# Project 1

2025-03-09

## Project 1 - Team 12

## Needed packages

## Exercise 4: Market Portfolio Returns

### Download monthly Fama-French data

```
start_date <- "1927-01-01"
end_date <- "2024-12-31"

#monthly
factors_ff_monthly_raw <- download_french_data("Fama/French 3 Factors")
```

```
## New names:
## New names:
## * `` -> `...1`
```

```
# first data set is the monthly data
mkt_rf_ff_monthly <- factors_ff_monthly_raw$subsets$data[[1]] %>%
  mutate(
    # transform the data to be first day of the month and of the form "yyyy-mm-dd"
    date = floor_date(ymd(paste0(date, "01")), "month"),
    # data in percentage format, therefore convert them to decimal form
    across(c(RF, `Mkt-RF`, SMB, HML), ~as.numeric(.) / 100),
    # drop all other columns
    .keep = "none"
  ) %>%
  # rename all columns for better readability
  rename_with(str_to_lower) %>%
  rename(mkt_excess = `mkt-rf`) %>%
  # filter for the given time frame
  filter(date >= start_date & date <= end_date) %>%
  # Rearranging columns
  select(date, mkt_excess, rf)

head(mkt_rf_ff_monthly)
```

```
## # A tibble: 6 x 3
##   date       mkt_excess     rf
##   <date>          <dbl>  <dbl>
## 1 1927-01-01    -0.0006 0.0025
## 2 1927-02-01     0.0418 0.0026
## 3 1927-03-01     0.0013 0.003
## 4 1927-04-01     0.0046 0.0025
## 5 1927-05-01     0.0544 0.003
## 6 1927-06-01    -0.0234 0.0026
```

### Calculate Market Portfolio Returns

The mkt-excess data set in the Fama-French data is the market excess return. Therefore, we need to add the riskfree rate “rf” to receive the market portfolio returns.

```r
mkt_ret_monthly <- mkt_rf_ff_monthly %>%
  mutate(
    mkt_ret = mkt_excess + rf
    ) %>%
  select(-mkt_excess,-rf)

# Function to calculate rolling cumulative returns
# width = the number of data we want to cumulate over --> roll monthly
# Fun = calculates the cumulative return
# align = "right" --> assure we take last month of the window
rolling_cum_return <- function(return_series, window) {
  rollapply(return_series, width = window, FUN = function(x) prod(1 + x) - 1, align = "right", fill = N
}

# Compute rolling returns
mkt_ret_rolling <- mkt_ret_monthly %>%
  arrange(date) %>%
  mutate(
    ret_1yr  = rolling_cum_return(mkt_ret, 12), # 1 year
    ret_10yr = rolling_cum_return(mkt_ret, 120), # 10 years
    ret_20yr = rolling_cum_return(mkt_ret, 240) # 20 years
  ) %>%
  select(-mkt_ret)

# 1. Average if rolling every month

# Compute average return for each investment duration
avg_ret_1yr_m  <- round(mean(mkt_ret_rolling$ret_1yr, na.rm = TRUE),4) *100
avg_ret_10yr_m <- round(mean(mkt_ret_rolling$ret_10yr, na.rm = TRUE),4) *100
avg_ret_20yr_m <- round(mean(mkt_ret_rolling$ret_20yr, na.rm = TRUE),4) *100

# 2. Average if rolling every year

mkt_ret_rolling_y <- mkt_ret_rolling %>%
  filter(month(date) == 1)

avg_ret_1yr_y  <- round(mean(mkt_ret_rolling_y$ret_1yr, na.rm = TRUE),4) *100
avg_ret_10yr_y <- round(mean(mkt_ret_rolling_y$ret_10yr, na.rm = TRUE),4) *100
avg_ret_20yr_y <- round(mean(mkt_ret_rolling_y$ret_20yr, na.rm = TRUE),4) *100


results <- data.frame(
  Rolling_Type = c("Monthly", "Yearly"),
  Average_1_year_Return = c(avg_ret_1yr_m, avg_ret_1yr_y),
  Average_10_year_Return = c(avg_ret_10yr_m, avg_ret_10yr_y),
  Average_20_year_Return = c(avg_ret_20yr_m, avg_ret_20yr_y)
)
```

Average Returns of the Market Portfolio [1927-2024] (in %)

| Rolling Type | Avg. 1 Year Ret. | Avg. 10 Year Ret. | Avg. 20 Year Ret. |
|---|---|---|---|
| Monthly | 12.14 | 198.14 | 797.02 |
| Yearly | 11.97 | 197.51 | 793.07 |

```r
colnames(results) <- c("Rolling Type","Avg. 1 Year Ret.", "Avg. 10 Year Ret.", "Avg. 20 Year Ret.")

results %>%
  gt() %>%
  tab_style(
    style = cell_borders(sides = "right",
                         color = "grey80",
                         weight = px(2)),
    locations = cells_body(columns = everything())
  ) %>%
  tab_style(
    style = cell_borders(sides = "right",
                         color = "grey80",
                         weight= px(2)),
    locations = cells_column_labels(columns = everything())  # Apply to column headers
  ) %>%
  tab_header(title = "Average Returns of the Market Portfolio [1927-2024] (in %)")
```

**Annualize Market Portfolio Returns**

```r
#function for annualizing returns with given input of the months = T
annualize_returns <- function(return,T){
  (1+return)^(12/T) - 1
}

# Annualize returns in the df mkt_ret_rolling using the  monthly and yearly rolling time frame

# Monthly
mkt_ret_rolling_m_ann <- mkt_ret_rolling %>%
  mutate(
    ret_10yr_ann = annualize_returns(ret_10yr,120),
    ret_20yr_ann = annualize_returns(ret_20yr,240)
  ) %>%
  select(-ret_10yr,-ret_20yr)

avg_ret_10yr_m_ann <- round(mean(mkt_ret_rolling_m_ann$ret_10yr_ann, na.rm = TRUE),4) *100
avg_ret_20yr_m_ann <- round(mean(mkt_ret_rolling_m_ann$ret_20yr_ann, na.rm = TRUE),4) *100


# Yearly
mkt_ret_rolling_y_ann <- mkt_ret_rolling_y %>%
  mutate(
    ret_10yr_ann = annualize_returns(ret_10yr,120),
    ret_20yr_ann = annualize_returns(ret_20yr,240)
  ) %>%
```

Average Annualized Returns of the Market Portfolio [1927-2024] (in %)

| Rolling Type | Avg. 1 Year Ret. | Avg. 10 Year Ret. | Avg. 20 Year Ret. |
|---|---|---|---|
| Monthly | 12.14 | 10.53 | 10.77 |
| Yearly | 11.97 | 10.50 | 10.74 |

```r
  select(-ret_10yr,-ret_20yr)

avg_ret_10yr_y_ann <- round(mean(mkt_ret_rolling_y_ann$ret_10yr_ann, na.rm = TRUE),4) *100
avg_ret_20yr_y_ann <- round(mean(mkt_ret_rolling_y_ann$ret_20yr_ann, na.rm = TRUE),4) *100

results <- data.frame(
  Rolling_Type = c("Monthly", "Yearly"),
  Average_1_year_Return = c(avg_ret_1yr_m, avg_ret_1yr_y),
  Average_10_year_Return = c(avg_ret_10yr_m_ann,avg_ret_10yr_y_ann),
  Average_20_year_Return = c(avg_ret_20yr_m_ann,avg_ret_20yr_y_ann)
)

colnames(results) <- c("Rolling Type","Avg. 1 Year Ret.", "Avg. 10 Year Ret.", "Avg. 20 Year Ret.")

results %>%
  gt() %>%
  tab_style(
    style = cell_borders(sides = "right",
                         color = "grey80",
                         weight = px(2)),
    locations = cells_body(columns = everything())
  ) %>%
  tab_style(
    style = cell_borders(sides = "right",
                         color = "grey80",
                         weight= px(2)),
    locations = cells_column_labels(columns = everything())  # Apply to column headers
  ) %>%
  tab_header(title = "Average Annualized Returns of the Market Portfolio [1927-2024] (in %)")
```

**Resample from the actual data and calculate the bootstrap standard error**

```r
# We want to sample from the actual return data series
# Repeat the sample 10,000 times and calculate the mean for every sample
# standard error is the sd of the sample means
# We use the annualized return series
bootstrap_se <- function(returns, num_samples = 10000) {
  boot_means <- replicate(num_samples, mean(sample(returns, size = length(returns), replace = TRUE)))
  return(sd(boot_means))
}

se_1yr <- bootstrap_se(na.omit(mkt_ret_rolling_y_ann$ret_1yr))
se_10yr <- bootstrap_se(na.omit(mkt_ret_rolling_y_ann$ret_10yr_ann))
se_20yr <- bootstrap_se(na.omit(mkt_ret_rolling_y_ann$ret_20yr_ann))
```

Bootstrap Standard Error of Average Annualized Returns (Ret. in %)

| Metric | Avg. 1 Year Ret. | Avg. 10 Year Ret. | Avg. 20 Year Ret. |
|---|---|---|---|
| Bootstrap SE | 2.01 | 0.55 | 0.36 |

```r
result_se <- data.frame(
  Metric = c("Bootstrap SE"),
  Average_1_year_Return = round(se_1yr,4) *100 ,
  Average_10_year_Return = round(se_10yr,4)*100,
  Average_20_year_Return = round(se_20yr,4)*100
)

colnames(result_se) <- c("Metric","Avg. 1 Year Ret.", "Avg. 10 Year Ret.", "Avg. 20 Year Ret.")

result_se %>%
  gt() %>%
  tab_style(
    style = cell_borders(sides = "right",
                         color = "grey80",
                         weight = px(2)),
    locations = cells_body(columns = everything())
  ) %>%
  tab_style(
    style = cell_borders(sides = "right",
                         color = "grey80",
                         weight= px(2)),
    locations = cells_column_labels(columns = everything())  # Apply to column headers
  ) %>%
  tab_header(title = "Bootstrap Standard Error of Average Annualized Returns (Ret. in %)")
```

**ADDITIONAL Bootstrap Standard Error with Confidence Intervals**

```r
# Bootstrap function to calculate standard error and confidence intervals
bootstrap_ci <- function(returns, num_samples = 10000, conf_level = 0.95) {
  # Generate bootstrap samples and calculate the statistic for each sample
  boot_stats <- replicate(num_samples, mean(sample(returns, size = length(returns), replace = TRUE)))
  # Calculate the standard error
  se <- sd(boot_stats)
  # Calculate the confidence interval
  alpha <- 1 - conf_level
  ci <- quantile(boot_stats, probs = c(alpha / 2, 1 - alpha / 2))
  return(list(se = se, ci = ci))
}

set.seed(123)  # For reproducibility
# Calculate bootstrap standard errors and confidence intervals
bootstrap_1yr <- bootstrap_ci(na.omit(mkt_ret_rolling_y_ann$ret_1yr))
bootstrap_10yr <- bootstrap_ci(na.omit(mkt_ret_rolling_y_ann$ret_10yr_ann))
bootstrap_20yr <- bootstrap_ci(na.omit(mkt_ret_rolling_y_ann$ret_20yr_ann))

# Create a results table
```

Bootstrap Standard Errors and Confidence Intervals at 95% for Annualized Returns (in %)

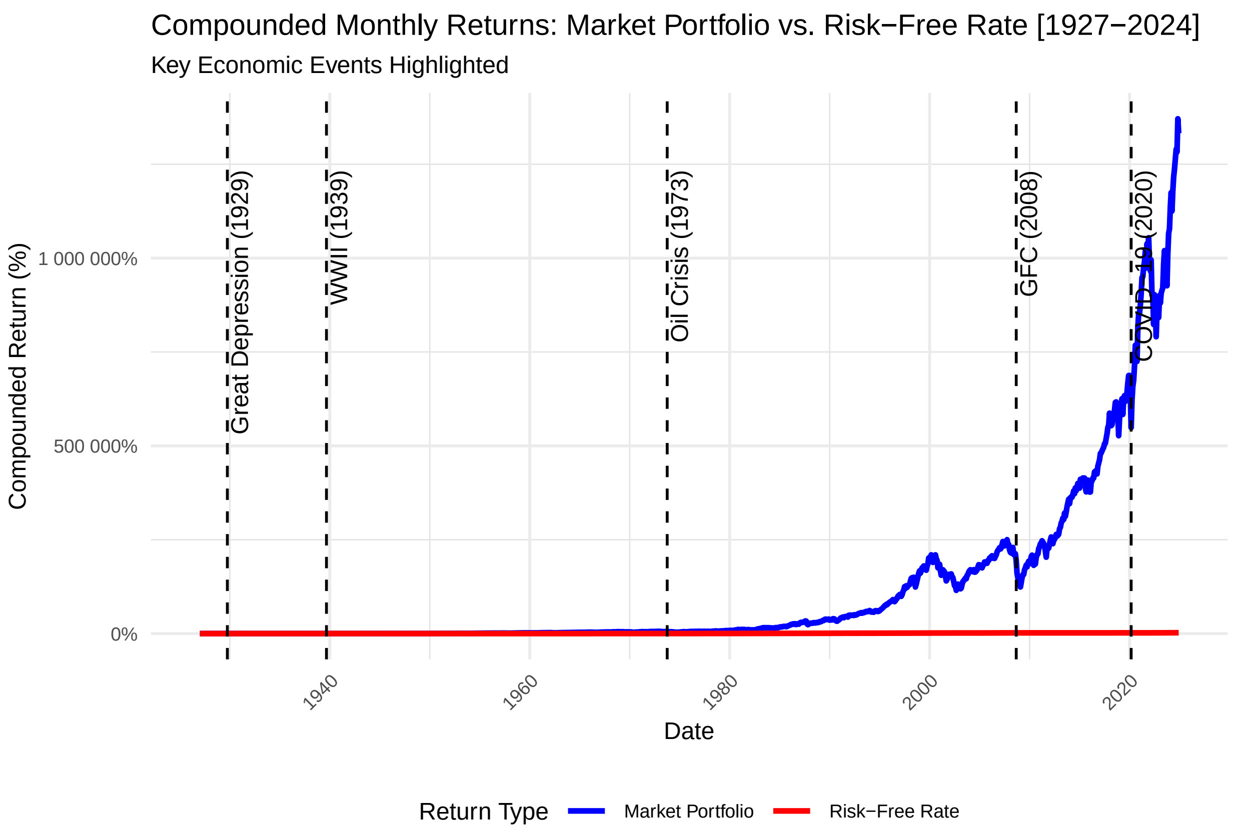
| Duration | Avg. Return (in %) | SE (in %) | CI Lower (in %) | CI Upper ( in%) |
|---|---|---|---|---|
| 1-Year | 11.97 | 2.03 | 7.99 | 15.94 |
| 10-Year | 10.50 | 0.56 | 9.42 | 11.58 |
| 20-Year | 10.74 | 0.35 | 10.04 | 11.44 |

```r
results_ci <- data.frame(
  Metric = c("1-Year", "10-Year", "20-Year"),
  Avg_Return = c(avg_ret_1yr_y,avg_ret_10yr_y_ann,avg_ret_20yr_y_ann),
  SE = round(c(bootstrap_1yr$se * 100,bootstrap_10yr$se * 100,bootstrap_20yr$se * 100),2),
  CI_Lower = round(c(bootstrap_1yr$ci[1] * 100,bootstrap_10yr$ci[1] * 100,bootstrap_20yr$ci[1] * 100),2
  CI_Upper = round(c(bootstrap_1yr$ci[2] * 100,bootstrap_10yr$ci[2] * 100,bootstrap_20yr$ci[2] * 100),2
)
colnames(results_ci) <- c("Duration", "Avg. Return (in %)", "SE (in %)", "CI Lower (in %)", "CI Upper (

# Display results
results_ci %>%
  gt() %>%
  tab_style(
    style = cell_borders(sides = "right", color = "grey80", weight = px(2)),
    locations = cells_body(columns = everything())
  ) %>%
  tab_style(
    style = cell_borders(sides = "right", color = "grey80", weight = px(2)),
    locations = cells_column_labels(columns = everything())
  ) %>%
  tab_header(title = "Bootstrap Standard Errors and Confidence Intervals at 95% for Annualized Returns
```

**Comparison of the returns of investment of the MP with riskfree rate**

```r
mkt_ret_monthly <- mkt_rf_ff_monthly %>%
  mutate(
    mkt_ret = mkt_excess + rf
    ) %>%
  select(-mkt_excess)

mkt_ret_monthly <- mkt_ret_monthly %>%
  mutate(
    mkt_comp = cumprod(1 + mkt_ret) - 1,
    rf_comp = cumprod(1 + rf) - 1
  )

# Reshape data for plotting
mkt_ret_monthly_long <- na.omit(mkt_ret_monthly) %>%
  select(date, mkt_comp , rf_comp) %>%
  pivot_longer(cols = c(mkt_comp,rf_comp),
               names_to = "Security",
               values_to = "Compound_Return")

# Key events
```

```r
key_events <- data.frame(
  event = c("Great Depression", "World War II", "Oil Crisis", "Global Financial Crisis", "COVID-19 Pand
  date = as.Date(c("1929-10-01", "1939-09-01", "1973-10-01", "2008-09-01", "2020-03-01")),
  label = c("Great Depression (1929)", "WWII (1939)", "Oil Crisis (1973)", "GFC (2008)", "COVID-19 (202
)


# Plot the compounded returns with annotations
ggplot(mkt_ret_monthly_long, aes(x = date, y = Compound_Return, color = Security)) +
  geom_line(linewidth = 1) +  # Line plot for compounded returns
  # Add vertical lines for key events
  geom_vline(data = key_events, aes(xintercept = date), linetype = "dashed", color = "black", linewidth
  # Add text annotations for key events
  geom_text(
    data = key_events,
    aes(x = date, y = max(mkt_ret_monthly_long$Compound_Return, na.rm = TRUE) * 0.9, label = label),
    angle = 90, hjust = 1, vjust = 1.2, color = "black", size = 3
  ) +
  labs(
    title = "Compounded Monthly Returns: Market Portfolio vs. Risk-Free Rate [1927-2024]",
    subtitle = "Key Economic Events Highlighted",
    x = "Date",
    y = "Compounded Return (%)",
    color = "Return Type"
  ) +
  theme_minimal() +  # Clean theme
  theme(
    legend.position = "bottom",
    text = element_text(size = 9),
    axis.text.x = element_text(angle = 45, hjust = 1),
    panel.grid.minor = element_line(color = "grey90")  # Add a subtle grid
  ) +
  scale_color_manual(
    values = c("mkt_comp" = "blue", "rf_comp" = "red"),
    labels = c("Market Portfolio", "Risk-Free Rate")
  ) +
  scale_y_continuous(labels = scales::percent)  # Format y-axis as percentages
```



**Housekeeping for Git**

```
save.image(file = "Pj1_Task4.RData")
```

## # Exercise 5: Find a proxy for the Market Portfolio

As Alnylam Pharmaceuticals, Inc. is a publicly traded large cap corporation in the US and it is part of the Russel 1000 and Russel 3000, we think that it is suitable to use the wider Russel 3000 index as the market portfolio.

**First download the data from Excel**

The price data for the Russel 3000 and for Alnylam Pharmaceuticals is in an Excel file, which we downloaded from Bloomberg.

```
ALNY_PX <- read.xlsx("Daily_Data_Case_1.xlsx", sheet = 2)
ALNY_PX$Date <- as.Date(ALNY_PX$Date,origin = "1899-12-30")

RUS_3_PX <- read.xlsx("Daily_Data_Case_1.xlsx", sheet = 1)
RUS_3_PX$Date <- as.Date(RUS_3_PX$Date,origin = "1899-12-30")

# Observe NA values

ALNY_NA <- sum(is.na(ALNY_PX$Last.Price))
RUS_3_NA <- sum(is.na(RUS_3_PX$Last.Price))

# One NA in ALNY_PX --> Lin. Interpolate
```

```r
na <- which(is.na(ALNY_PX$Last.Price))

ALNY_PX$Last.Price[na] <- (ALNY_PX$Last.Price[na-1] + ALNY_PX$Last.Price[na+1]) * 0.5
```

**Calculate Arithmic Average Annual Return and Compound Annual Return**

```r
ALNY_PX_xts <- xts(ALNY_PX$Last.Price, order.by = as.Date(ALNY_PX$Date))
RUS_3_PX_xts <- xts(RUS_3_PX$Last.Price, order.by = as.Date(RUS_3_PX$Date))

PX_data <- list(ALNY_PX_xts,RUS_3_PX_xts)

time <- c("daily", "weekly", "monthly")
time_2 <- c(252, 52, 12)
type <- c("Alnylam", "Russel 3000 Index")

ret <- list()  # List to store returns
avg_an_ret <- vector("numeric", 3)
comp_an_ret <- vector("numeric", 3)
summary_ret <- list()

for (j in 1:2){
  for (i in 1:3) {
    # Calculate returns
    ret[[i]] <- coredata(periodReturn(PX_data[[j]]["/2019-01-01"], period = time[i], type = "arithmetic

    # Average Arithmetic Annual Return
    avg_an_ret[i] <- (1 + mean(ret[[i]])) ^ time_2[i] - 1

    # Compound Annual Return
    comp_returns <- cumprod(1 + ret[[i]])
    # Annualize the return by adjusting for the number of periods
    comp_an_ret[i] <- (comp_returns[length(comp_returns)]) ^ (time_2[i] / length(comp_returns)) - 1
  }

summary_ret[[j]] <- data.frame(
  "Period" = time,
  "Art_Avg_An_Ret (in %)" = round(avg_an_ret,4)*100,
  "CAGR (in %)" = round(comp_an_ret,4)*100
    )
colnames(summary_ret[[j]]) <- c("Period", "Arithmetic Average Annual Return (in %)", "Compound Annual Re
}


summary_ret[[1]] %>%
    gt() %>%
    tab_style(
      style = cell_borders(sides = "right",
                           color = "grey80",
                           weight = px(2)),
      locations = cells_body(columns = everything())
    ) %>%
    tab_style(
      style = cell_borders(sides = "right",
```

Arithmetic Average Annualized Returns vs Compound Annual Returns of Alnylam

| Period | Arithmetic Average Annual Return (in %) | Compound Annual Return (in %) |
|---|---|---|
| daily | 33.00 | 11.25 |
| weekly | 32.66 | 11.16 |
| monthly | 30.51 | 11.23 |

Arithmetic Average Annualized Returns vs Compound Annual Returns of Russel 3000 Index

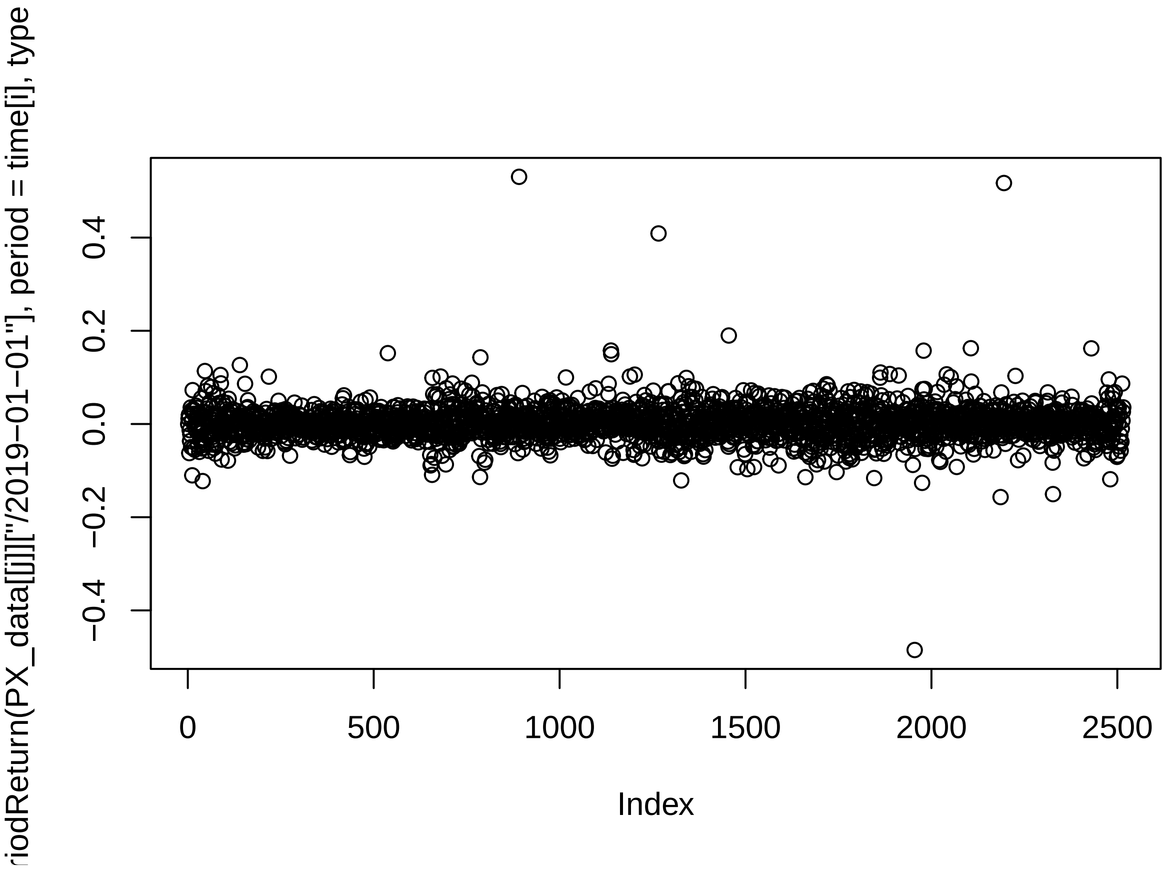
| Period | Arithmetic Average Annual Return (in %) | Compound Annual Return (in %) |
|---|---|---|
| daily | 12.26 | 10.63 |
| weekly | 12.00 | 10.56 |
| monthly | 11.74 | 10.63 |

```
                           color = "grey80",
                           weight= px(2)),
      locations = cells_column_labels(columns = everything())
    ) %>%
    tab_header(title = paste0("Arithmetic Average Annualized Returns vs Compound Annual Returns of ", ty
```

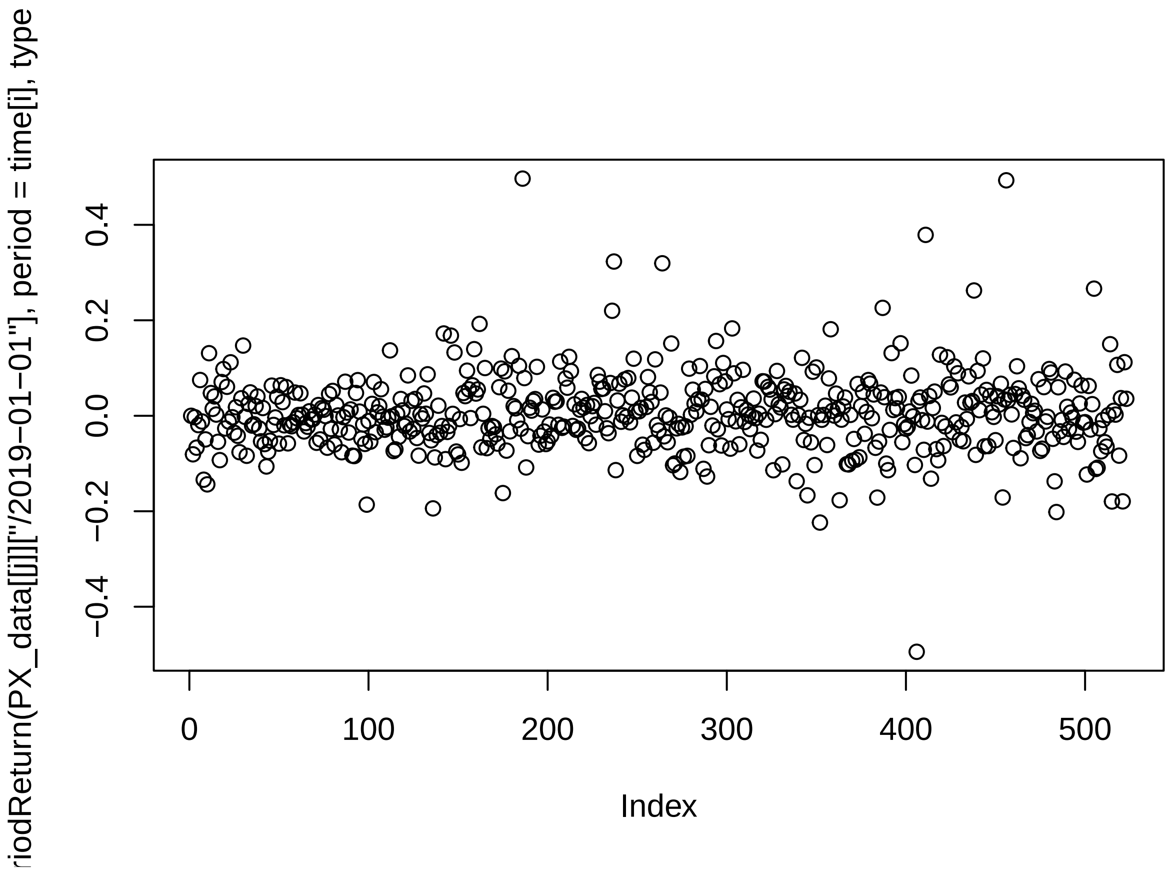
```
summary_ret[[2]] %>%
    gt() %>%
    tab_style(
      style = cell_borders(sides = "right",
                           color = "grey80",
                           weight = px(2)),
      locations = cells_body(columns = everything())
    ) %>%
    tab_style(
      style = cell_borders(sides = "right",
                           color = "grey80",
                           weight= px(2)),
      locations = cells_column_labels(columns = everything())
    ) %>%
    tab_header(title = paste0("Arithmetic Average Annualized Returns vs Compound Annual Returns of ", ty
```

**Estimate Return Volatility**

```
st_dev <- vector("numeric",3)

summary_dev <- data.frame(
  "Period" = time
)

for(j in 1:2){
  for (i in 1:3){
    st_dev[i] <- round(sd(coredata(periodReturn(PX_data[[j]]["/2019-01-01"], period = time[i], type = "a
    print(plot(coredata(periodReturn(PX_data[[j]]["/2019-01-01"], period = time[i], type = "arithmetic")
  }
  summary_dev <- cbind(summary_dev, st_dev)
}
```

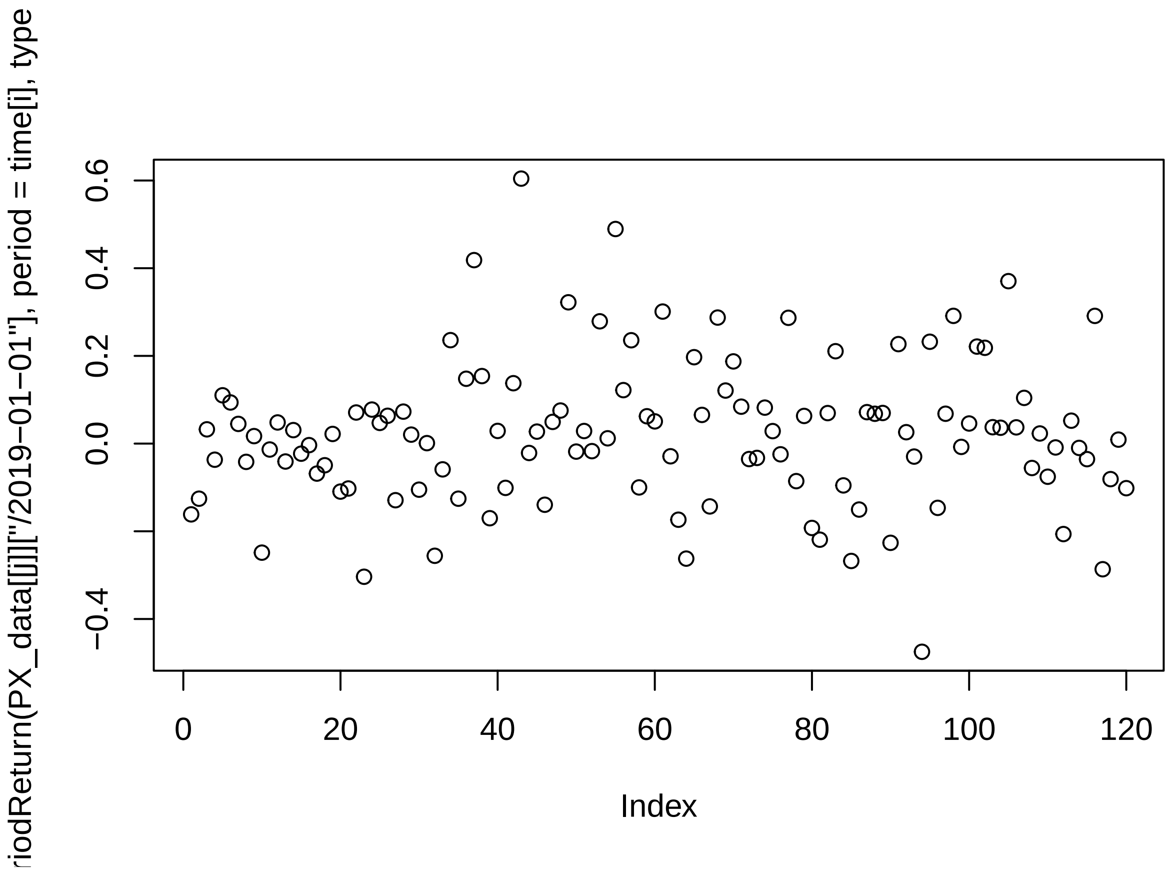


```
## NULL
```

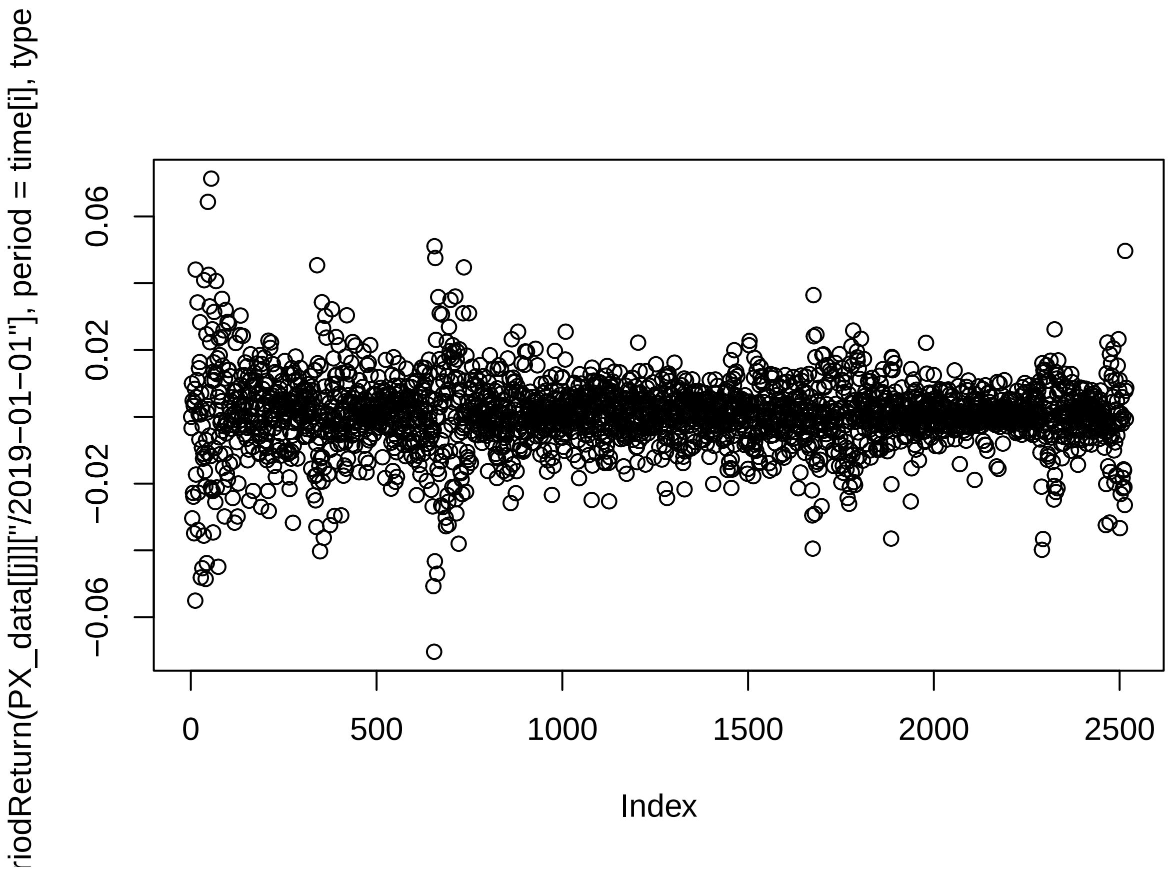


riodReturn(PX_data[[j]]["/2019−01−01"], period = time[i], type
−0.4
−0.2
0.0
0.2
0.4
0
100
200
300
400
500
Index

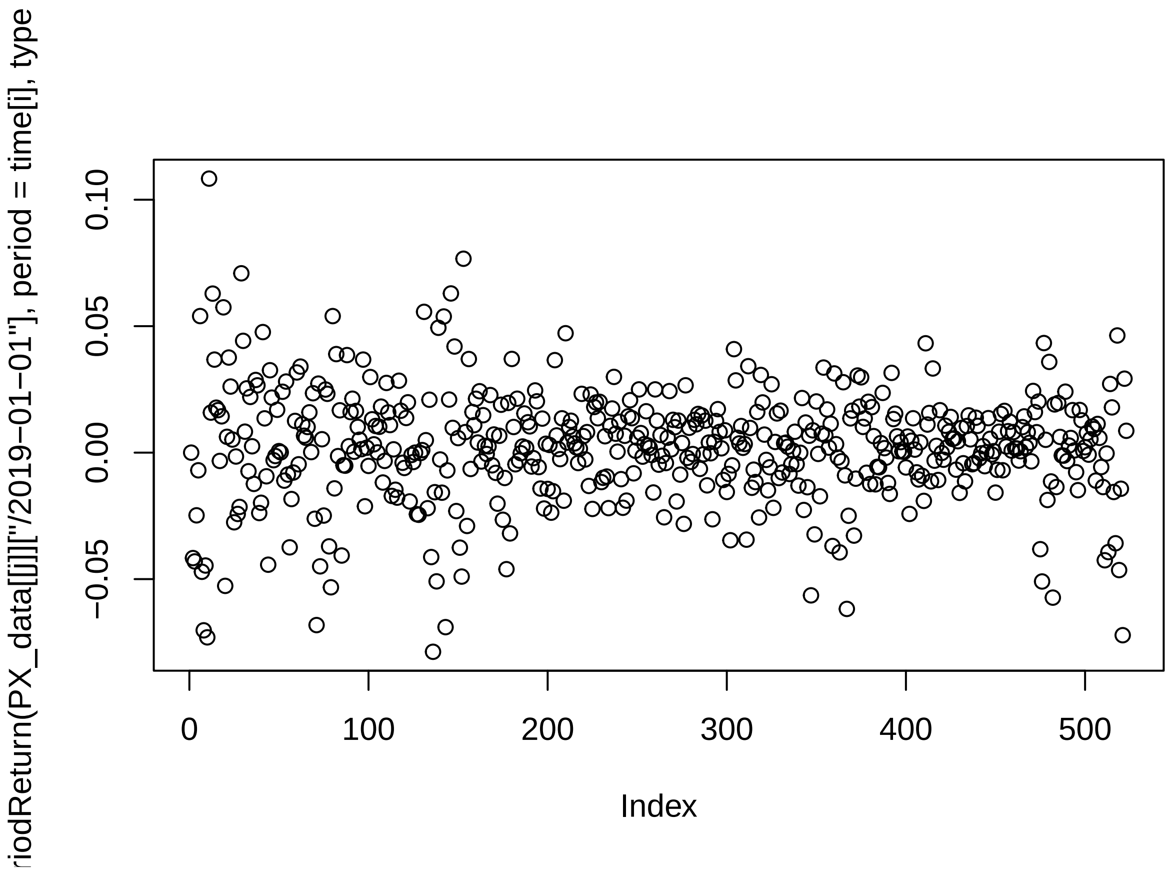
```
## NULL
```


riodReturn(PX_data[[j]]["/2019−01−01"], period = time[i], type
−0.4
0.0
0.2
0.4
0.6
0
20
40
60
80
100
120
Index

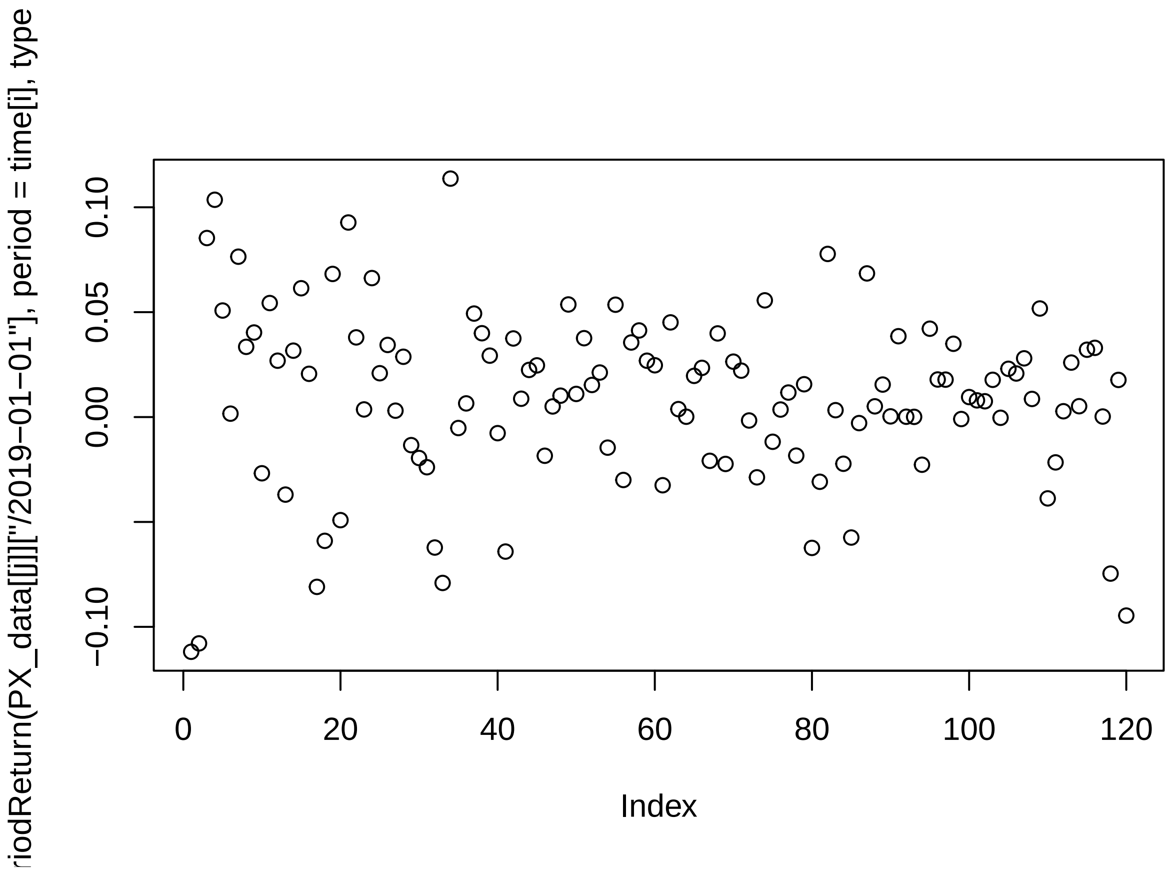
```
## NULL
```


riodReturn(PX_data[[j]]["/2019−01−01"], period = time[i], type
0.06
0.02
−0.02
−0.06
0
500
1000
1500
2000
2500
Index

```
## NULL
```


riodReturn(PX_data[[j]][["2019−01−01"], period = time[i], type
0.10
0.05
0.00
−0.05
0
100
200
300
400
500
Index

```
## NULL
```



```
## NULL
```

```
colnames(summary_dev) <- c("Period Type", "Alnylam","Russel 3000 Index")

summary_dev %>%
gt() %>%
tab_style(
  style = cell_borders(sides = "right",
                       color = "grey80",
                       weight = px(2)),
  locations = cells_body(columns = everything())
) %>%
tab_style(
  style = cell_borders(sides = "right",
                       color = "grey80",
                       weight= px(2)),
  locations = cells_column_labels(columns = everything())  # Apply to column headers
) %>%
tab_header(title = "Estimated Return Volatility for Alnylam and Russel 3000 Index")
```

**Plot the rolling 2 years (104 weeks) Return Volatility for your firm and your**

Market Portfolio with weekly returns from 1/1/2009 to 12/31/2024

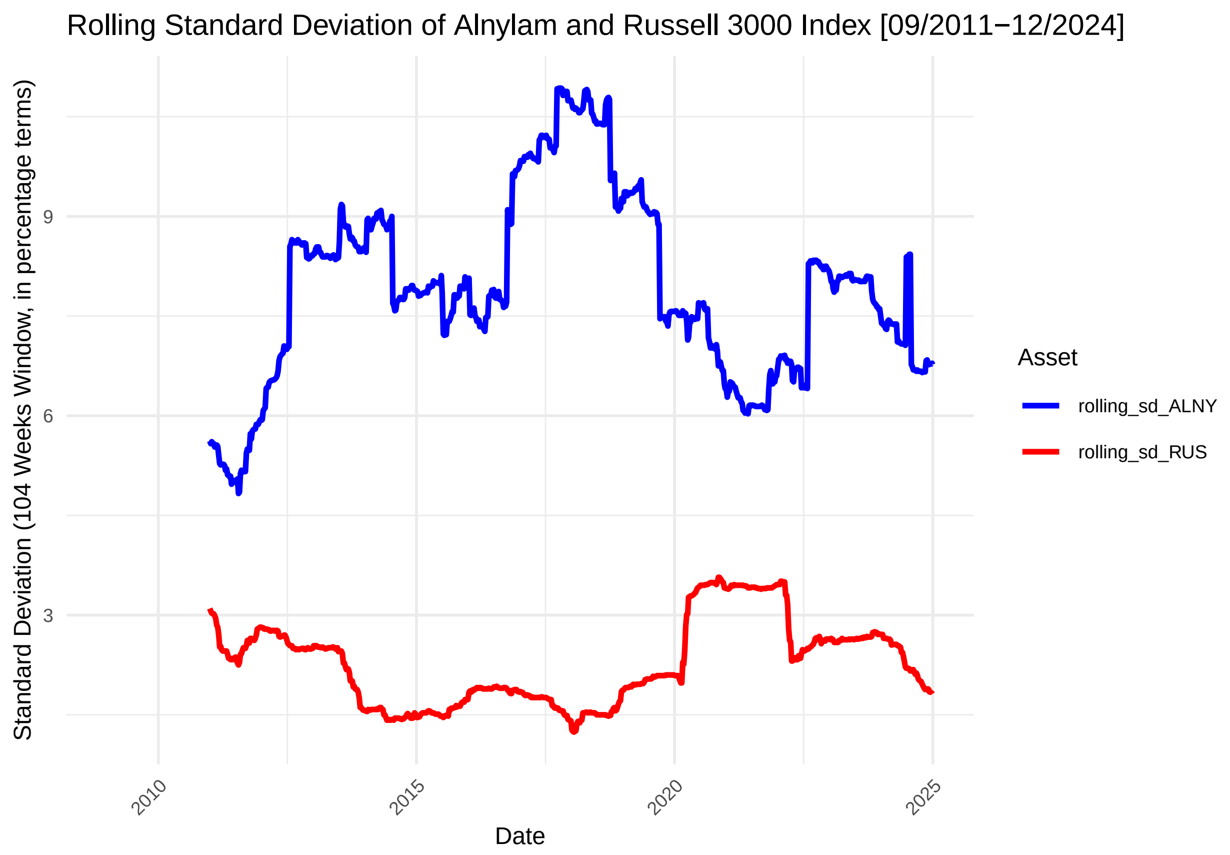
```
returns_weekly_ALNY <- periodReturn(PX_data[[1]], period = "weekly", type = "arithmetic")
returns_weekly_RUS <- periodReturn(PX_data[[2]], period = "weekly", type = "arithmetic")
```

Estimated Return Volatility for Alnylam and Russel 3000 Index

| Period Type | Alnylam | Russel 3000 Index |
|---|---|---|
| daily | 0.0380 | 0.0108 |
| weekly | 0.0832 | 0.0223 |
| monthly | 0.1667 | 0.0410 |

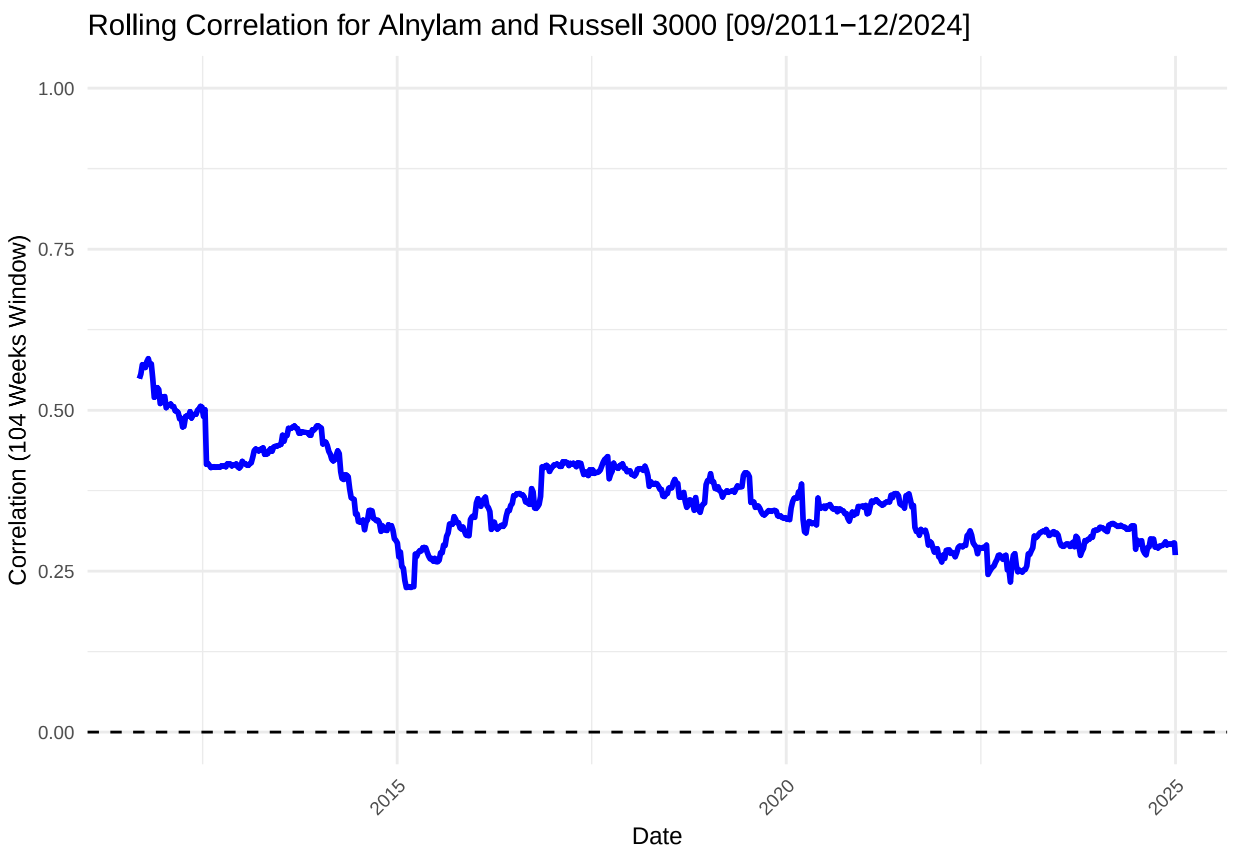
```r
returns_weekly_ALNY_df <- data.frame(Date = index(returns_weekly_ALNY), coredata(returns_weekly_ALNY))
returns_weekly_RUS_df <- data.frame(Date = index(returns_weekly_RUS), coredata(returns_weekly_RUS))

returns_weekly <- inner_join(returns_weekly_ALNY_df, returns_weekly_RUS_df, by = "Date")
colnames(returns_weekly) <- c("Date","ALNY","Russel3000")
returns_weekly <- returns_weekly[-1,]

# Calculate Rolling Volatility
returns_weekly$rolling_sd_ALNY <- round(rollapply(returns_weekly$ALNY, width = 104, FUN = sd, align = "
returns_weekly$rolling_sd_RUS <- round(rollapply(returns_weekly$Russel3000, width = 104, FUN = sd, alig

# Calculate Rolling Correlation
returns_weekly$rolling_cor <- runCor(
  x = returns_weekly$ALNY,
  y = returns_weekly$Russel3000,
  n = 140
)

# For Plotting, put into long format
sd_long <- returns_weekly %>%
  pivot_longer(cols = c(rolling_sd_ALNY, rolling_sd_RUS),
               names_to = "Company",
               values_to = "Rolling_SD")

# Plot Rolling Standard Deviatioin
ggplot(sd_long, aes(x = Date, y = Rolling_SD, color = Company)) +
  geom_line(linewidth = 1) +
  labs(
    title = "Rolling Standard Deviation of Alnylam and Russell 3000 Index [09/2011-12/2024]",
    x = "Date",
    y = "Standard Deviation (104 Weeks Window, in percentage terms)",
    color = "Asset"
  ) +
  theme_minimal() +
  theme(
    axis.text.x = element_text(angle = 45, hjust = 1),
    text = element_text(size = 9)
  ) +
  scale_color_manual(values = c("rolling_sd_ALNY" = "blue", "rolling_sd_RUS" = "red"))
```

```
## Warning: Removed 206 rows containing missing values or values outside the scale range
## (`geom_line()`).
```



```r
# Plot rolling correlation
ggplot(returns_weekly, aes(x = Date, y = rolling_cor)) +
  geom_line(color = "blue", linewidth = 1) +
  labs(
    title = "Rolling Correlation for Alnylam and Russell 3000 [09/2011-12/2024]",
    x = "Date",
    y = "Correlation (104 Weeks Window)"
  ) +
  theme_minimal() +
  theme(
    axis.text.x = element_text(angle = 45, hjust = 1),
    text = element_text(size = 9)
  ) +
  xlim(as.Date("2011-09-09"), as.Date("2024-12-31")) +
  ylim(0,1)+
  geom_hline(yintercept = 0, linetype = "dashed", color = "black")
```

```
## Warning: Removed 139 rows containing missing values or values outside the scale range
## (`geom_line()`).
```



Rolling Correlation for Alnylam and Russell 3000 [09/2011−12/2024]
Correlation (104 Weeks Window)
1.00
0.75
0.50
0.25
0.00
2015
2020
2025
Date