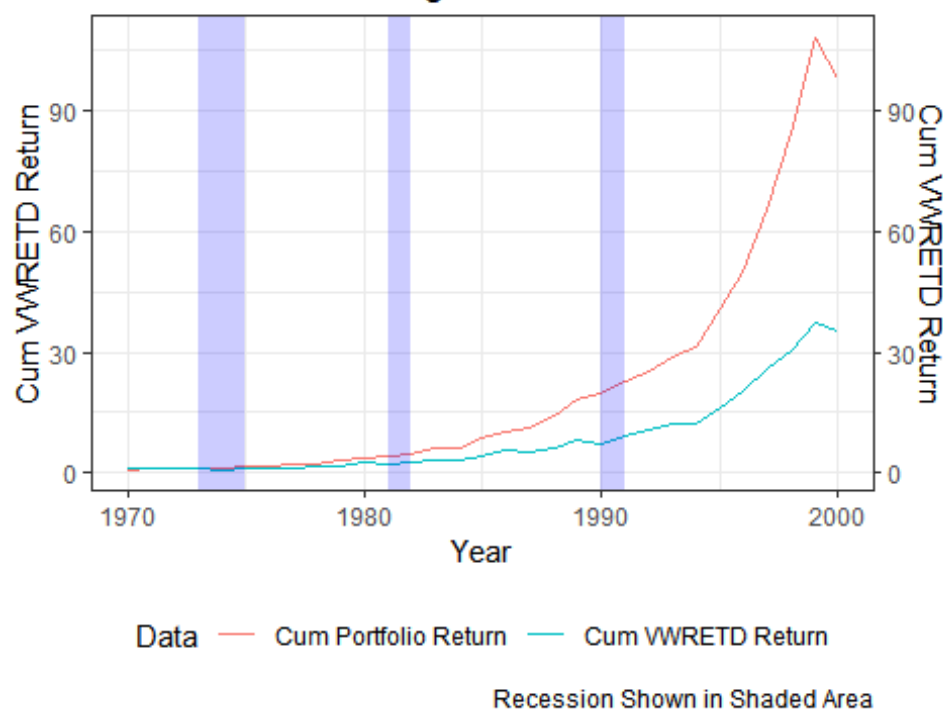
Fundamental Indexing based on: Revenue



```
funda_indexing("Revenue", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.137        -0.0751         0.863         0.925
## 2 1971         0.152         0.129         0.994         1.04
## 3 1972         0.265         0.266         1.26         1.32
## 4 1973        -0.0634        -0.188         1.18         1.07
## 5 1974        -0.120        -0.251         1.04         0.805
## 6 1975         0.461         0.351         1.51         1.09
## 7 1976         0.244         0.181         1.88         1.28
## 8 1977         0.0613         0.0217         2.00         1.31
## 9 1978         0.171         0.0753         2.34         1.41
## 10 1979         0.322         0.231         3.09         1.74
## # ... with 21 more rows
```

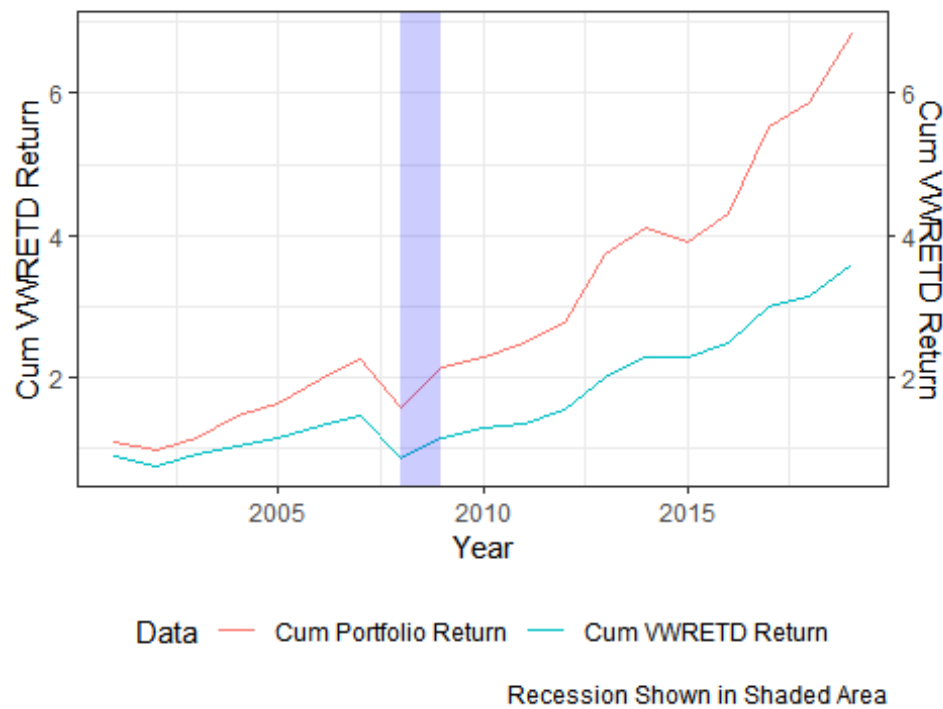
Fundamental Indexing based on: Revenue



```
funda_indexing("Revenue", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001         0.0950        -0.110         1.10         0.890
## 2 2002        -0.121        -0.149         0.962         0.757
## 3 2003         0.180         0.205         1.14         0.913
## 4 2004         0.273         0.141         1.45         1.04
## 5 2005         0.122         0.107         1.62         1.15
## 6 2006         0.209         0.154         1.96         1.33
## 7 2007         0.153         0.0891        2.26         1.45
## 8 2008        -0.309        -0.398         1.56         0.872
## 9 2009         0.370         0.305         2.14         1.14
## 10 2010         0.0691         0.134         2.29         1.29
## 11 2011         0.0919         0.0519        2.50         1.36
## 12 2012         0.112         0.148         2.78         1.56
## 13 2013         0.347         0.287         3.74         2.01
## 14 2014         0.0981         0.138         4.11         2.28
## 15 2015        -0.0495         0.00194        3.90         2.29
## 16 2016         0.102         0.0814        4.30         2.47
## 17 2017         0.287         0.214         5.53         3.00
## 18 2018         0.0621         0.0422        5.87         3.13
## 19 2019         0.165         0.144         6.84         3.58
```

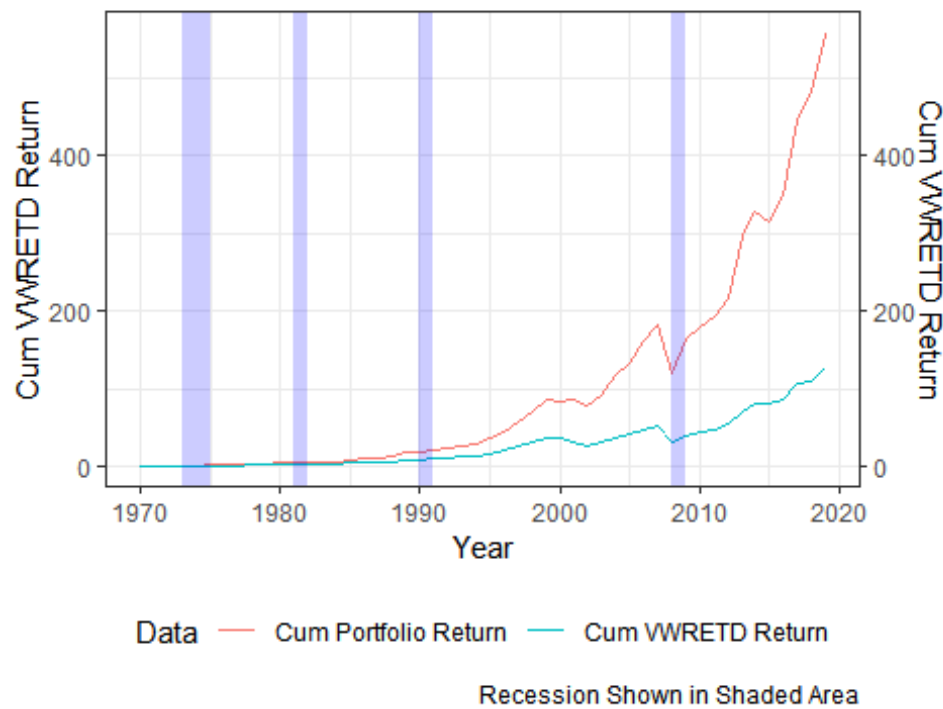
Fundamental Indexing based on: Revenue



```
funda_indexing("Sales", 1970, 2019)
```

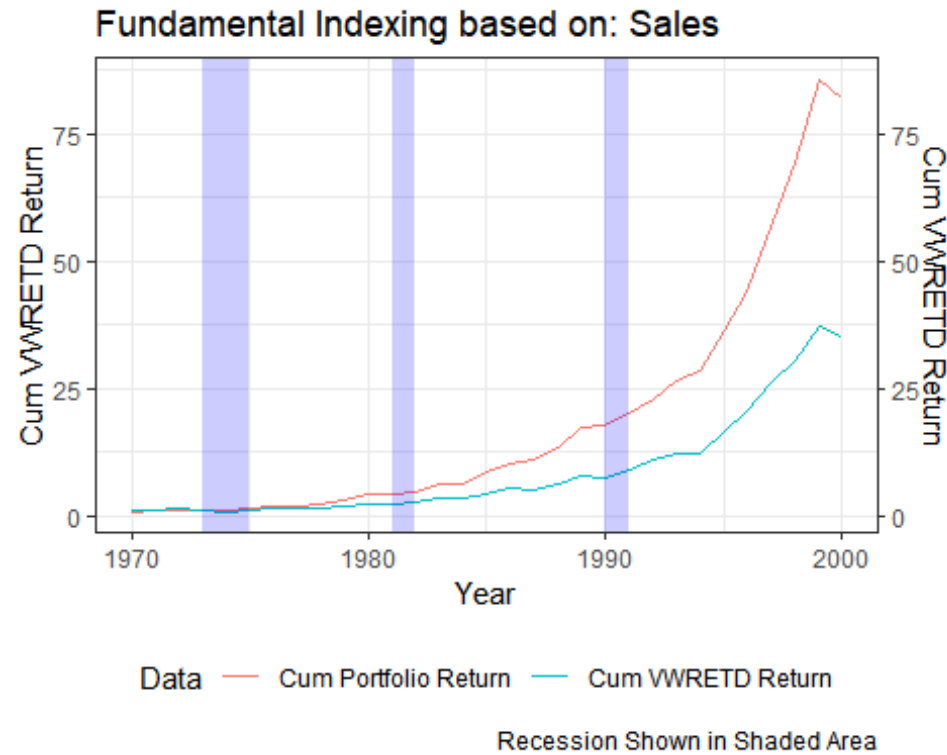
```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.130         -0.0751         0.870         0.925
## 2 1971          0.146          0.129         0.998         1.04
## 3 1972          0.266          0.266         1.26         1.32
## 4 1973        -0.0711        -0.188         1.17         1.07
## 5 1974        -0.124        -0.251         1.03         0.805
## 6 1975          0.462          0.351         1.50         1.09
## 7 1976          0.242          0.181         1.87         1.28
## 8 1977          0.0646         0.0217         1.99         1.31
## 9 1978          0.166          0.0753         2.32         1.41
## 10 1979          0.323          0.231         3.06         1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: Sales



```
funda_indexing("Sales", 1970, 2000)
```

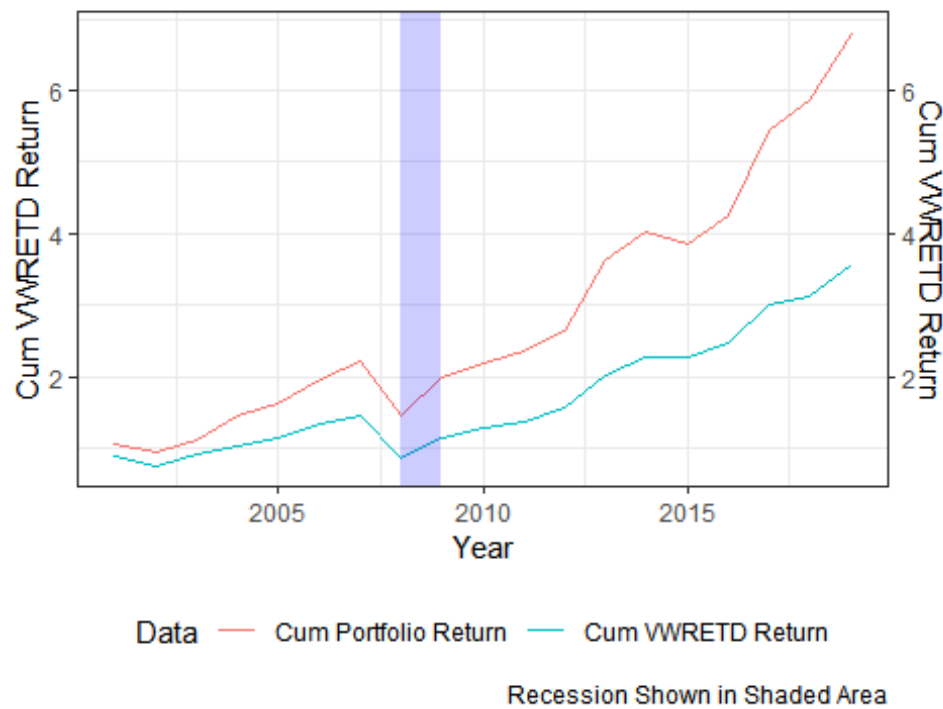
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.130         -0.0751         0.870         0.925
## 2 1971          0.146          0.129         0.998         1.04
## 3 1972          0.266          0.266         1.26         1.32
## 4 1973        -0.0711        -0.188         1.17         1.07
## 5 1974        -0.124        -0.251         1.03         0.805
## 6 1975          0.462          0.351         1.50         1.09
## 7 1976          0.242          0.181         1.87         1.28
## 8 1977          0.0646         0.0217         1.99         1.31
## 9 1978          0.166          0.0753         2.32         1.41
## 10 1979          0.323          0.231         3.06         1.74
## # ... with 21 more rows
```



```
funda_indexing("Sales", 2001, 2019)
```

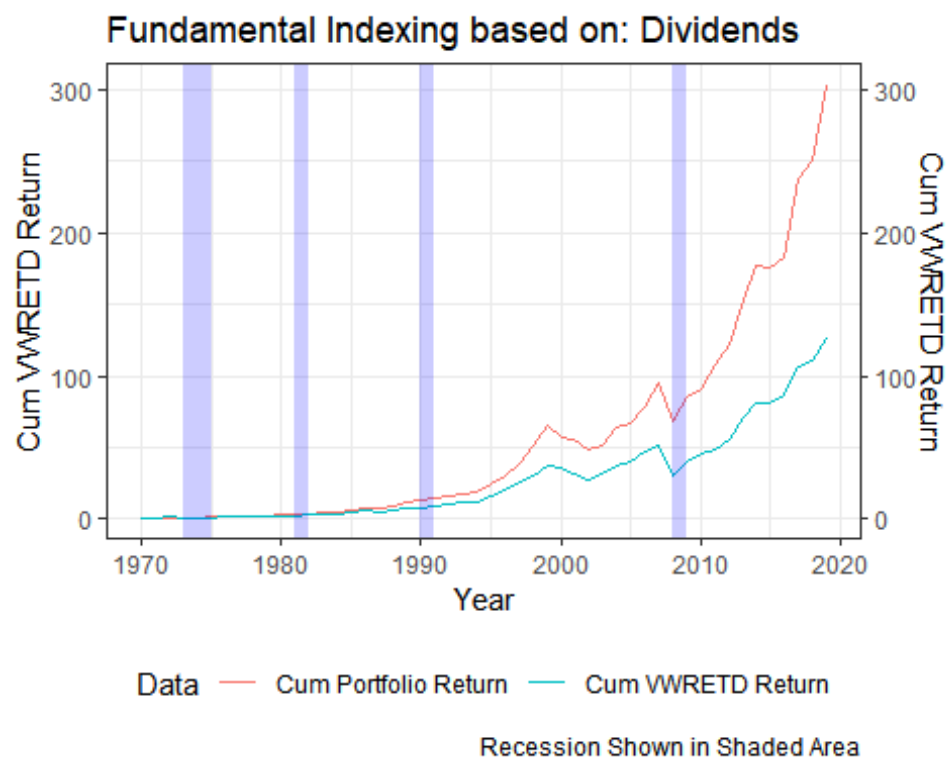
```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001         0.0537        -0.110         1.05         0.890
## 2 2002        -0.110        -0.149         0.938         0.757
## 3 2003         0.200         0.205         1.13         0.913
## 4 2004         0.282         0.141         1.44         1.04
## 5 2005         0.118         0.107         1.61         1.15
## 6 2006         0.212         0.154         1.95         1.33
## 7 2007         0.134         0.0891        2.21         1.45
## 8 2008        -0.338        -0.398         1.47         0.872
## 9 2009         0.364         0.305         2.00         1.14
## 10 2010         0.0891         0.134         2.18         1.29
## 11 2011         0.0837         0.0519        2.36         1.36
## 12 2012         0.116         0.148         2.63         1.56
## 13 2013         0.372         0.287         3.61         2.01
## 14 2014         0.110         0.138         4.01         2.28
## 15 2015        -0.0396         0.00194        3.85         2.29
## 16 2016         0.0993         0.0814        4.24         2.47
## 17 2017         0.283         0.214         5.43         3.00
## 18 2018         0.0804         0.0422        5.87         3.13
## 19 2019         0.158         0.144         6.80         3.58
```

Fundamental Indexing based on: Sales



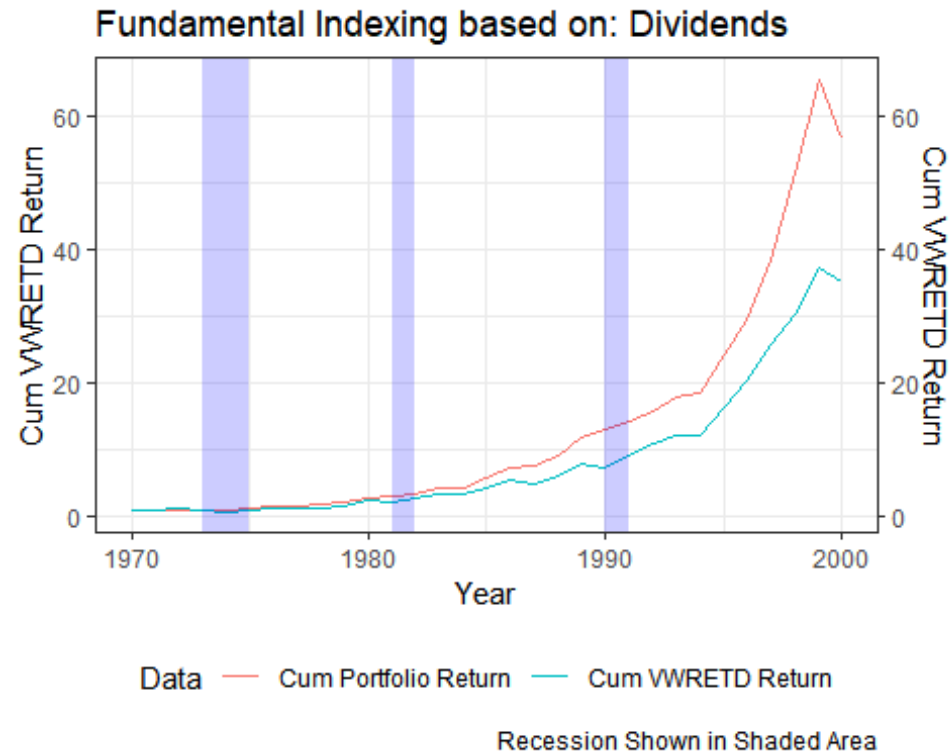
```
funda_indexing("Dividends", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970             0         -0.0751             1         0.925
## 2 1971             0          0.129             1         1.04
## 3 1972             0          0.266             1         1.32
## 4 1973             0         -0.188             1         1.07
## 5 1974             0         -0.251             1         0.805
## 6 1975          0.329          0.351            1.33         1.09
## 7 1976          0.237          0.181            1.64         1.28
## 8 1977          0.0350         0.0217            1.70         1.31
## 9 1978          0.119          0.0753            1.90         1.41
## 10 1979          0.151          0.231            2.19         1.74
## # ... with 40 more rows
```

```
funda_indexing("Dividends", 1970, 2000)
```

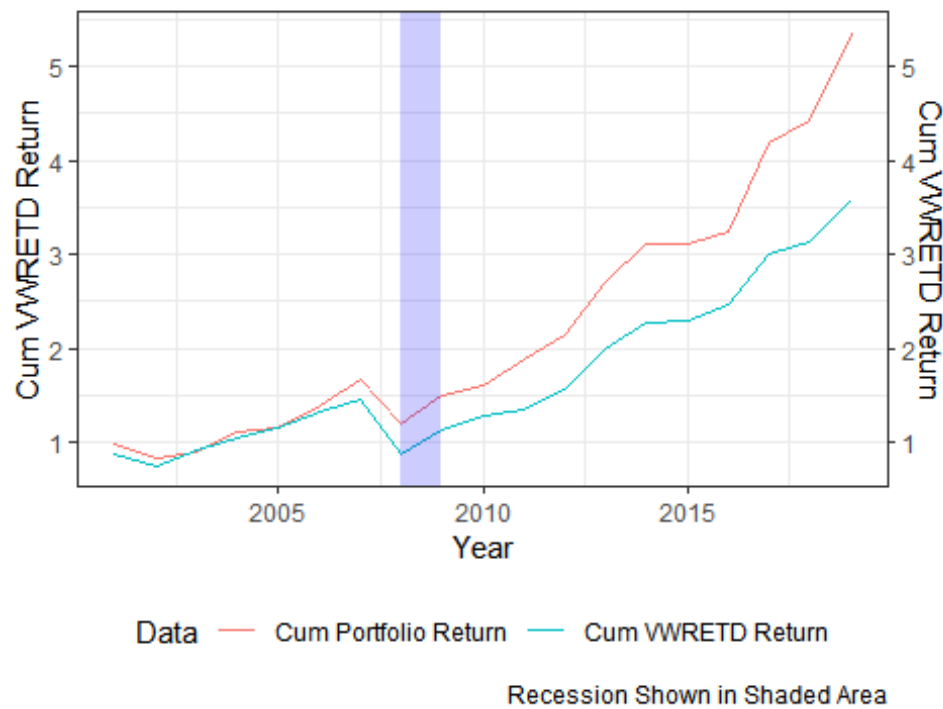
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970             0         -0.0751             1           0.925
## 2 1971             0          0.129             1           1.04
## 3 1972             0          0.266             1           1.32
## 4 1973             0         -0.188             1           1.07
## 5 1974             0         -0.251             1           0.805
## 6 1975          0.329          0.351            1.33           1.09
## 7 1976          0.237          0.181            1.64           1.28
## 8 1977          0.0350         0.0217            1.70           1.31
## 9 1978          0.119          0.0753            1.90           1.41
## 10 1979          0.151          0.231            2.19           1.74
## # ... with 21 more rows
```



```
funda_indexing("Dividends", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001      -0.0144      -0.110         0.986         0.890
## 2 2002      -0.143       -0.149         0.845         0.757
## 3 2003       0.0691       0.205         0.903         0.913
## 4 2004       0.237       0.141         1.12          1.04
## 5 2005       0.0462       0.107         1.17          1.15
## 6 2006       0.189       0.154         1.39          1.33
## 7 2007       0.203       0.0891        1.67          1.45
## 8 2008      -0.284      -0.398         1.20          0.872
## 9 2009       0.252       0.305         1.50          1.14
##10 2010       0.0723       0.134         1.61          1.29
##11 2011       0.176       0.0519        1.89          1.36
##12 2012       0.137       0.148         2.15          1.56
##13 2013       0.257       0.287         2.70          2.01
##14 2014       0.152       0.138         3.11          2.28
##15 2015     -0.00250       0.00194        3.10          2.29
##16 2016       0.0411       0.0814        3.23          2.47
##17 2017       0.298       0.214         4.19          3.00
##18 2018       0.0568       0.0422        4.43          3.13
##19 2019       0.207       0.144         5.35          3.58
```

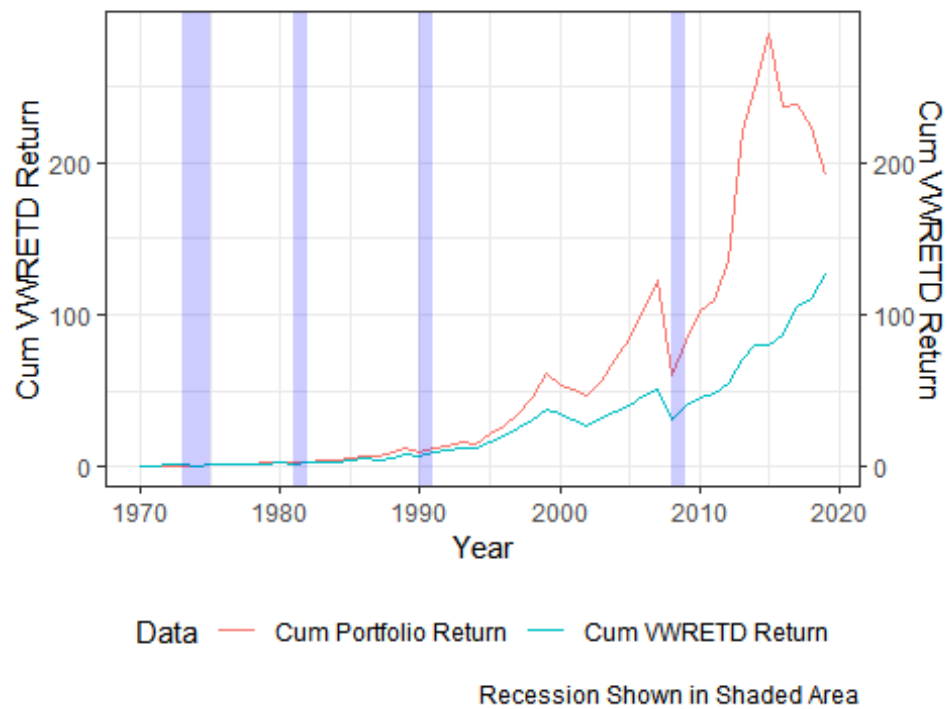
Fundamental Indexing based on: Dividends



```
funda_indexing("Investment", 1970, 2019)
```

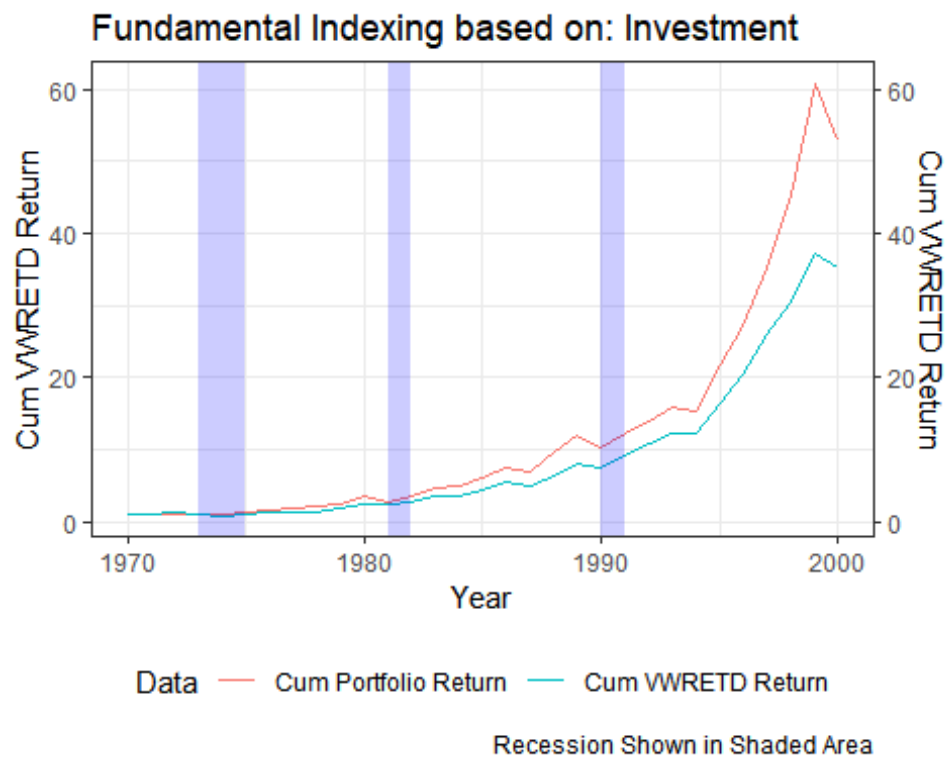
```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970             0         -0.0751             1           0.925
## 2 1971             0          0.129             1           1.04
## 3 1972             0          0.266             1           1.32
## 4 1973        -0.119        -0.188           0.881           1.07
## 5 1974             0        -0.251           0.881           0.805
## 6 1975          0.403          0.351           1.24           1.09
## 7 1976          0.225          0.181           1.51           1.28
## 8 1977          0.149          0.0217          1.74           1.31
## 9 1978          0.145          0.0753          1.99           1.41
## 10 1979          0.213          0.231          2.42           1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: Investment



```
funda_indexing("Investment", 1970, 2000)
```

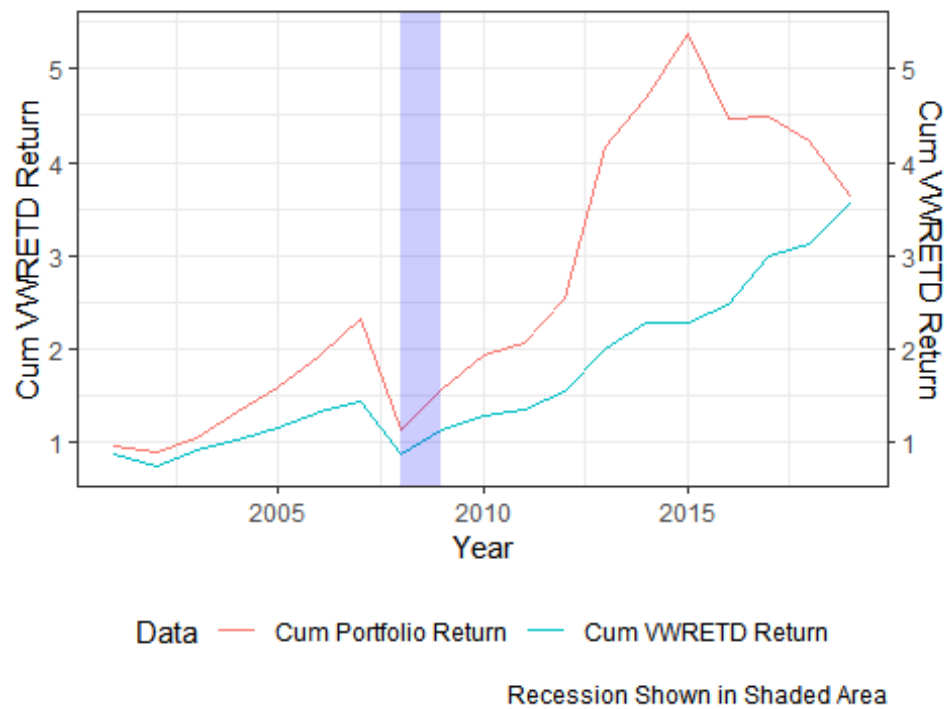
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970             0         -0.0751             1           0.925
## 2 1971             0           0.129             1           1.04
## 3 1972             0           0.266             1           1.32
## 4 1973        -0.119        -0.188           0.881           1.07
## 5 1974             0        -0.251           0.881           0.805
## 6 1975         0.403         0.351           1.24           1.09
## 7 1976         0.225         0.181           1.51           1.28
## 8 1977         0.149         0.0217          1.74           1.31
## 9 1978         0.145         0.0753          1.99           1.41
## 10 1979         0.213         0.231          2.42           1.74
## # ... with 21 more rows
```



```
funda_indexing("Investment", 2001, 2019)
```

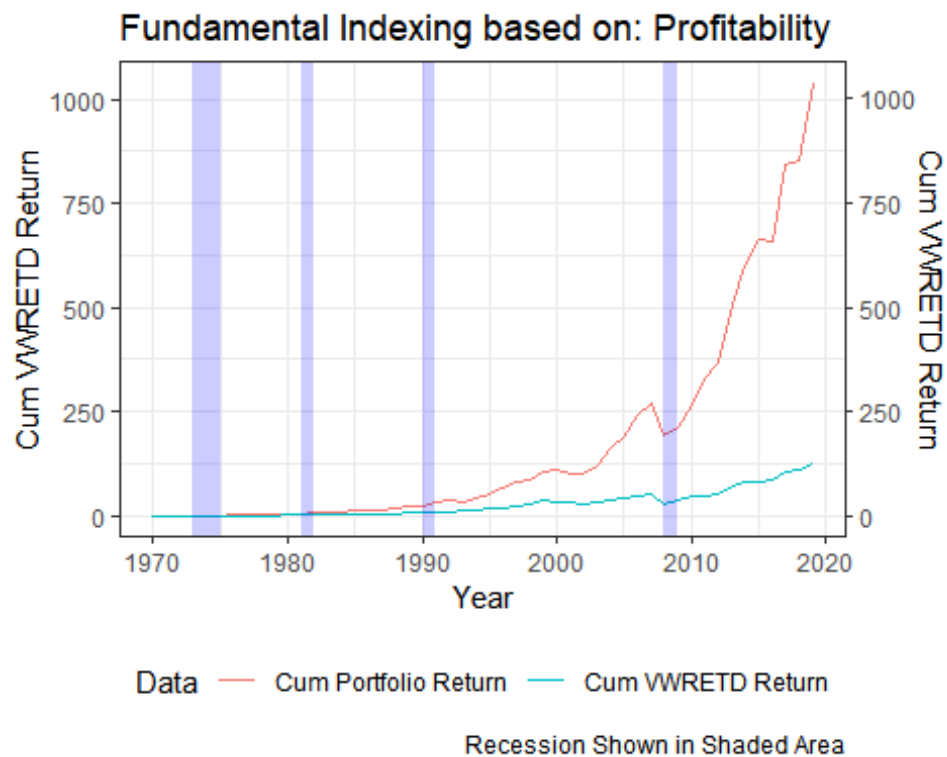
```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001      -0.0422      -0.110         0.958         0.890
## 2 2002      -0.0653      -0.149         0.895         0.757
## 3 2003       0.173       0.205         1.05          0.913
## 4 2004       0.271       0.141         1.33          1.04
## 5 2005       0.190       0.107         1.59          1.15
## 6 2006       0.216       0.154         1.93          1.33
## 7 2007       0.203       0.0891        2.32          1.45
## 8 2008      -0.507      -0.398         1.15          0.872
## 9 2009       0.364       0.305         1.56          1.14
## 10 2010      0.246       0.134         1.95          1.29
## 11 2011      0.0646      0.0519        2.07          1.36
## 12 2012      0.230       0.148         2.55          1.56
## 13 2013      0.633       0.287         4.17          2.01
## 14 2014      0.124       0.138         4.68          2.28
## 15 2015      0.148       0.00194        5.38          2.29
## 16 2016     -0.168       0.0814         4.47          2.47
## 17 2017      0.00313      0.214         4.49          3.00
## 18 2018     -0.0581      0.0422         4.23          3.13
## 19 2019     -0.145       0.144         3.61          3.58
```

Fundamental Indexing based on: Investment



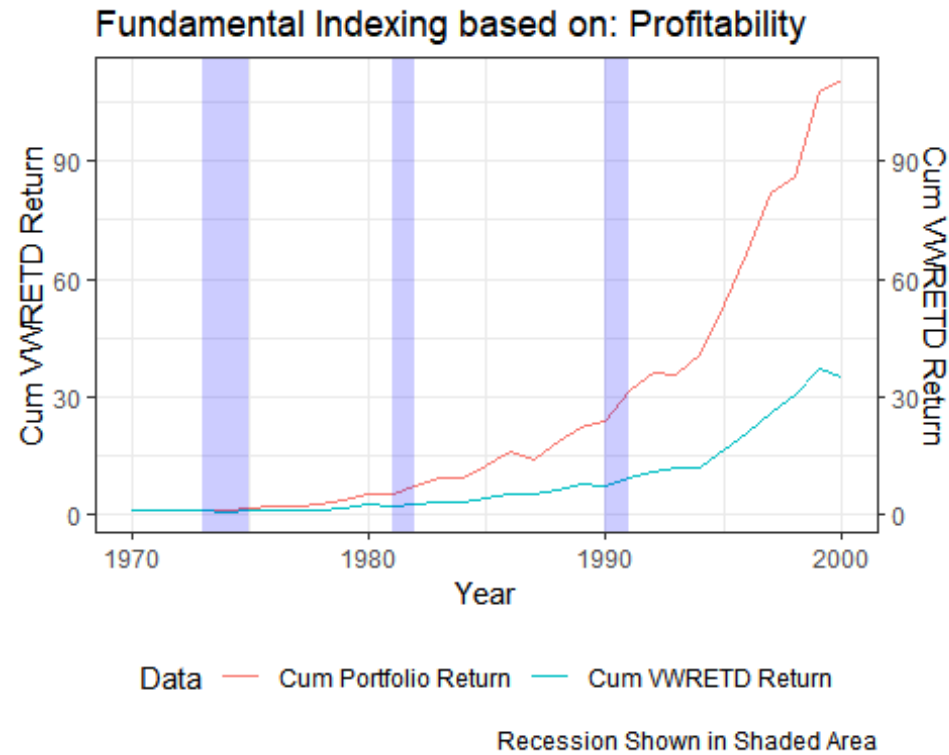
```
funda_indexing("Profitability", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.0760        -0.0751         0.924         0.925
## 2 1971         0.147         0.129         1.06         1.04
## 3 1972         0.269         0.266         1.34         1.32
## 4 1973         0.00900        -0.188         1.36         1.07
## 5 1974        -0.127        -0.251         1.18         0.805
## 6 1975         0.432         0.351         1.70         1.09
## 7 1976         0.173         0.181         1.99         1.28
## 8 1977         0.124         0.0217        2.23         1.31
## 9 1978         0.179         0.0753        2.63         1.41
## 10 1979         0.325         0.231         3.49         1.74
## # ... with 40 more rows
```



```
funda_indexing("Profitability", 1970, 2000)
```

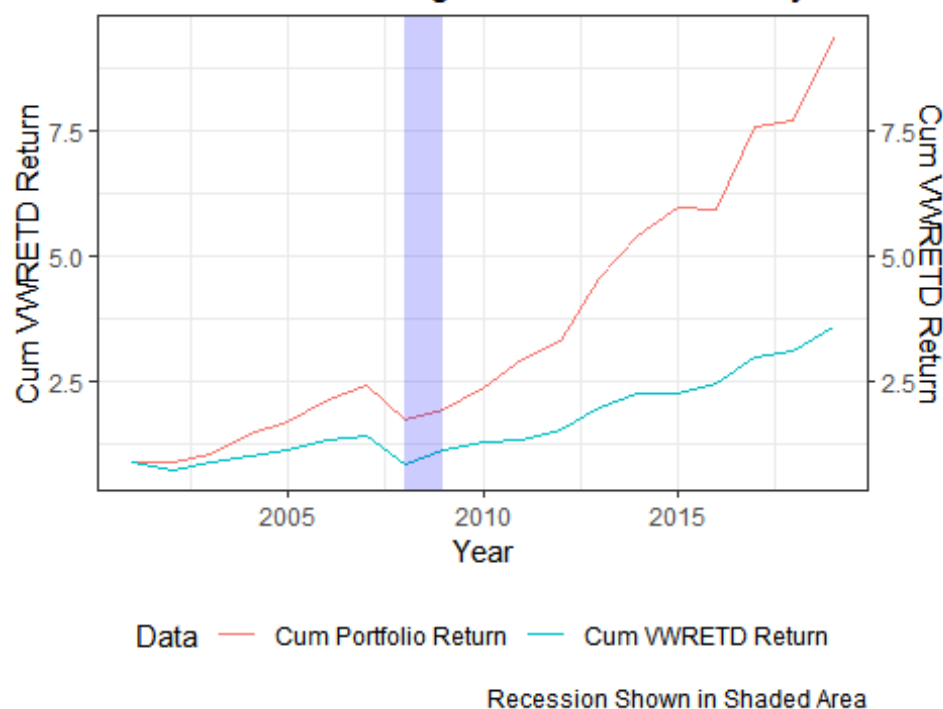
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0760      -0.0751         0.924         0.925
## 2 1971       0.147       0.129         1.06         1.04
## 3 1972       0.269       0.266         1.34         1.32
## 4 1973       0.00900     -0.188         1.36         1.07
## 5 1974      -0.127      -0.251         1.18         0.805
## 6 1975       0.432       0.351         1.70         1.09
## 7 1976       0.173       0.181         1.99         1.28
## 8 1977       0.124       0.0217        2.23         1.31
## 9 1978       0.179       0.0753        2.63         1.41
## 10 1979       0.325       0.231         3.49         1.74
## # ... with 21 more rows
```



```
funda_indexing("Profitability", 2001, 2019)
```

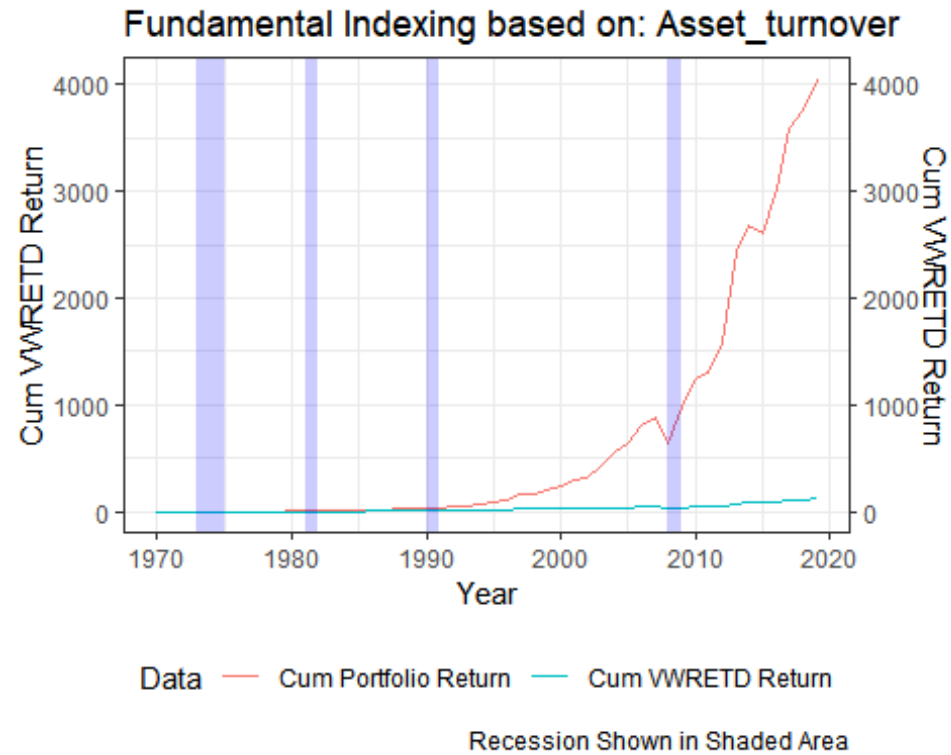
```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001      -0.0931      -0.110         0.907         0.890
## 2 2002     -0.00893     -0.149         0.899         0.757
## 3 2003       0.208       0.205         1.09          0.913
## 4 2004       0.355       0.141         1.47          1.04
## 5 2005       0.156       0.107         1.70          1.15
## 6 2006       0.270       0.154         2.16          1.33
## 7 2007       0.126       0.0891        2.43          1.45
## 8 2008      -0.286      -0.398         1.73          0.872
## 9 2009       0.118       0.305         1.94          1.14
## 10 2010      0.241       0.134         2.41          1.29
## 11 2011      0.234       0.0519        2.97          1.36
## 12 2012      0.124       0.148         3.34          1.56
## 13 2013      0.371       0.287         4.58          2.01
## 14 2014      0.186       0.138         5.43          2.28
## 15 2015      0.103       0.00194        5.99          2.29
## 16 2016     -0.00552     0.0814         5.95          2.47
## 17 2017      0.275       0.214         7.59          3.00
## 18 2018      0.0123      0.0422         7.69          3.13
## 19 2019      0.218       0.144         9.36          3.58
```


Fundamental Indexing based on: Profitability



```
funda_indexing("Asset_turnover", 1970, 2019)
```

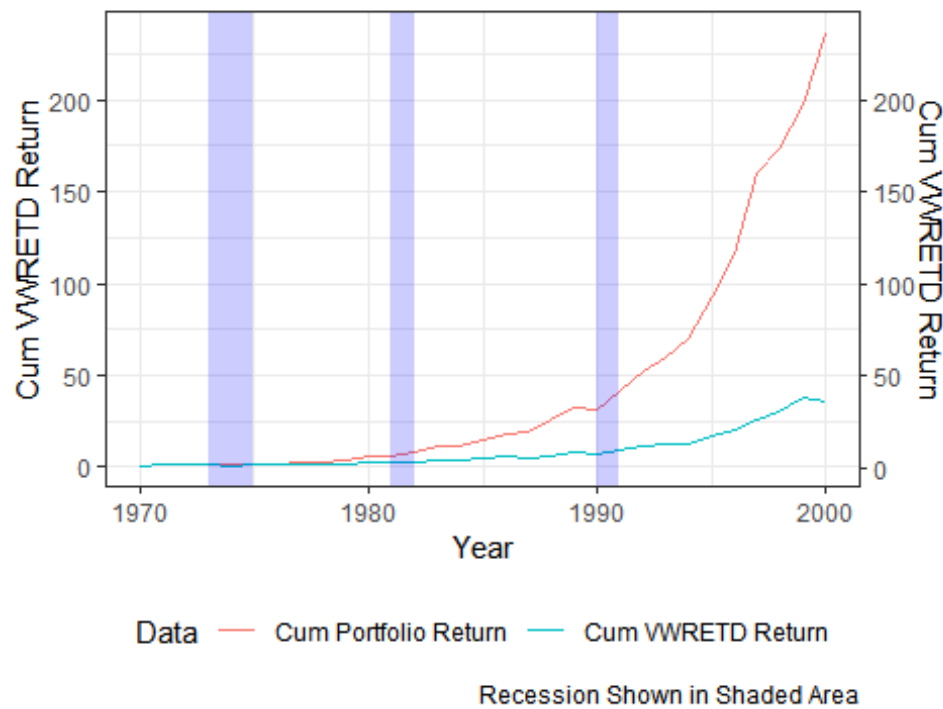
```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.0758         -0.0751         0.924         0.925
## 2 1971          0.185          0.129          1.09          1.04
## 3 1972          0.254          0.266          1.37          1.32
## 4 1973         -0.0920         -0.188          1.25          1.07
## 5 1974         -0.0982         -0.251          1.12          0.805
## 6 1975          0.512          0.351          1.70          1.09
## 7 1976          0.212          0.181          2.06          1.28
## 8 1977          0.147          0.0217         2.37          1.31
## 9 1978          0.215          0.0753         2.88          1.41
## 10 1979          0.333          0.231          3.83          1.74
## # ... with 40 more rows
```



```
funda_indexing("Asset_turnover", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0758      -0.0751         0.924         0.925
## 2 1971       0.185       0.129          1.09          1.04
## 3 1972       0.254       0.266          1.37          1.32
## 4 1973      -0.0920      -0.188          1.25          1.07
## 5 1974      -0.0982      -0.251          1.12          0.805
## 6 1975       0.512       0.351          1.70          1.09
## 7 1976       0.212       0.181          2.06          1.28
## 8 1977       0.147       0.0217         2.37          1.31
## 9 1978       0.215       0.0753         2.88          1.41
## 10 1979       0.333       0.231          3.83          1.74
## # ... with 21 more rows
```

Fundamental Indexing based on: Asset_turnover

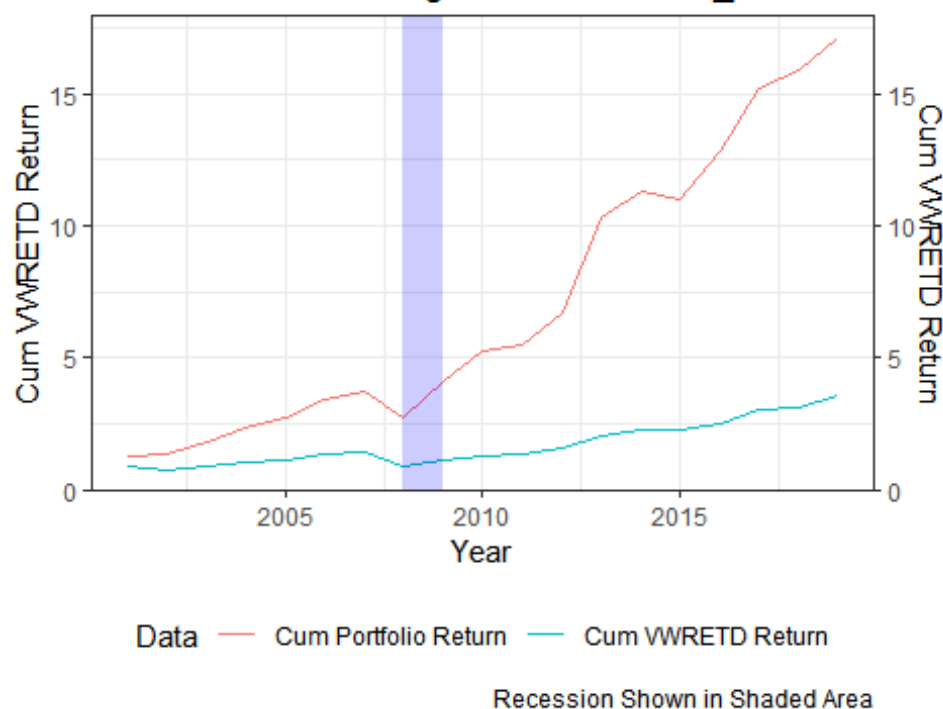


```
funda_indexing("Asset_turnover", 2001, 2019)
```

```
## # A tibble: 19 x 5
```

##	Year	portfolio_return	annual_VWRETD	cum_port_return	cum_VWRETD
##	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	2001	0.278	-0.110	1.28	0.890
## 2	2002	0.0282	-0.149	1.31	0.757
## 3	2003	0.375	0.205	1.81	0.913
## 4	2004	0.305	0.141	2.36	1.04
## 5	2005	0.146	0.107	2.70	1.15
## 6	2006	0.274	0.154	3.44	1.33
## 7	2007	0.0832	0.0891	3.73	1.45
## 8	2008	-0.267	-0.398	2.73	0.872
## 9	2009	0.512	0.305	4.13	1.14
## 10	2010	0.271	0.134	5.25	1.29
## 11	2011	0.0494	0.0519	5.51	1.36
## 12	2012	0.213	0.148	6.68	1.56
## 13	2013	0.546	0.287	10.3	2.01
## 14	2014	0.0955	0.138	11.3	2.28
## 15	2015	-0.0259	0.00194	11.0	2.29
## 16	2016	0.162	0.0814	12.8	2.47
## 17	2017	0.185	0.214	15.2	3.00
## 18	2018	0.0492	0.0422	15.9	3.13
## 19	2019	0.0765	0.144	17.1	3.58

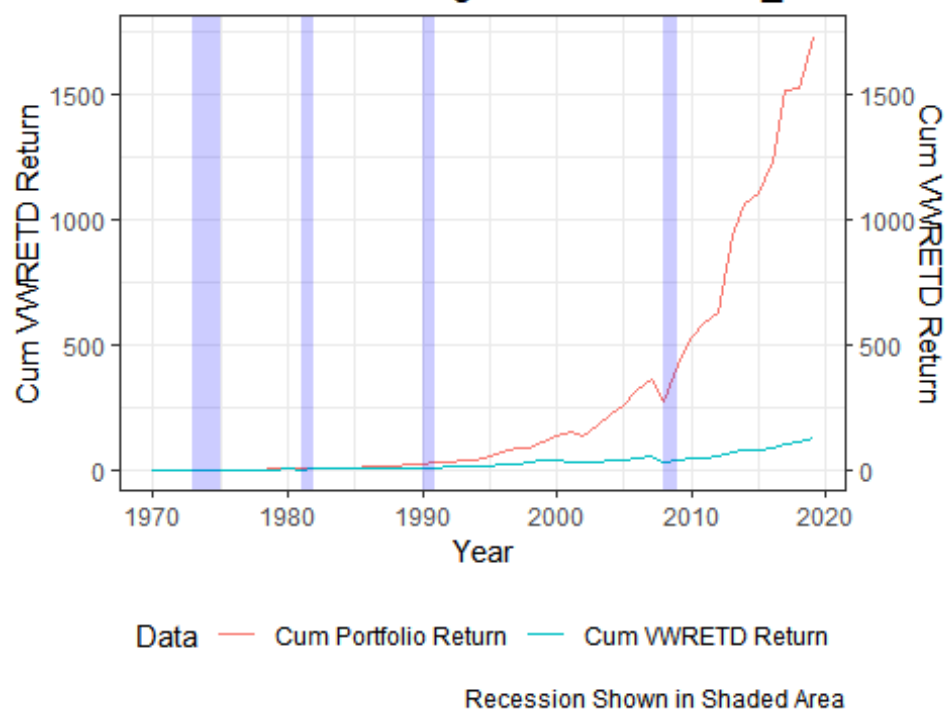
Fundamental Indexing based on: Asset_turnover



```
funda_indexing("Altman_Z", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.0291         -0.0751         0.971         0.925
## 2 1971          0.149          0.129          1.12          1.04
## 3 1972          0.279          0.266          1.43          1.32
## 4 1973         -0.0457         -0.188          1.36          1.07
## 5 1974         -0.0989         -0.251          1.23          0.805
## 6 1975          0.283          0.351          1.58          1.09
## 7 1976          0.0323          0.181          1.63          1.28
## 8 1977          0.107          0.0217          1.80          1.31
## 9 1978          0.198          0.0753          2.16          1.41
## 10 1979          0.318          0.231          2.84          1.74
## # ... with 40 more rows
```

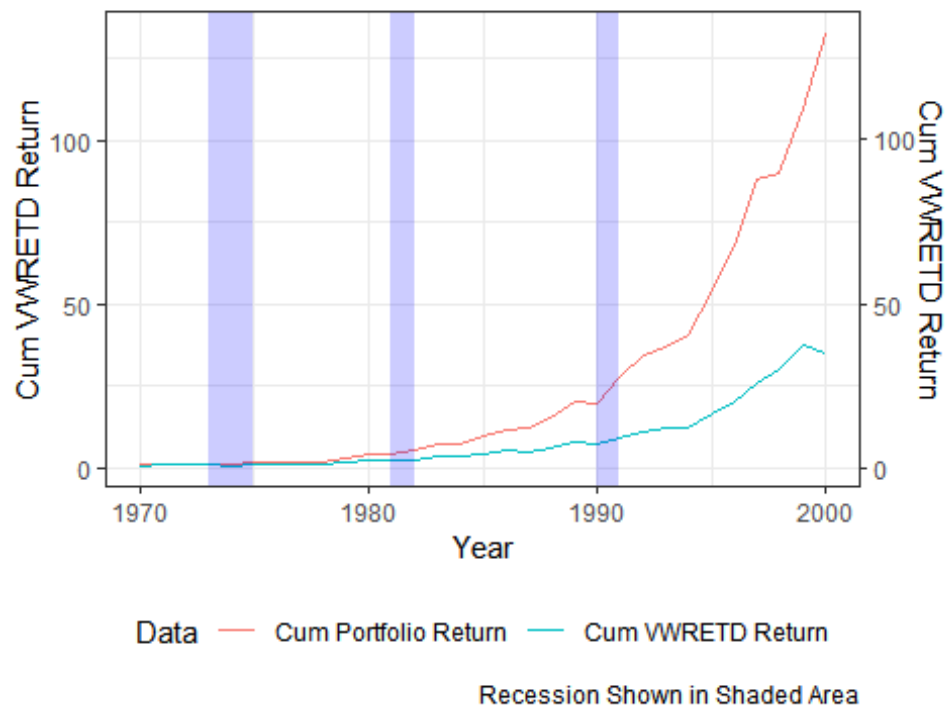
Fundamental Indexing based on: Altman_Z



```
funda_indexing("Altman_Z", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.0291        -0.0751         0.971         0.925
## 2 1971         0.149         0.129         1.12         1.04
## 3 1972         0.279         0.266         1.43         1.32
## 4 1973        -0.0457        -0.188         1.36         1.07
## 5 1974        -0.0989        -0.251         1.23         0.805
## 6 1975         0.283         0.351         1.58         1.09
## 7 1976         0.0323         0.181         1.63         1.28
## 8 1977         0.107         0.0217        1.80         1.31
## 9 1978         0.198         0.0753        2.16         1.41
## 10 1979         0.318         0.231        2.84         1.74
## # ... with 21 more rows
```

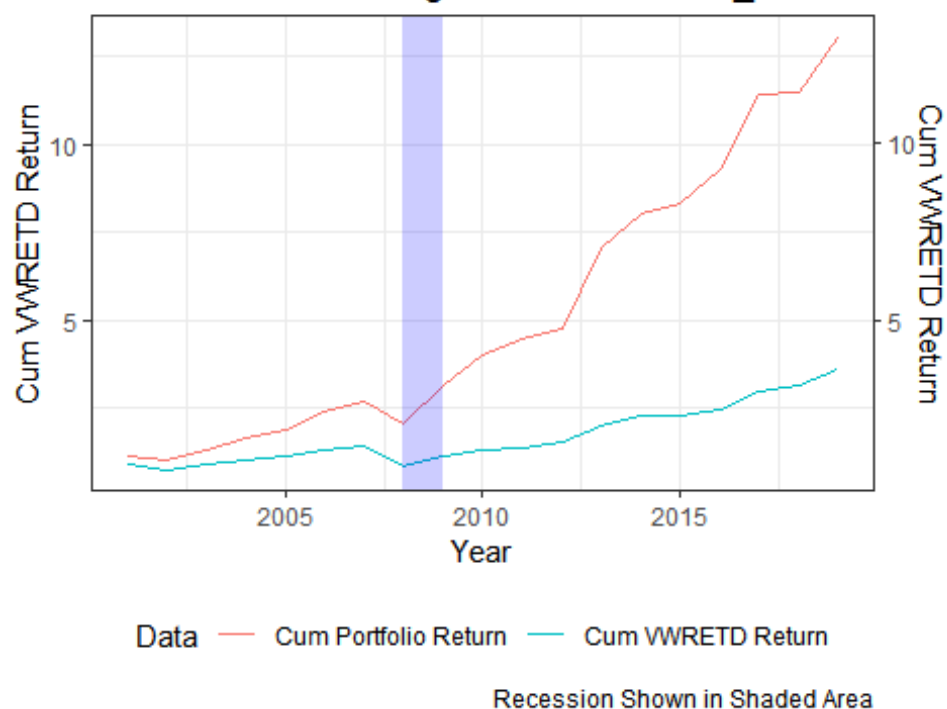
Fundamental Indexing based on: Altman_Z



```
funda_indexing("Altman_Z", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001         0.117         -0.110         1.12         0.890
## 2 2002        -0.0852        -0.149         1.02         0.757
## 3 2003         0.308         0.205         1.34         0.913
## 4 2004         0.244         0.141         1.66         1.04
## 5 2005         0.146         0.107         1.91         1.15
## 6 2006         0.273         0.154         2.43         1.33
## 7 2007         0.114         0.0891        2.70         1.45
## 8 2008        -0.239        -0.398         2.06         0.872
## 9 2009         0.535         0.305         3.15         1.14
##10 2010         0.270         0.134         4.01         1.29
##11 2011         0.108         0.0519        4.44         1.36
##12 2012         0.0667         0.148         4.74         1.56
##13 2013         0.489         0.287         7.05         2.01
##14 2014         0.136         0.138         8.01         2.28
##15 2015         0.0366         0.00194        8.31         2.29
##16 2016         0.119         0.0814         9.29         2.47
##17 2017         0.229         0.214        11.4         3.00
##18 2018         0.00455        0.0422        11.5         3.13
##19 2019         0.136         0.144        13.0         3.58
```

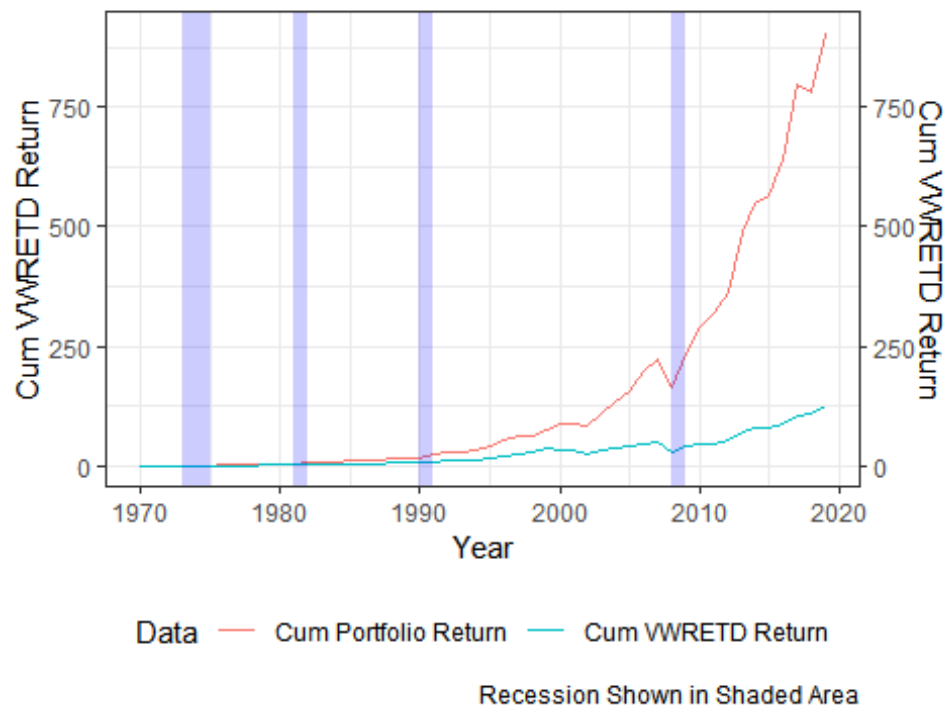
Fundamental Indexing based on: Altman_Z



```
funda_indexing("Ohlson_0", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.0729        -0.0751         0.927         0.925
## 2 1971         0.126         0.129         1.04         1.04
## 3 1972         0.303         0.266         1.36         1.32
## 4 1973        -0.0572        -0.188         1.28         1.07
## 5 1974        -0.115        -0.251         1.13         0.805
## 6 1975         0.420         0.351         1.61         1.09
## 7 1976         0.171         0.181         1.89         1.28
## 8 1977         0.109         0.0217        2.09         1.31
## 9 1978         0.189         0.0753        2.49         1.41
## 10 1979         0.297         0.231        3.23         1.74
## # ... with 40 more rows
```

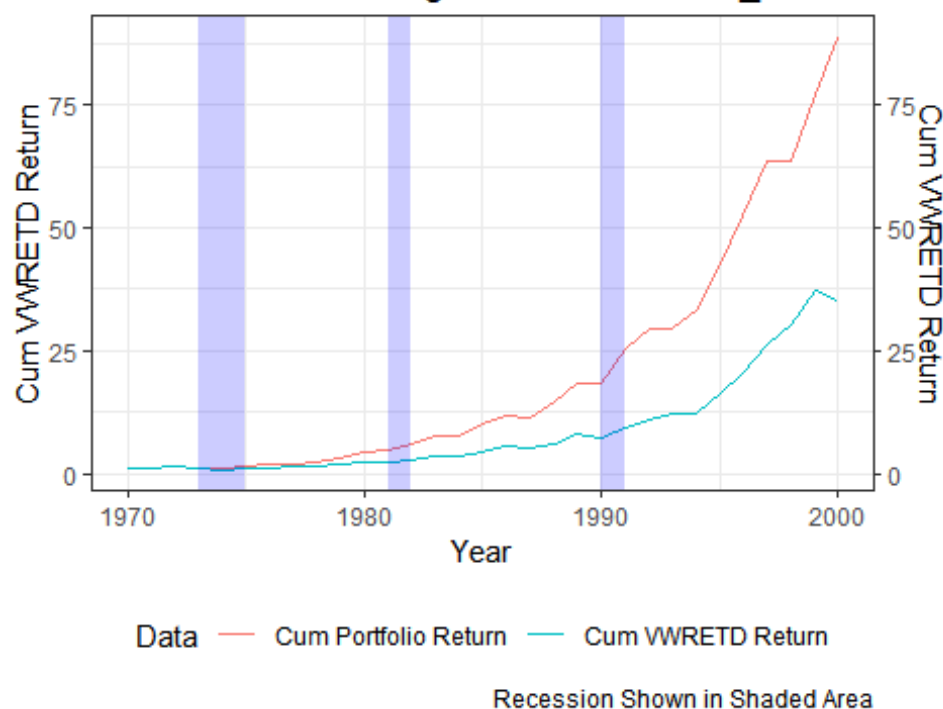
Fundamental Indexing based on: Ohlson_O



```
funda_indexing("Ohlson_O", 1970, 2000)
```

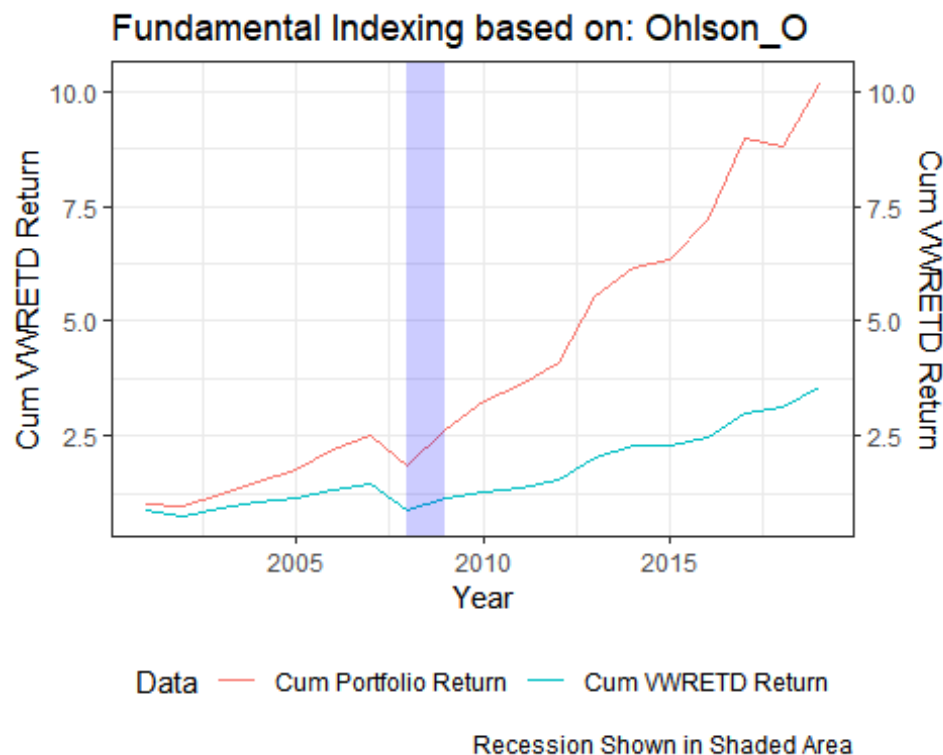
```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0729      -0.0751         0.927         0.925
## 2 1971       0.126       0.129         1.04         1.04
## 3 1972       0.303       0.266         1.36         1.32
## 4 1973      -0.0572      -0.188         1.28         1.07
## 5 1974      -0.115      -0.251         1.13         0.805
## 6 1975       0.420       0.351         1.61         1.09
## 7 1976       0.171       0.181         1.89         1.28
## 8 1977       0.109       0.0217        2.09         1.31
## 9 1978       0.189       0.0753        2.49         1.41
## 10 1979       0.297       0.231         3.23         1.74
## # ... with 21 more rows
```


Fundamental Indexing based on: Ohlson_O



```
funda_indexing("Ohlson_O", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001         0.00539        -0.110         1.01         0.890
## 2 2002        -0.0431        -0.149         0.962         0.757
## 3 2003         0.256         0.205         1.21         0.913
## 4 2004         0.253         0.141         1.51         1.04
## 5 2005         0.152         0.107         1.74         1.15
## 6 2006         0.269         0.154         2.21         1.33
## 7 2007         0.130         0.0891        2.50         1.45
## 8 2008        -0.261        -0.398         1.85         0.872
## 9 2009         0.435         0.305         2.65         1.14
##10 2010         0.235         0.134         3.28         1.29
##11 2011         0.107         0.0519        3.63         1.36
##12 2012         0.123         0.148         4.07         1.56
##13 2013         0.357         0.287         5.53         2.01
##14 2014         0.116         0.138         6.17         2.28
##15 2015         0.0290         0.00194        6.35         2.29
##16 2016         0.137         0.0814         7.22         2.47
##17 2017         0.248         0.214         9.01         3.00
##18 2018        -0.0225         0.0422         8.80         3.13
##19 2019         0.157         0.144        10.2         3.58
```



The function to compute the descriptive statistics and ratios

```
library("e1071")

## Warning: package 'e1071' was built under R version 3.6.3

describe_funda_indexing <- function(funda) {
  funda <- as.name(funda)
  dif <- merged %>% group_by(Year) %>%
    mutate(weight = eval(funda)/sum(eval(funda), na.rm = T),
           weighted_return = annual_return*weight) %>% group_by(Year) %>%
    summarize(portfolio_return = sum(weighted_return, na.rm = T),
              annual_VWRETD = mean(annual_VWRETD), #annual_VWRET has been
calculated before
              dif = portfolio_return - annual_VWRETD) %>% #so use mean to get
its values
    mutate(cum_port_return = cumprod(portfolio_return + 1),
           cum_VWRETD = cumprod(annual_VWRETD + 1),
           cum_dif = cum_port_return - cum_VWRETD)
  print(dif)

  ratios <- merged %>% group_by(Year) %>%
    mutate(weight = eval(funda)/sum(eval(funda), na.rm = T),
           weighted_return = annual_return*weight) %>% group_by(Year) %>%
    summarize(portfolio_return = sum(weighted_return, na.rm = T),
              annual_VWRETD = mean(annual_VWRETD),
              RF = mean(annual_RF)) %>%
```

```

mutate(cum_port_return = cumprod(portfolio_return + 1),
       cum_VWRETD = cumprod(annual_VWRETD + 1)) %>%
summarize(volatility = sd(portfolio_return),
          skewness = skewness(portfolio_return),
          kurtosis = kurtosis(portfolio_return),
          Sharpe_ratio = mean(portfolio_return-RF)/volatility,
          Information_ratio = mean(portfolio_return-annual_VWRETD)/
                                sd(portfolio_return-annual_VWRETD))

print(ratios)
}

describe_funda_indexing("Book")

## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
## 1 1970          -0.0864          -0.0630 -0.0235          0.914
##   0.937
## 2 1971           0.0600           0.121 -0.0606          0.968      1.05
## 3 1972           0.287           0.232  0.0556          1.25      1.29
## 4 1973          -0.0999          -0.146  0.0457          1.12      1.11
## 5 1974          -0.148          -0.201  0.0528          0.956
##   0.883
## 6 1975           0.256           0.320 -0.0635          1.20      1.17
## 7 1976           0.268           0.167  0.101          1.52      1.36
## 8 1977           0.0515           0.0220  0.0295          1.60      1.39
## 9 1978           0.0969           0.0730  0.0238          1.76      1.49
## 10 1979           0.210           0.213 -0.00302         2.13      1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>      <dbl>      <dbl>      <dbl>          <dbl>
## 1    0.171   -0.763      1.11      0.520          0.240

describe_funda_indexing("Cash_Flow")

## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
## 1 1970           0          -0.0630  0.0630          1      0.937
## 2 1971           0           0.121 -0.121          1      1.05
## 3 1972           0           0.232 -0.232          1      1.29
## 4 1973           0          -0.146  0.146          1      1.11
## 5 1974           0          -0.201  0.201          1      0.883
## 6 1975           0           0.320 -0.320          1      1.17
## 7 1976           0           0.167 -0.167          1      1.36
## 8 1977           0           0.0220 -0.0220          1      1.39
## 9 1978           0           0.0730 -0.0730          1      1.49
## 10 1979           0           0.213 -0.213          1      1.81

```

```
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
## 1      0.129      0.432     -0.910      0.332      -0.179
```

`describe_funda_indexing("Revenue")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD      dif cum_port_return cum_VWRETD
##   <dbl>      <dbl>      <dbl> <dbl>      <dbl>      <dbl>
## 1 1970      -0.137      -0.0630 -0.0744      0.863      0.937
## 2 1971       0.152       0.121  0.0312      0.994      1.05
## 3 1972       0.265       0.232  0.0335      1.26      1.29
## 4 1973     -0.0634     -0.146  0.0822      1.18      1.11
## 5 1974     -0.120     -0.201  0.0812      1.04      0.883
## 6 1975       0.461       0.320  0.141      1.51      1.17
## 7 1976       0.244       0.167  0.0778      1.88      1.36
## 8 1977       0.0613      0.0220  0.0393      2.00      1.39
## 9 1978       0.171       0.0730  0.0977      2.34      1.49
## 10 1979       0.322       0.213  0.108      3.09      1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
## 1      0.154     -0.569      0.295      0.702      0.590
```

`describe_funda_indexing("Sales")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD      dif cum_port_return cum_VWRETD
##   <dbl>      <dbl>      <dbl> <dbl>      <dbl>      <dbl>
## 1 1970      -0.130     -0.0630 -0.0669      0.870      0.937
## 2 1971       0.146       0.121  0.0258      0.998      1.05
## 3 1972       0.266       0.232  0.0343      1.26      1.29
## 4 1973     -0.0711     -0.146  0.0744      1.17      1.11
## 5 1974     -0.124     -0.201  0.0764      1.03      0.883
## 6 1975       0.462       0.320  0.142      1.50      1.17
## 7 1976       0.242       0.167  0.0757      1.87      1.36
## 8 1977       0.0646      0.0220  0.0426      1.99      1.39
## 9 1978       0.166       0.0730  0.0927      2.32      1.49
## 10 1979       0.323       0.213  0.110      3.06      1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
## 1      0.154     -0.552      0.535      0.673      0.658
```

`describe_funda_indexing("Dividends")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          0          -0.0630 0.0630          1
0.937
## 2 1971          0          0.121 -0.121          1      1.05
## 3 1972          0          0.232 -0.232          1      1.29
## 4 1973          0          -0.146 0.146          1      1.11
## 5 1974          0          -0.201 0.201          1
0.883
## 6 1975          0.329          0.320 0.00963          1.33      1.17
## 7 1976          0.237          0.167 0.0708          1.64      1.36
## 8 1977          0.0350          0.0220 0.0130          1.70      1.39
## 9 1978          0.119          0.0730 0.0460          1.90      1.49
## 10 1979          0.151          0.213 -0.0620          2.19      1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>
## 1    0.133   -0.581    0.323    0.654    0.219
```

`describe_funda_indexing("Investment")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          0          -0.0630 6.30e-2          1
0.937
## 2 1971          0          0.121 -1.21e-1          1      1.05
## 3 1972          0          0.232 -2.32e-1          1      1.29
## 4 1973          -0.119          -0.146 2.61e-2          0.881      1.11
## 5 1974          0          -0.201 2.01e-1          0.881
0.883
## 6 1975          0.403          0.320 8.35e-2          1.24      1.17
## 7 1976          0.225          0.167 5.88e-2          1.51      1.36
## 8 1977          0.149          0.0220 1.27e-1          1.74      1.39
## 9 1978          0.145          0.0730 7.19e-2          1.99      1.49
## 10 1979          0.213          0.213 -8.39e-4          2.42      1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>
## 1    0.209   -0.356    0.409    0.430    0.176
```

`describe_funda_indexing("Profitability")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          -0.0760          -0.0630 -0.0130          0.924
0.937
## 2 1971           0.147           0.121  0.0260          1.06          1.05
## 3 1972           0.269           0.232  0.0369          1.34          1.29
## 4 1973           0.00900         -0.146  0.155          1.36          1.11
## 5 1974          -0.127          -0.201  0.0735          1.18
0.883
## 6 1975           0.432           0.320  0.113          1.70          1.17
## 7 1976           0.173           0.167  0.00613         1.99          1.36
## 8 1977           0.124           0.0220  0.102          2.23          1.39
## 9 1978           0.179           0.0730  0.106          2.63          1.49
## 10 1979          0.325           0.213  0.111          3.49          1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>
## 1    0.157   -0.519   -0.130    0.752    0.597
```

`describe_funda_indexing("Asset_turnover")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
## 1 1970          -0.0758          -0.0630 -0.0129          0.924          0.937
## 2 1971           0.185           0.121  0.0642          1.09          1.05
## 3 1972           0.254           0.232  0.0226          1.37          1.29
## 4 1973          -0.0920          -0.146  0.0536          1.25          1.11
## 5 1974          -0.0982          -0.201  0.103          1.12          0.883
## 6 1975           0.512           0.320  0.193          1.70          1.17
## 7 1976           0.212           0.167  0.0458          2.06          1.36
## 8 1977           0.147           0.0220  0.125          2.37          1.39
## 9 1978           0.215           0.0730  0.142          2.88          1.49
## 10 1979          0.333           0.213  0.119          3.83          1.81
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>
## 1    0.169   -0.216   -0.0663    0.895    0.878
```

`describe_funda_indexing("Altman_Z")`

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
## 1 1970          -0.0291          -0.0630  0.0338          0.971          0.937
## 2 1971           0.149           0.121  0.0288          1.12          1.05
```

```
## 3 1972      0.279      0.232  0.0475      1.43      1.29
## 4 1973     -0.0457     -0.146  0.0999      1.36      1.11
## 5 1974     -0.0989     -0.201  0.102      1.23      0.883
## 6 1975      0.283      0.320 -0.0364      1.58      1.17
## 7 1976      0.0323      0.167 -0.134      1.63      1.36
## 8 1977      0.107      0.0220 0.0852      1.80      1.39
## 9 1978      0.198      0.0730 0.125      2.16      1.49
## 10 1979      0.318      0.213  0.104      2.84      1.81
```

```
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
```

```
## # A tibble: 1 x 5
```

```
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
```

```
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
```

```
## 1      0.157 -0.0853  -0.176      0.824      0.745
```

```
describe_funda_indexing("Ohlson_0")
```

```
## # A tibble: 50 x 7
```

```
##   Year portfolio_return annual_VWRETD      dif cum_port_return
```

```
cum_VWRETD
```

```
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
```

```
<dbl>
```

```
## 1 1970      -0.0729      -0.0630 -0.00997      0.927
```

```
0.937
```

```
## 2 1971      0.126      0.121  0.00503      1.04      1.05
```

```
## 3 1972      0.303      0.232  0.0711      1.36      1.29
```

```
## 4 1973     -0.0572     -0.146  0.0883      1.28      1.11
```

```
## 5 1974     -0.115     -0.201  0.0858      1.13
```

```
0.883
```

```
## 6 1975      0.420      0.320  0.101      1.61      1.17
```

```
## 7 1976      0.171      0.167  0.00469      1.89      1.36
```

```
## 8 1977      0.109      0.0220 0.0874      2.09      1.39
```

```
## 9 1978      0.189      0.0730 0.116      2.49      1.49
```

```
## 10 1979      0.297      0.213  0.0839      3.23      1.81
```

```
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
```

```
## # A tibble: 1 x 5
```

```
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
```

```
##   <dbl>      <dbl>      <dbl>      <dbl>      <dbl>
```

```
## 1      0.148 -0.406  -0.213      0.767      0.656
```

The function to compare portfolio returns with MKT, SMB, and HML returns

```
compare_funda_indexing <- function(funda) {
funda <- as.name(funda)
output <- merged %>% group_by(Year) %>%
  mutate(
    weight = eval(funda)/sum(eval(funda), na.rm = T),
    weighted_return = annual_return*weight) %>% group_by(Year) %>%
    summarize(portfolio_return = sum(weighted_return, na.rm = T),
      MKT = mean(annual_Mkt.RF), #annual MKT, SMB, and HML have
already been caculated
      SMB = mean(annual_SMB), #from monthly data)
```

```

HML = mean(annual_HML)) %>% #so use mean to extract the values
mutate(cum_port_return = cumprod(portfolio_return + 1),
       cum_MKT= cumprod(MKT + 1),
       cum_SMB= cumprod(SMB + 1),
       cum_HML= cumprod(HML + 1))

```

```

print(output)
}

```

```
compare_funda_indexing ("Book")
```

```

## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
##   <dbl>          <dbl> <dbl> <dbl> <dbl>          <dbl>
## 1 1970          -0.0864 -0.115 -0.144  0.159          0.914
## 2 1971           0.0600  0.0749  0.0501 -0.0712         0.968
## 3 1972           0.287   0.192 -0.0526  0.0362         1.25
## 4 1973          -0.0999 -0.194 -0.185   0.135         1.12
## 5 1974          -0.148 -0.248 -0.00355  0.134         0.956
## 6 1975           0.256   0.265  0.0749  0.0483         1.20
## 7 1976           0.268   0.115  0.0729  0.183         1.52
## 8 1977           0.0515 -0.0231  0.227   0.0877         1.60
## 9 1978           0.0969  0.0134  0.132   0.00349        1.76
## 10 1979          0.210   0.102  0.138  -0.0159        2.13
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
##   <dbl>

```

```
compare_funda_indexing ("Cash_Flow")
```

```

## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
##   <dbl>          <dbl> <dbl> <dbl> <dbl>          <dbl>
## 1 1970           0 -0.115 -0.144  0.159          1
## 2 1971           0  0.0749  0.0501 -0.0712         1
## 3 1972           0  0.192 -0.0526  0.0362         1
## 4 1973           0 -0.194 -0.185   0.135         1

```



```

0.914
## 5 1974          0 -0.248 -0.00355  0.134          1
0.687
## 6 1975          0  0.265  0.0749  0.0483          1
0.870
## 7 1976          0  0.115  0.0729  0.183          1
0.970
## 8 1977          0 -0.0231  0.227   0.0877          1
0.947
## 9 1978          0  0.0134  0.132   0.00349          1
0.960
## 10 1979         0  0.102  0.138  -0.0159          1  1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```

compare_funda_indexing ("Revenue")

```

## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl>   <dbl>   <dbl>          <dbl>
<dbl>
## 1 1970          -0.137 -0.115 -0.144   0.159          0.863
0.885
## 2 1971           0.152  0.0749  0.0501 -0.0712          0.994
0.952
## 3 1972           0.265  0.192 -0.0526  0.0362          1.26  1.13
## 4 1973          -0.0634 -0.194 -0.185   0.135          1.18
0.914
## 5 1974          -0.120 -0.248 -0.00355  0.134          1.04
0.687
## 6 1975           0.461  0.265  0.0749  0.0483          1.51
0.870
## 7 1976           0.244  0.115  0.0729  0.183          1.88
0.970
## 8 1977           0.0613 -0.0231  0.227   0.0877          2.00
0.947
## 9 1978           0.171  0.0134  0.132   0.00349          2.34
0.960
## 10 1979          0.322  0.102  0.138  -0.0159          3.09  1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```

compare_funda_indexing ("Sales")

```

## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl>   <dbl>   <dbl>          <dbl>
<dbl>
## 1 1970          -0.130 -0.115 -0.144   0.159          0.870

```

```

0.885
## 2 1971      0.146  0.0749  0.0501 -0.0712      0.998
0.952
## 3 1972      0.266  0.192 -0.0526  0.0362      1.26  1.13
## 4 1973     -0.0711 -0.194 -0.185  0.135      1.17
0.914
## 5 1974     -0.124 -0.248 -0.00355  0.134      1.03
0.687
## 6 1975      0.462  0.265  0.0749  0.0483      1.50
0.870
## 7 1976      0.242  0.115  0.0729  0.183      1.87
0.970
## 8 1977      0.0646 -0.0231  0.227  0.0877      1.99
0.947
## 9 1978      0.166  0.0134  0.132  0.00349      2.32
0.960
## 10 1979      0.323  0.102  0.138 -0.0159      3.06  1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```

`compare_funda_indexing ("Dividends")`

```

## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>      <dbl> <dbl> <dbl> <dbl>      <dbl>
<dbl>
## 1 1970      0      -0.115 -0.144  0.159      1
0.885
## 2 1971      0      0.0749  0.0501 -0.0712      1
0.952
## 3 1972      0      0.192 -0.0526  0.0362      1  1.13
## 4 1973      0     -0.194 -0.185  0.135      1
0.914
## 5 1974      0     -0.248 -0.00355  0.134      1
0.687
## 6 1975      0.329  0.265  0.0749  0.0483      1.33
0.870
## 7 1976      0.237  0.115  0.0729  0.183      1.64
0.970
## 8 1977      0.0350 -0.0231  0.227  0.0877      1.70
0.947
## 9 1978      0.119  0.0134  0.132  0.00349      1.90
0.960
## 10 1979      0.151  0.102  0.138 -0.0159      2.19  1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```

`compare_funda_indexing ("Investment")`

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl>   <dbl>   <dbl>   <dbl>          <dbl>
<dbl>
## 1 1970              0    -0.115 -0.144    0.159              1
0.885
## 2 1971              0     0.0749 0.0501 -0.0712              1
0.952
## 3 1972              0     0.192 -0.0526 0.0362              1    1.13
## 4 1973          -0.119 -0.194 -0.185    0.135              0.881
0.914
## 5 1974              0    -0.248 -0.00355 0.134              0.881
0.687
## 6 1975          0.403    0.265    0.0749 0.0483              1.24
0.870
## 7 1976          0.225    0.115    0.0729 0.183              1.51
0.970
## 8 1977          0.149 -0.0231 0.227    0.0877              1.74
0.947
## 9 1978          0.145    0.0134 0.132    0.00349              1.99
0.960
## 10 1979          0.213    0.102    0.138   -0.0159              2.42    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>
```

compare_funda_indexing ("Profitability")

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl>   <dbl>   <dbl>   <dbl>          <dbl>
<dbl>
## 1 1970          -0.0760 -0.115 -0.144    0.159              0.924
0.885
## 2 1971          0.147    0.0749 0.0501 -0.0712              1.06
0.952
## 3 1972          0.269    0.192 -0.0526 0.0362              1.34    1.13
## 4 1973          0.00900 -0.194 -0.185    0.135              1.36
0.914
## 5 1974          -0.127 -0.248 -0.00355 0.134              1.18
0.687
## 6 1975          0.432    0.265    0.0749 0.0483              1.70
0.870
## 7 1976          0.173    0.115    0.0729 0.183              1.99
0.970
## 8 1977          0.124 -0.0231 0.227    0.0877              2.23
0.947
## 9 1978          0.179    0.0134 0.132    0.00349              2.63
0.960
```

```
## 10 1979          0.325    0.102    0.138   -0.0159          3.49    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>
```

```
compare_funda_indexing ("Asset_turnover")
```

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl>    <dbl>    <dbl>          <dbl>
<dbl>
## 1 1970          -0.0758 -0.115  -0.144    0.159          0.924
0.885
## 2 1971           0.185   0.0749  0.0501  -0.0712         1.09
0.952
## 3 1972           0.254   0.192  -0.0526  0.0362         1.37    1.13
## 4 1973          -0.0920 -0.194  -0.185    0.135         1.25
0.914
## 5 1974          -0.0982 -0.248  -0.00355  0.134         1.12
0.687
## 6 1975           0.512   0.265   0.0749  0.0483         1.70
0.870
## 7 1976           0.212   0.115   0.0729  0.183         2.06
0.970
## 8 1977           0.147  -0.0231  0.227    0.0877         2.37
0.947
## 9 1978           0.215   0.0134  0.132    0.00349        2.88
0.960
## 10 1979          0.333   0.102   0.138   -0.0159         3.83    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>
```

```
compare_funda_indexing ("Altman_Z")
```

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl>    <dbl>    <dbl>          <dbl>
<dbl>
## 1 1970          -0.0291 -0.115  -0.144    0.159          0.971
0.885
## 2 1971           0.149   0.0749  0.0501  -0.0712         1.12
0.952
## 3 1972           0.279   0.192  -0.0526  0.0362         1.43    1.13
## 4 1973          -0.0457 -0.194  -0.185    0.135         1.36
0.914
## 5 1974          -0.0989 -0.248  -0.00355  0.134         1.23
0.687
## 6 1975           0.283   0.265   0.0749  0.0483         1.58
0.870
## 7 1976           0.0323  0.115   0.0729  0.183         1.63
```

```

0.970
## 8 1977          0.107 -0.0231 0.227    0.0877          1.80
0.947
## 9 1978          0.198  0.0134 0.132    0.00349          2.16
0.960
## 10 1979         0.318  0.102  0.138   -0.0159          2.84    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

compare_funda_indexing ("Ohlson_0")

## # A tibble: 50 x 9
##   Year portfolio_return    MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl>    <dbl>    <dbl>          <dbl>
<dbl>
## 1 1970         -0.0729 -0.115 -0.144    0.159          0.927
0.885
## 2 1971          0.126  0.0749 0.0501  -0.0712          1.04
0.952
## 3 1972          0.303  0.192 -0.0526  0.0362          1.36    1.13
## 4 1973         -0.0572 -0.194 -0.185    0.135          1.28
0.914
## 5 1974         -0.115 -0.248 -0.00355 0.134          1.13
0.687
## 6 1975          0.420  0.265  0.0749  0.0483          1.61
0.870
## 7 1976          0.171  0.115  0.0729  0.183          1.89
0.970
## 8 1977          0.109 -0.0231 0.227    0.0877          2.09
0.947
## 9 1978          0.189  0.0134 0.132    0.00349          2.49
0.960
## 10 1979         0.297  0.102  0.138   -0.0159          3.23    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```

To make the beta dataset able to be merged with the CRSP dataset

```

library("reshape2")

## Warning: package 'reshape2' was built under R version 3.6.3

##
## Attaching package: 'reshape2'

## The following object is masked from 'package:tidyr':
##
##   smiths

beta <- melt(betadata, id.vars = "PERMNO")
names(beta)[2] <- "Year"

```

```
names(beta)[3] <- "Beta"
beta$Year <- beta$Year %>% as.character %>% as.numeric()
```

To merge the market variables data to the msf data

```
msf_market_variable <- msf_annual_return %>% left_join(beta, by = c("PERMNO",
"Year")) %>%
  left_join(total_volatility_1[,c("PERMNO", "Year",
"volatility1")]) %>%
  left_join(total_volatility_2[,c("PERMNO", "Year",
"volatility2")]) %>%
  left_join(idiosync_vol1[,c("PERMNO", "Year",
"Idiosyncratic_vol1")]) %>%
  left_join(idiosync_vol2[,c("PERMNO", "Year",
"Idiosyncratic_vol2")]) %>%
  left_join(idiosync_vol3[,c("PERMNO", "Year",
"Idiosyncratic_vol3")])

## Joining, by = c("PERMNO", "Year")
## Joining, by = c("PERMNO", "Year")
## Joining, by = c("PERMNO", "Year")
## Joining, by = c("PERMNO", "Year")
## Joining, by = c("PERMNO", "Year")
```

The function to calculate portfolio return based on market variables and plot the results together with VWRETD returns

```
market_value_indexing <- function(funda_value, y1, y2){
  funda <- as.name(funda_value)
  recession_data <- recession %>% filter(start>=y1 & end <= y2)

  output <-

  msf_market_variable %>% filter(Year>=y1 & Year<=y2) %>% group_by(Year) %>%
  mutate(weight = eval(funda)/sum(eval(funda), na.rm = T),
    weighted_return = annual_return*weight) %>% group_by(Year) %>%
  summarize(portfolio_return = sum(weighted_return, na.rm = T),
    annual_VWRETD = median(annual_VWRETD)) %>%
  mutate(cum_port_return = cumprod((portfolio_return + 1)),
    cum_VWRETD = cumprod(annual_VWRETD + 1))

  print(output)

  plt <- output %>% ggplot(aes(x = Year)) +
    geom_line(aes(y = log(cum_port_return),
      color = "Cum Portfolio Return")) +
    geom_line(aes(y = log(cum_VWRETD),
      color = "Cum VWRETD Return")) +
    scale_y_continuous(name = "Cum VWRETD Return (logged)",
```

```

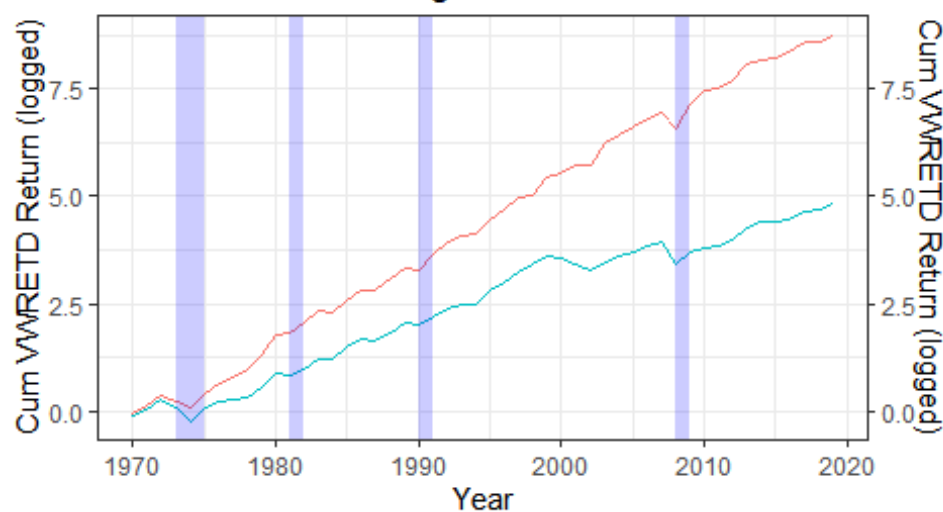
sec.axis = sec_axis(~ ., name = "Cum VWRETD Return
(logged)")) +
  labs(title = paste("Fundamental Indexing based on:",
    as.character(funda_value)), color =
"Data") +
  geom_rect(data=recession_data,
    aes(xmin=start,xmax=end, ymin=-Inf,ymax=Inf),
    inherit.aes = FALSE, fill= "blue", alpha=0.2) +
  labs(caption = "Recession are shown in shaded area\n
    Returns are logged for illustration") +
theme_bw() +
  theme(legend.position = "bottom")
print(plt)
}

```

```
market_value_indexing("Beta", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.0529         -0.0751         0.947         0.925
## 2 1971          0.232          0.129          1.17          1.04
## 3 1972          0.258          0.266          1.47          1.32
## 4 1973         -0.153         -0.188          1.24          1.07
## 5 1974         -0.119         -0.251          1.10          0.805
## 6 1975          0.404          0.351          1.54          1.09
## 7 1976          0.273          0.181          1.96          1.28
## 8 1977          0.152          0.0217         2.25          1.31
## 9 1978          0.175          0.0753         2.65          1.41
## 10 1979          0.422          0.231          3.77          1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: Beta



Data — Cum Portfolio Return — Cum VWRETD Return

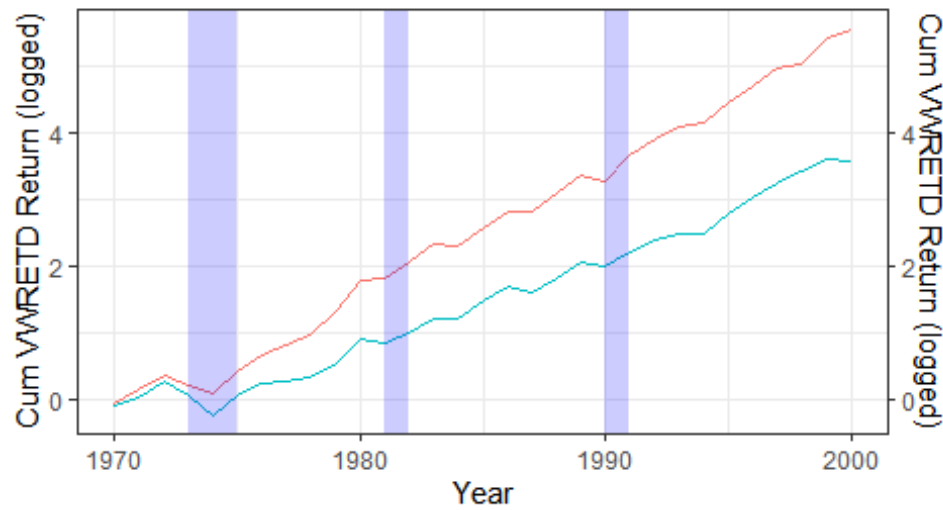
Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Beta", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0529      -0.0751         0.947         0.925
## 2 1971       0.232       0.129          1.17          1.04
## 3 1972       0.258       0.266          1.47          1.32
## 4 1973      -0.153      -0.188          1.24          1.07
## 5 1974      -0.119      -0.251          1.10          0.805
## 6 1975       0.404       0.351          1.54          1.09
## 7 1976       0.273       0.181          1.96          1.28
## 8 1977       0.152       0.0217         2.25          1.31
## 9 1978       0.175       0.0753         2.65          1.41
## 10 1979       0.422       0.231          3.77          1.74
## # ... with 21 more rows
```


Fundamental Indexing based on: Beta



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

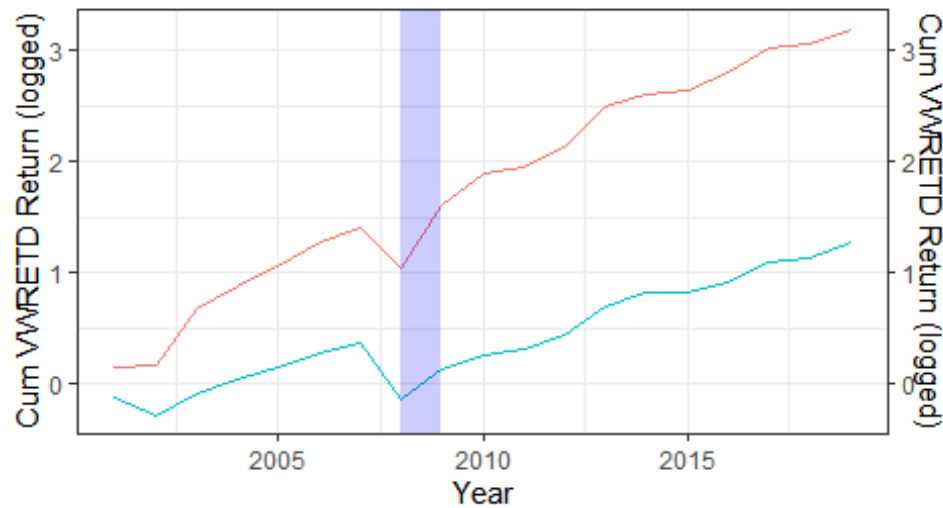
Returns are logged for illustration

```
market_value_indexing("Beta", 2001, 2019)
```

```
## # A tibble: 19 x 5
```

##	Year	portfolio_return	annual_VWRETD	cum_port_return	cum_VWRETD
##	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	2001	0.165	-0.110	1.17	0.890
## 2	2002	0.0178	-0.149	1.19	0.757
## 3	2003	0.654	0.205	1.96	0.913
## 4	2004	0.225	0.141	2.40	1.04
## 5	2005	0.195	0.107	2.87	1.15
## 6	2006	0.244	0.154	3.57	1.33
## 7	2007	0.132	0.0891	4.04	1.45
## 8	2008	-0.302	-0.398	2.82	0.872
## 9	2009	0.760	0.305	4.96	1.14
## 10	2010	0.345	0.134	6.67	1.29
## 11	2011	0.0645	0.0519	7.10	1.36
## 12	2012	0.192	0.148	8.47	1.56
## 13	2013	0.445	0.287	12.2	2.01
## 14	2014	0.109	0.138	13.6	2.28
## 15	2015	0.0429	0.00194	14.2	2.29
## 16	2016	0.159	0.0814	16.4	2.47
## 17	2017	0.247	0.214	20.5	3.00
## 18	2018	0.0368	0.0422	21.2	3.13
## 19	2019	0.151	0.144	24.4	3.58

Fundamental Indexing based on: Beta



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

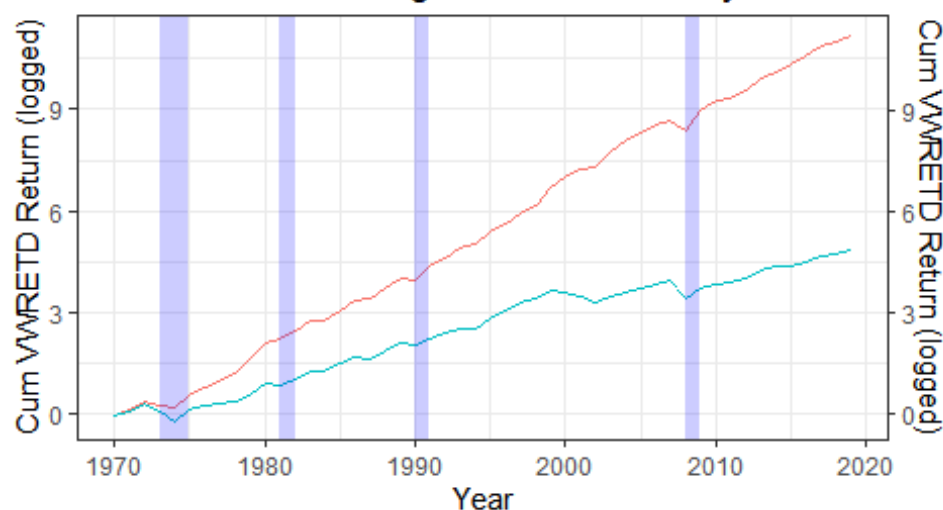
Returns are logged for illustration

```
market_value_indexing("volatility1", 1970, 2019)
```

```
## # A tibble: 50 x 5
```

```
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.0612        -0.0751         0.939         0.925
## 2 1971         0.223         0.129         1.15         1.04
## 3 1972         0.265         0.266         1.45         1.32
## 4 1973        -0.119        -0.188         1.28         1.07
## 5 1974       -0.0986       -0.251         1.15         0.805
## 6 1975         0.494         0.351         1.72         1.09
## 7 1976         0.289         0.181         2.22         1.28
## 8 1977         0.187         0.0217        2.64         1.31
## 9 1978         0.239         0.0753        3.27         1.41
## 10 1979         0.511         0.231         4.94         1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: volatility1



Data — Cum Portfolio Return — Cum VWRETD Return

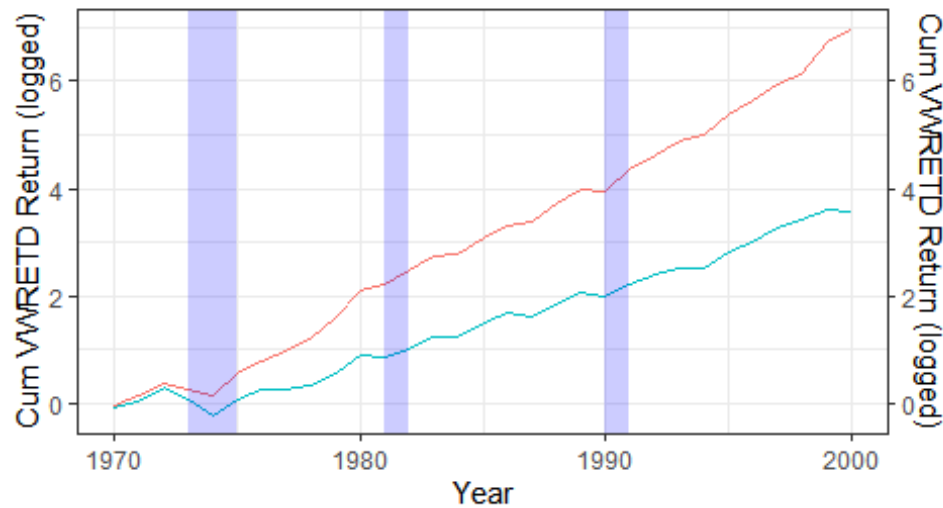
Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("volatility1", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0612      -0.0751         0.939         0.925
## 2 1971       0.223       0.129         1.15         1.04
## 3 1972       0.265       0.266         1.45         1.32
## 4 1973      -0.119      -0.188         1.28         1.07
## 5 1974     -0.0986     -0.251         1.15         0.805
## 6 1975       0.494       0.351         1.72         1.09
## 7 1976       0.289       0.181         2.22         1.28
## 8 1977       0.187       0.0217        2.64         1.31
## 9 1978       0.239       0.0753        3.27         1.41
## 10 1979       0.511       0.231         4.94         1.74
## # ... with 21 more rows
```

Fundamental Indexing based on: volatility1



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

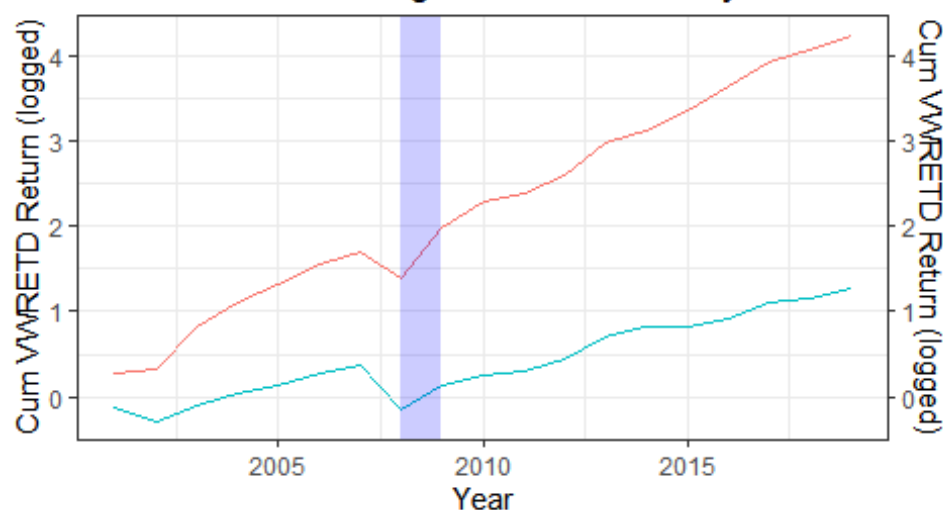
Returns are logged for illustration

```
market_value_indexing("volatility1", 2001, 2019)
```

```
## # A tibble: 19 x 5
```

##	Year	portfolio_return	annual_VWRETD	cum_port_return	cum_VWRETD
##	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	2001	0.311	-0.110	1.31	0.890
## 2	2002	0.0482	-0.149	1.37	0.757
## 3	2003	0.666	0.205	2.29	0.913
## 4	2004	0.320	0.141	3.02	1.04
## 5	2005	0.229	0.107	3.72	1.15
## 6	2006	0.277	0.154	4.75	1.33
## 7	2007	0.146	0.0891	5.44	1.45
## 8	2008	-0.270	-0.398	3.97	0.872
## 9	2009	0.829	0.305	7.27	1.14
## 10	2010	0.363	0.134	9.90	1.29
## 11	2011	0.0939	0.0519	10.8	1.36
## 12	2012	0.222	0.148	13.2	1.56
## 13	2013	0.475	0.287	19.5	2.01
## 14	2014	0.156	0.138	22.6	2.28
## 15	2015	0.274	0.00194	28.8	2.29
## 16	2016	0.317	0.0814	37.9	2.47
## 17	2017	0.316	0.214	49.9	3.00
## 18	2018	0.158	0.0422	57.8	3.13
## 19	2019	0.195	0.144	69.0	3.58

Fundamental Indexing based on: volatility1



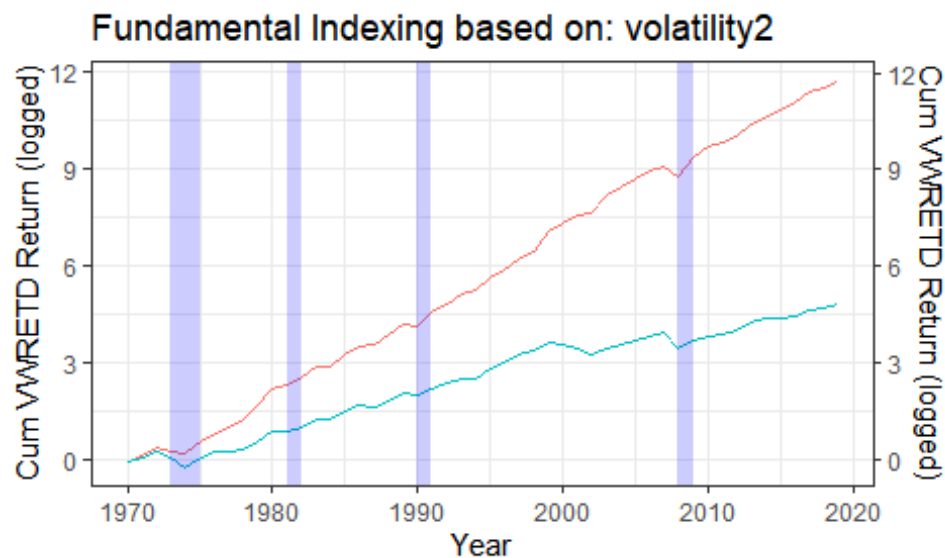
Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("volatility2", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0621      -0.0751         0.938         0.925
## 2 1971       0.242       0.129         1.17         1.04
## 3 1972       0.279       0.266         1.49         1.32
## 4 1973      -0.122      -0.188         1.31         1.07
## 5 1974      -0.103      -0.251         1.17         0.805
## 6 1975       0.513       0.351         1.78         1.09
## 7 1976       0.314       0.181         2.33         1.28
## 8 1977       0.196       0.0217        2.79         1.31
## 9 1978       0.250       0.0753        3.49         1.41
## 10 1979       0.546       0.231         5.39         1.74
## # ... with 40 more rows
```



Data — Cum Portfolio Return — Cum VWRETD Return

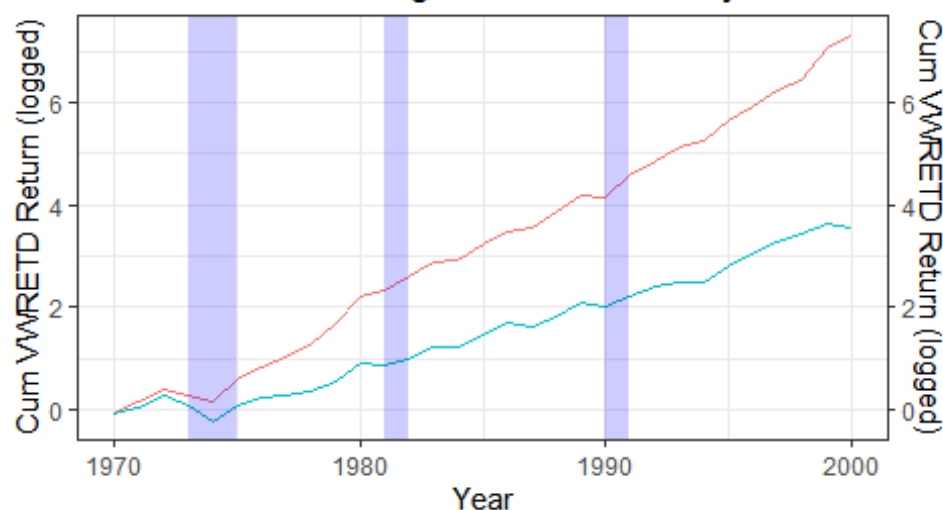
Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("volatility2", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0621      -0.0751         0.938         0.925
## 2 1971       0.242       0.129         1.17         1.04
## 3 1972       0.279       0.266         1.49         1.32
## 4 1973      -0.122      -0.188         1.31         1.07
## 5 1974      -0.103      -0.251         1.17         0.805
## 6 1975       0.513       0.351         1.78         1.09
## 7 1976       0.314       0.181         2.33         1.28
## 8 1977       0.196       0.0217        2.79         1.31
## 9 1978       0.250       0.0753        3.49         1.41
## 10 1979       0.546       0.231         5.39         1.74
## # ... with 21 more rows
```

Fundamental Indexing based on: volatility2



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

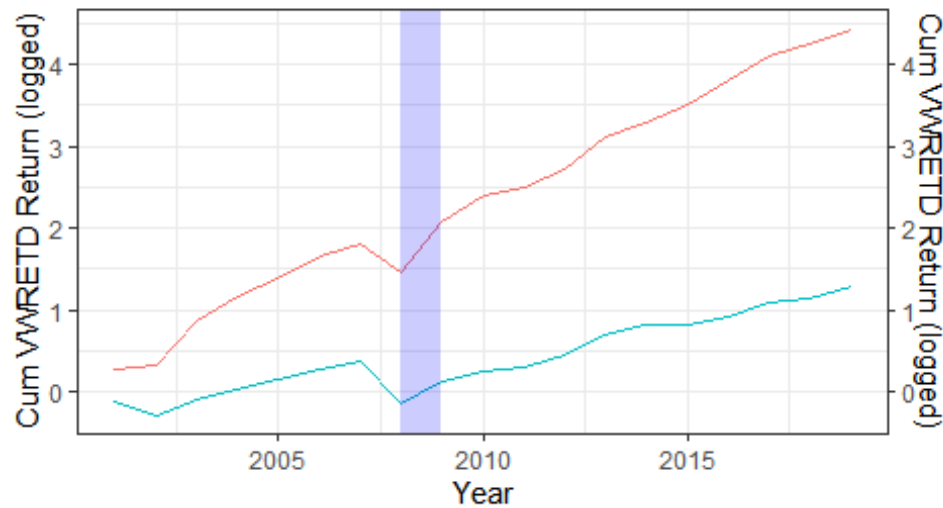
Returns are logged for illustration

```
market_value_indexing("volatility2", 2001, 2019)
```

```
## # A tibble: 19 x 5
```

##	Year	portfolio_return	annual_VWRETD	cum_port_return	cum_VWRETD
##	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	2001	0.329	-0.110	1.33	0.890
## 2	2002	0.0544	-0.149	1.40	0.757
## 3	2003	0.702	0.205	2.39	0.913
## 4	2004	0.349	0.141	3.22	1.04
## 5	2005	0.247	0.107	4.02	1.15
## 6	2006	0.293	0.154	5.19	1.33
## 7	2007	0.157	0.0891	6.01	1.45
## 8	2008	-0.276	-0.398	4.35	0.872
## 9	2009	0.850	0.305	8.05	1.14
## 10	2010	0.380	0.134	11.1	1.29
## 11	2011	0.0971	0.0519	12.2	1.36
## 12	2012	0.235	0.148	15.0	1.56
## 13	2013	0.504	0.287	22.6	2.01
## 14	2014	0.165	0.138	26.4	2.28
## 15	2015	0.276	0.00194	33.6	2.29
## 16	2016	0.329	0.0814	44.7	2.47
## 17	2017	0.330	0.214	59.5	3.00
## 18	2018	0.168	0.0422	69.4	3.13
## 19	2019	0.205	0.144	83.6	3.58

Fundamental Indexing based on: volatility2



Data — Cum Portfolio Return — Cum VWRETD Return

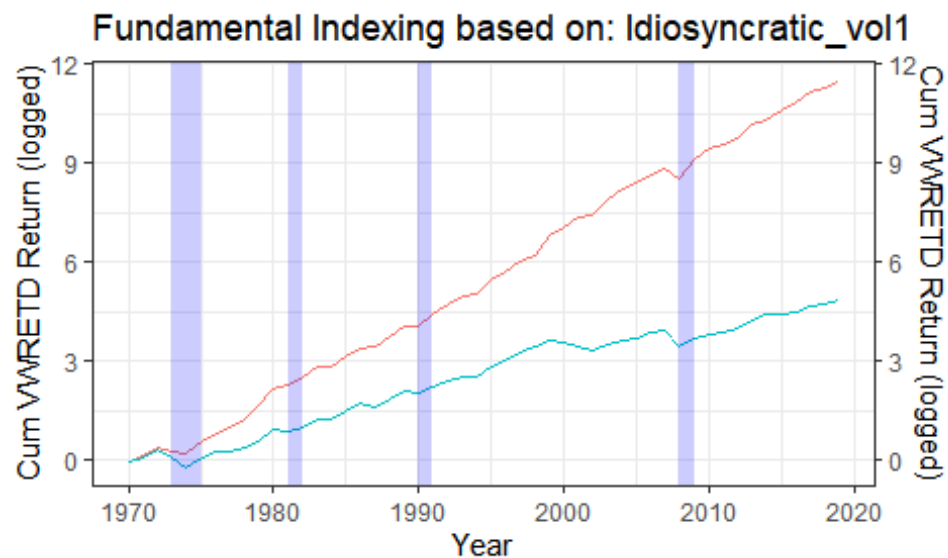
Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol1", 1970, 2019)
```

```
## # A tibble: 50 x 5
```

```
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0608      -0.0751         0.939         0.925
## 2 1971       0.222       0.129         1.15          1.04
## 3 1972       0.271       0.266         1.46          1.32
## 4 1973      -0.0990      -0.188         1.31          1.07
## 5 1974      -0.0943      -0.251         1.19          0.805
## 6 1975       0.479       0.351         1.76          1.09
## 7 1976       0.286       0.181         2.27          1.28
## 8 1977       0.194       0.0217        2.70          1.31
## 9 1978       0.250       0.0753        3.38          1.41
## 10 1979       0.544       0.231         5.22          1.74
## # ... with 40 more rows
```

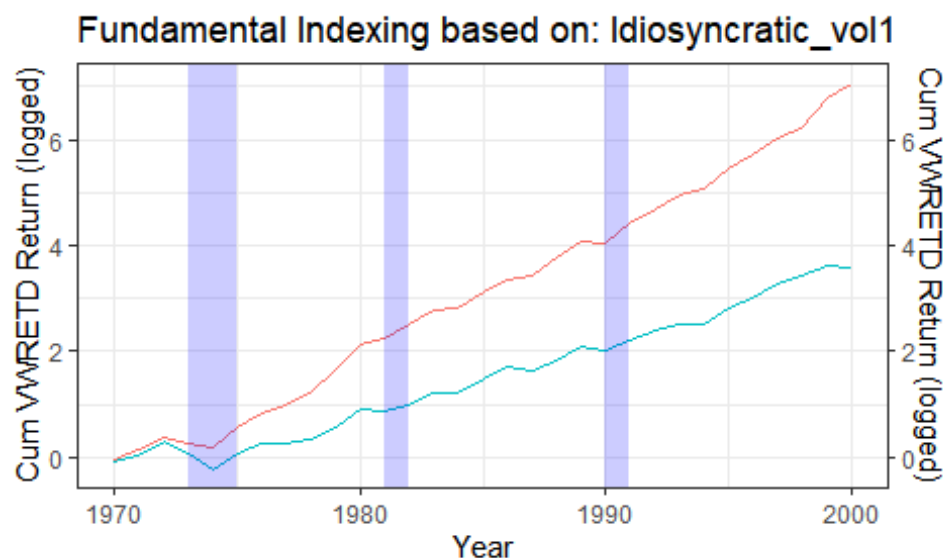
Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol1", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.0608        -0.0751         0.939         0.925
## 2 1971         0.222         0.129         1.15         1.04
## 3 1972         0.271         0.266         1.46         1.32
## 4 1973        -0.0990        -0.188         1.31         1.07
## 5 1974        -0.0943        -0.251         1.19         0.805
## 6 1975         0.479         0.351         1.76         1.09
## 7 1976         0.286         0.181         2.27         1.28
## 8 1977         0.194         0.0217        2.70         1.31
## 9 1978         0.250         0.0753        3.38         1.41
## 10 1979         0.544         0.231         5.22         1.74
## # ... with 21 more rows
```



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

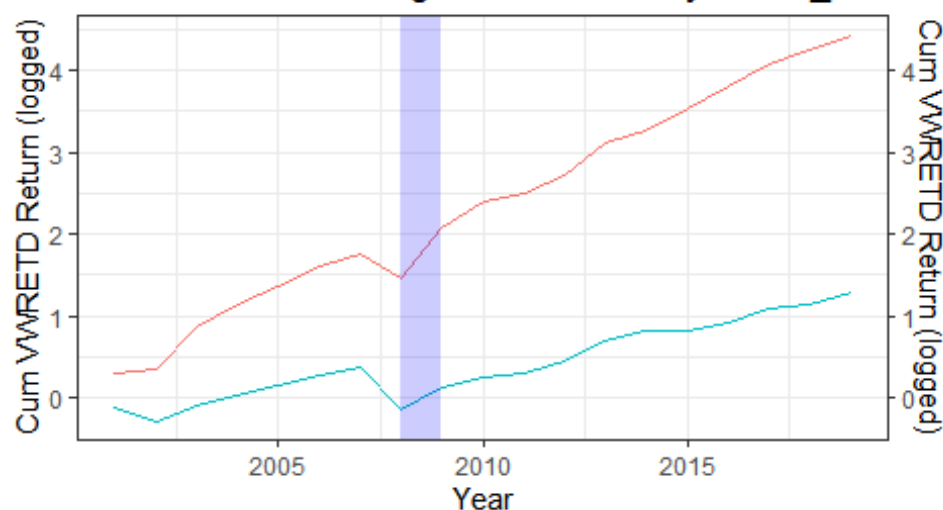
Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol1", 2001, 2019)
```

```
## # A tibble: 19 x 5
```

##	Year	portfolio_return	annual_VWRETD	cum_port_return	cum_VWRETD
##	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	2001	0.338	-0.110	1.34	0.890
## 2	2002	0.0618	-0.149	1.42	0.757
## 3	2003	0.679	0.205	2.38	0.913
## 4	2004	0.323	0.141	3.15	1.04
## 5	2005	0.239	0.107	3.91	1.15
## 6	2006	0.278	0.154	4.99	1.33
## 7	2007	0.149	0.0891	5.74	1.45
## 8	2008	-0.258	-0.398	4.26	0.872
## 9	2009	0.861	0.305	7.93	1.14
## 10	2010	0.379	0.134	10.9	1.29
## 11	2011	0.118	0.0519	12.2	1.36
## 12	2012	0.229	0.148	15.0	1.56
## 13	2013	0.488	0.287	22.4	2.01
## 14	2014	0.157	0.138	25.9	2.28
## 15	2015	0.314	0.00194	34.0	2.29
## 16	2016	0.320	0.0814	44.9	2.47
## 17	2017	0.321	0.214	59.2	3.00
## 18	2018	0.167	0.0422	69.1	3.13
## 19	2019	0.210	0.144	83.6	3.58

Fundamental Indexing based on: Idiosyncratic_vol1



Data — Cum Portfolio Return — Cum VWRETD Return

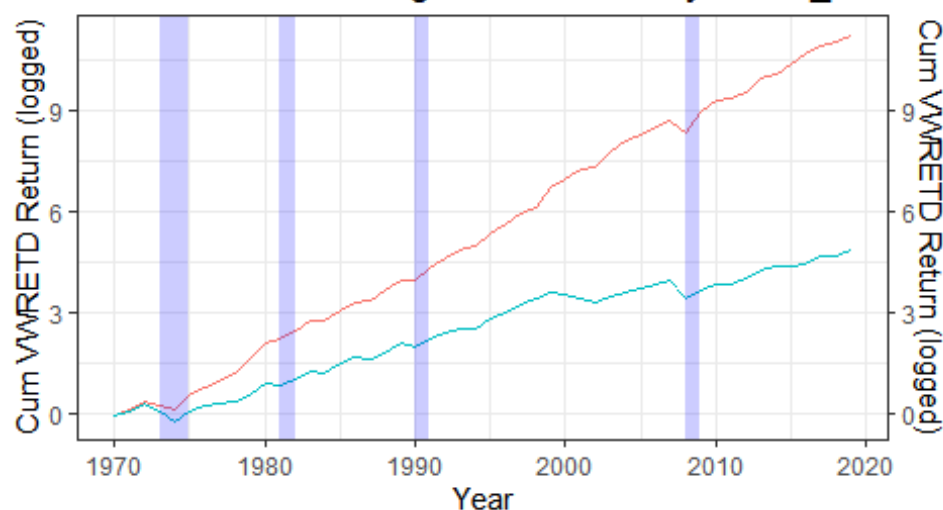
Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol2", 1970, 2019)
```

```
## # A tibble: 50 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970         -0.0659         -0.0751         0.934         0.925
## 2 1971          0.224          0.129          1.14          1.04
## 3 1972          0.267          0.266          1.45          1.32
## 4 1973         -0.124         -0.188          1.27          1.07
## 5 1974         -0.106         -0.251          1.13          0.805
## 6 1975          0.502          0.351          1.70          1.09
## 7 1976          0.296          0.181          2.21          1.28
## 8 1977          0.194          0.0217         2.63          1.31
## 9 1978          0.241          0.0753         3.27          1.41
## 10 1979          0.516          0.231          4.95          1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: Idiosyncratic_vol2



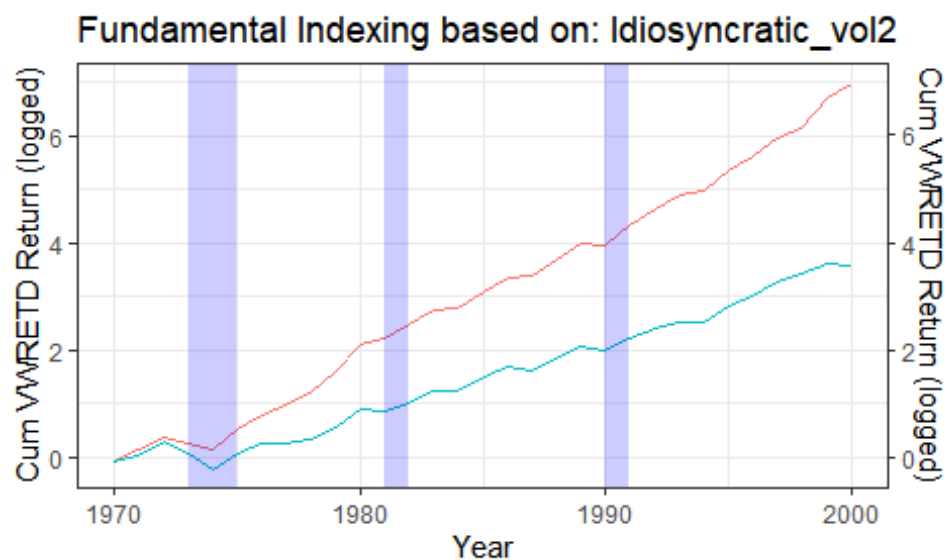
Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol2", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0659      -0.0751         0.934         0.925
## 2 1971       0.224       0.129         1.14         1.04
## 3 1972       0.267       0.266         1.45         1.32
## 4 1973      -0.124      -0.188         1.27         1.07
## 5 1974      -0.106      -0.251         1.13         0.805
## 6 1975       0.502       0.351         1.70         1.09
## 7 1976       0.296       0.181         2.21         1.28
## 8 1977       0.194       0.0217        2.63         1.31
## 9 1978       0.241       0.0753        3.27         1.41
## 10 1979       0.516       0.231         4.95         1.74
## # ... with 21 more rows
```



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

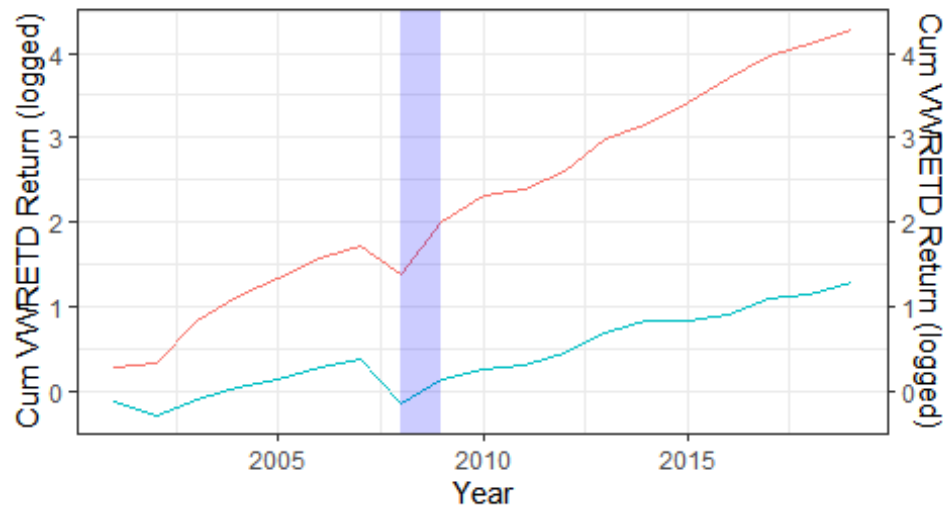
Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol2", 2001, 2019)
```

```
## # A tibble: 19 x 5
```

##	Year	portfolio_return	annual_VWRETD	cum_port_return	cum_VWRETD
##	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
## 1	2001	0.314	-0.110	1.31	0.890
## 2	2002	0.0555	-0.149	1.39	0.757
## 3	2003	0.678	0.205	2.33	0.913
## 4	2004	0.312	0.141	3.05	1.04
## 5	2005	0.234	0.107	3.77	1.15
## 6	2006	0.276	0.154	4.81	1.33
## 7	2007	0.150	0.0891	5.53	1.45
## 8	2008	-0.272	-0.398	4.03	0.872
## 9	2009	0.829	0.305	7.36	1.14
## 10	2010	0.368	0.134	10.1	1.29
## 11	2011	0.0877	0.0519	11.0	1.36
## 12	2012	0.227	0.148	13.4	1.56
## 13	2013	0.488	0.287	20.0	2.01
## 14	2014	0.158	0.138	23.2	2.28
## 15	2015	0.316	0.00194	30.5	2.29
## 16	2016	0.318	0.0814	40.2	2.47
## 17	2017	0.318	0.214	52.9	3.00
## 18	2018	0.149	0.0422	60.8	3.13
## 19	2019	0.191	0.144	72.5	3.58

Fundamental Indexing based on: Idiosyncratic_vol2



Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

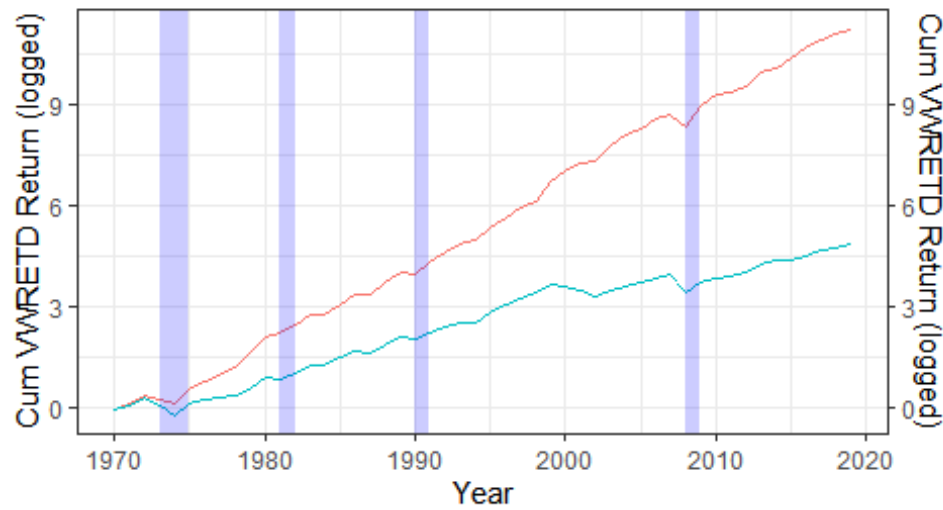
Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol3", 1970, 2019)
```

```
## # A tibble: 50 x 5
```

```
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970        -0.0759        -0.0751         0.924         0.925
## 2 1971         0.218         0.129         1.13         1.04
## 3 1972         0.260         0.266         1.42         1.32
## 4 1973        -0.133        -0.188         1.23         1.07
## 5 1974        -0.102        -0.251         1.10         0.805
## 6 1975         0.515         0.351         1.67         1.09
## 7 1976         0.301         0.181         2.18         1.28
## 8 1977         0.195         0.0217        2.60         1.31
## 9 1978         0.237         0.0753        3.22         1.41
## 10 1979         0.519         0.231         4.89         1.74
## # ... with 40 more rows
```

Fundamental Indexing based on: Idiosyncratic_vol3



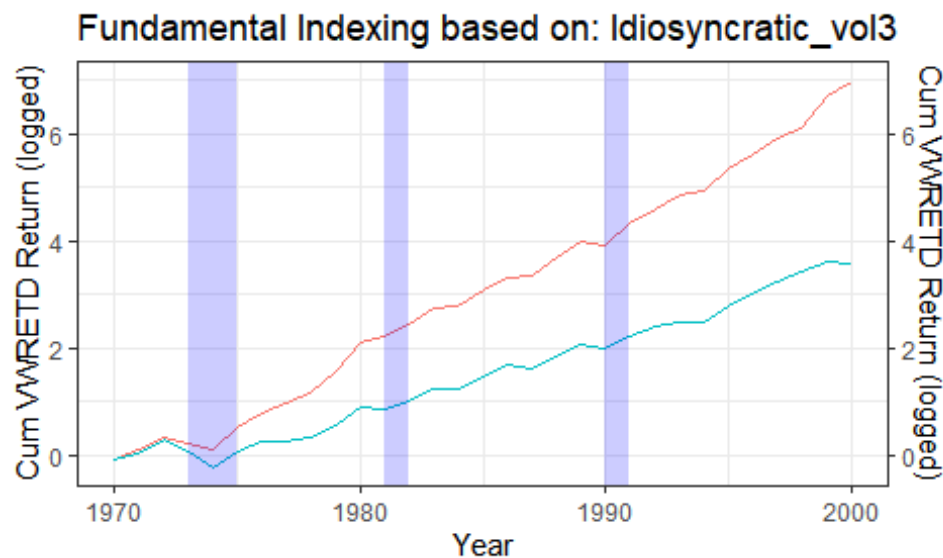
Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol3", 1970, 2000)
```

```
## # A tibble: 31 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 1970      -0.0759      -0.0751         0.924         0.925
## 2 1971       0.218       0.129          1.13          1.04
## 3 1972       0.260       0.266          1.42          1.32
## 4 1973      -0.133      -0.188          1.23          1.07
## 5 1974      -0.102      -0.251          1.10          0.805
## 6 1975       0.515       0.351          1.67          1.09
## 7 1976       0.301       0.181          2.18          1.28
## 8 1977       0.195       0.0217         2.60          1.31
## 9 1978       0.237       0.0753         3.22          1.41
## 10 1979       0.519       0.231          4.89          1.74
## # ... with 21 more rows
```



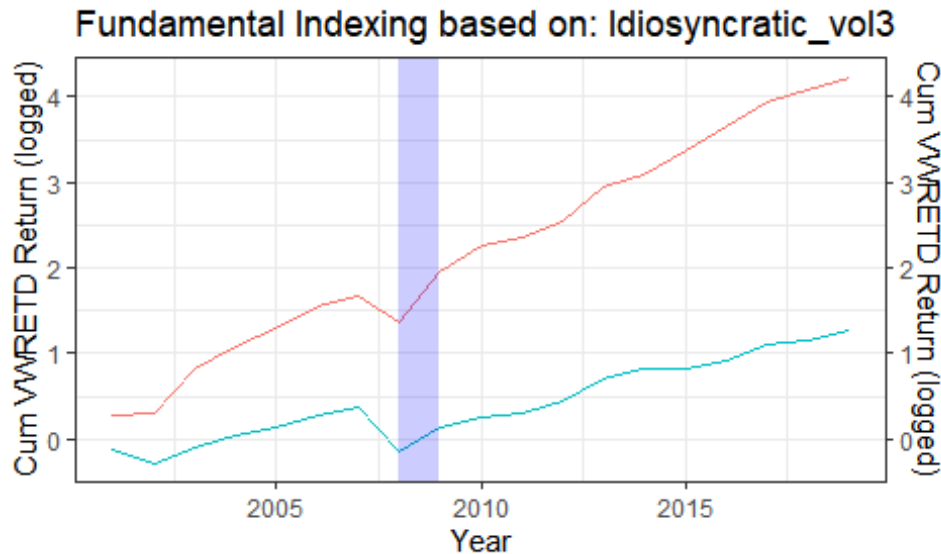
Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

Returns are logged for illustration

```
market_value_indexing("Idiosyncratic_vol3", 2001, 2019)
```

```
## # A tibble: 19 x 5
##   Year portfolio_return annual_VWRETD cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl>         <dbl>         <dbl>
## 1 2001           0.310          -0.110           1.31          0.890
## 2 2002           0.0400         -0.149           1.36          0.757
## 3 2003           0.673           0.205           2.28          0.913
## 4 2004           0.304           0.141           2.97          1.04
## 5 2005           0.230           0.107           3.66          1.15
## 6 2006           0.281           0.154           4.68          1.33
## 7 2007           0.148           0.0891          5.38          1.45
## 8 2008          -0.276          -0.398           3.89          0.872
## 9 2009           0.817           0.305           7.07          1.14
## 10 2010           0.359           0.134           9.61          1.29
## 11 2011           0.0872          0.0519          10.5          1.36
## 12 2012           0.213           0.148          12.7          1.56
## 13 2013           0.491           0.287          18.9          2.01
## 14 2014           0.164           0.138          22.0          2.28
## 15 2015           0.325           0.00194         29.2          2.29
## 16 2016           0.322           0.0814          38.6          2.47
## 17 2017           0.319           0.214          50.9          3.00
## 18 2018           0.161           0.0422          59.1          3.13
## 19 2019           0.164           0.144          68.8          3.58
```

Data — Cum Portfolio Return — Cum VWRETD Return

Recession are shown in shaded area

Returns are logged for illustration

The function to compute the descriptive statistics and ratios

```
describe_market_indexing <- function(funda) {
  funda <- as.name(funda)
  dif <- msf_market_variable %>% group_by(Year) %>%
    mutate(weight = eval(funda)/sum(eval(funda), na.rm = T),
           weighted_return = annual_return*weight) %>% group_by(Year) %>%
    summarize(portfolio_return = sum(weighted_return, na.rm = T),
              annual_VWRETD = mean(annual_VWRETD), #annual_VWRET has been
calculated before
              dif = portfolio_return - annual_VWRETD) %>% #so use mean to get
its values
    mutate(cum_port_return = cumprod(portfolio_return + 1),
           cum_VWRETD = cumprod(annual_VWRETD + 1),
           cum_dif = cum_port_return - cum_VWRETD)
  print(dif)

  ratios <- msf_market_variable %>% group_by(Year) %>%
    mutate(weight = eval(funda)/sum(eval(funda), na.rm = T),
           weighted_return = annual_return*weight) %>% group_by(Year) %>%
    summarize(portfolio_return = sum(weighted_return, na.rm = T),
              annual_VWRETD = mean(annual_VWRETD),
              RF = mean(annual_RF)) %>%
    mutate(cum_port_return = cumprod(portfolio_return + 1),
           cum_VWRETD = cumprod(annual_VWRETD + 1)) %>%
    summarize(volatility = sd(portfolio_return),
              skewness = skewness(portfolio_return),
```

```

    kurtosis = kurtosis(portfolio_return),
    Sharpe_ratio = mean(portfolio_return-RF)/volatility,
    Information_ratio = mean(portfolio_return-annual_VWRETD)/
                        sd(portfolio_return-annual_VWRETD))
print(ratios)
}

describe_market_indexing("Beta")

## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
##   cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
##   <dbl>
## 1 1970          -0.0529          -0.0583 0.00540          0.947
## 0.942
## 2 1971           0.232           0.120 0.111           1.17          1.05
## 3 1972           0.258           0.241 0.0174          1.47          1.31
## 4 1973          -0.153          -0.150 -0.00306         1.24          1.11
## 5 1974          -0.119          -0.204 0.0852           1.10
## 0.885
## 6 1975           0.404           0.317 0.0867           1.54          1.17
## 7 1976           0.273           0.170 0.103           1.96          1.36
## 8 1977           0.152           0.0217 0.131           2.25          1.39
## 9 1978           0.175           0.0790 0.0961           2.65          1.50
## 10 1979           0.422           0.214 0.207           3.77          1.83
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>    <dbl>    <dbl>    <dbl>    <dbl>
## 1    0.203    0.185    0.390    0.827    0.949

describe_market_indexing("volatility1")

## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
##   cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
##   <dbl>
## 1 1970          -0.0612          -0.0583 -0.00296          0.939
## 0.942
## 2 1971           0.223           0.120 0.103           1.15          1.05
## 3 1972           0.265           0.241 0.0245          1.45          1.31
## 4 1973          -0.119          -0.150 0.0313          1.28          1.11
## 5 1974          -0.0986          -0.204 0.105           1.15
## 0.885
## 6 1975           0.494           0.317 0.177           1.72          1.17
## 7 1976           0.289           0.170 0.119           2.22          1.36
## 8 1977           0.187           0.0217 0.165           2.64          1.39
## 9 1978           0.239           0.0790 0.160           3.27          1.50
## 10 1979           0.511           0.214 0.297           4.94          1.83

```

```
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>      <dbl>      <dbl>      <dbl>          <dbl>
## 1      0.215      0.218      0.653          1.06          1.26
```

```
describe_market_indexing("volatility2")
```

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD      dif cum_port_return
cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          -0.0621          -0.0583 -0.00387          0.938
0.942
## 2 1971           0.242           0.120    0.122          1.17          1.05
## 3 1972           0.279           0.241    0.0388          1.49          1.31
## 4 1973          -0.122          -0.150    0.0278          1.31          1.11
## 5 1974          -0.103          -0.204    0.101          1.17
0.885
## 6 1975           0.513           0.317    0.196          1.78          1.17
## 7 1976           0.314           0.170    0.144          2.33          1.36
## 8 1977           0.196           0.0217   0.174          2.79          1.39
## 9 1978           0.250           0.0790   0.171          3.49          1.50
## 10 1979          0.546           0.214    0.332          5.39          1.83
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>      <dbl>      <dbl>      <dbl>          <dbl>
## 1      0.227      0.245      0.638          1.08          1.28
```

```
describe_market_indexing("Idiosyncratic_vol1")
```

```
## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD      dif cum_port_return
cum_VWRETD
##   <dbl>          <dbl>          <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          -0.0608          -0.0583 -0.00254          0.939
0.942
## 2 1971           0.222           0.120    0.102          1.15          1.05
## 3 1972           0.271           0.241    0.0301          1.46          1.31
## 4 1973          -0.0990          -0.150    0.0513          1.31          1.11
## 5 1974          -0.0943          -0.204    0.110          1.19
0.885
## 6 1975           0.479           0.317    0.162          1.76          1.17
## 7 1976           0.286           0.170    0.117          2.27          1.36
## 8 1977           0.194           0.0217   0.172          2.70          1.39
## 9 1978           0.250           0.0790   0.171          3.38          1.50
## 10 1979          0.544           0.214    0.330          5.22          1.83
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
```

```
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>     <dbl>     <dbl>     <dbl>         <dbl>
## 1      0.215     0.256     0.729         1.10         1.28

describe_market_indexing("Idiosyncratic_vol2")

## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return
##   <dbl>         <dbl>         <dbl> <dbl>         <dbl>
## 1 1970      -0.0659      -0.0583 -0.00761      0.934
## 2 1971       0.224       0.120  0.103      1.14      1.05
## 3 1972       0.267       0.241  0.0265     1.45      1.31
## 4 1973      -0.124      -0.150  0.0259     1.27      1.11
## 5 1974      -0.106      -0.204  0.0976     1.13
## 6 1975       0.502       0.317  0.185     1.70      1.17
## 7 1976       0.296       0.170  0.126     2.21      1.36
## 8 1977       0.194       0.0217  0.172     2.63      1.39
## 9 1978       0.241       0.0790  0.162     3.27      1.50
## 10 1979       0.516       0.214  0.302     4.95      1.83
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>     <dbl>     <dbl>     <dbl>         <dbl>
## 1      0.218     0.178     0.555         1.06         1.24

describe_market_indexing("Idiosyncratic_vol3")

## # A tibble: 50 x 7
##   Year portfolio_return annual_VWRETD dif cum_port_return cum_VWRETD
##   <dbl>         <dbl>         <dbl> <dbl>         <dbl>
## 1 1970      -0.0759      -0.0583 -0.0176      0.924      0.942
## 2 1971       0.218       0.120  0.0982      1.13      1.05
## 3 1972       0.260       0.241  0.0191      1.42      1.31
## 4 1973      -0.133      -0.150  0.0177      1.23      1.11
## 5 1974      -0.102      -0.204  0.102      1.10      0.885
## 6 1975       0.515       0.317  0.198      1.67      1.17
## 7 1976       0.301       0.170  0.132      2.18      1.36
## 8 1977       0.195       0.0217  0.173      2.60      1.39
## 9 1978       0.237       0.0790  0.158      3.22      1.50
## 10 1979       0.519       0.214  0.305      4.89      1.83
## # ... with 40 more rows, and 1 more variable: cum_dif <dbl>
## # A tibble: 1 x 5
##   volatility skewness kurtosis Sharpe_ratio Information_ratio
##   <dbl>     <dbl>     <dbl>     <dbl>         <dbl>
## 1      0.220     0.163     0.464         1.04         1.22
```

The function to compare market variable indexing portfolio returns with MKT, SMB, and HML returns

```
compare_market_indexing <- function(funda) {
funda <- as.name(funda)
output <- msf_market_variable %>% group_by(Year) %>%
  mutate(
    weight = eval(funda)/sum(eval(funda), na.rm = T),
    weighted_return = annual_return*weight) %>% group_by(Year) %>%
    summarize(portfolio_return = sum(weighted_return, na.rm = T),
      MKT = mean(annual_Mkt.RF), #annual MKT, SMB, and HML have
already been caculated
      SMB = mean(annual_SMB), #from monthly data
      HML = mean(annual_HML)) %>% #so use mean to extract the values
    mutate(cum_port_return = cumprod(portfolio_return + 1),
      cum_MKT= cumprod(MKT + 1),
      cum_SMB= cumprod(SMB + 1),
      cum_HML= cumprod(HML + 1))
print(output)
}

compare_market_indexing("Beta")

## # A tibble: 50 x 9
##   Year portfolio_return    MKT    SMB    HML cum_port_return
##   <dbl>          <dbl> <dbl> <dbl> <dbl>          <dbl>
## 1 1970          -0.0529 -0.113 -0.142  0.157          0.947
## 2 1971           0.232  0.0740  0.0491 -0.0728          1.17
## 3 1972           0.258  0.199 -0.0519  0.0363          1.47
## 4 1973          -0.153 -0.199 -0.188  0.138          1.24
## 5 1974          -0.119 -0.246 -0.00552  0.137          1.10
## 6 1975           0.404  0.258  0.0719  0.0467          1.54
## 7 1976           0.273  0.116  0.0738  0.183          1.96
## 8 1977           0.152 -0.0243  0.236  0.0909          2.25
## 9 1978           0.175  0.0150  0.136  0.00246          2.65
## 10 1979          0.422  0.101  0.135 -0.0153          3.77
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
## <dbl>

compare_market_indexing("volatility1")
```

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl> <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          -0.0612 -0.113 -0.142  0.157          0.939
0.887
## 2 1971           0.223  0.0740  0.0491 -0.0728          1.15
0.952
## 3 1972           0.265  0.199 -0.0519  0.0363          1.45    1.14
## 4 1973          -0.119 -0.199 -0.188  0.138          1.28
0.914
## 5 1974          -0.0986 -0.246 -0.00552  0.137          1.15
0.689
## 6 1975           0.494  0.258  0.0719  0.0467          1.72
0.867
## 7 1976           0.289  0.116  0.0738  0.183          2.22
0.967
## 8 1977           0.187 -0.0243  0.236  0.0909          2.64
0.944
## 9 1978           0.239  0.0150  0.136  0.00246          3.27
0.958
## 10 1979          0.511  0.101  0.135 -0.0153          4.94    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>
```

`compare_market_indexing("volatility2")`

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl> <dbl> <dbl>          <dbl>
<dbl>
## 1 1970          -0.0621 -0.113 -0.142  0.157          0.938
0.887
## 2 1971           0.242  0.0740  0.0491 -0.0728          1.17
0.952
## 3 1972           0.279  0.199 -0.0519  0.0363          1.49    1.14
## 4 1973          -0.122 -0.199 -0.188  0.138          1.31
0.914
## 5 1974          -0.103 -0.246 -0.00552  0.137          1.17
0.689
## 6 1975           0.513  0.258  0.0719  0.0467          1.78
0.867
## 7 1976           0.314  0.116  0.0738  0.183          2.33
0.967
## 8 1977           0.196 -0.0243  0.236  0.0909          2.79
0.944
## 9 1978           0.250  0.0150  0.136  0.00246          3.49
0.958
```

```
## 10 1979          0.546  0.101  0.135  -0.0153          5.39  1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>
```

```
compare_market_indexing("Idiosyncratic_vol1")
```

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl>  <dbl>  <dbl>  <dbl>          <dbl>
<dbl>
## 1 1970          -0.0608 -0.113 -0.142  0.157          0.939
0.887
## 2 1971           0.222  0.0740 0.0491 -0.0728          1.15
0.952
## 3 1972           0.271  0.199 -0.0519 0.0363          1.46  1.14
## 4 1973          -0.0990 -0.199 -0.188  0.138          1.31
0.914
## 5 1974          -0.0943 -0.246 -0.00552 0.137          1.19
0.689
## 6 1975           0.479  0.258  0.0719 0.0467          1.76
0.867
## 7 1976           0.286  0.116  0.0738 0.183          2.27
0.967
## 8 1977           0.194 -0.0243 0.236  0.0909          2.70
0.944
## 9 1978           0.250  0.0150 0.136  0.00246          3.38
0.958
## 10 1979          0.544  0.101  0.135  -0.0153          5.22  1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>
```

```
compare_market_indexing("Idiosyncratic_vol2")
```

```
## # A tibble: 50 x 9
##   Year portfolio_return      MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl>  <dbl>  <dbl>  <dbl>          <dbl>
<dbl>
## 1 1970          -0.0659 -0.113 -0.142  0.157          0.934
0.887
## 2 1971           0.224  0.0740 0.0491 -0.0728          1.14
0.952
## 3 1972           0.267  0.199 -0.0519 0.0363          1.45  1.14
## 4 1973          -0.124 -0.199 -0.188  0.138          1.27
0.914
## 5 1974          -0.106 -0.246 -0.00552 0.137          1.13
0.689
## 6 1975           0.502  0.258  0.0719 0.0467          1.70
0.867
## 7 1976           0.296  0.116  0.0738 0.183          2.21
```

```

0.967
## 8 1977          0.194 -0.0243  0.236    0.0909          2.63
0.944
## 9 1978          0.241  0.0150  0.136    0.00246          3.27
0.958
## 10 1979          0.516  0.101  0.135   -0.0153          4.95    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```

```
compare_market_indexing("Idiosyncratic_vol3")
```

```

## # A tibble: 50 x 9
##   Year portfolio_return    MKT      SMB      HML cum_port_return
cum_MKT
##   <dbl>          <dbl> <dbl>    <dbl>    <dbl>          <dbl>
<dbl>
## 1 1970          -0.0759 -0.113 -0.142    0.157          0.924
0.887
## 2 1971          0.218  0.0740  0.0491 -0.0728          1.13
0.952
## 3 1972          0.260  0.199 -0.0519  0.0363          1.42    1.14
## 4 1973          -0.133 -0.199 -0.188    0.138          1.23
0.914
## 5 1974          -0.102 -0.246 -0.00552  0.137          1.10
0.689
## 6 1975          0.515  0.258  0.0719  0.0467          1.67
0.867
## 7 1976          0.301  0.116  0.0738  0.183          2.18
0.967
## 8 1977          0.195 -0.0243  0.236    0.0909          2.60
0.944
## 9 1978          0.237  0.0150  0.136    0.00246          3.22
0.958
## 10 1979          0.519  0.101  0.135   -0.0153          4.89    1.06
## # ... with 40 more rows, and 2 more variables: cum_SMB <dbl>, cum_HML
<dbl>

```