Load R Packages

```
install.packages(c("dplyr", "dtplyr", "data.table", "lubridate",
"ggplot2", "PerformanceAnalytics", "xts"))
```

```
The downloaded binary packages are in
    /var/folders/by/g895l7l128j9y19qqn66xcxh0000gn/T//RtmpHEdE2f/downloaded_packages
```

```
library(dplyr)
library(dtplyr)
library(data.table)
library(lubridate)
library(ggplot2)
library(PerformanceAnalytics)
library(xts)

options(repr.plot.width = 10, repr.plot.height = 5)  # For Jupyter notebooks
```

```
df <- fread("/Users/ivanhung/Documents/GitHub/final-r-assignment/dataset.csv")
```

Cleaning dataset

```
# Setting datadate to a date object
df %>% mutate(datadate = as.Date(datadate, format = "%m/%d/%Y")) -> df

# Remove irrelevant columns and other stocks except for Pfizer (PFE)
pfe <- df[tic == "PFE",
          .(datadate, cshtrd, prccd, prchd, prcld, prcod)]
```

```r
head(pfe)

# Plot time series of PFE's closing prices
ggplot(data = pfe, aes(x = datadate, y = prccd)) +
  geom_line() +
  labs(title = "Pfizer (PFE) Closing Stock Prices Over Time",
       x = "Date",
       y = "Closing Price (USD)") +
  theme_minimal()
```

A data.table: 6 × 6

datadate <date>	cshtrd <dbl>	prccd <dbl>	prchd <dbl>	prcld <dbl>	prcod <dbl>
2010-01-04	52074710	18.93	18.94	18.235	18.27
2010-01-05	43368460	18.66	18.93	18.550	18.92
2010-01-06	41405070	18.60	18.81	18.510	18.66
2010-01-07	39427720	18.53	18.67	18.460	18.64
2010-01-08	30403370	18.68	18.71	18.520	18.62
2010-01-11	32442710	18.83	18.95	18.670	18.83

Next, calculate simple returns so that we can make our prices stationary and allow us to have a better understanding our data as we can proceed to plot Pfizer's ACF and PACF plots and confirm for certain statistical characteristics.

```
# Calculating simple returns (simple returns in %),
# which we will denote as s_ret (s_ret_per)

pfe <- pfe %>%
    mutate(ret = round(((prccd/lag(prccd))-1), 4)) %>%
    mutate(s_ret = round(((prccd/lag(prccd))-1)*100, 4))

head(pfe)
```

A data.table: 6 × 8

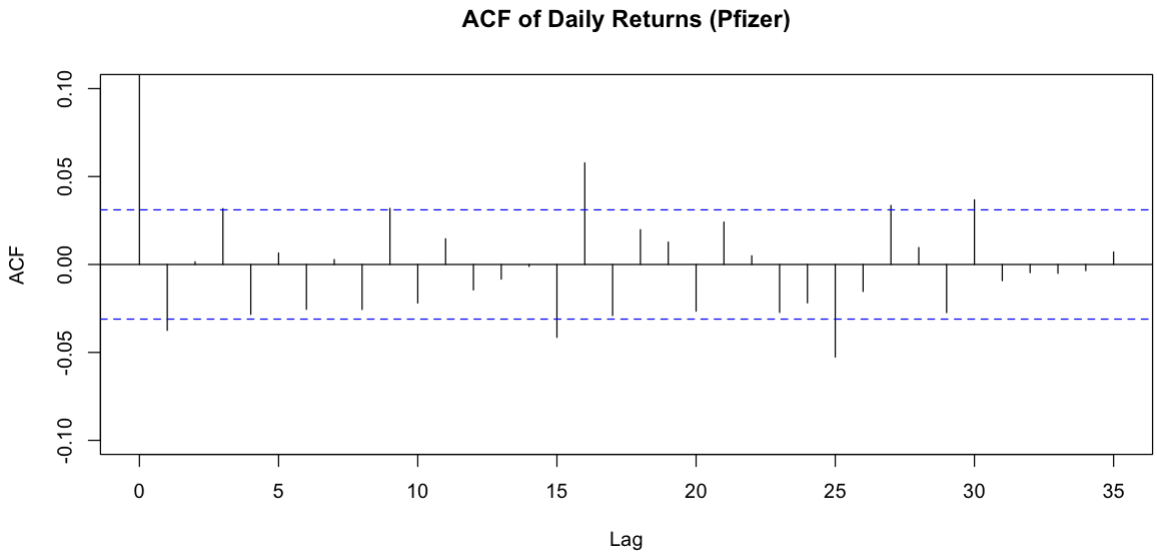
datadate <date>	cshtrd <dbl>	prccd <dbl>	prchd <dbl>	prcld <dbl>	prcod <dbl>	ret <dbl>	s_ret <dbl>
2010-01-04	52074710	18.93	18.94	18.235	18.27	NA	NA
2010-01-05	43368460	18.66	18.93	18.550	18.92	-0.0143	-1.4263
2010-01-06	41405070	18.60	18.81	18.510	18.66	-0.0032	-0.3215
2010-01-07	39427720	18.53	18.67	18.460	18.64	-0.0038	-0.3763
2010-01-08	30403370	18.68	18.71	18.520	18.62	0.0081	0.8095
2010-01-11	32442710	18.83	18.95	18.670	18.83	0.0080	0.8030

Next, we should plot the autocorrelation and partial-autocorrelation functions of our closing prices to identify if there are any seasonal structures or autocorrelation that we might need to deal with.

```
# ACF plot to identify any autocorrelation or seasonality patterns in our data
#| warning: hide
#| results: hide
acf(pfe$ret, lags = 20,
    na.action = na.omit,
    main = "ACF of Daily Returns (Pfizer)",
    ylim = c(-0.1,0.1))
```

```
Warning message in plot.window(...):
""lags" is not a graphical parameter"
```

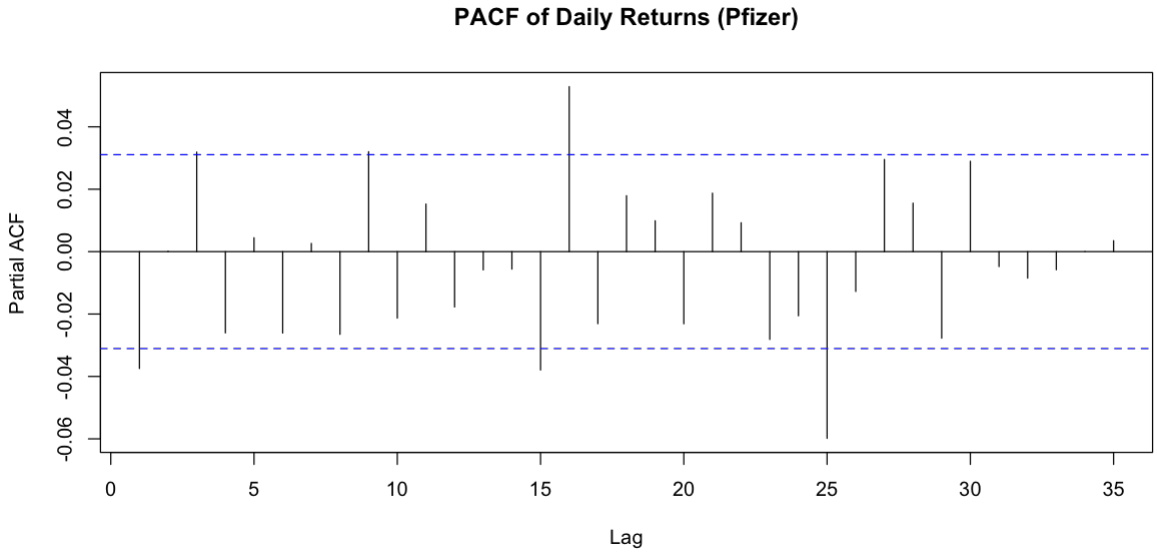
```
Warning message in plot.xy(xy, type, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in box(...):
""lags" is not a graphical parameter"
Warning message in plot.xy(xy, type, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in box(...):
""lags" is not a graphical parameter"
Warning message in title(...):
""lags" is not a graphical parameter"
Warning message in title(...):
""lags" is not a graphical parameter"
```




```
# PACF plot
#| warning: hide
#| results: hide
```

```r
pacf(pfe$ret, lags = 20,
    na.action = na.omit,
    main = "PACF of Daily Returns (Pfizer)")
```

```
Warning message in plot.window(...):
""lags" is not a graphical parameter"
Warning message in plot.xy(xy, type, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in box(...):
""lags" is not a graphical parameter"
Warning message in title(...):
""lags" is not a graphical parameter"
Warning message in plot.xy(xy, type, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in axis(side = side, at = at, labels = labels, ...):
""lags" is not a graphical parameter"
Warning message in box(...):
""lags" is not a graphical parameter"
Warning message in title(...):
""lags" is not a graphical parameter"
```

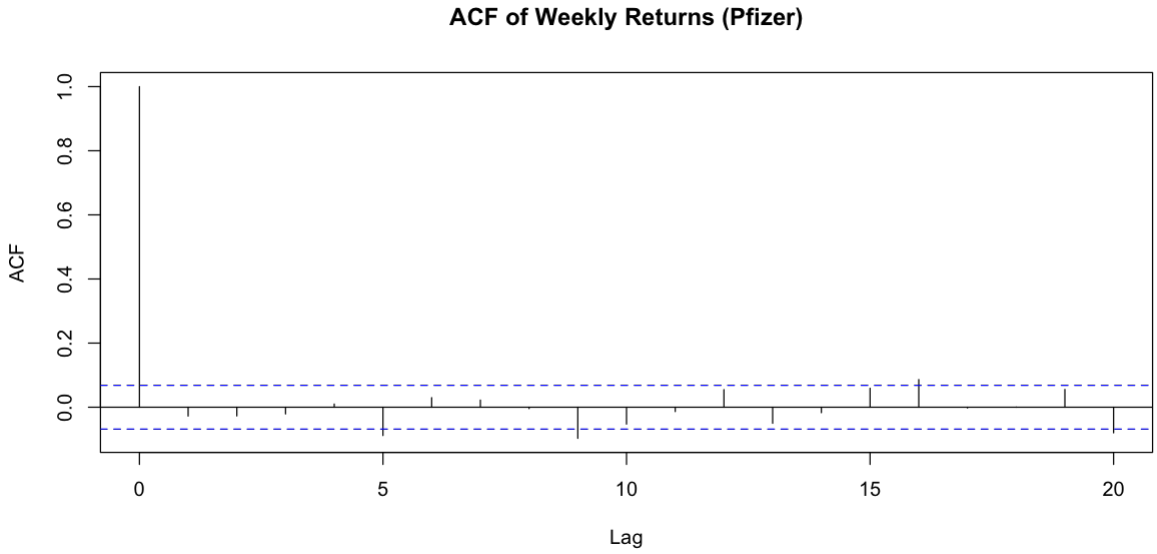


We can focus in on a specific time horizon and see if autocorrelation exists within a certain timeframe. This evidence can help us to determine whether there is statistical arbitrage in which our trading strategy can detect a pattern can profit from (potentially short term momentum), as opposed to having white noise (returns which follow a strong form of the EMH where all information about the stock is reflected in its prices). We decide to focus on a relatively long horizon as it can provide us more information of how the stock's price changed before, during, and after COVID; providing us with a holistic story and finding opportunities for statistical arbitrage in the '3' phases of COVID.

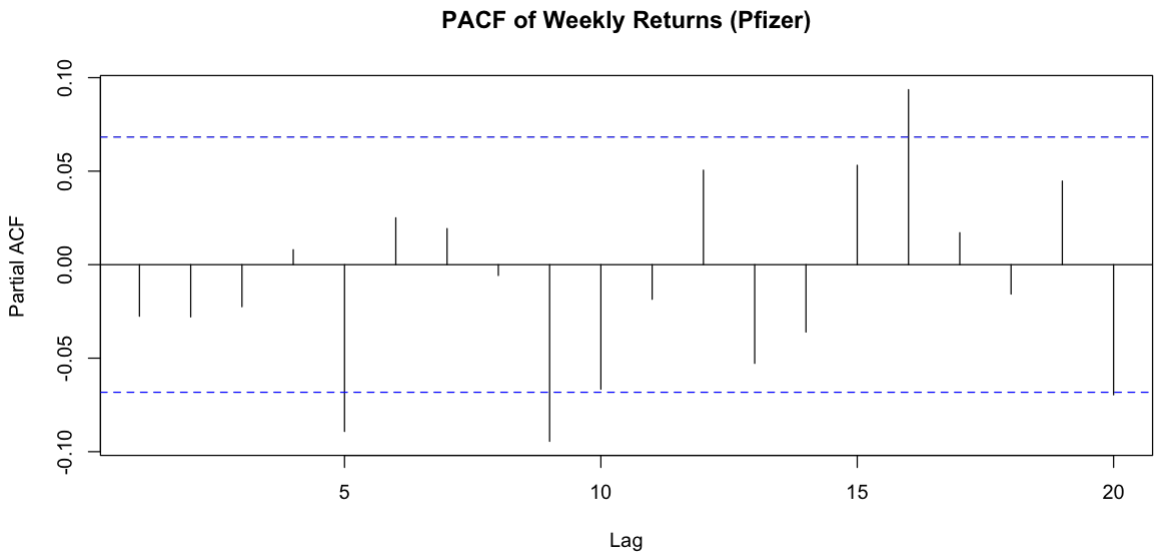
```
# Create a list of periods we want to look at
periods <- list(
    weekly = "week",
    monthly = "month",
    semi_annually = "6 months",
    annually = "year"
)

# Loop through each time period
for (period_name in names(periods)) {
    cat("Processing:", toupper(period_name), "\n")

    # Create proper period returns (one observation per period)
    pfe_period <- pfe %>%
        mutate(period = floor_date(datadate, periods[[period_name]])) %>%
        group_by(period) %>%
```

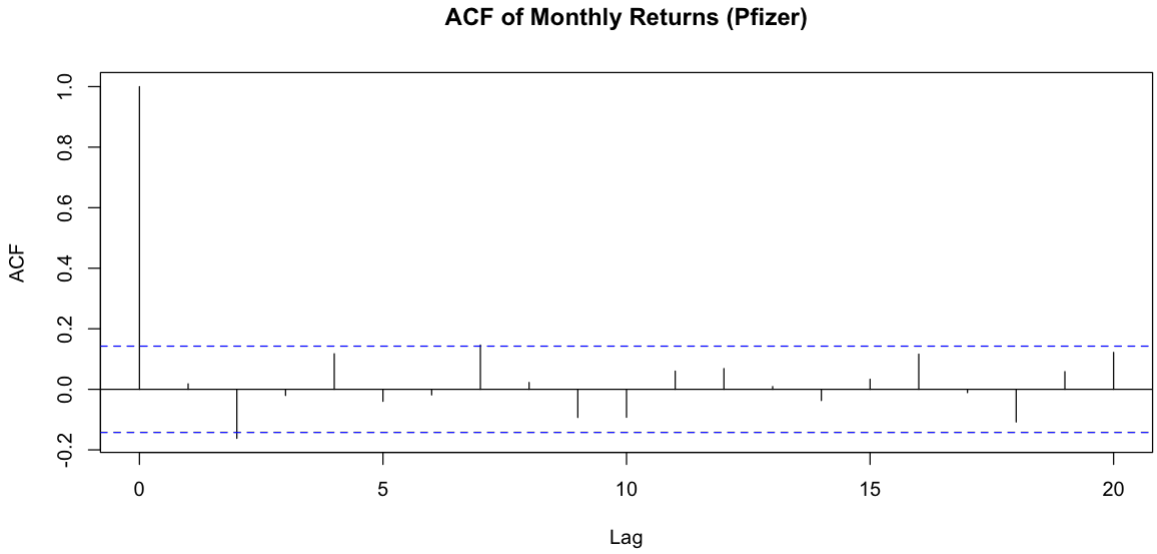
```
        arrange(datadate) %>%
        slice_tail(n = 1) %>%
        ungroup() %>%
        arrange(datadate) %>%
        mutate(period_ret = (prccd / lag(prccd)) - 1) %>%
        filter(!is.na(period_ret))

    # View tibble (dataframe) using the following:
    # print(head(pfe_period))
    # cat("Number of periods:", nrow(pfe_period), "\n\n")

    # ACF of actual period returns (suppress warnings)
    suppressWarnings(
        acf(pfe_period$period_ret, lag.max = 20,
            na.action = na.omit,
            main = paste("ACF of",
            tools::toTitleCase(gsub("_", " ", period_name)),
            "Returns (Pfizer)"))
    )

    # PACF of actual period returns (suppress warnings)
    suppressWarnings(
        pacf(pfe_period$period_ret, lag.max = 20,
             na.action = na.omit,
             main = paste("PACF of",
             tools::toTitleCase(gsub("_", " ", period_name)),
             "Returns (Pfizer)"))
    )
}
```

```
Processing: WEEKLY
```

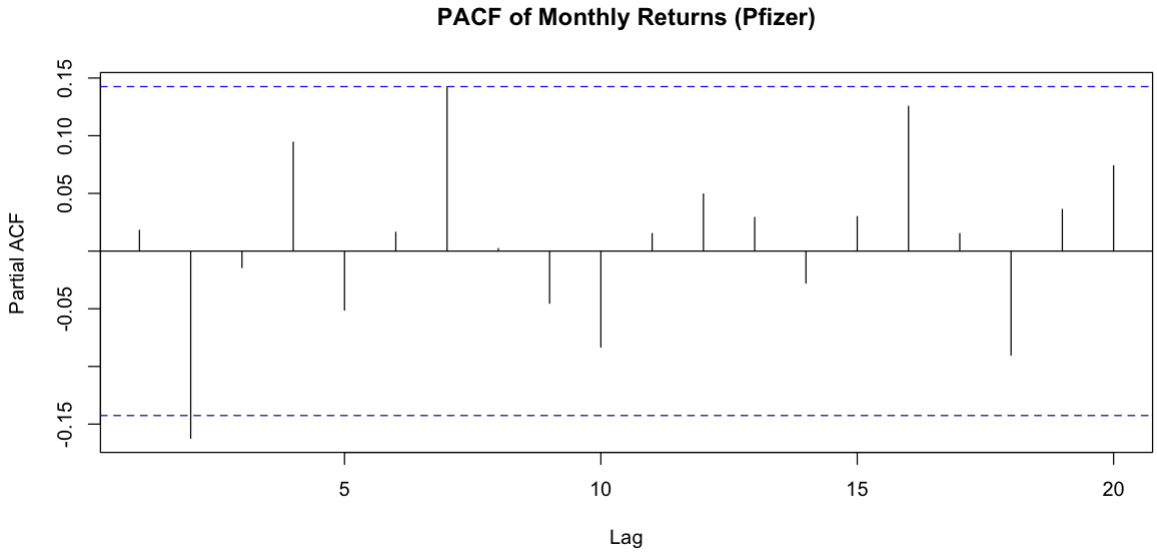


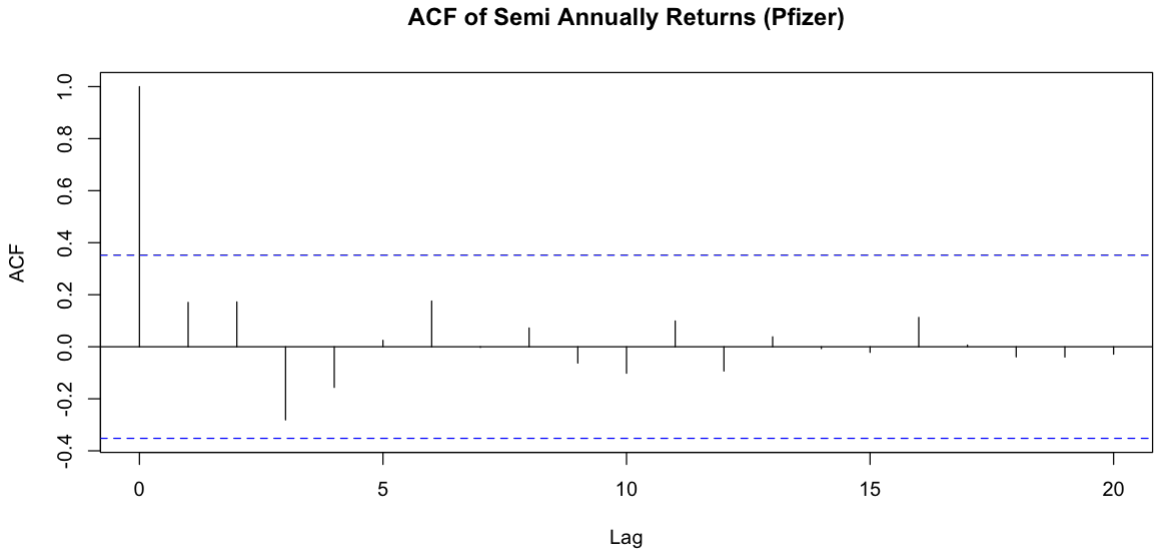

```
Processing: MONTHLY
```



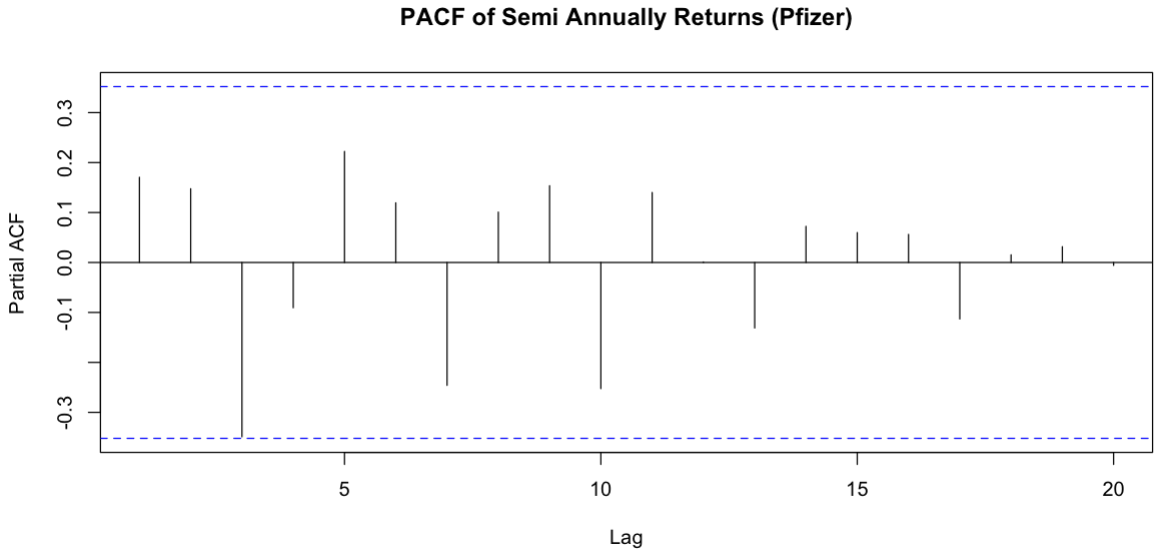


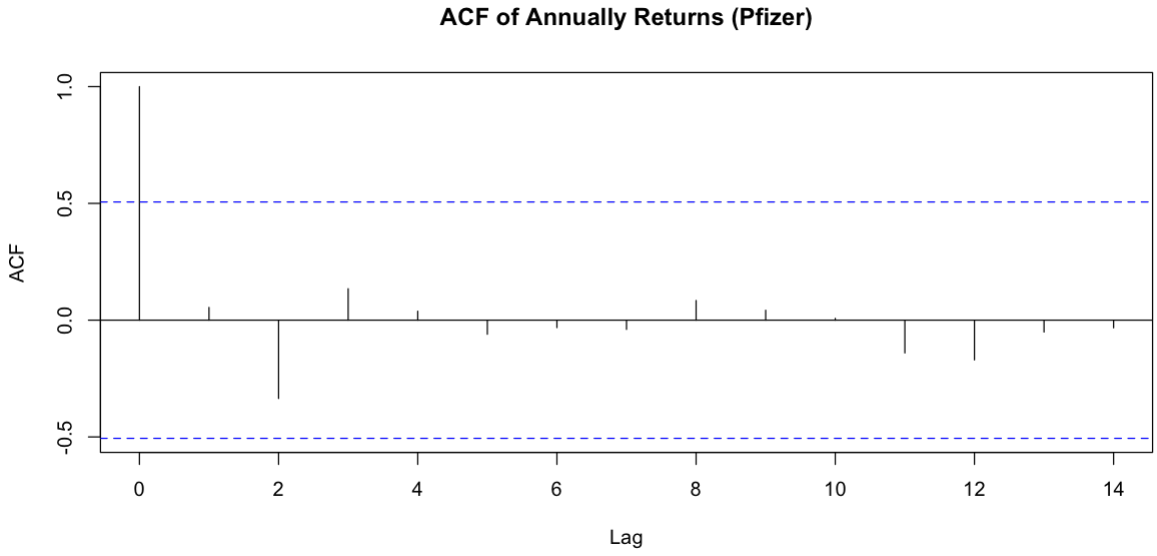

```
Processing: SEMI_ANNUALLY
```

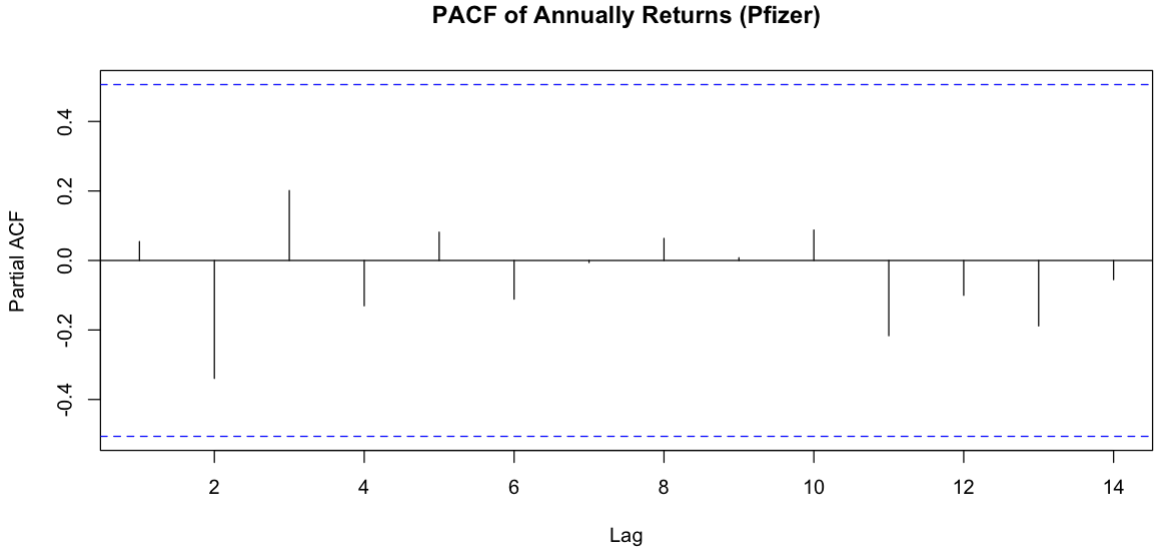





```
Processing: ANNUALLY
```



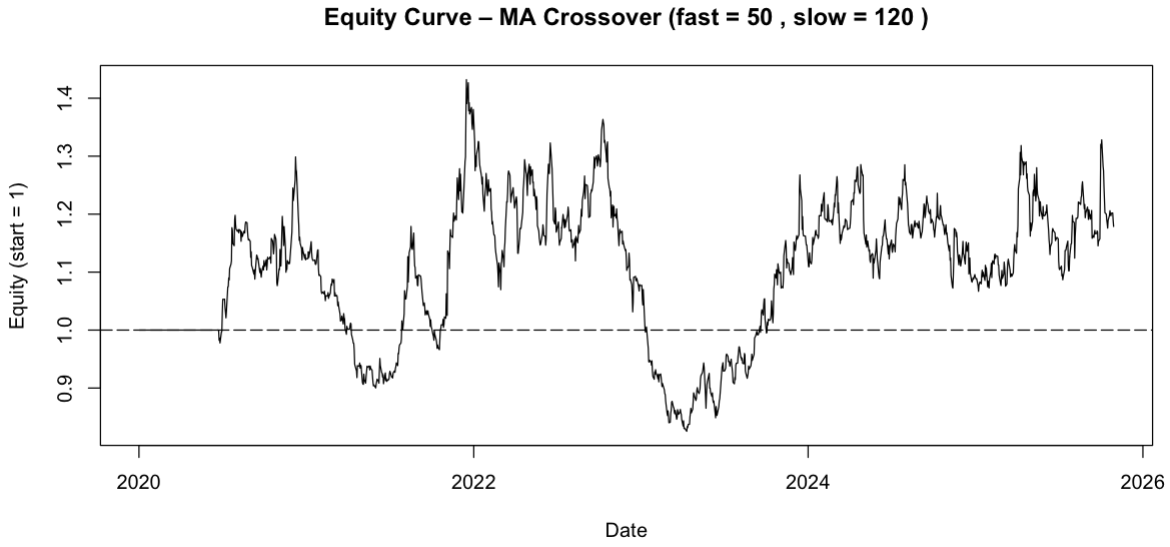





```
pfe <- pfe %>%
  filter(datadate >= as.Date("2020-01-01")) %>%
  arrange(datadate)
```

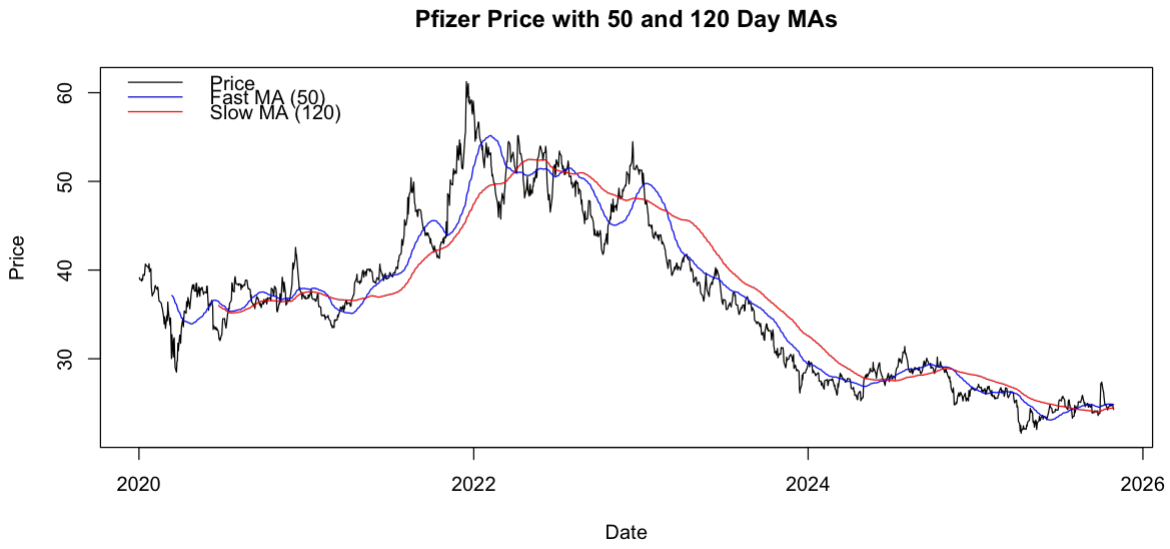
```
price <- pfe$prccd

# Generate signals and backtest using the optimal windows
```

```r
best_signal <- ma_signal(price, fast = best_fast, slow = best_slow)
best_bt     <- backtest_ma(price, signal = best_signal)

# Equity curve plot
plot(
  pfe$datadate, best_bt$equity, type = "l",
  xlab = "Date", ylab = "Equity (start = 1)",
  main = paste("Equity Curve - MA Crossover (fast =", best_fast,
               ", slow =", best_slow, ")")
)
abline(h = 1, lty = 5)
```



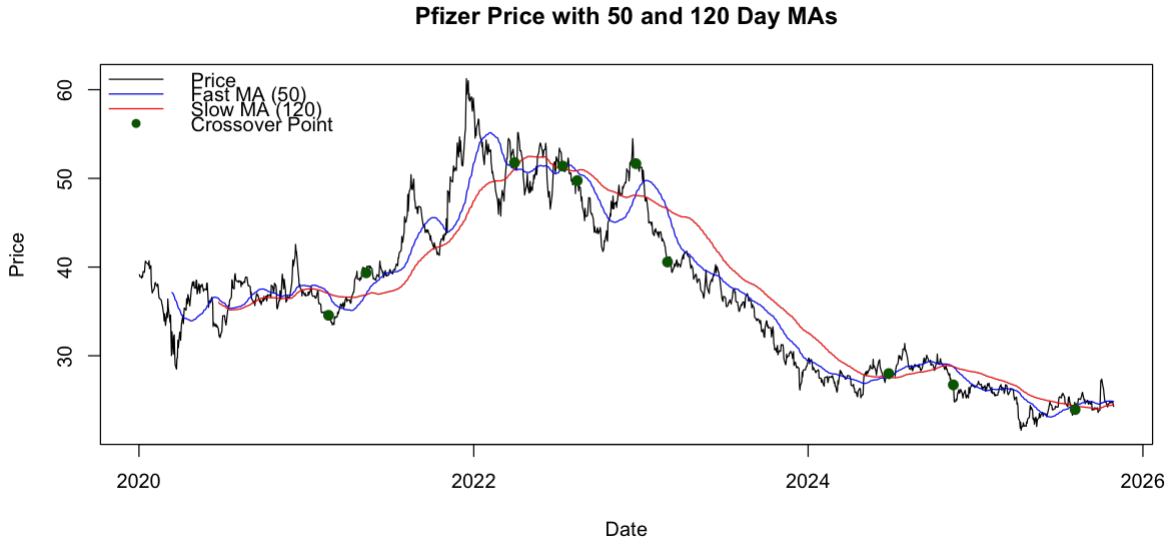

```r
# Compute moving averages for the best windows
fast_ma_best <- moving_avg(price, win_size = best_fast)
slow_ma_best <- moving_avg(price, win_size = best_slow)

# Base plot: price
plot(
  pfe$datadate, price, type = "l",
  xlab = "Date", ylab = "Price",
  main = paste("Pfizer Price with", best_fast, "and", best_slow, "Day MAs")
)

# Add MAs
```

```r
lines(pfe$datadate, fast_ma_best, col = "blue")
lines(pfe$datadate, slow_ma_best, col = "red")

legend(
  "topleft",
  legend = c("Price",
             paste0("Fast MA (", best_fast, ")"),
             paste0("Slow MA (", best_slow, ")")),
  col = c("black", "blue", "red"),
  lty = 1, bty = "n"
)

# Mark crossover points (where fast and slow swap order)
spread    <- fast_ma_best - slow_ma_best
cross_idx <- which(diff(sign(spread)) != 0) + 1

points(
  price[cross_idx],
  pch = 16, col = "darkgreen"
)
```

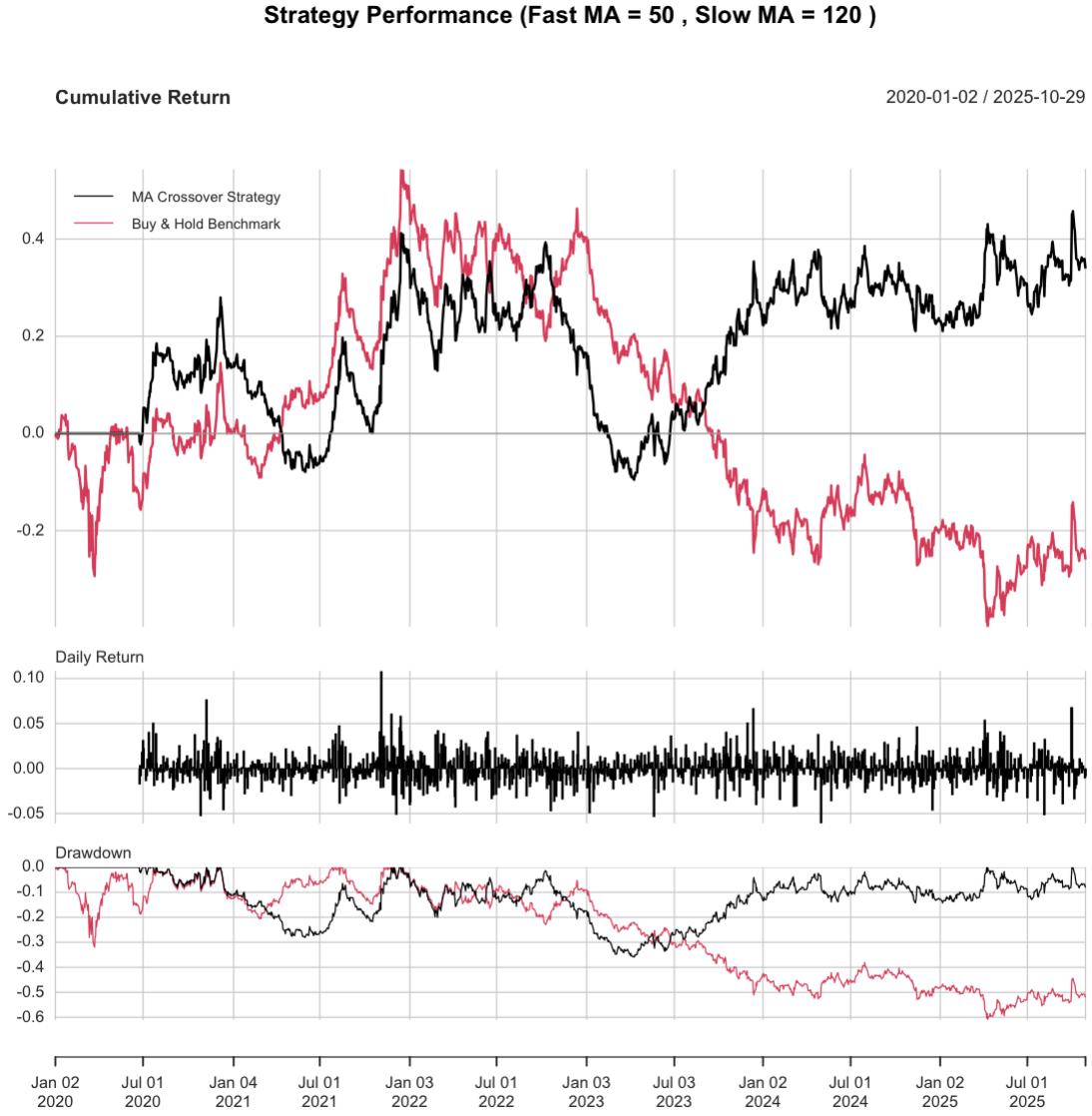



```r
# Compute moving averages for the best windows
fast_ma_best <- moving_avg(price, win_size = best_fast)
slow_ma_best <- moving_avg(price, win_size = best_slow)
```

```r
# Base plot: price
plot(
  pfe$datadate, price, type = "l",
  xlab = "Date", ylab = "Price",
  main = paste("Pfizer Price with", best_fast,
  "and", best_slow, "Day MAs")
)

# Add moving averages
lines(pfe$datadate, fast_ma_best, col = "blue")
lines(pfe$datadate, slow_ma_best, col = "red")

# Identify crossover points
spread    <- fast_ma_best - slow_ma_best
cross_idx <- which(diff(sign(spread)) != 0) + 1

# Add crossover markers to the plot
points(
  pfe$datadate[cross_idx],
  price[cross_idx],
  pch = 16, col = "darkgreen", cex = 1.2
)

legend(
  "topleft",
  legend = c(
    "Price",
    paste0("Fast MA (", best_fast, ")"),
    paste0("Slow MA (", best_slow, ")"),
    "Crossover Point"
  ),
  col = c("black", "blue", "red", "darkgreen"),
  lty = c(1, 1, 1, NA),
  pch = c(NA, NA, NA, 16),
  bty = "n"
)
```




```
# Store data in an xts readable dataframe
strategy_returns <- xts(best_bt$returns, order.by = pfe$datadate)
benchmark_returns <- xts(pfe$ret, order.by = pfe$datadate)

colnames(strategy_returns) <- ("MA Crossover Strategy (50,120)")
colnames(benchmark_returns) <- ("Buy & Hold Benchmark (PFE Returns)")

# Performance Summary Chart
options(repr.plot.width = 10, repr.plot.height = 10) # Adjust plot dim.
charts.PerformanceSummary(
    comparison,
    geometric = FALSE,
    main = paste("Strategy Performance (Fast MA =",
        best_fast, ", Slow MA =", best_slow, ")")
)

# Reset to default height
options(repr.plot.width = 10, repr.plot.height = 5)
```


Strategy Performance (Fast MA = 50 , Slow MA = 120)
Cumulative Return
2020-01-02 / 2025-10-29
MA Crossover Strategy
Buy & Hold Benchmark
0.4
0.2
0.0
-0.2
Daily Return
0.10
0.05
0.00
-0.05
Drawdown
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Jan 02 2020
Jul 01 2020
Jan 04 2021
Jul 01 2021
Jan 03 2022
Jul 01 2022
Jan 03 2023
Jul 03 2023
Jan 02 2024
Jul 01 2024
Jan 02 2025
Jul 01 2025