Presentation of Project of GDM

Analysis of Stock Market Data of Vaccine Companies in COVID19 Pandemic

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Introduction I

On 31 December 2019, WHO was informed of cases of pneumonia of unknown cause in Wuhan City, China. A novel corona virus was identified as the cause by Chinese authorities on 7 January 2020 and was temporarily named *2019-nCoV*. Whenever virus spread to the other countries, it has named *COVID19* and WHO announced this disease as global pandemic in March 11, 2020. This pandemic has become worst disease since the Spanish Flu.

Introduction II

As expected, almost each part of industry has affected negatively. Especially in stock prices of transportation and food services significant decrease can be observed. For instance, while Lufthansa Airlines has stock price 16.41 in December 1, 2019 this value became 8.16 in April 1, 2020.

Introduction III

To summarize, 2020 became an unlucky year for many sector. However, last days of December 2020 some health companies such as Moderna Inc., BioNTech and AstraZeneca(University of Oxford) announced their success in development of COVID19 vaccine. Henceforth in 2021 both society and global economy took a sigh of relief.

Introduction IV

Based on affects of pandemic in stock markets, we encouraged to make this project. In this project, statistical analysis and comparison between stock price data of three vaccine company Moderna Inc., Pfizer& BioNTech and AstraZeneca by splitting data into critical dates such as authorization date in a region or starting dates of phase 1,2,3 for those companies will be performed.

Introduction V

It is planned to take the data from a time interval from January 1, 2020 to October 1, 2021. Additionally, some data visualization techniques will be used during this project in order to provide a clear explanation of our work. Statistical analyses are also added.

Introduction VI

Main goal of this project is analysis of successes in terms of increasing their stock price values of certain vaccine companies during COVID19.

Data

Yahoo Finance, which is one of the well-known finance data providers will be source of data sets of the project. As explained, three vaccine companies will be considered in whole analysis and comparisons. Reader could be curious about the why only BioNTech will be included while Pfizer excluded. The main reason is to prevent confusions. It is obvious that stock prizes of Pfizer and BioNTech are positively correlated. The data sets has taken as csv files and converted to the regular xlsx files. Each data set has been taken from NasdaqGS in terms of USD currency.

Libraries I

We used libraries knitr, tidyverse and readxl in taking raw data sets, reshaping them, and visualize them. Specifically, we used ggridges for distribution graphs, plotly for interactive charts and cowplot for merging two charts.

Codes and Graphs I

```
library(rmarkdown)
library(readxl)
library(tidyverse)
library(knitr)
library(ggridges)
library(plotly)
library(cowplot)
```

BioNTech I

BioNTech (short for Biopharmaceutical New Technologies) is a German biotechnology company based in Mainz that develops and manufactures active immunotherapies for patient-specific approaches to the treatment of diseases. Among the society, this company known for developing mRNA type vaccine for COVID19. The stock data of BioNTech that project aims to consider is closing values of stock prices of days in range January 1,2020 and October 1, 2021. The data set imported from Yahoo Finance and it has cleaned from unwanted data.

```
biontechdata=read_excel("biontech.xlsx")
biontechdata= biontechdata %>% select(Date | Close)
```

BioNTech II

Critical dates are listed below, these dates has been taken from news websites.

```
cridateseventsbiontech=read_excel("criticaldatesbiontech.xlsx")
cridateseventsbiontech %>%
  filter(Date==cridateseventsbiontech$Date[2] |Date==cridateseventsbiontech$Date[3] |
           Date==cridateseventsbiontech$Date[6] |Date==cridateseventsbiontech$Date[7]) %>%
  kable()
```

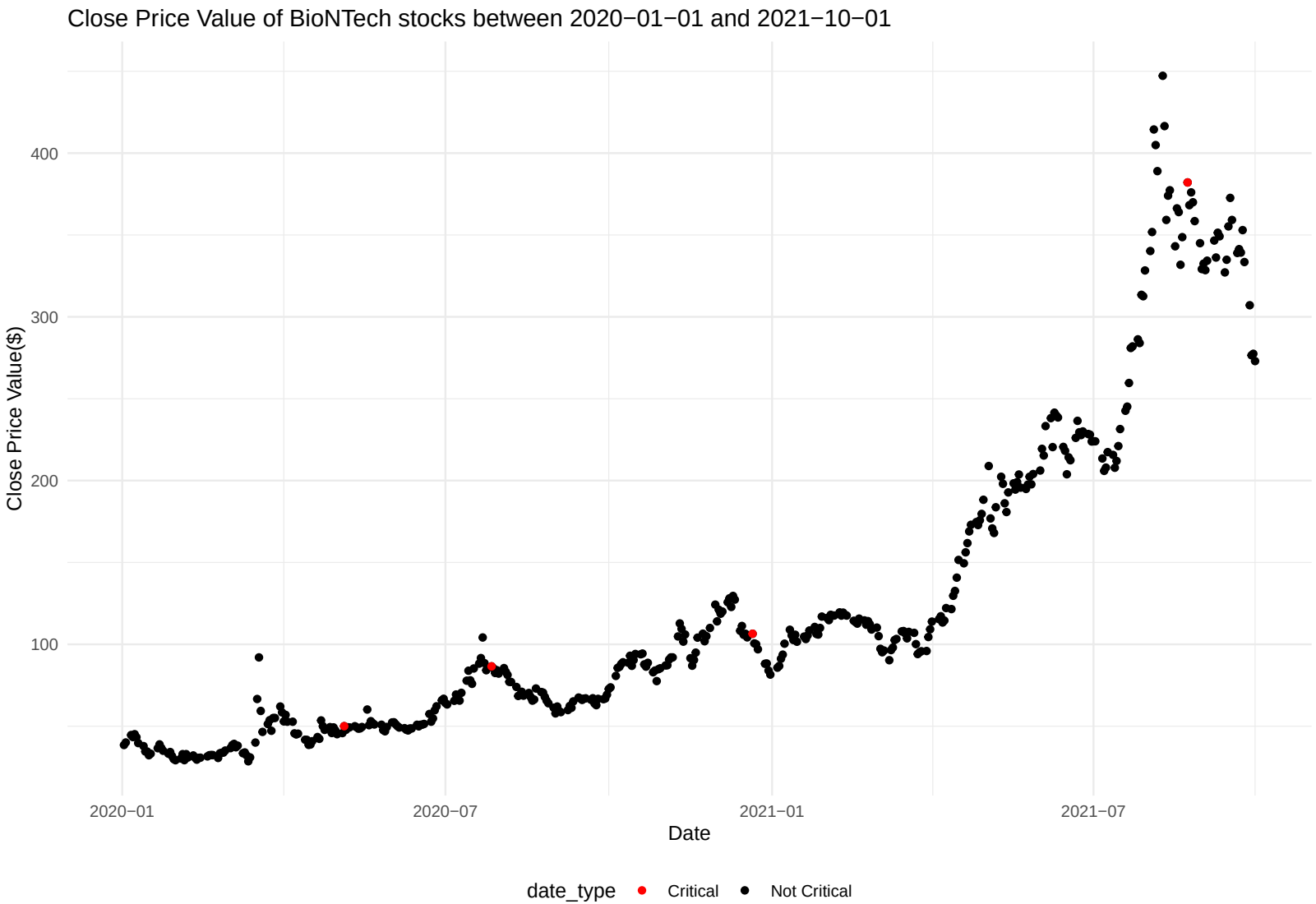
Date	Event
2020-05-05	First Volunteer in United States Receives Vaccine
2020-07-27	Phase 2 and 3 are started
2020-12-21	Authorized in European Union
2021-08-23	FDA grants full approval

BioNTech III

The following graph illustrates closed prices of stock data of BioNTech in time interval, moreover critical dates can be seen in red points.

```
biontechdata$Date <- as.Date(biontechdata$Date)
newcridates=as.Date(c("2020-05-05","2020-07-27","2020-12-21","2021-08-23"))
biontechdata=biontechdata %>%
  mutate(date_type=case_when(biontechdata$Date
                             %in% newcridates ~ "Critical", TRUE ~ "Not Critical"))
highlight=biontechdata %>%
  filter(date_type=="Critical")
closevalue=ggplot(biontechdata, aes(x = Date, y = Close))+
  geom_point()+
  geom_point(data=highlight,aes(x = Date, y = Close,color=date_type))+
  labs(x = "Date", y="Close Price Value($)",
       title= "Close Price Value of BioNTech stocks between 2020-01-01 and 2021-10-01")+
  scale_color_manual(values = c("Critical" = "red",
                                "Not Critical" = "black"))
closevalue= closevalue+
  theme_minimal()+
  theme(legend.position = "bottom")
closevalue
```

BioNTech IV

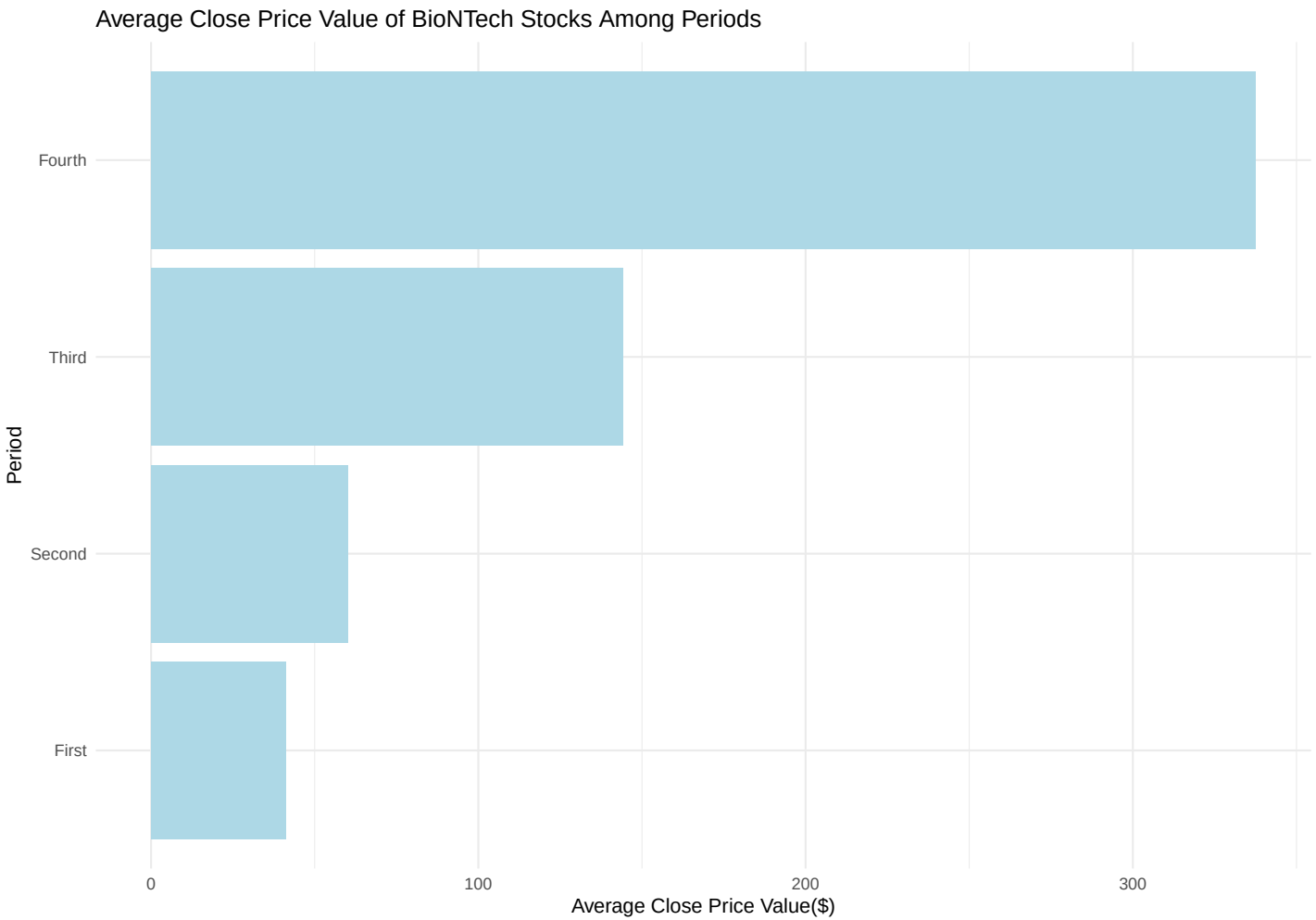

Close Price Value of BioNTech stocks between 2020−01−01 and 2021−10−01
Close Price Value($)
400
300
200
100
2020−01
2020−07
2021−01
2021−07
Date
date_type
Critical
Not Critical

BioNTech V

The following bar chart contains mean of the stock close price data at each section.

```
biontechdata = biontechdata %>%
  mutate(Period=case_when(Date <= "2020-05-05" ~ 1,
                          Date > "2020-05-05" & Date <= "2020-07-27" ~ 2,
                          Date > "2020-07-27" & Date <= "2021-08-23" ~ 3,
                          Date > "2021-08-23" ~ 4 ))
avg=biontechdata %>%
  group_by(Period) %>%
  summarise(Average=mean(Close))
ggplot(avg,aes(x= Average,y=factor(Period)))+
  geom_col(fill="lightblue")+
  scale_y_discrete(labels=c("First","Second","Third","Fourth"))+
  labs(x = "Average Close Price Value($)",
       y="Period",
       title= "Average Close Price Value of BioNTech Stocks Among Periods")+
  theme_minimal()+
  theme(legend.position = "bottom")
```

BioNTech VI

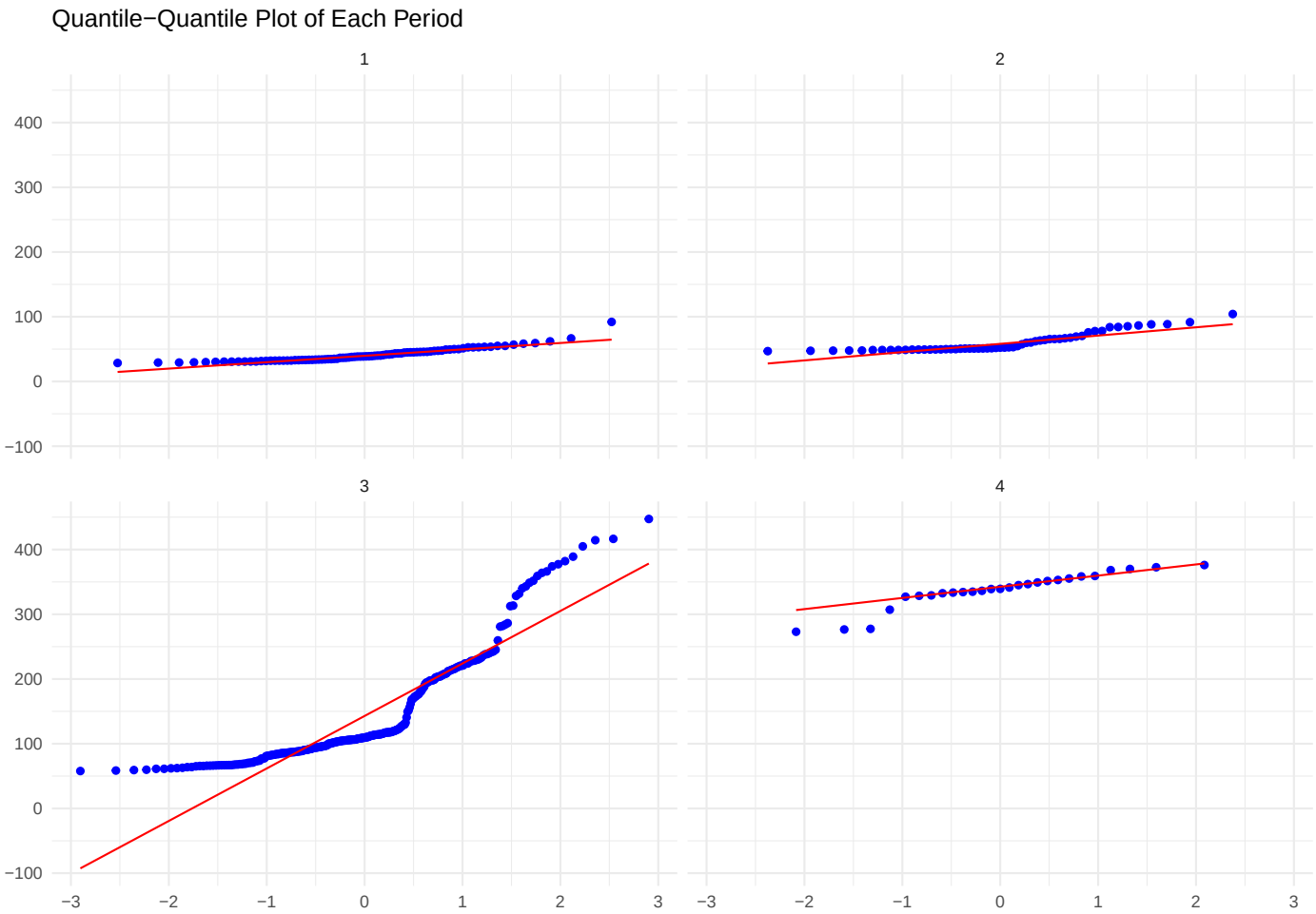

Average Close Price Value of BioNTech Stocks Among Periods
Fourth
Third
Second
First
Period
0
100
200
300
Average Close Price Value($)

BioNTech VII

To prepare our data set into statistical tests, we need to determine the amount of its closeness to the normal distribution. We can measure this by quantile-quantile plot of each period.

```
ggplot(biontechdata,aes(sample=Close))+
  stat_qq(color="blue")+
  stat_qq_line(color="red")+
  facet_wrap(~Period)+
  labs(x = " ", y=" ",
       title= "Quantile-Quantile Plot of Each Period")+
  theme_minimal()+
  theme(legend.position = "bottom")
```

BioNTech VIII



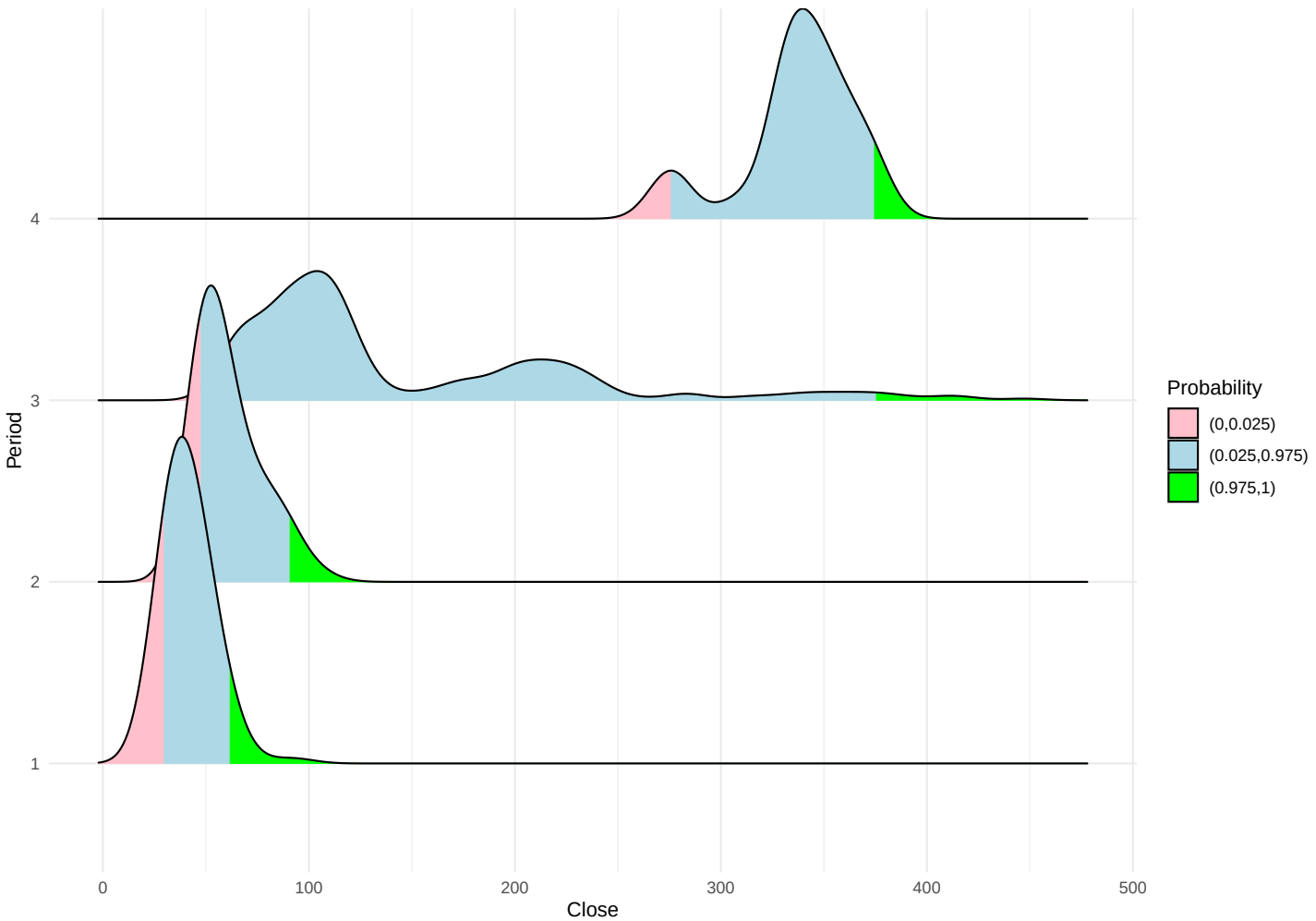
BioNTech IX

Following chart shows distribution and 95% confidence intervals for mean of each period.

```
ggplot(biontechdata, aes(x= Close, y= factor(Period), fill=factor(stat(quantile))))+
  stat_density_ridges(geom="density_ridges_gradient",

                              calc_ecdf=T, quantiles
                      =c(0.025,0.975))+ylab("Period")+
  scale_fill_manual(name="Probability",
                    values=c("pink","lightblue","green"),
                    labels=c("(0,0.025)","(0.025,0.975)","(0.975,1)"))+
  theme_minimal()
```

BioNTech X

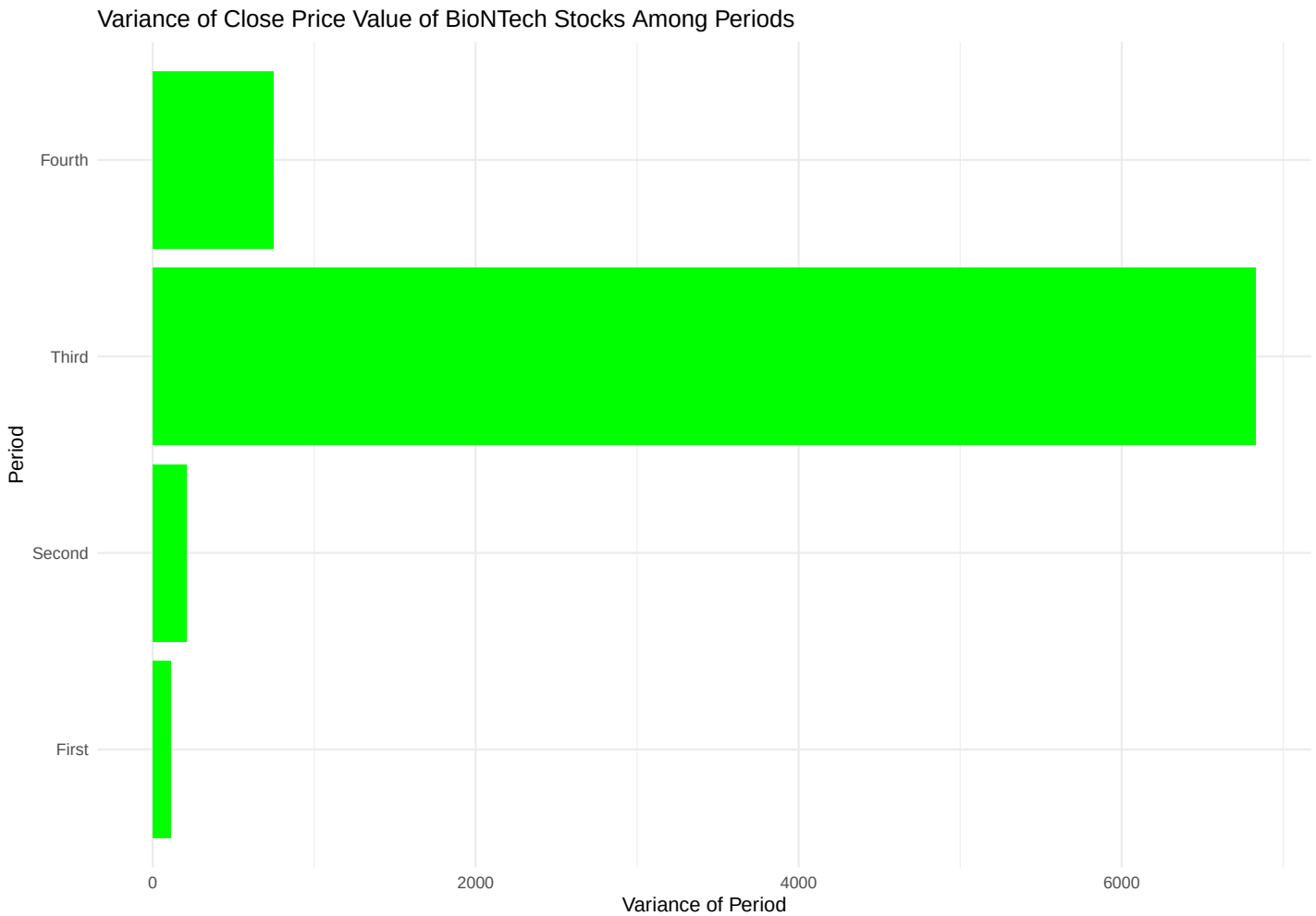

Period
4
3
2
1
0
100
200
300
400
500
Close
Probability
(0,0.025)
(0.025,0.975)
(0.975,1)

BioNTech XI

The following plot indicates the variances of each period.

```
variance=biontechdata %>%
  group_by(Period) %>%
  summarise(Variance=var(Close))
ggplot(variance,aes(x=Variance,y=factor(Period)))+
  geom_col(fill="green")+
  scale_y_discrete(labels=c("First","Second","Third","Fourth"))+
  labs(x = "Variance of Period",
       y="Period",
       title= "Variance of Close Price Value of BioNTech Stocks Among Periods")+
  theme_minimal()+
  theme(legend.position = "bottom")
```

BioNTech XII



Moderna Inc. I

Moderna Inc. (Moderna Inc. Covid-19 vaccine producer) Moderna Inc., Inc. operates as a clinical stage biotechnology company. The Company focuses on the discovery and development of messenger RNA therapeutics and vaccines. Moderna Inc. Inc. which is based in Cambridge, Massachusetts, develops mRNA medicines for infectious, immuno-oncology, and cardiovascular diseases. Among the society, this company known for developing mRNA type vaccine for COVID19. The stock data of Moderna Inc. Inc. that project aims to consider the closing values of stock prices of days in range January 1,2020 and October 1, 2021. The Moderna Inc. Inc stock values have been imported from Yahoo Finance and the unnecessary data have been cleaned from the data and the charts.

```
ModernaData = read_excel("Moderna.xlsx")
ModernaData = ModernaData %>% select(Date | Close)
```

Moderna Inc. II

The news that have had high impact on stock prices, have been marked(These dates were found in internet news such as NYTimes, Bloomberg etc.).

```
criticalDatesModerna = read_excel("criticalDateModerna.xlsx")
criticalDatesModerna %>%
  filter(Date == criticalDatesModerna$Date[1] |
           Date == criticalDatesModerna$Date[2] | Date== criticalDatesModerna$Date[3] |
           Date == criticalDatesModerna$Date[4] |
           Date == criticalDatesModerna$Date[5]) %>%
  kable()
```

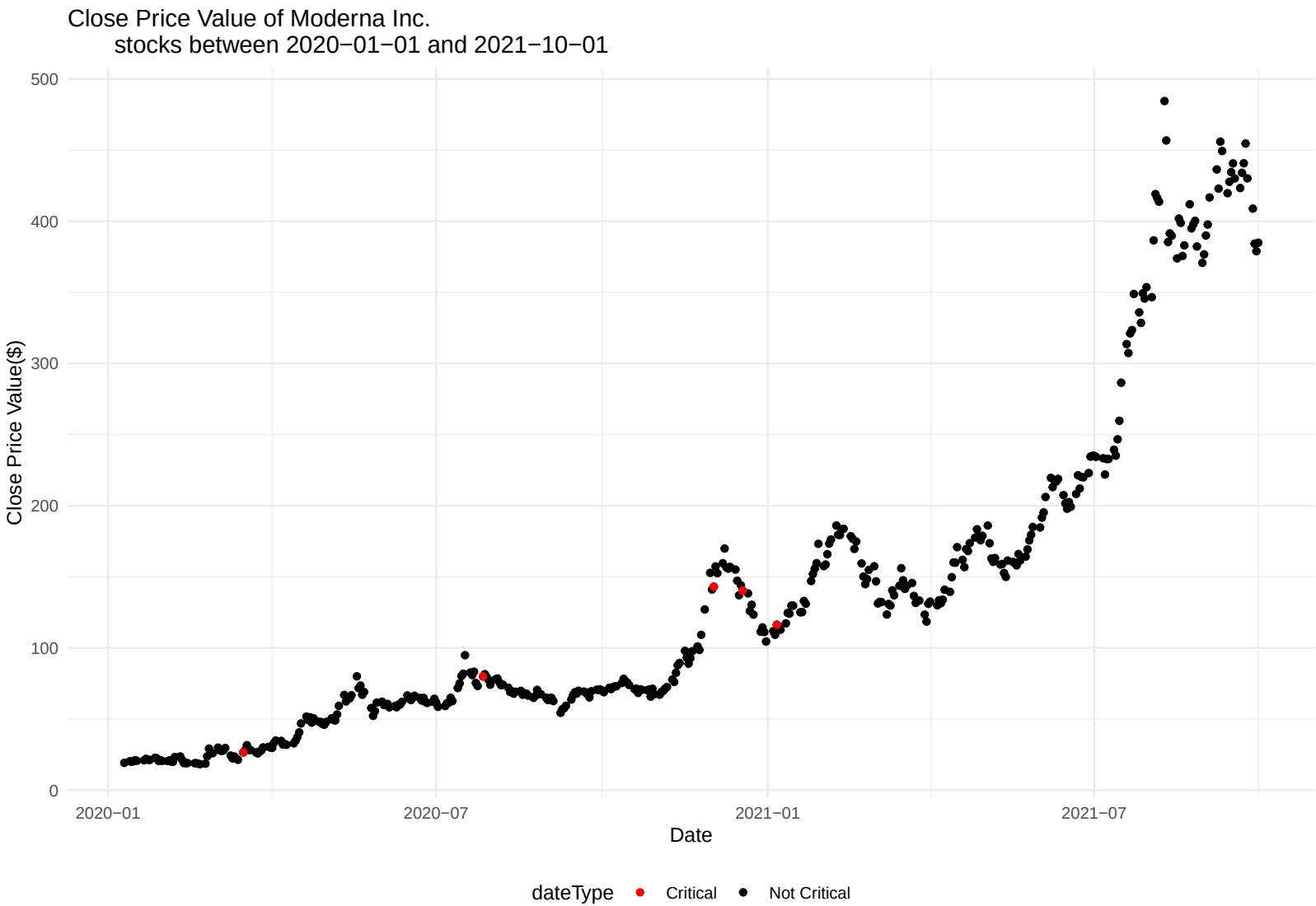
Date	Event
2020-03-16	First Volunteer in America receives first vax
2020-07-27	Phase 2 & 3 have started
2020-12-02	Authorized in UK
2020-12-18	Authorized in USA
2021-01-06	Authorized in EU

Moderna Inc. III

The following graph illustrates closing prices of "Moderna Inc. Inc" in time interval, where critical dates can be seen in red points.

```
ModernaData$Date <- as.Date(ModernaData$Date)
newCriticalDates=as.Date(c("2020-03-16","2020-07-27",
                           "2020-12-02","2020-12-18",
                           "2021-01-06"))
ModernaData=ModernaData %>%
  mutate(dateType=case_when(ModernaData$Date %in%
                              newCriticalDates ~ "Critical",
                            TRUE ~ "Not Critical"))
highLight=ModernaData %>%
  filter(dateType=="Critical")
closeValue=ggplot(ModernaData, aes(x = Date, y = Close))+
  geom_point()+
  geom_point(data=highLight,aes(x = Date, y = Close,color=dateType))+
  labs(x = "Date", y="Close Price Value($)",
       title= "Close Price Value of Moderna Inc.
       stocks between 2020-01-01 and 2021-10-01")+
  scale_color_manual(values = c("Critical" = "red",
                                "Not Critical" = "black"))
closevalue=closeValue+theme_minimal()+
theme(legend.position = "bottom")
closevalue
```

Moderna Inc. IV

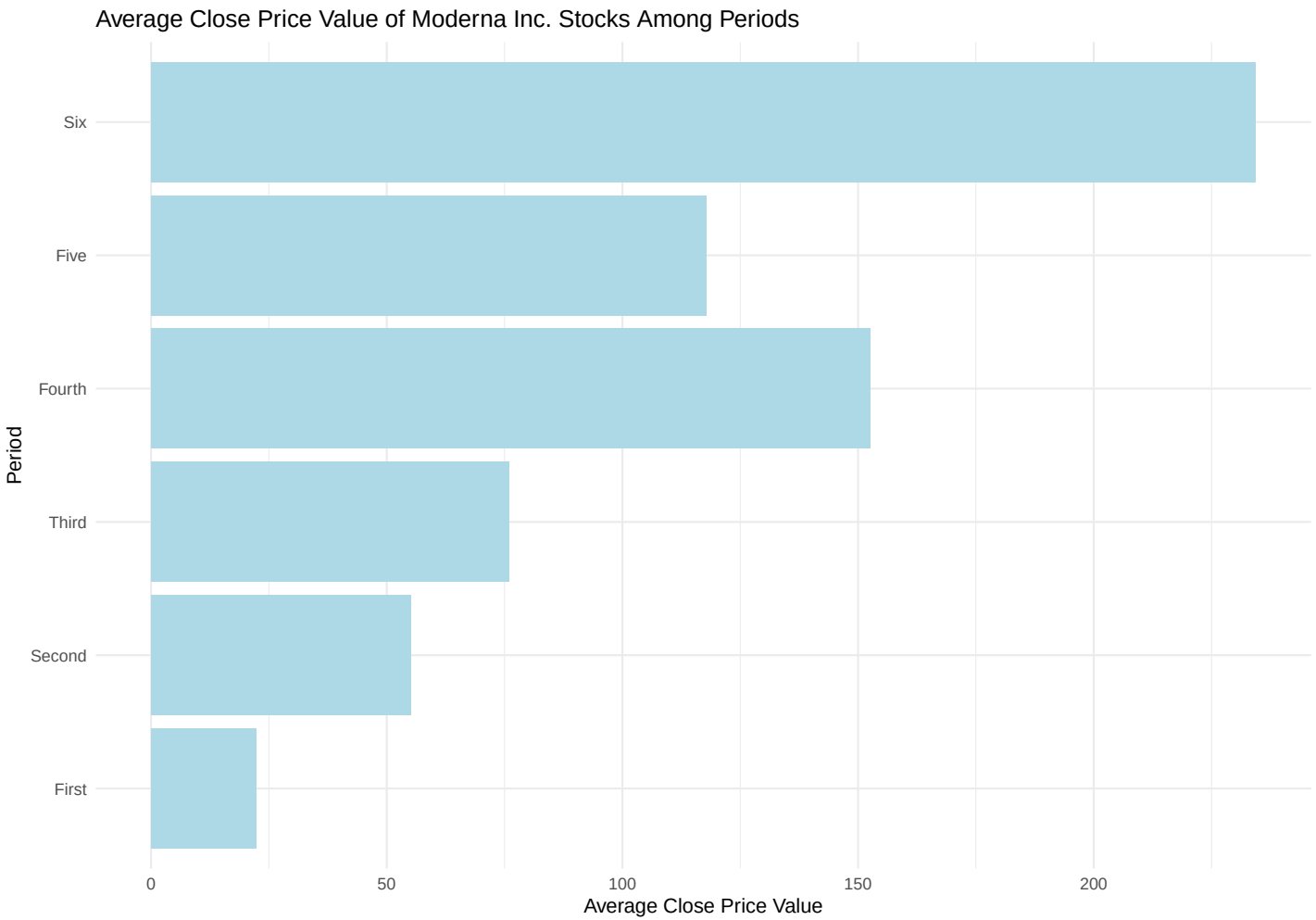


Moderna Inc. V

The following bar chart contains mean of the stock close price data at each section.

```
ModernaData = ModernaData %>%
  mutate(Period=case_when(Date <= "2020-03-16" ~ 1,
                          Date > "2020-03-16" & Date <= "2020-07-27" ~ 2,
                          Date > "2020-07-27" & Date <= "2020-12-02" ~ 3,
                          Date > "2020-12-02" & Date <= "2020-12-18" ~ 4,
                          Date > "2020-12-18" & Date <= "2021-01-06" ~ 5,
                          Date > "2021-01-06" & Date <= "2021-12-18" ~ 6))
average=ModernaData %>%
  group_by(Period) %>%
  summarise(Average=mean(Close))
ggplot(average,aes(x= Average,y=factor(Period)))+
  geom_col(fill="lightblue")+
  scale_y_discrete(labels=c("First","Second","Third",
                            "Fourth", "Five", "Six"))+
  labs(x = "Average Close Price Value",
       y="Period",
       title= "Average Close Price Value of Moderna Inc. Stocks Among Periods")+
  theme_minimal()+
  theme(legend.position = "bottom")
```

Moderna Inc. VI

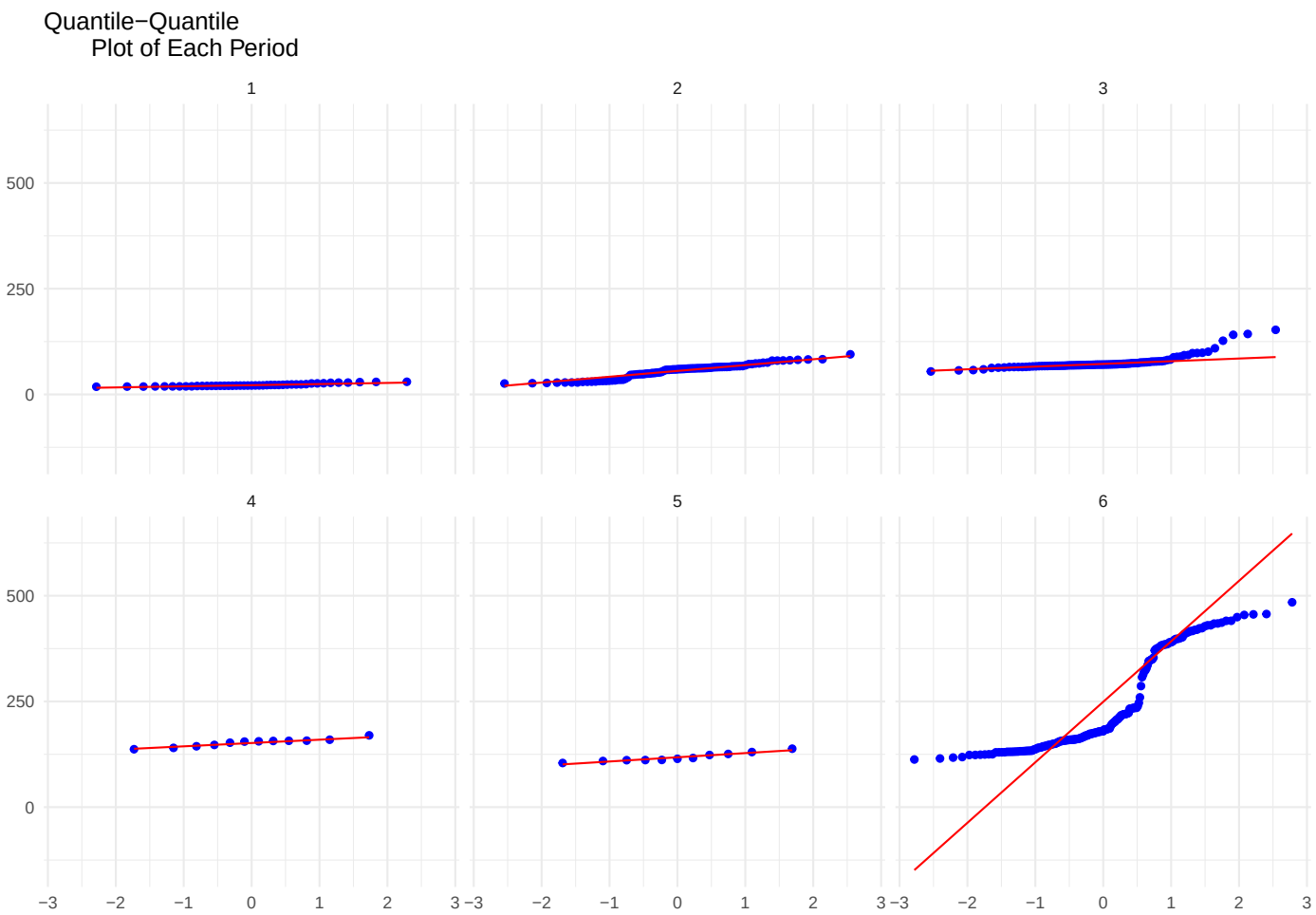


Moderna Inc. VII

To prepare our dataset into statistical tests, we will be determining the amount of its closeness to the normal distribution.

```
ggplot(ModernaData,aes(sample=Close))+
  stat_qq(color="blue")+
  stat_qq_line(color="red")+
  facet_wrap(~Period)+
  labs(x = " ", y=" ",title= "Quantile-Quantile
       Plot of Each Period")+
  theme_minimal()+
  theme(legend.position = "bottom")
```

Moderna Inc. VIII



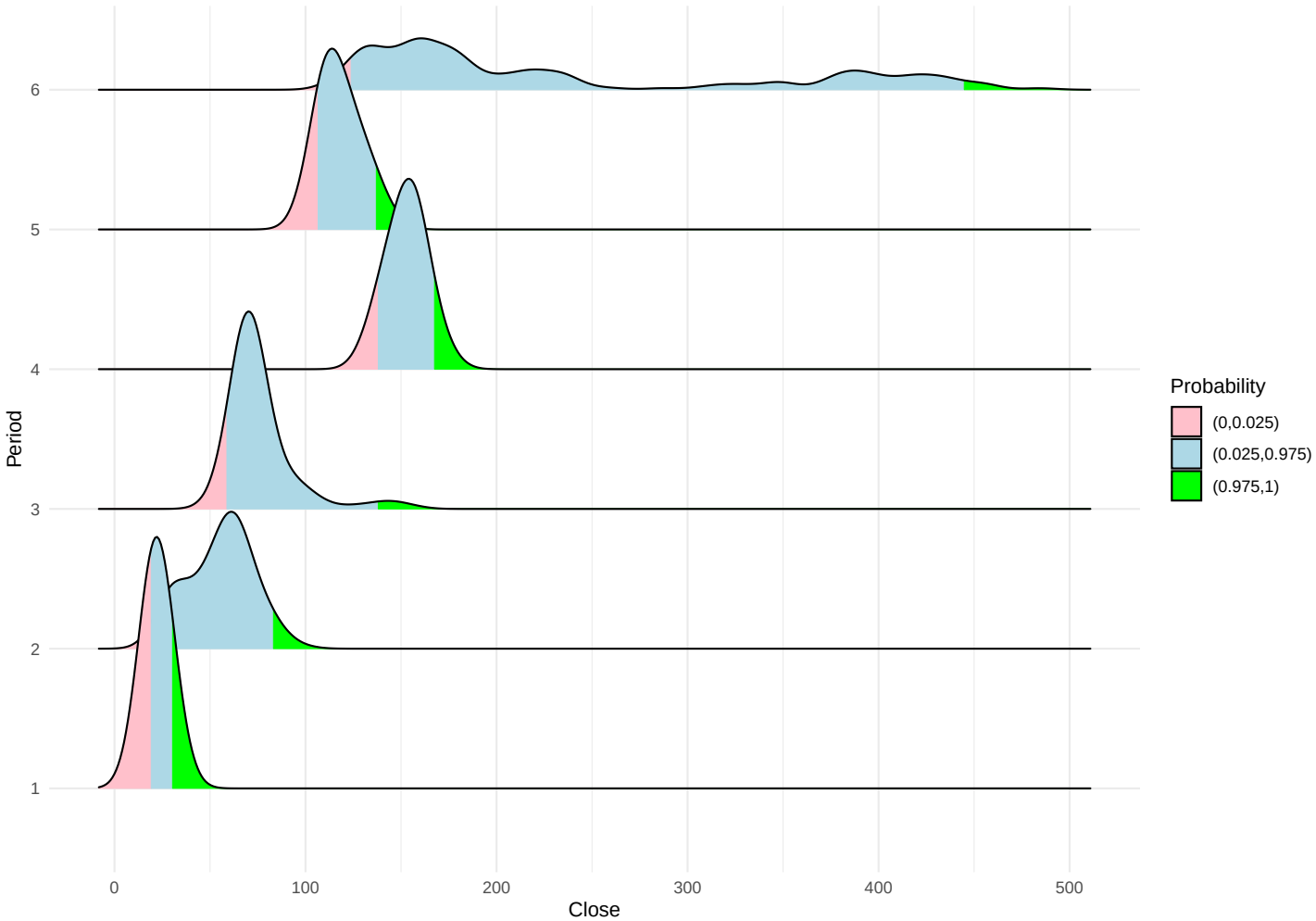
Moderna Inc. IX

The normality of periods can be observed from following density plot better. Moreover, this plot shows 95 confidence intervals of each period.

```
ggplot(ModernaData, aes(x= Close, y= factor(Period),
                        fill=factor(stat(quantile))))+
  stat_density_ridges(geom="density_ridges_gradient",

                      calc_ecdf=T, quantiles = c(0.025,0.975))+
  ylab("Period")+
  scale_fill_manual(name="Probability",
                    values=c("pink","lightblue","green"),
                    labels=c("(0,0.025)","(0.025,0.975)","(0.975,1)"))+
  theme_minimal()
```

Moderna Inc. X

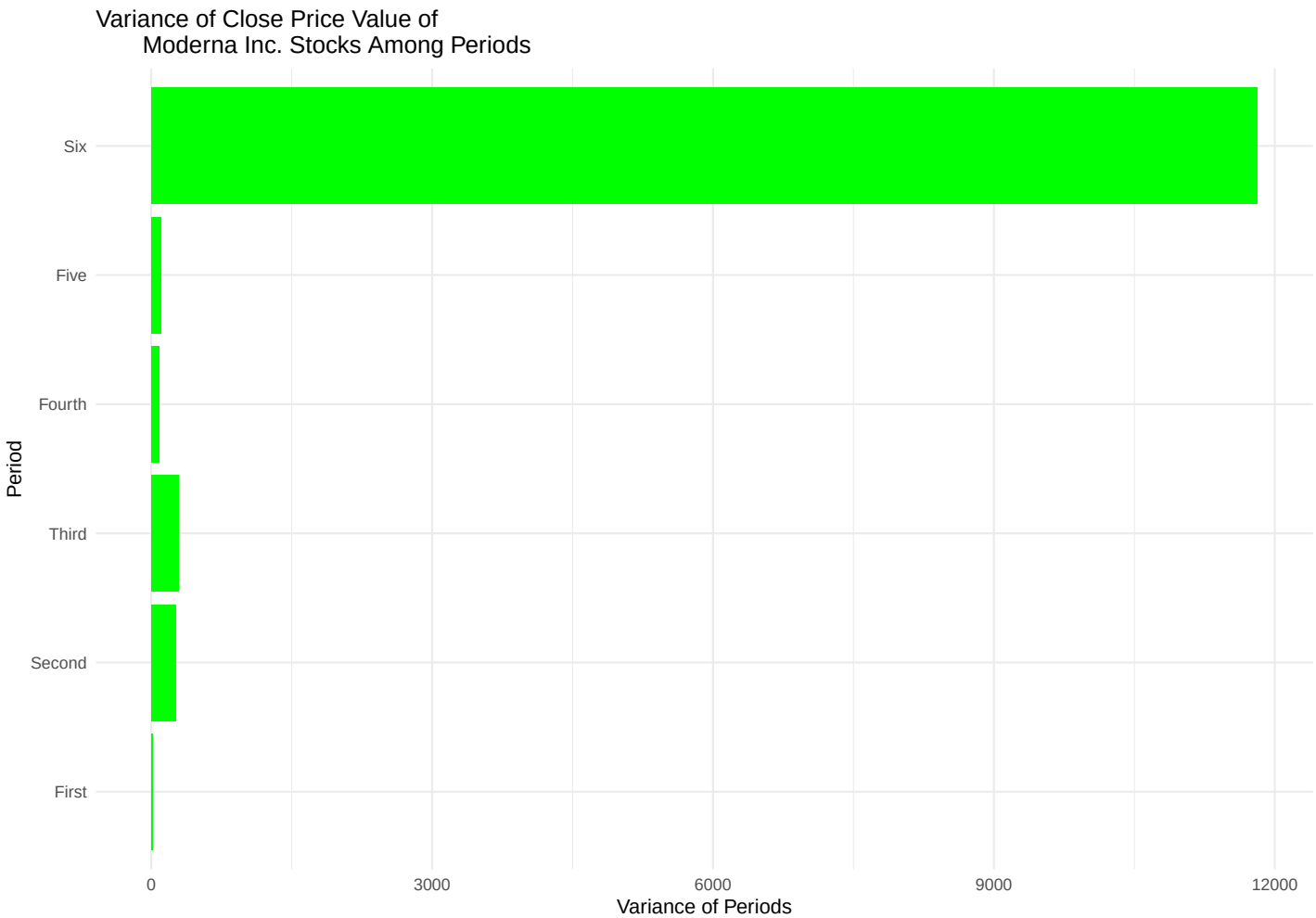


Moderna Inc. XI

The following bar chart indicates variances of each period.

```
varians=ModernaData %>%
  group_by(Period) %>%
  summarise(Variance=var(Close))
ggplot(varians,aes(x=Variance,y=factor(Period)))+
  geom_col(fill="green")+
  scale_y_discrete(labels=c("First","Second","Third",
                            "Fourth", "Five", "Six"))+
  labs(x = "Variance of Periods", y="Period",
       title= "Variance of Close Price Value of
       Moderna Inc. Stocks Among Periods")+
  theme_minimal()+
  theme(legend.position = "bottom")
```

Moderna Inc. XII



AstraZeneca I

AstraZeneca plc is a British-Swedish multinational pharmaceutical and biotechnology company with its headquarters at the Cambridge Biomedical Campus in Cambridge, England. It has a portfolio of products for major diseases in areas including oncology, cardiovascular, gastrointestinal, infection, neuroscience, respiratory, and inflammation. It has been involved in developing the Oxford-AstraZeneca COVID-19 vaccine. The company was founded in 1999 through the merger of the Swedish Astra AB and the British Zeneca Group. Since the merger it has been among the world's largest pharmaceutical companies and has made numerous corporate acquisitions, including Cambridge Antibody Technology (in 2006), MedImmune (in 2007), Spirogen (in 2013) and Definiens (by MedImmune in 2014). AstraZeneca has a primary listing on the London Stock Exchange and is a constituent of the FTSE 100 Index.

AstraZeneca II

It has secondary listings on Nasdaq OMX Stockholm, Nasdaq New York, the Bombay Stock Exchange and on the National Stock Exchange of India.The stock price of AstraZeneca was imported from Yahoo Finance and cleaned from unnecessary and untidy data.

```
astrazenecadata=read_excel("astrazeneca.xlsx")
astrazenecadata=astrazenecadata %>% select(Date | Close)
```

AstraZeneca III

The critical dates have been chosen according to the news about AstraZeneca and listed below.

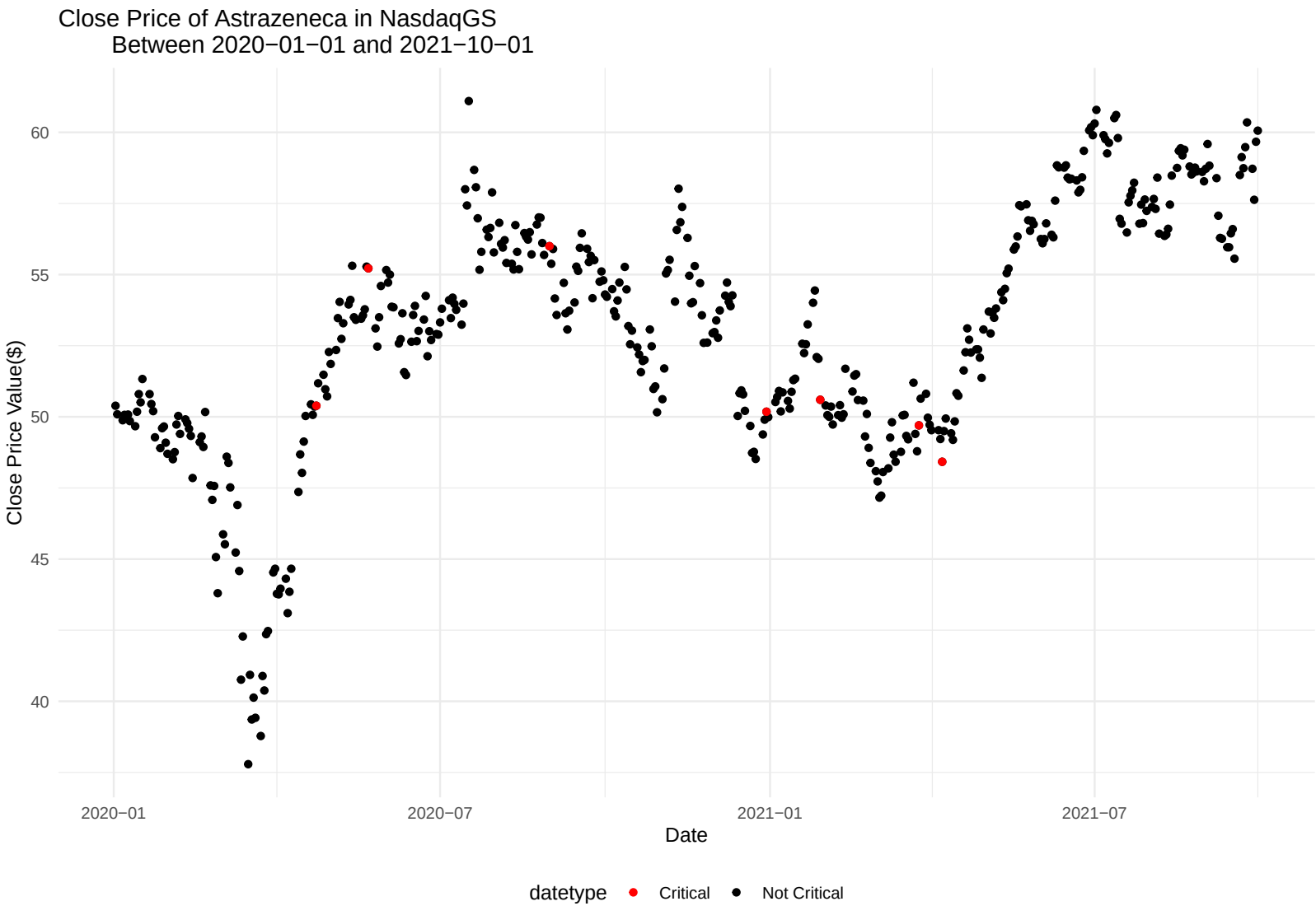
```
  datesAstrazeneca=as.Date(c("2020-04-23","2020-05-22","2020-08-31",
                       "2020-12-3020","21-01-29","2021-03-25","2021-04-07"))
eventsAstrazeneca=c("First  volunteer given vaccine",
                    "Phase 2","US phase 3 trial begins","Authorized in Uk",
                    "Authorized in EU",
                    "Reuses data after US",
                    "EMA funds possible casval link between vaccine
and rare clotting events")
cridatesAstraZeneca=tibble(datesAstrazeneca,eventsAstrazeneca)
cridatesAstraZeneca %>% rename("Date"=datesAstrazeneca ,
                               "Event"=eventsAstrazeneca) %>%
  kable()
```

Date	Event
2020-04-23	First volunteer given vaccine
2020-05-22	Phase 2
2020-08-31	US phase 3 trial begins
2020-12-30	Authorized in Uk
0021-01-29	Authorized in EU
2021-03-25	Reuses data after US
2021-04-07	EMA funds possible casval link between vaccine
and rare clotting events	

AstraZeneca IV

```
astrazenecadata$Date <- as.Date(astrazenecadata$Date)
newCriticalDates=as.Date(c("2020-04-23","2020-05-22",
                           "2020-08-31","2020-12-30",
                           "2021-01-29" , "2021-03-25", "2021-04-07"))
astrazenecadata=astrazenecadata %>%
  mutate(datetype=case_when(astrazenecadata$Date %in%
                              newCriticalDates ~ "Critical",
                               TRUE ~ "Not Critical"))
 highLight=astrazenecadata %>%
     filter(datetype=="Critical")
 closeValue=ggplot(astrazenecadata,
                   aes(x = Date, y = Close))+
     geom_point()+
     geom_point(data=highLight,
                aes(x = Date, y = Close,color=datetype))+
     labs(x = "Date",
          y="Close Price Value($)",
          title= "Close Price of Astrazeneca in NasdaqGS
        Between 2020-01-01 and 2021-10-01")+
     scale_color_manual(values = c("Critical" = "red",
                                   "Not Critical" = "black"))
 closeValue=closeValue+theme_minimal()+
   theme(legend.position = "bottom")
 closeValue
```

AstraZeneca V

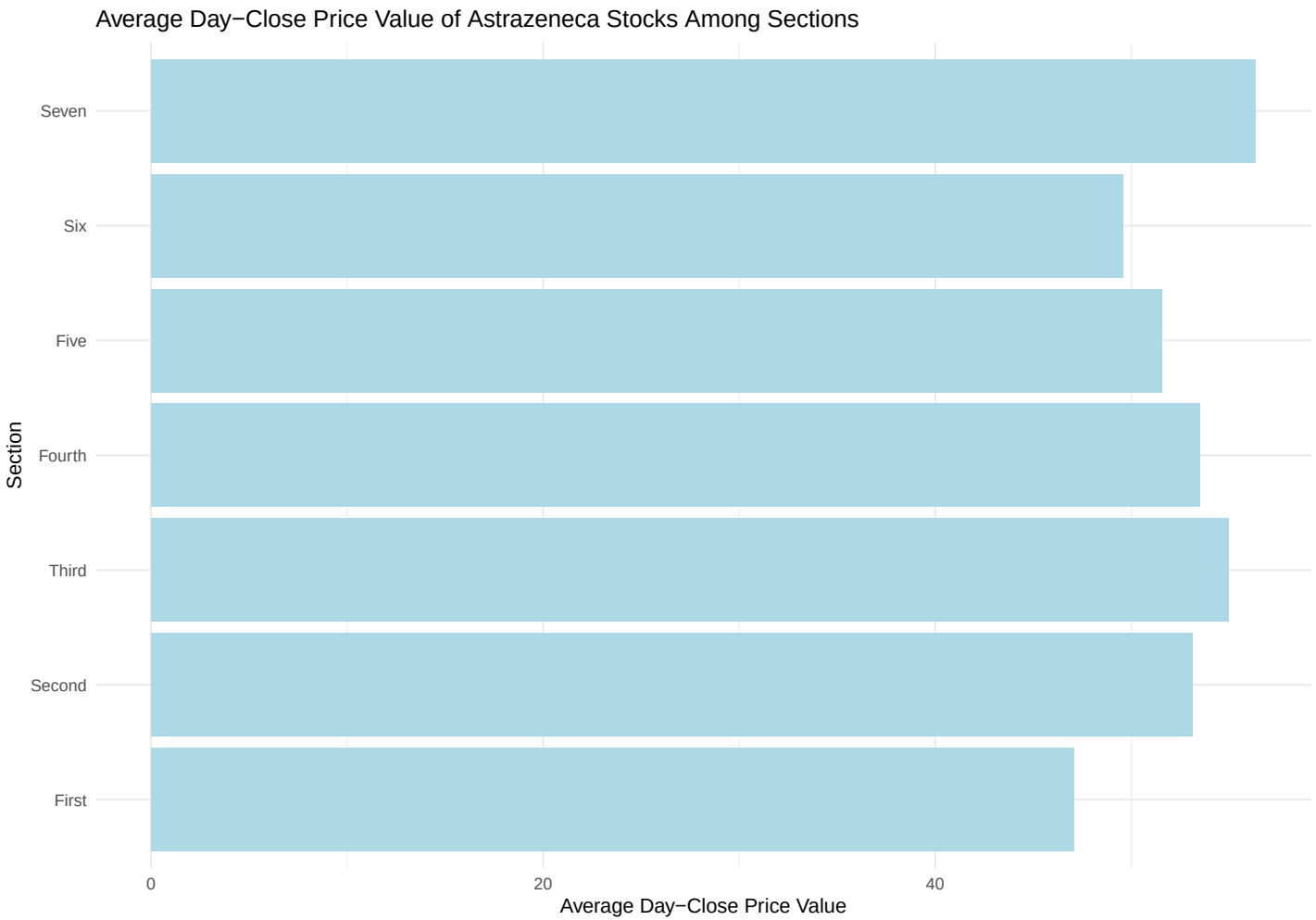


AstraZeneca VI

The following bar chart contains information about means of periods separately.

```
 astrazenecadata = astrazenecadata %>%
     mutate(Section=case_when(Date <= "2020-04-23" ~ 1,
                              Date > "2020-04-23" & Date <= "2020-05-22" ~ 2,
                              Date > "2020-05-22" & Date <= "2020-08-31" ~ 3,
                              Date > "2020-08-31" & Date <= "2020-12-30" ~ 4,
                              Date > "2020-12-30" & Date <= "2021-01-29" ~ 5,
                              Date > "2021-01-29" & Date <= "2021-03-25" ~ 6,
                              Date > "2021-03-25" ~ 7))
average=astrazenecadata %>%
     group_by(Section) %>%
     summarise(Average=mean(Close))
ggplot(average,aes(x= Average,y=factor(Section)))+
     geom_col(fill="lightblue")+
     scale_y_discrete(labels=c("First","Second","Third",
                               "Fourth", "Five", "Six", "Seven"))+
     labs(x = "Average Day-Close Price Value",
          y="Section",
          title= "Average Day-Close Price Value of Astrazeneca Stocks Among Sections")+
     theme_minimal()+
     theme(legend.position = "bottom")
```

AstraZeneca VII

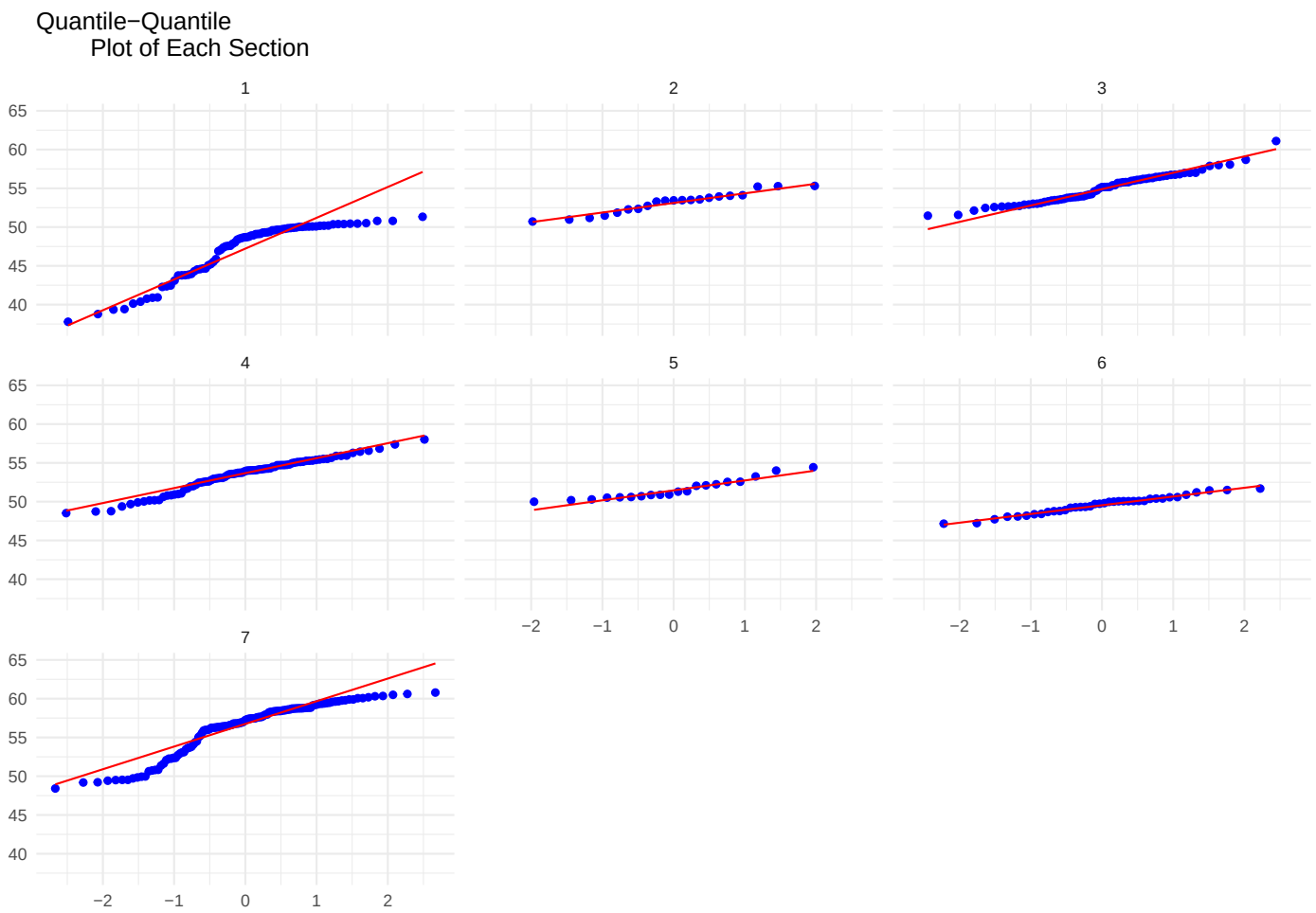


AstraZeneca VIII

The following quantile-quantile plot measures their closeness to a normal distribution.

```
ggplot(astrazenecadata,aes(sample=Close))+
     stat_qq(color="blue")+
     stat_qq_line(color="red")+
     facet_wrap(~Section)+
     labs(x = " ", y=" ",title= "Quantile-Quantile
        Plot of Each Section")+
     theme_minimal()+
     theme(legend.position = "bottom")
```

AstraZeneca IX

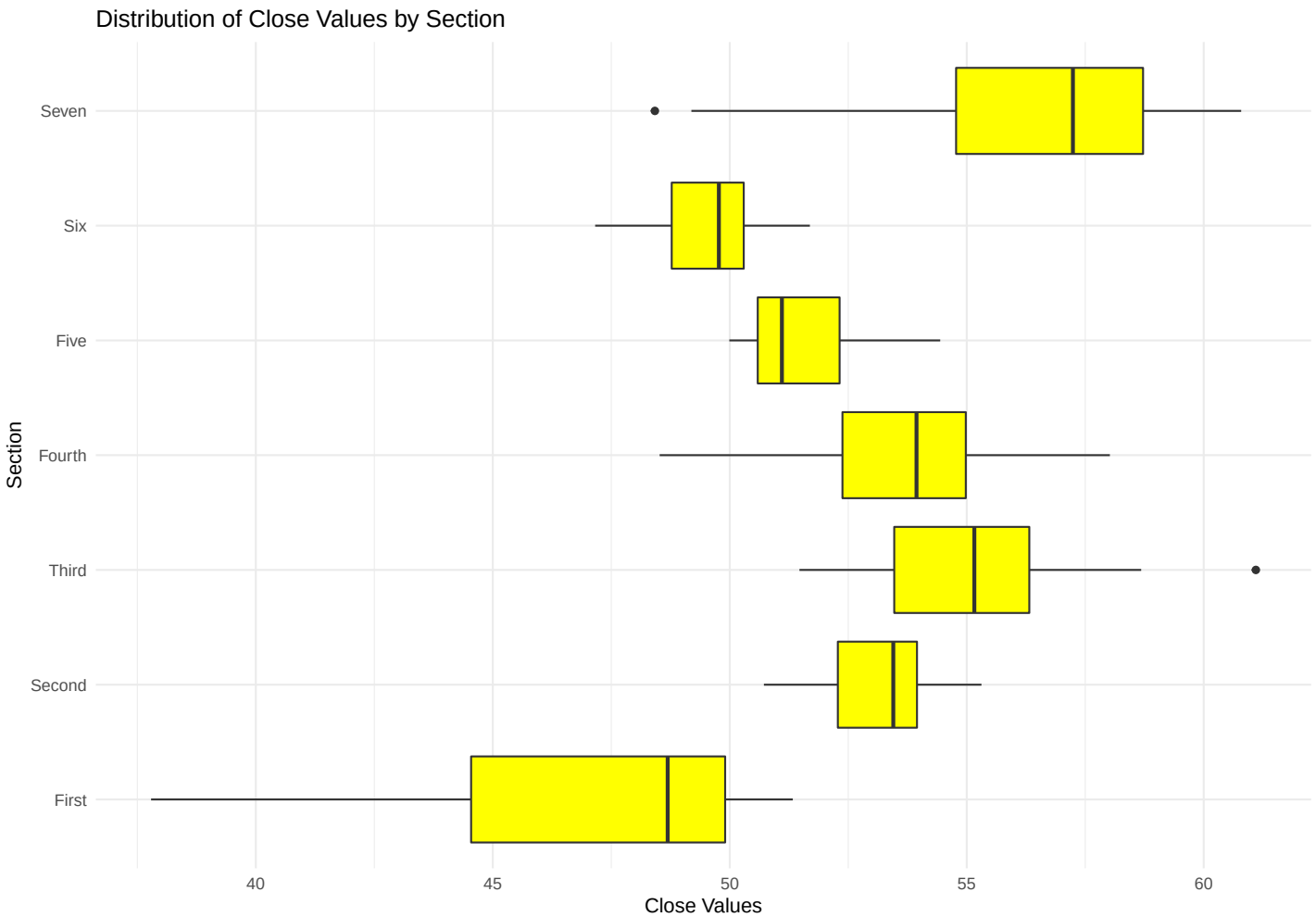


AstraZeneca X

The following box plot gives more information about distribution of each period.

```
ggplot(astrazenecadata, aes(x=Close ,y=factor(Section)))+
     geom_boxplot(fill="yellow")+
     scale_y_discrete(labels=c("First","Second",
                               "Third","Fourth", "Five",
                               "Six", "Seven"))+
     labs(x = "Close Values", y="Section",
          title= "Distribution of Close Values by Section")+
     theme_minimal()+
     theme(legend.position = "bottom")
```

AstraZeneca XI

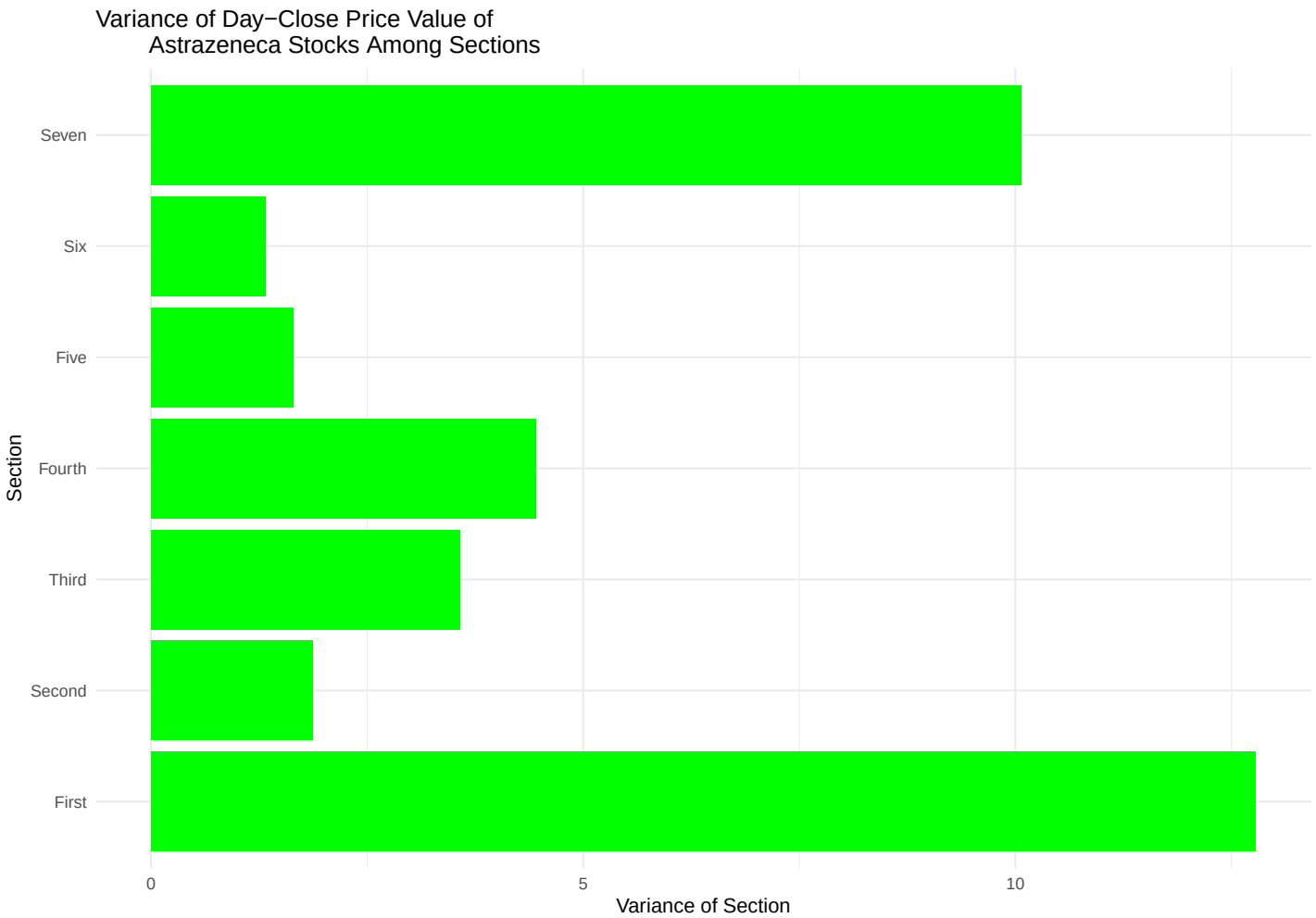


AstraZeneca XII

The following bar chart compares variances of each period.

```
 varians=astrazenecadata %>%
     group_by(Section) %>%
     summarise(Variance=var(Close))
ggplot(varians,aes(x=Variance,y=factor(Section)))+
     geom_col(fill="green")+
     scale_y_discrete(labels=c("First","Second","Third",
                               "Fourth", "Five", "Six", "Seven"))+
     labs(x = "Variance of Section", y="Section",
          title= "Variance of Day-Close Price Value of
        Astrazeneca Stocks Among Sections")+
     theme_minimal()+
     theme(legend.position = "bottom")
```

AstraZeneca XIII



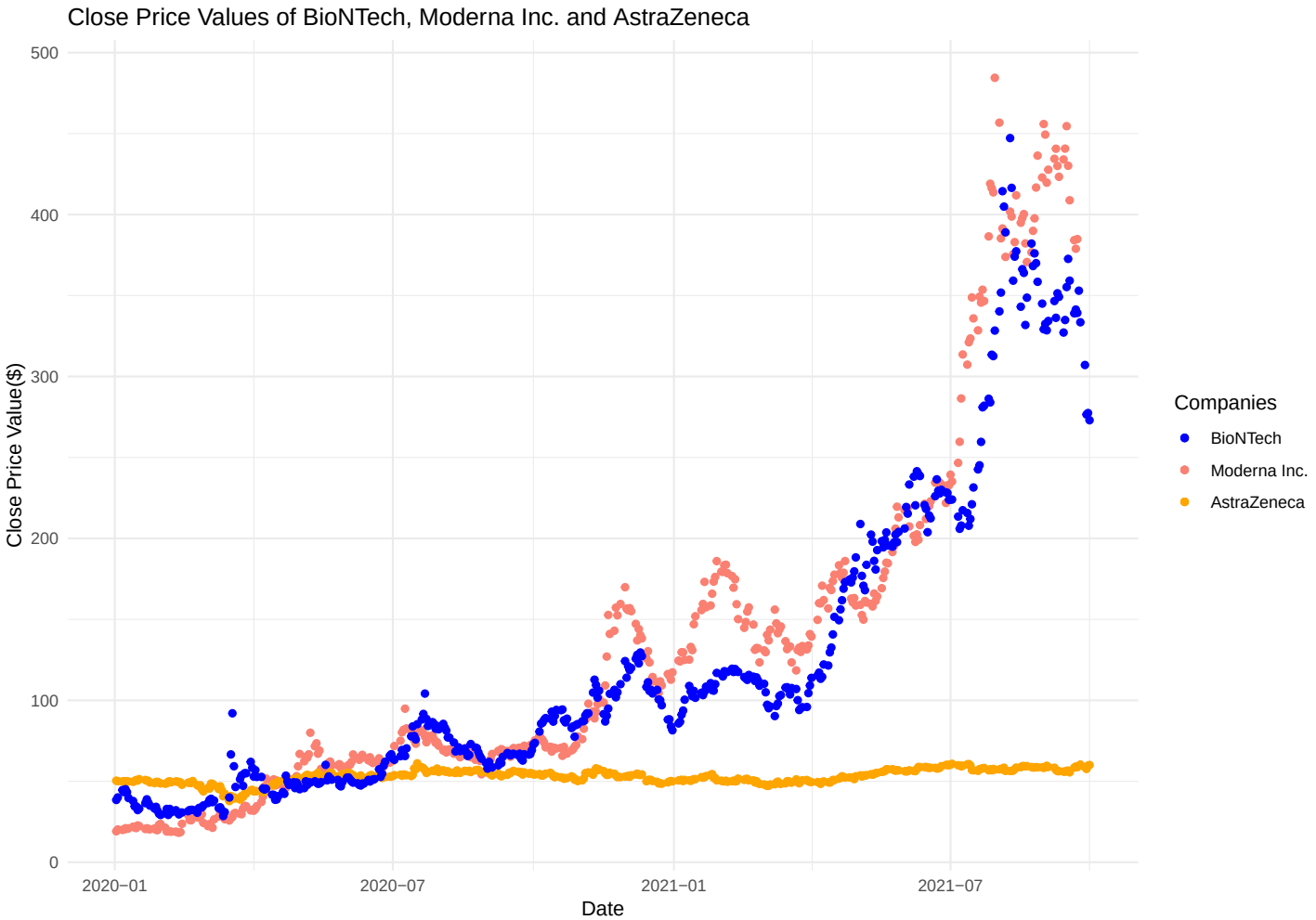
Comparison of Vaccine Companies I

In this section, we combine our foundings and make statistical analyses with them. Results will be visualized. First of all it is essential to visualize all raw data from each vaccine company in same graph. To create such a graph, we merged our data sets for vaccine companies as mergedata.xlsx.

Comparison of Vaccine Companies II

```
merged_data=read_excel("mergedata.xlsx")
merged_data$Date=as.Date(merged_data$Date)
companies=c("Moderna Inc.","BioNTech","AstraZeneca")
p=ggplot(merged_data,aes(x=Date, y))+
  geom_point(aes(x=Date,
                 y=ModernaClose,color=companies[1]))+
  geom_point(aes(x=Date,
                 y=AstrazenecaClose,colour=companies[3]))+
  geom_point(aes(x=Date,
                 y=BiontechClose,colour=companies[2]))+
  labs(title = "Close Price Values of BioNTech, Moderna Inc. and AstraZeneca",
       x="Date",y="Close Price Value($)",
       colour=" Companies")+
  scale_color_manual(values =c("BioNTech" = "blue",
                               "Moderna Inc." = "salmon", "AstraZeneca"="orange"))+
  theme_minimal()
p
```

Comparison of Vaccine Companies III



As we partitioned

Comparison of Vaccine Companies IV

the data sets into periods, now we compare similar periods of each company. We make comparisons with three three main events, these are the period of first volunteer gets vaccine, period of phases 2-3, and period of authorizations. Additionally, we compare the effects of FDA approval on BioNTech's stock prices and EMA founding on AstraZeneca's stock prices. We need to arrange periods for those comparisons.

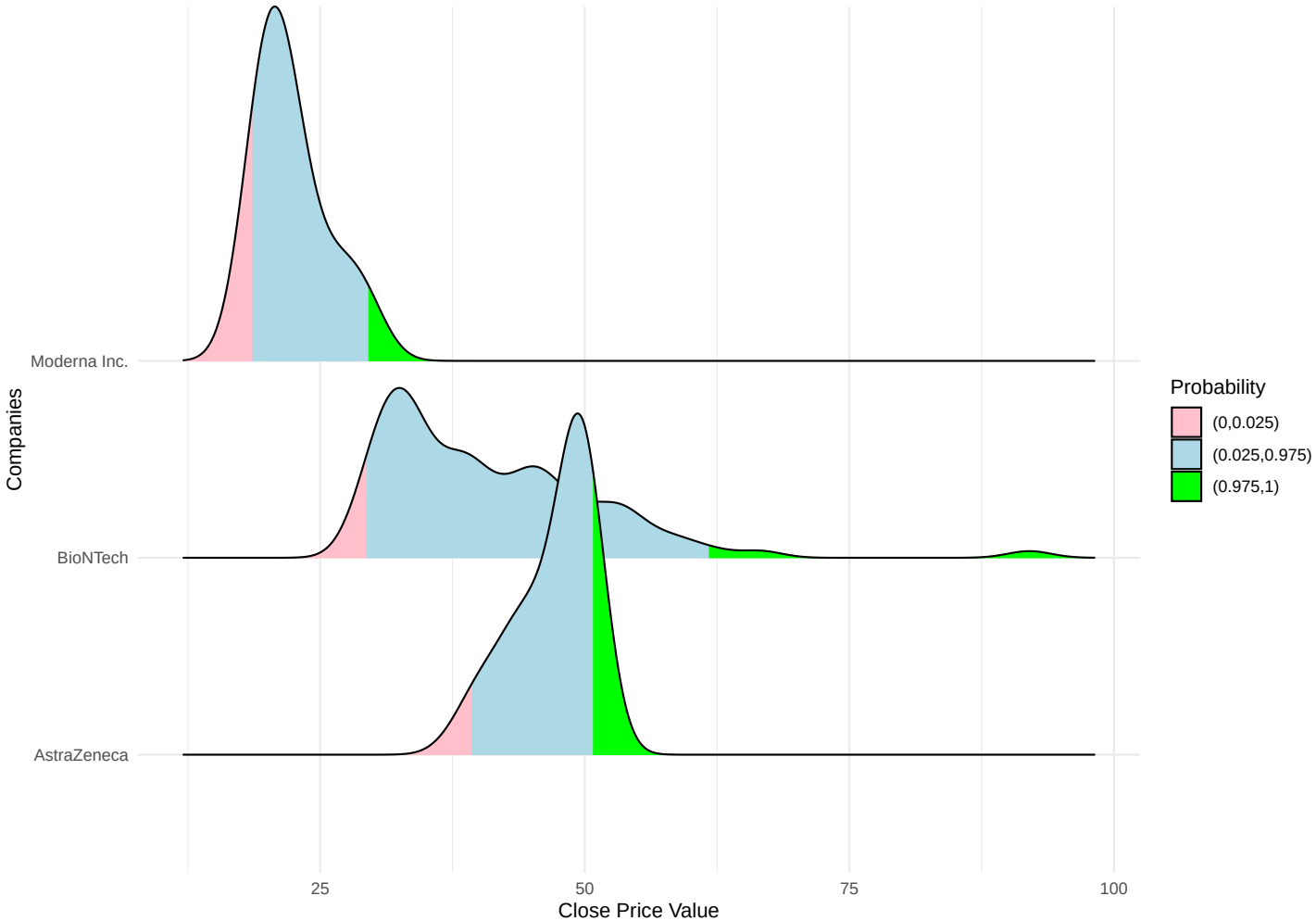
```
biontech_first_volunteer=biontechdata  %>% filter(Period==1) %>% mutate(company="BioNTech")
moderna_first_volunteer=ModernaData %>% filter(Period==1) %>% mutate(company="Moderna Inc.")
astrazeneca_first_volunteer= astrazenecadata %>% filter(Section==1) %>% mutate(company="AstraZeneca")
biontech_phase=biontechdata  %>% filter(Period==2) %>% mutate(company="BioNTech")
moderna_phase=ModernaData  %>% filter(Period==2) %>% mutate(company="Moderna Inc.")
astrazeneca_phase= astrazenecadata %>% filter(Section==2 | Section==3) %>% mutate(company="AstraZeneca")
biontech_authorization=biontechdata %>% filter(Period==3) %>% mutate(company="BioNTech")
moderna_authorization=ModernaData %>% filter(Period==3 | Period==4 | Period==5) %>%
  mutate(company="Moderna Inc.")
astrazeneca_authorization= astrazenecadata %>% filter(Section==4 | Section==4) %>%
  mutate(company="AstraZeneca")
biontech_FDA=biontechdata %>% filter(Period==4) %>% mutate(company="BioNTech")
astrazeneca_EMA=astrazenecadata %>% filter(Section==7)
```

Comparison of Vaccine Companies V

The following graphs includes confidence intervals for mean of periods of each company. First the following distribution graph compares the distribution of period "first volunteer gets vaccine" of each company.

```
firstvolunteer=data.frame(a=biontech_first_volunteer$Close %>%
                            append(moderna_first_volunteer$Close) %>%
                            append(astrazeneca_first_volunteer$Close),
                          b=biontech_first_volunteer$company %>%
                            append(moderna_first_volunteer$company) %>%
                            append(astrazeneca_first_volunteer$company))
ggplot(firstvolunteer, aes(x= a, y= factor(b),
                           fill=factor(stat(quantile))))+
  stat_density_ridges(geom="density_ridges_gradient",
                      calc_ecdf=T, quantiles = c(0.025,0.975))+
  ylab("Companies")+xlab("Close Price Value")+
  scale_fill_manual(name="Probability",
                    values=c("pink","lightblue","green"),
                    labels=c("(0,0.025)","(0.025,0.975)","(0.975,1)"))+
  theme_minimal()
```

Comparison of Vaccine Companies VI

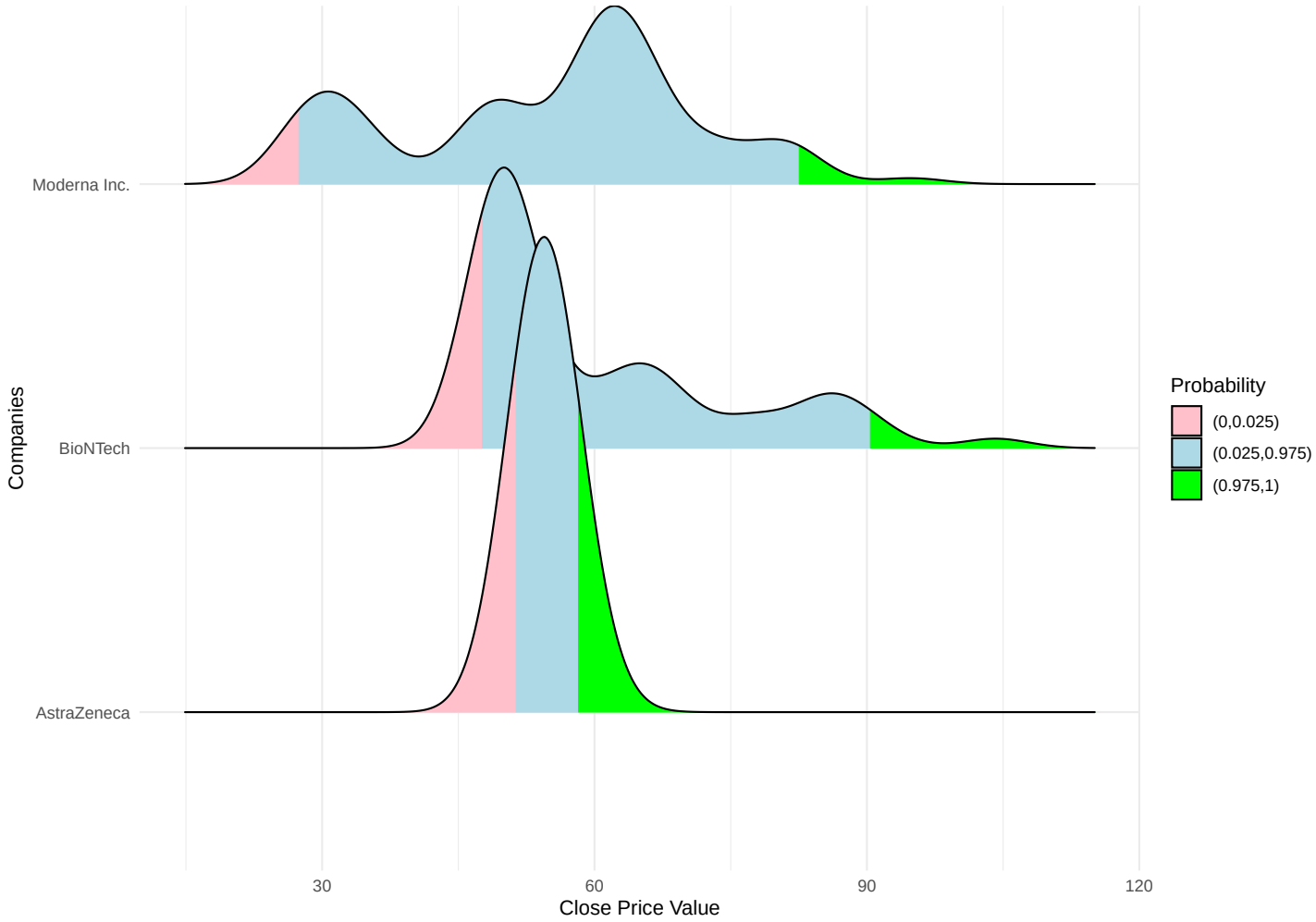


Comparison of Vaccine Companies VII

The following chart indicates the distributions of each company in "phases" period.

```
phase=data.frame(a=biontech_phase$Close %>%
                   append(moderna_phase$Close) %>%
                   append(astrazeneca_phase$Close),
                 b=biontech_phase$company %>%
                   append(moderna_phase$company) %>%
                   append(astrazeneca_phase$company))
ggplot(phase, aes(x= a, y= factor(b),
                          fill=factor(stat(quantile))))+
  stat_density_ridges(geom="density_ridges_gradient",
                      calc_ecdf=T, quantiles = c(0.025,0.975))+
  ylab("Companies")+xlab("Close Price Value")+
  scale_fill_manual(name="Probability",
                    values=c("pink","lightblue","green"),
                    labels=c("(0,0.025)","(0.025,0.975)","(0.975,1)"))+
  theme_minimal()
```

Comparison of Vaccine Companies VIII



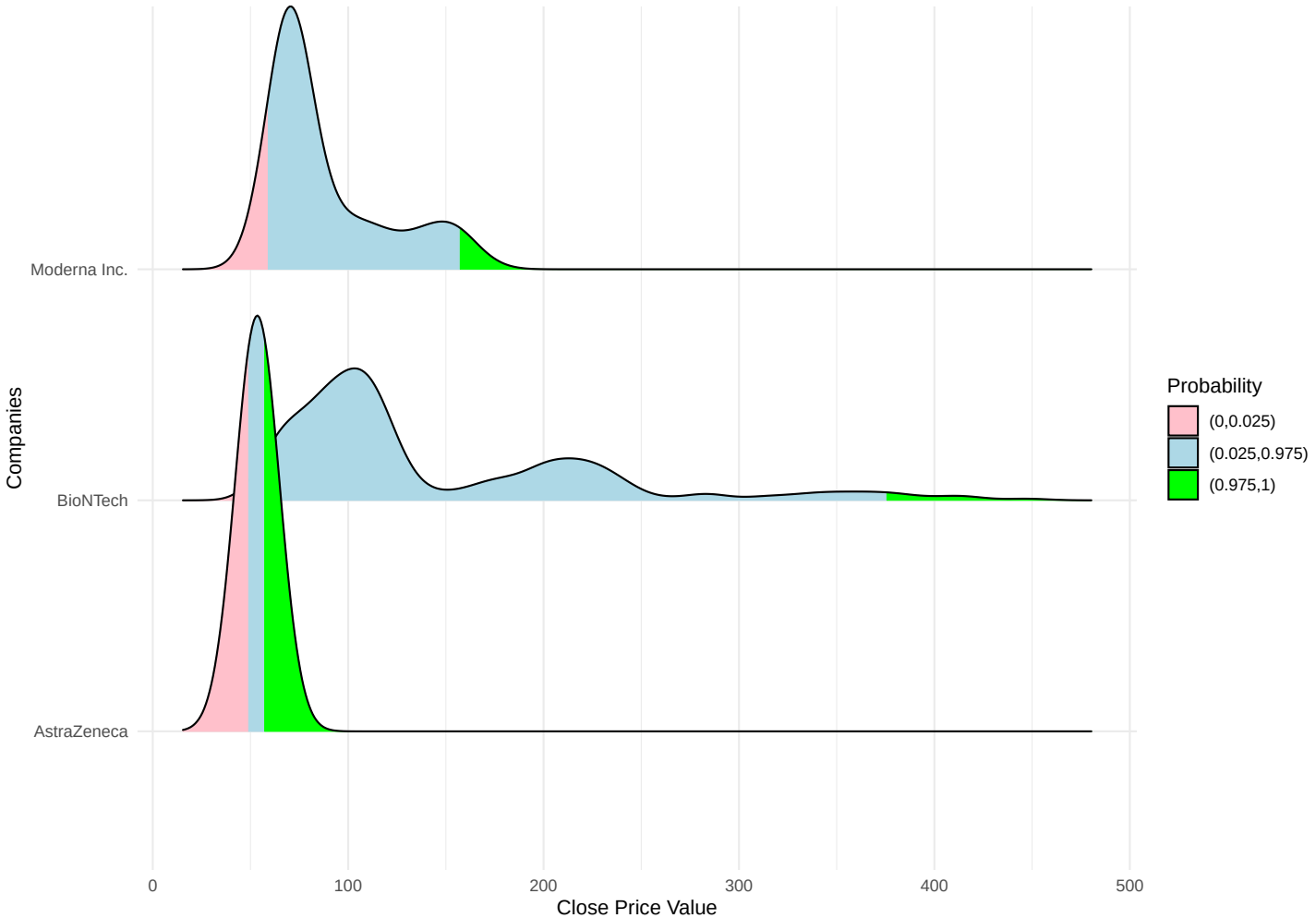
The following

Comparison of Vaccine Companies IX

chart indicates the distributions of each company in “authorization” period.

```
authorization=data.frame(a=biontech_authorization$Close %>%
                           append(moderna_authorization$Close) %>% append(astrazeneca_authorization$Close),
                         b=biontech_authorization$company %>%
                           append(moderna_authorization$company) %>%
                           append(astrazeneca_authorization$company))
ggplot(authorization, aes(x= a, y= factor(b),
                          fill=factor(stat(quantile))))+
  stat_density_ridges(geom="density_ridges_gradient",
                      calc_ecdf=T, quantiles = c(0.025,0.975))+
  ylab("Companies")+xlab("Close Price Value")+
  scale_fill_manual(name="Probability",
                    values=c("pink","lightblue","green"),
                    labels=c("(0,0.025)","(0.025,0.975)","(0.975,1)"))+
  theme_minimal()
```

Comparison of Vaccine Companies X



Comparison of Vaccine Companies XI

The following code calculates the rate of changes in company stock prices in each period.

```
rates=data.frame(Company=
                   c("BioNTech","BioNTech","BioNTech",
                     "Moderna Inc.","Moderna Inc.","Moderna Inc.",
                     "AstraZeneca","AstraZeneca","AstraZeneca"),
                 rate_types=
                   c("First Volunteer","Phase","Authorization",
                     "First Volunteer","Phase","Authorization","
                     First Volunteer","Phase","Authorization"),
                Values=
                   c((firstvolunteer[86,1]-firstvolunteer[1,1])/firstvolunteer[1,1]*100,
                     (phase[57,1]-phase[1,1])/phase[1,1]*100,
                      (authorization[271,1]-authorization[1,1])/authorization[1,1]*100,
                     (firstvolunteer[129,1]-firstvolunteer[87,1])/firstvolunteer[87,1]*100,
                     (phase[149,1]-phase[58,1])/phase[58,1]*100,
                      (authorization[384,1]-authorization[272,1])/authorization[272,1]*100,
                     (firstvolunteer[209,1]-firstvolunteer[130,1])/firstvolunteer[130,1]*100,
                      (phase[239,1]-phase[150,1])/phase[150,1]*100 ,
                    (authorization[468,1]-authorization[385,1])/authorization[385,1]*100))
```

Comparison of Vaccine Companies XII

The graph of AstraZeneca contains more fluctuations than other companies, and according to the bar chart the periods phase and authorization had slight impacts on data set. Hence it would be useful to test whether those events have affect on stock prices of AstraZeneca in statistical importance. So we need to test
$H_0 : \mu_{FirstVolunteer} = \mu_{Authorization} = \mu_{Phase}$ $H_1 : \mu_{FirstVolunteer} \neq \mu_{Authorization} \neq \mu_{phase}$

```
astrazen_rate <- data.frame(
  Y=
    c(astrazeneca_first_volunteer$Close %>%
        append(astrazeneca_phase$Close) %>%
        append(astrazeneca_authorization$Close)),
  Period=
    factor(rep(c("First Volunteer","Phase", "Authorization"),
               c(length(astrazeneca_first_volunteer$Close),
                 length(astrazeneca_phase$Close),
                 length(astrazeneca_authorization$Close)))))
k=anova(lm(astrazen_rate$Y~astrazen_rate$Period))
rownames(k) <- c("Period", "Residuals")
k %>% kable()
```

Comparison of Vaccine Companies XIII

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Period	2	2663.909	1331.954330	196.5779	0
Residuals	249	1687.151	6.775708	NA	NA

Comparison of Vaccine Companies XIV

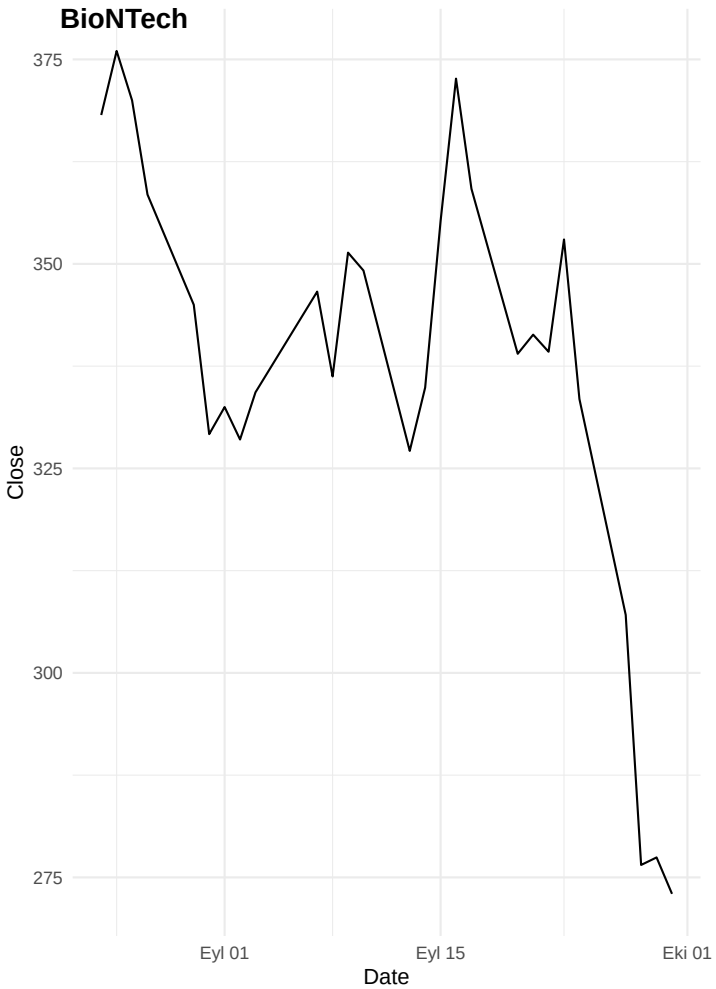
It is clear that there are no statistical difference between each period of AstraZeneca, therefore we can say that phase and authorization periods has not significant effect on AstraZeneca's stock prices. Since other relations can be seen obvious we did not make ANOVA tables for them.

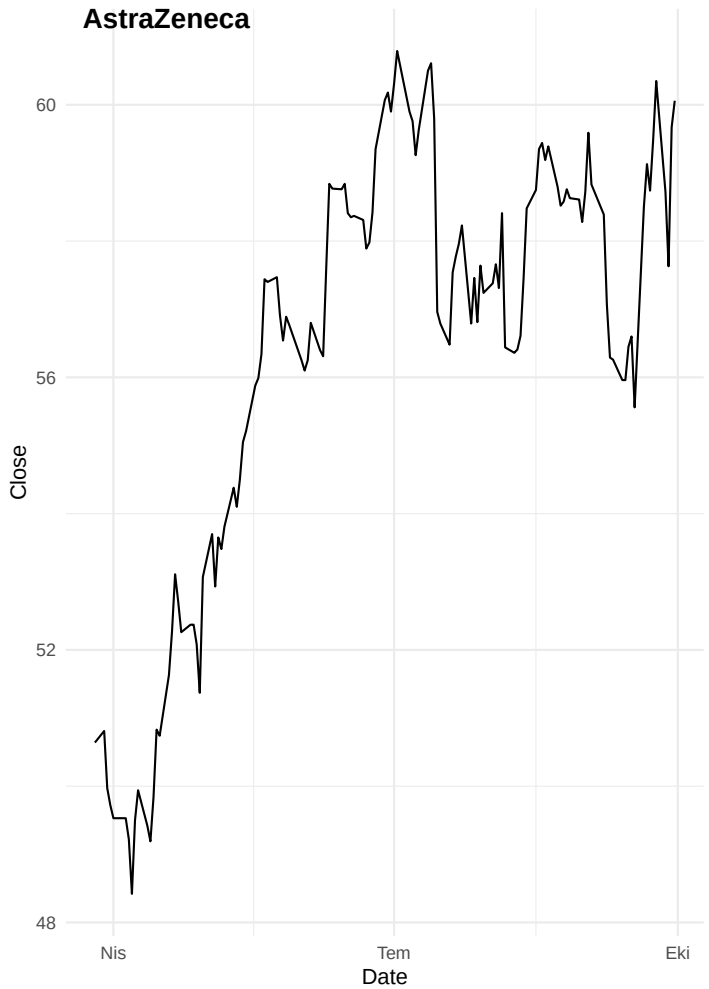
Comparison of Vaccine Companies XV

Finally, we can analyze final periods of each company, we compare EMA founding period of AstraZeneca with FDA period of BioNTech. The following graph shows the rate of changes of stock prices of AstraZeneca at EMA period and BioNTech at FDA period.

```
p1=ggplot()+ geom_line(biontech_FDA ,mapping=aes(x=Date,y=Close))+theme_minimal()
p2=ggplot()+geom_line(astrazeneca_EMA,mapping=aes(x=Date,y=Close))+theme_minimal()
plot_grid(p1, p2,labels=c("BioNTech", "AstraZeneca"), ncol = 2, nrow = 1)
```

Comparison of Vaccine Companies XVI





The result is

Comparison of Vaccine Companies XVII

unexpected because FDA approval should increase the stock prices of BioNTech but we can observe a significant decrease, while EMA foundings was expected to decrease stock prices of AstraZeneca it increased by approximately 25. This result is fundamental for stock data analysis, because a positive event might not imply an increase likewise a negative event might not imply a decrease. It is evident that AstraZeneca was not as successful as Moderna Inc. and BioNTech companies in stock prices during the pandemic. But there need to be more economical parameters other than we tested in this project to determine the most successful company. It is clear the answer is Moderna Inc. or BioNTech, but we can not answer without knowing more economical analysis methods, but by statistical tests we can conclude that Moderna Inc. and BioNTech became very successful to increase their stock prices even though their graph shows a clear decrease in their last days of time scope of this project.

Conclusions I

During the pandemic, numerous health company started to research for develop a COVID19 vaccine, and many of them became successful. AstraZeneca, BioNTech and Moderna Inc. was three of them and they were most-known ones. So we obtained their stock price data for a time interval in pandemic via Yahoo Finance and performed statistical analyses on them and visualized our foundings and explained them. We concluded that AstraZeneca did not showed economical performance as good as BioNTech and Moderna Inc..

References

- Dataset of BioNTech Stocks
- Dataset of Moderna Inc. Stocks
- Dataset of AstraZeneca Stocks