Performances and Changes in the Stock Market of Four Electronic Companies during Covid-19 and Their Future Market Predictions

Jialin Guo

***Abstract*—The electronic industry has grown faster and faster in recent years. The market is huge, and demand is constantly high for different services. This paper looks at the stocks of four different companies that belong to the electronic industry: Nintendo, Sony, AMC and IBM. Although all belong to the same category, each of them focus on different fields and provide various services. We look at the performances of their stock during three major timberlines that split up into three periods: before, during and after covid-19. The daily returns of these stocks are analyzed to determine their consistency with three fitted model distributions: maximum-likelihood fitted normal, robust-fitted normal, and maximum-likelihood fitted Laplace. Through making hypotheses and careful analysis of the goodness-of-fit of these models, we draw the following conclusions: NTDOY and SNE are best fit by the Laplace MLE Model; AMC and IBM are best fit by the combination of Robust and Laplace MLE Model. Based on these analyses and evaluation of each stock's general trend, we predict that each company will experience a raise in stock price in later quarters of 2021.**

***Index Terms*—Stock market, Covid-19, nintendo, Sony, IBM, AMC, daily percent return.**

I. Introduction

Nowadays, the electronic industry has become one of the most popular industries and even seems to be taking the lead in various markets across the world. The electronic industry goes across a wide span of fields. It's a business of enormous inventions, production, designing, and sales of different electronic devices that includes TV, computers, video games etc [1]. The consumer branch is worth about $240 US dollar in 2004. According to Consumer Electronics Market Forecast 2026, it is said that the global consumer electronics market was valued about 1 trillion USD in 2019. And is expected to reach about $1.5 trillion by 2016 and grow at a CAGR of 7% from 2020 all the way to 2026[2]. There has been constant demand in the production of new smart phones, Artificial Intelligence Technology (AI) etc. Not to mention that due to the influence of Big Data and constant market shifts, many are undergoing significant digital transformations. We believe the electronic industry will nevertheless continue to take the lead in all industries and prosper in future markets.

In this paper, we will take a deep dive into the developments of four different and representative electronic corporations. These four companies all belong to electronic industries but yet they are different in the service they provide or products they sell. We use different fitted models to analyze the major trend of these companies from 2017 until 2021. For each stock, we examine the performance through each period, find the best-fit distribution from the three models, and make future predictions. These analyses are conducted for three successive analysis periods: before the outbreak of coronavirus, during the virus and finally years after invasion of the virus.

The four different companies' stocks that we choose are: Nintendo (NTDOY), Sony Corporation (SNE), International Business Machines Corporation (IBM) and AMC Entertainment (AMC).

Nintendo Co., Ltd is a multinational electronics and video games production company. It is probably well known by most video-games lovers. The head quarter is located in Japan. The company started in 1889 by Nintendo Kuruta. In 1977, the company developed its first game console, and color-TV Game. And following that, the company developed quickly by constantly contributing different video game consoles and video games. Nintendo made its name famous quickly. Now, it has already set up different subsidiaries in Japan and all around the world. A few famous games of Nintendo are Mario, The Legend of Zelda, Pokémon all come from Nintendo. In addition to making games, Nintendo also manufactures popular game consoles, including Nintendo Switch, NDSL etc [3].

Sony Group Corporation is a multinational Japanese company that has business all across the globe. Founded by Tokyo Tsushin Kogyo K.K in 1946, Sony by that time was only a small company with 20 employees. It gradually grew the huge company with over 111 thousand employees in 2011 and conducts business all across the globe. The company focuses on electronic products and video games consoles. Also, it has Sony Entertainment Inc that whose main business line is Sony music. Sony Group Corporation is a huge group that has several branch offices including Sony Corporation, Sony Semiconductor Solutions, Sony Entertainment, Sony Interactive Entertainment, and Sony Financial Holdings. One of Sony's world-famous game controller is the Play Station Series (PS). The most recent product launch is PlayStation5 which was released Nov.12th, 2020. Its impact on the world gaming market has been huge. The company's slogan is "Fill the world with emotion, through the power of creativity and technology" [4].

AMC Entertainment Holdings, Inc. or AMC Theaters is the biggest American movie theater chain. In 1920, Maurice, Edward and Barnet Dubinsky bought a small local theater in Kansas City. That was the first AMC. Its current CEO is

Manuscript received October 8, 2021; revised January 23, 2022.
The author is with Boston University, USA (e-mail: sally21@bu.edu).

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Adam Aron. As the biggest movie theater in US, each year AMC serves about 200 million customers and many top, popular movies are shown in AMC exclusively. It is fair to say offline cinemas are the major revenues for AMC. However, bad news came as covid-19 stuck AMC. In March 2020, due to the increasing threat of the virus, AMC was forced to shut down all its theaters. With no income, the company was forced to let go many employees and even core members of the company. Despite these layoffs, AMC still lost over 2.2 billion US dollar, and the company almost declared bankruptcy. Now, as everything is about to come back on track, the potential to fill theater seats is still an issue, but AMC is gradually getting its revenue back [5].

International Business Machines (IBM) is a huge multinational IT corporation. Originally when company first started in 1911, it was called the Computing-Tabulating-Recoding Company (CTR). Soon in 1924, it changed its name to IBM. The current chairman is Arvind Krishna. The company majors in electronic products, hardware, middleware, software development, and artificial intelligence. Its service is diverse and advanced across multiple fields. In 2011, IBM developed the first AI application to understand fluid language (Watson), which beat the champions of the TV show Jeopardy! In 2019, IBM revealed the first commercial quantum computer IBM Q System One. And in 2021, the company intends to focus more on hybrid cloud platform and artificial intelligence [6].

II. Initial Data Analysis

Now we will be looking at daily stock-price data and daily percent returns for these companies. We extract our data from Yahoo. Finance and look at the performance of these stocks from 2017 to April 22, 2021.

First, here is to present the summary statistics on the daily prices of these companies for the analysis period:

General Info	NTDOY	SNE	AMC	IBM
Total observation	1082	1082	1082	1082
Mean	48.44	57.25	11.52	124.49
Standard Deviation	12.85	19.96	5.80	9.73
Variance	3.58	4.47	2.41	3.12

Fig. 1. Stock summary of four companies.

Then, to be more specific, we divide up the time into five different time periods by years.

```
##      Period list.startdate list.enddate
## [1,] "1"    "2017-01-03"   "2021-04-22"
## [2,] "2"    "2017-02-01"   "2018-05-31"
## [3,] "3"    "2018-06-01"   "2019-12-31"
## [4,] "4"    "2020-01-01"   "2020-12-31"
## [5,] "5"    "2021-01-01"   "2021-04-22"
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Fig. 2. R Studio reference.

- The first period is 2017-01-03 to 2021-04-22. It covers the overall time interval we are looking at.
- The second period is 2017-02-01 to 2018-05-31. This is just a general period that allows us to look at the performance of company on a regular basis. During this period, a company may publish new products, experience economic boost or even experience a downfall that results in internal changes at the company.
- The third period is 2018-06-01 to 2019-12-31. This is the period right before the outbreak of covid-19 and serves as the comparison group.
- The fourth period is 2020-01-01 to 2020-12-31. This year, businesses experienced huge challenges due to the coronavirus outbreaks. Due to stay-at-home and social distancing policy, almost every company has been largely affected. During this period, there are also huge fluctuations in the stock market. Hence, stock data during this period is quite reflective of the company's overall performances and allow people to see how different companies react to the crisis.
- The last period is from 2021-01-01 to 2021-04-22. This is the apparent post-peak covid-19 period where the pandemic has been largely under control. Vaccines have been developed, shops are opening, and business activity is returning to normal.

The first stock we look at is NTDOY:

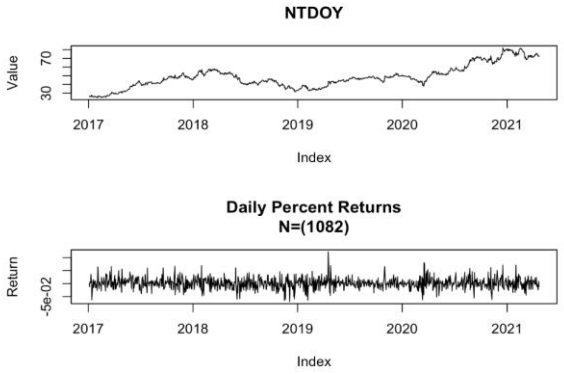

Fig. 3. NTDOY Stock: 2017-2021.

This is the trend of the company's stock price from 2017 to 2021 and its return:

As we can see from the first graph, although there are several fluctuations, overall NTDOY stock increases from $30 per share to around $70 per share from 2017 to 2021. Several major twists happen throughout this five-year span. In 2017 third quarter, Nintendo released its top-hit game console, *Nintendo Switch*, and thanks to the strong sale of Switch, the stock price increased dramatically at a constant rate. Following that, the company's stock price experienced a down trend or slump in 2018 and came back a little bit in 2020 first quarter. However, in later quarters in 2020, the year of pandemic, Nintendo's stock excelled due to the stay-at-home and work-from-home policy around the world. This is apparent from the time series plot where there is a literal jump in stock price in 2020[7]. During the first half of the year (2020-01 to 2021-06), the covid-19 crisis was beginning and started to largely affect everyone, the stock of Nintendo experienced some fluctuations in the beginning of 2020. Then, in later half of 2020, the trend experiences straight up increase, and NTDOY simply boosts. During the virus, as people are required to stay home or work at home, such policies limited what people could do in their spare time and brought huge commercial opportunities to the video games markets. Nintendo Switch has been constantly out of stock online in all websites and even in-store. These daily observations are also illustrated in the time series of the daily returns of NTDOY. We clearly notice that from Q1 of 2020,

there are gathered vibrations in return chart where there are major twists happening inside company.

The second stock we look at is *SNE:*

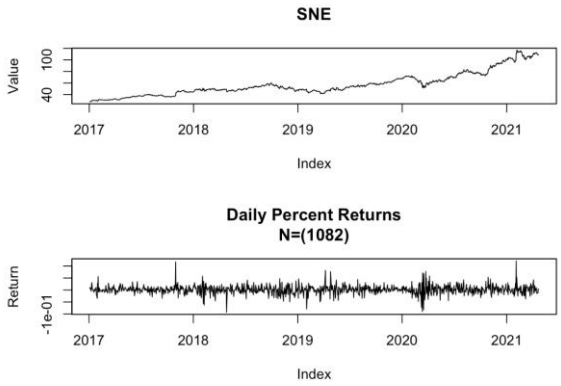

Fig. 4. SNE Stock: 2017-2021.

This is the trend of the company's stock price from 2017 to 2021 and its return:

Sony has a similar trend compare with Nintendo. In general, SNE grows from $40 per share in 2017 all the way to above $100 per share in 2021. In general, from 2017 to 2019 Sony experiences a steady increase in its stock price. Before the covid-19, there is no clear trend in Sony's stock. And during the covid-19 period, Sony company makes a serious profit as the demand for entertainment increases. Increasing demand for Sony music, cloud gaming or PS4 and other products contributed to raise of Sony's stock price. Furthermore, announced in Nov. 2020, Sony published one of its landmark gaming consoles, *PlayStation5(PS5)*. The sales of PS5 reached a new peak within only 12 hours of sales and the total sales exceeded the historical sales of PS4 within a few weeks of its publication. The tremendous success of PS5 boosts Sony stock and along with policy of covid-19, with people spending more time at home, the demand for a home video game console and new video games grew dramatically. This can be seen in the graph where Sony stock increases sharply since 2021 first quarter[8]. Complementing the time series graph of prices, the time series of daily returns especially during 2020 Q1 when PS5 first published, the details the huge return variability.

The third stock we look at is *AMC.*

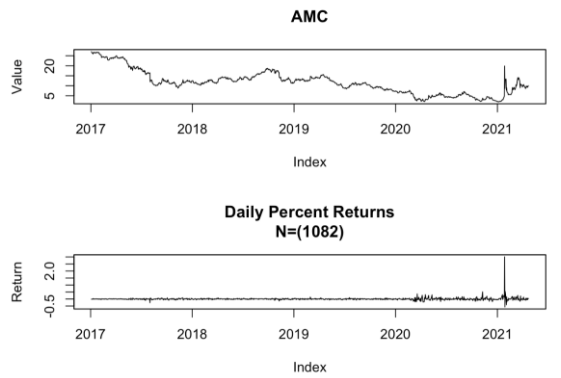

Fig. 5. AMC Stock: 2017-2021.

This is the trend of the company's stock price from 2017 to 2021 and its return:

Overall, AMC stock price experiences several slumps throughout 2017 to the end of 2020.As more and more company starts their digital transformation, the revenue for offline theater simply shrinks to a concerning level. To add on to that, the outbreak of coronavirus again strikes movie, theatre industry and results in AMC's stock price reaching its minimum value in 2020, less than $5 per share. Since during the pandemic, most people simply stay home. They work from home, go to online classes etc. Theaters were required to shut down. Hence in 2020, the company suffered extraordinary financial crisis, losing most of their revenues and almost going into bankruptcy. However, in 2021, when several actions have been taken by the government, and the covid-19 crisis conditions gradually improving, there was a clear and sharp rise in AMC stock price. This was mostly due to Reddit's WallStreetBets's short squeeze to AMC stock that helped to bring back the stock price [9]. As we can also see from the return, in Q1 of 2021, AMC return shows huge fluctuation that corresponds to our findings above.

The fourth stock we look at is *IBM.*

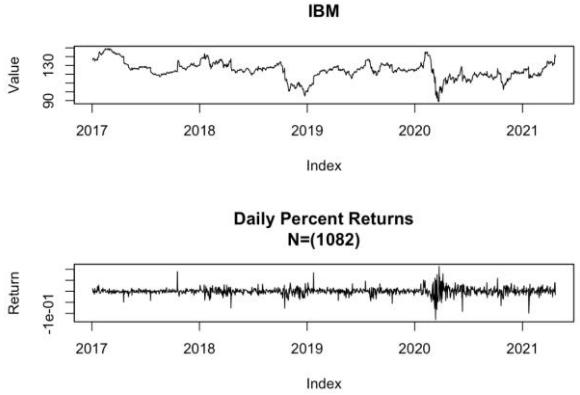

Fig. 6. IBM Stock: 2017-2021.

This is the trend of the company's stock price from 2017 to 2021 and its return:

Although the general trend for IBM corporation experiences multiple ups and downs throughout 2017 to 2021, their stock price per share still remains to be the highest among all four companies, $130 per share. From 2017 to 2020, the stock price of IBM could be best described as steady. It goes through some small increases and decreases, but there is no sharp change overall. But when it comes to 2020 and 2021, it is clear from the stock chart that IBM experiences large slumps in stock price. Similar conditions also happened to many other huge IT corporations where they experience large revenue losses. Shifts in current market trends, faster growth of more and more competitive start-ups all contributes to the loss of general revenue for IBM. There has been hard times for IBM [10]. In the first quarter of 2021, IBM is trying its best to reverse the situation and CEO announced that company will focus more on hybrid cloud platform and artificial intelligence technology in order to cope with future market and gain more revenue in 2021 [11]. Indeed in 2021, there has been an increase in stock price, and the price per share has returned to previous highs.

III. Hypotheses

In this paper, we evaluate three potential fitted models on

given analysis periods for each stock: Normal MLE Fitted Model, Normal Robust Fitted Model and Laplace LME Fitted Model. The Laplace model is more appropriate for distributions with heavy tails or high volatility. A robust model is suitable when there are no significant outliers in the data. Based of that and according to the trend of different stocks, we make the following hypothesis:

1) NTDOY and SNE best suit for Laplace MLE Model.
2) AMC best suits for Normal MLE Model.
3) IBM best suits for Normal Robust Model.

We group these four different companies' stock into three groups. The first group is NTDOY+ SNE; second group is AMC and the third group is IBM. We make the first hypothesis since after careful daily observation, we notice that NTDOY and SNE have similar performances. They both tend to be increasing overall. Hence, we predict they should fit a similar distribution as well. Since AMC stock in general is on a decreasing trend while IBM tends to be a deadlock in trading range where the price increases for a while then decrease and continue this process, we group each of them into a separate group, group two and group three. Due to the distinctive market, we predict two of them will fit a different model. That's why we have hypotheses two and three.

IV. Results and Analysis

In the following part, we look at our four stocks in five different time periods and by analyzing the goodness-of-fit and general trends, we find out exactly which model is the best fit model for individual stocks.

A. Nintendo Co., Ltd (NTDOY)

1) Period One (2017-01-03 to 2021-04-22)

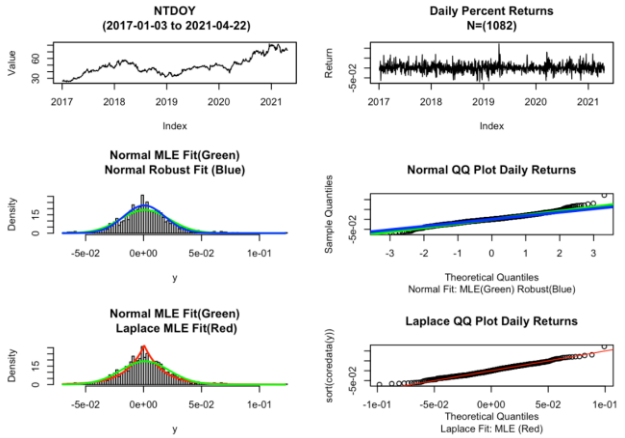

Fig. 7. NTDOY: Period one.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

For the histograms on the left side, clearly, we can tell that for both Normal Robust-Fitted Percentiles and Laplace MLE-Fitted Percentiles contain less frequencies come above the limits of blue line compare with Normal MLE Fit. On the right side, we reject Robust Model due to p-value(4.04e-05) smaller than level of significance (a=0.05). Among the other two, Laplace MLE-Fitted Model has the smallest chi-square statistic of 118 and the biggest p-value of 9.36e-02. This p-value is largely greater than the level of significant(alpha=0.05). If the Laplace MLE model were true, the chance of observing as large a Chi-Square statistic is 0.0936.

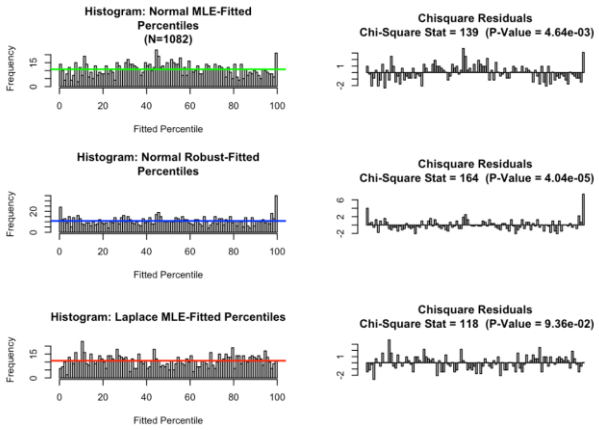

Fig. 8. NTDOY: Percentile and residuals plot.

Finally, we draw the conclusion that **Laplace MLE Model** is the best-fit model during first period for Nintendo Company.

2) Period Two (2017-02-01 to 2018-05-31)

The second period is just a normal period where we can look at general performances of company on a regular basis. It has 335 daily observations overall. On the left side, the graph continues to be bell-shaped with a couple outliers and skewed towards center. As we can see, the blue and green line almost overlaps with each other and shows that Normal MLE Model has similar traits with the Robust Model. However, these two models fail to take into considerations of the maximum points at y=0, and only Laplace MLE model reaches high enough to follow the density. The QQ plot return also tells us a similar story: red line closely overlaps with dotted points on two ends where blue and green lines miss them. We make our initial finding that perhaps Laplace MLE model is the best fit.

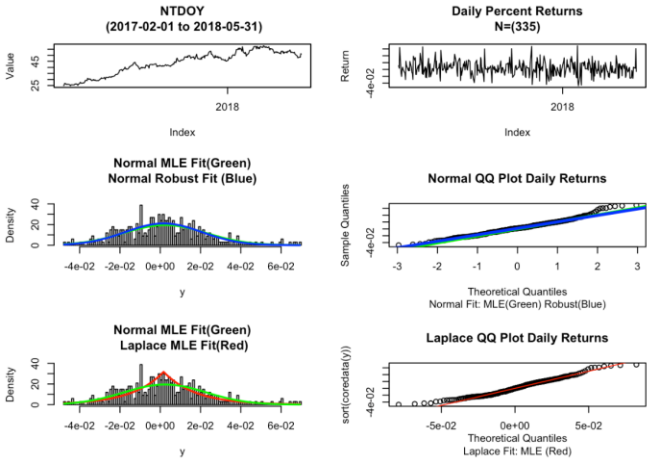

Fig. 9. NTDOY: Period two.

To prove our findings, we look at the chi-square residuals and histogram of three models.

From histogram on the left side, we notice both Robust Fit and Laplace MLE Fit contains less frequencies that go above the limits. Outliers includes: Robust Fit does a poor job at the 0% and 99% percentile; Laplace MLE Fit looks all right at

both ends but not so good from 20% to 80% percentile. Most of the data remain below the line. However, on the right-side residual plot, we fail to reject all three models. They all seem to fit the data on a certain level, but Laplace MLE model has the smallest chi-square statistic of 104 and largest p-value of 3.07e-01. If the Laplace MLE model were true, then there is a 30.7% chance of observing a chi-square test statistic that is as large as 104. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model.

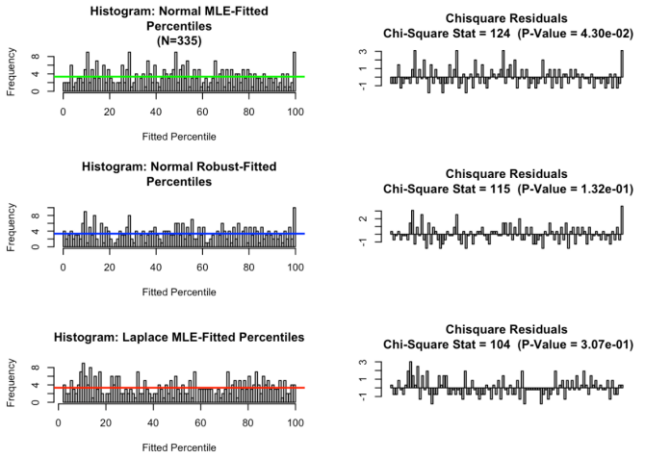

Fig. 10. NTDOY: Percentile and residuals plot.

Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during second period for Nintendo Company.

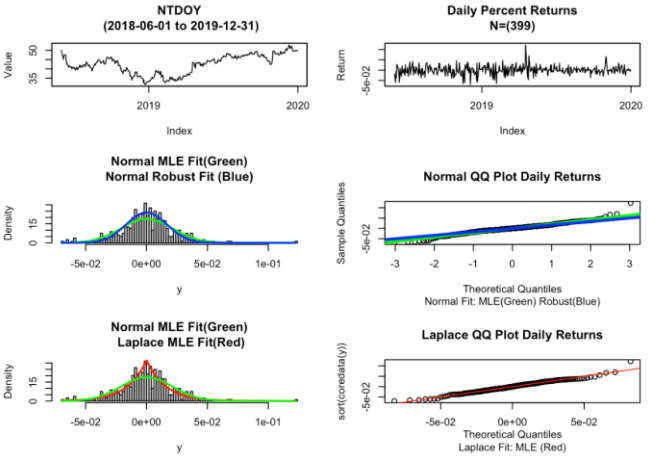

Fig. 11. NTDOY: Period three.

3) *Period Three (2018-06-01 to 2019-12-31)*

The third period is years right before the outbreak of covid-19 and serves as the comparison group with later on. There are 399 daily observations during this period. During this period, the graph tends to be bell-shaped but a little bit skewed left. In the middle of the bell shape curve, the density reaches max point. Compare with graphs on the left side: the blue line best describes the general trend and fit with most density on x axis; the sharp angle of red line accounts for the several maximum points of the graph but disregard some points on two ends, and finally the green line seems to totally disregard the points at y=0 and does not reach high enough. And to look at the QQ plot daily returns, again the red line and blue line seems to be more closely to the original dots. So far we can draw the finding that Normal Robust Fit(Blue) and Laplace MLE Fit(Red) fits this period better.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

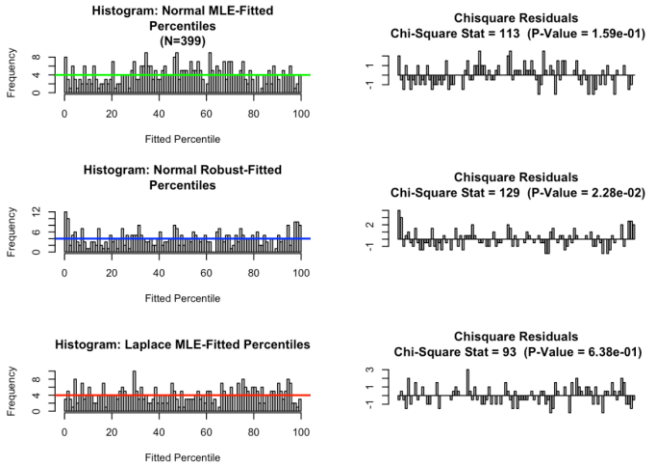

Fig. 12. NTDOY: Percentile and residuals plot.

From the histogram on the left side, we notice the Robust Fit does a poor job at the 1% and 99% percentile; Laplace MLE Fit looks good at both ends and the bins are relatively close to the red line. There are several outliers, but most of the data remain below the line. But, on the right-side chi-square residual plot, although all three model have p-value greater than level of significance(a=0.05) and fail to reject null hypothesis, The Laplace MLE model has the smallest chi-square statistic of 93 and largest p-value of 6.38e-01. There is a 63.8% chance that the chi-square test statistic is 93 or larger, assuming the Laplace MLE fit is the true model. Hence, we draw the conclusion that **Laplace MLE Model** is the best fit model during third period for Nintendo Company.

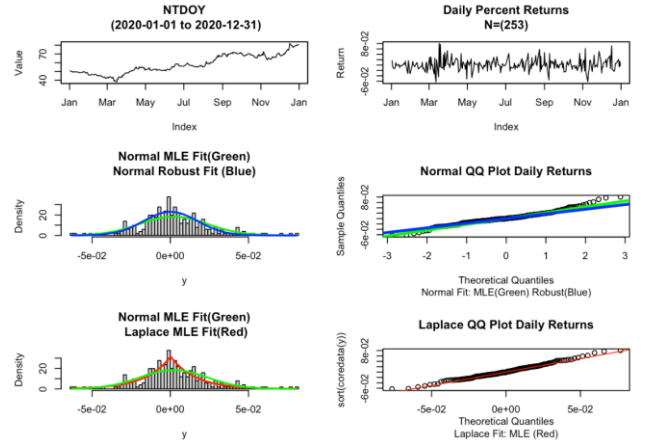

Fig. 13. NTDOY: Period four.

4) *Period Four (2020-01-01 to 2020-12-31)*

The fourth period is exactly the time that covid-19 outbreaks. It contains representative data that can directly show how different companies react to the crisis and how the stock price is doing under the pressure of covid and new policy from government. There are 253 daily observations during this period. During this period, the graph tends to be bell-shaped and centered at the middle point. In the middle of

the bell shape curve, the density reaches max point. Compare with graphs on the left side: the blue line best describes the general trend but fail to include the center point; the red line indeed accounts for the maximum points of the graph but disregard a few points on two ends, and finally the green line does not do a good job in fitting the histogram. And to look at the QQ plot daily returns, again the red line and blue line seems to be more closely to the original dots. So far we can draw the finding that Normal Robust Fit(Blue) and Laplace MLE Fit(Red) fits this period better.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

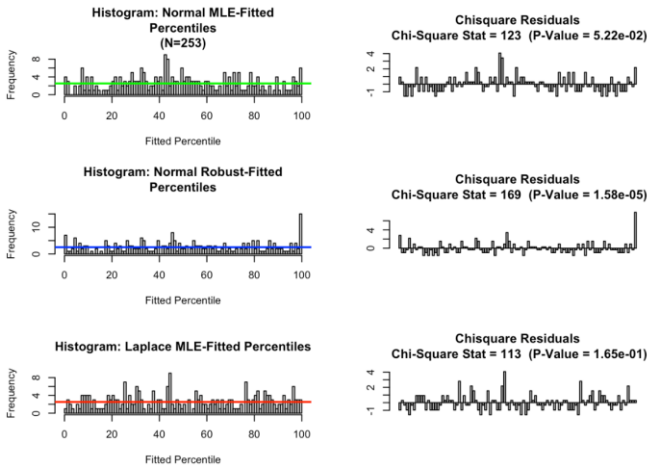

Fig. 14. NTDOY: Percentile and residuals plot.

From histogram on the left side, although Robust Fit Percentile seems to contain less frequencies that go above the limits, it certainly does not explain well the data on the 0 and 99% percentile. Most of the data remain below the line. On the right-side chi-square residual plot, we reject the Robust Model since its p-value (1.548e-05) is smaller than alpha (0.05). This leaves us with Laplace MLE and Normal MLE model. Between the two, Laplace MLE model has the smallest chi-square statistic of 113 and largest p-value of 1.65e-01. There is a 16.5% chance that the chi-square test statistic is 113 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model.

We draw the conclusion that **Laplace MLE Model** is the best fit model during fourth period for Nintendo Company.

5) Period Five (2021-01-01 to 2021-04-22)

The fifth period is the afterwards of covid-19 where the pandemic has been largely under control. Since the period only covers the first half years of 2021, there is only about 76 daily observations. Due to this limited amount of data, the result we gain may not be fully accurate and can be biased. We will look at this data in a critical way.

As mentions before, the data may not be accurate. On the left side, we notice the general trend of histogram is unclear. It looks like a bell-shaped curve, but there are a great number of outliers where density is high at *y*=-2e-02, 0e+00 or even 2e-02. Still, just like second period, we find out that Normal MLE Model has similar traits with Robust Model as blue line and green line almost overlaps with each other. Although the QQ plot return again shows the three lines seem to overlap with the dotted line, neither of these two models do a good job in describing the general trend of plot, and only Laplace MLE model reaches high enough to follow the density. In such, we make our initial finding that perhaps Laplace MLE model is a good fit for this period.

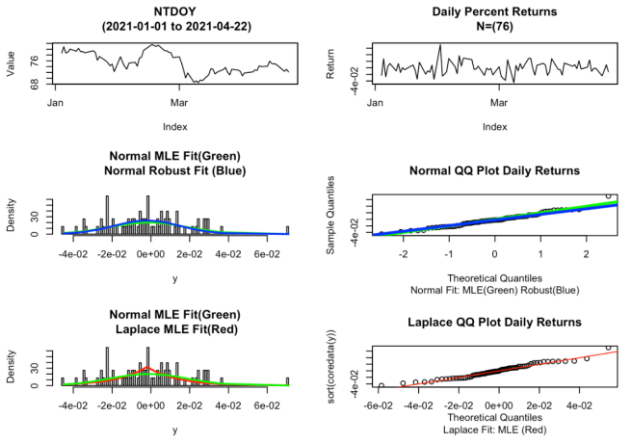

Fig. 15. NTDOY: Period five.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

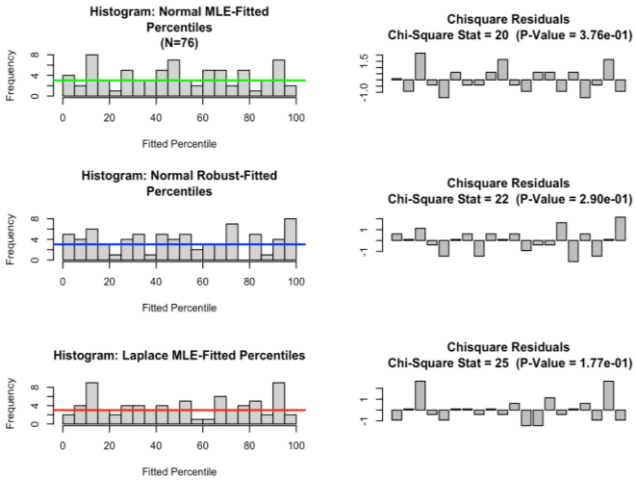

Fig. 16. NTDOY: Percentile and residuals plot.

This time it is hard to tell the difference between which graph performs better by looking at percentiles' histogram on the left side. Although they look rather similar, still we can tell the red line is a rather good fit with most of the data below the line, on the right side, due to our limited sample size, we reduce the number of bins from 100 to 25 to prevent any empty bins in the chi-square goodness of fit. Under such condition, we do not reject any of the model since all p-values are greater than 0.05. The Laplace MLE model has the smallest chi-square statistic of 25 and largest p-value of 1.77e-01. There is a 17.7% chance that the chi-square test statistic is 25 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. But due to our limited sample size, this result we get will not be that statistically significant.

In such, we draw the conclusion that **Laplace MLE Model** is the best fit model during final period for Nintendo Company, but we'll only use this result as a reference to other

periods.

Conclusion: In each period, we find out that the best fit model is Laplace MLE Model. Hence combining with our conclusions with five different periods, we draw our final conclusion that the best fit stock model overall for Nintendo Company is **Laplace MLE Model.**

B. Sony Corporation (SNE)

1) Period One (2017-01-03 to 2021-04-22)

This is the overall time span of our stock market. There are 1082 daily observations overall during this period. On the left side, the histogram graph of daily percent returns appears to be a very standard bell-shaped curve and skewed towards center. As we can see, the blue line best describes the entire bell shape but lack a little when it goes to the max point at y=0; red line goes straight up and accounts for the max point but does not fully accounts for points on two sides. Two lines have their own flaws. And to look at the QQ plot daily returns, again the red line and blue line seems to be more closely to the original dots. Hence, we can draw the finding that Normal Robust Fit(Blue) and Laplace MLE Fit(Red) fits this period better.

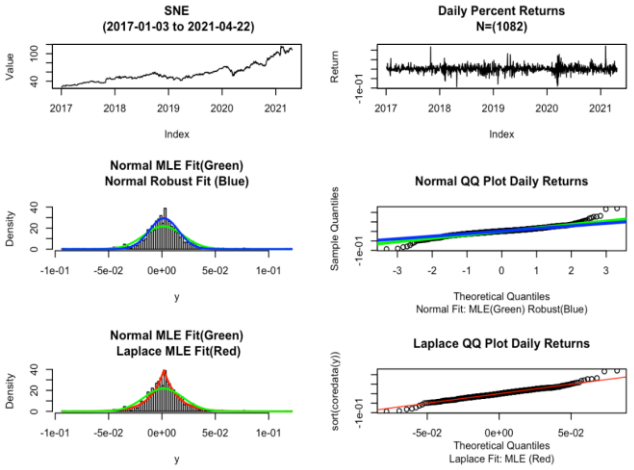

Fig. 17. SNE: Period one.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

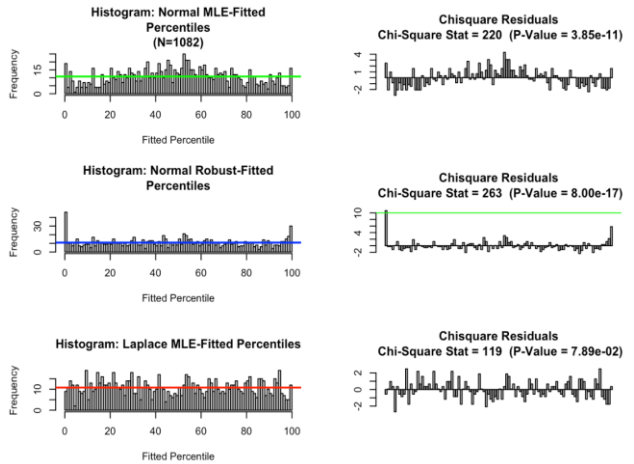

Fig. 18. SNE: Percentile and residuals plot.

From histogram on the left side, although Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. On the right-side chi-square residual plot, we reject both Normal MLE and Normal Robust Model as their p-value tend to be way smaller than 5% significant level. None of these two models truly fit our data well. However, Laplace MLE model has the smallest chi-square statistic of 119 and largest p-value of 7.89e-02. This p-value is greater than alpha, in this way we fail to reject the null hypothesis. There is a 7.89% chance that the chi-square test statistic is 119 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model.

Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during first period for Sony Corporation.

2) Period Two (2017-02-01 to 2018-05-31)

The second period is just a normal period where we can look at general performances of company on a regular basis. It contains 335 daily observations overall. The second period's distribution graph is very similar with first period. The histogram graph of daily percent returns is a very standard bell-shaped curve and skewed towards center, and also the blue line and red line seem to better describe the general trend of stock than green line. This daily observation is further proved in QQ plot daily returns. Here we notice red line and blue line seems to be more closely to the original dots, while green line is a bit off the track. Hence, we can draw the finding that Normal Robust Fit(Blue) and Laplace MLE curve can be a good bit.

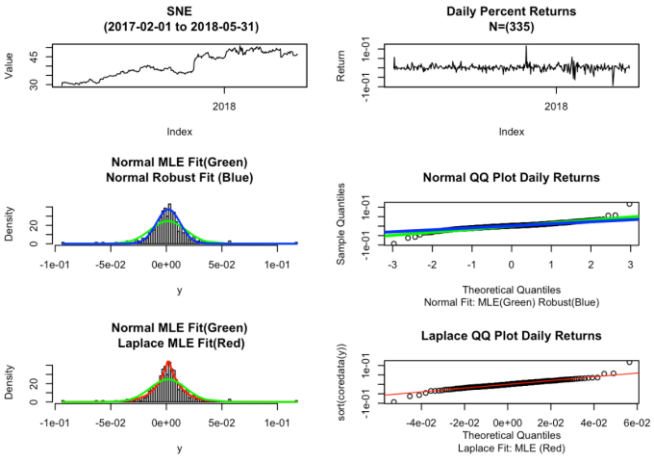

Fig. 19. SNE: Period two.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

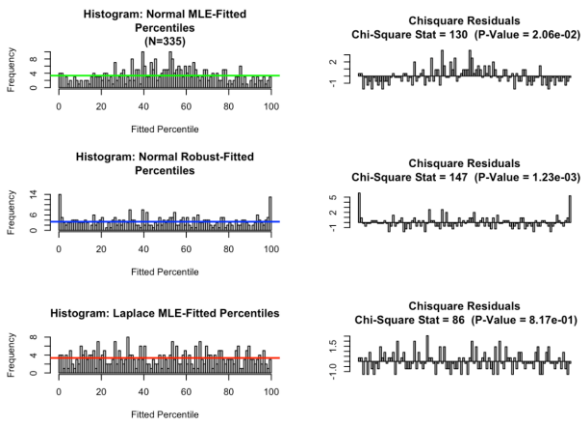

Fig. 20. SNE: Percentile and residuals plot.

From histogram on the left side, we notice that Normal MLE Fit and Laplace MLE Fit fits well on the 0% and 99% percentile but not so well in the middle part. While Robust Fit does poorly on both ends but presents well in the middle percentile. Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. On the right-side chi-square residual plot, we reject both Normal MLE (p-value 2.06e-02) and Normal Robust Model(p-value 1.23e-03) as their p-value tend to be way smaller than 5% significant level. None of these two models truly fit our data well. However, Laplace MLE model has the smallest chi-square statistic of 86 and largest p-value of 8.17e-01. This p-value is greater than alpha, in this way we fail to reject the null hypothesis. There is a 81.7% chance that the chi-square test statistic is 86 or larger, assuming the Laplace MLE fit is the true model. With such p-value, we can conclude that current model is indeed a good fit.

Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during second period for Sony Corporation.

3) Period Three (2018-06-01 to 2019-12-31)

The third period is years right before the outbreak of covid-19 and serves as the comparison group with later on. It has 399 daily observations overall. On the left side, the histogram graph of daily percent returns continues to be a standard bell-shaped with only a few outliers and skewed towards center. As we can see, the blue and red line in general do a good job in describing the behavior of the histogram. But blue and green line fail to take into considerations of the maximum points at y=0, and only Laplace MLE model reaches high enough to follow the density. In QQ plot, both blue and green lines poorly describe the behavior of the upper level of dotted line. The red line closely overlaps with dotted points on two ends where blue and green lines miss them. We make our initial finding that perhaps Laplace MLE model is the best fit.

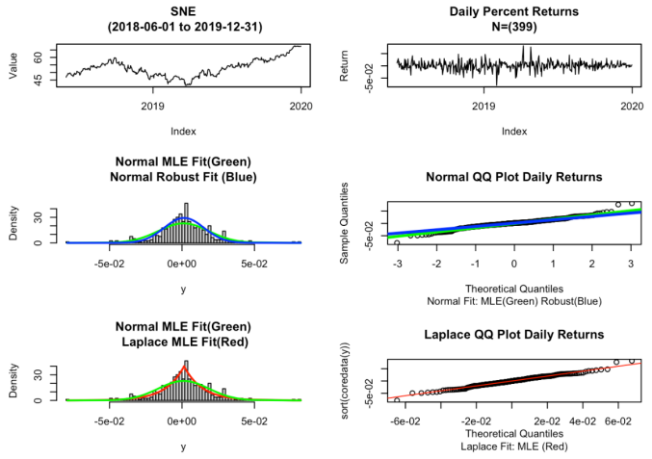

Fig. 21. SNE: Percentile and residuals plot.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

From histogram on the left side, we notice that Laplace MLE Fit in general fits good on the 0% percentile and less well on 99% or the middle part. While Robust Fit does poorly on both ends but presents well in the middle percentile. Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. On the right-side chi-square residual plot, we reject both Normal MLE (p-value 4.52e-03) and Normal Robust Model (p-value 5.19e-09) as their p-value tend to be way smaller than 5% significant level. None of these two models truly fit our data well. However, Laplace MLE model has the smallest chi-square statistic of 108 and largest p-value of 2.52e-01. This p-value is greater than alpha, in this way we fail to reject the null hypothesis. There is a 25.2% chance that the chi-square test statistic is 108 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model.

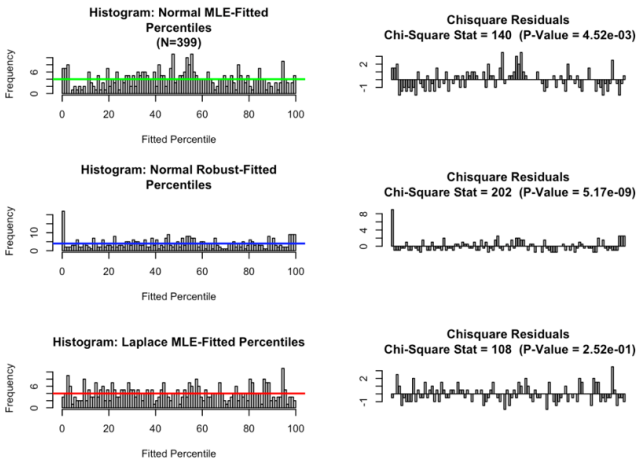

Fig. 22. SNE: Percentile and residuals plot.

Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during third period for Sony Corporation.

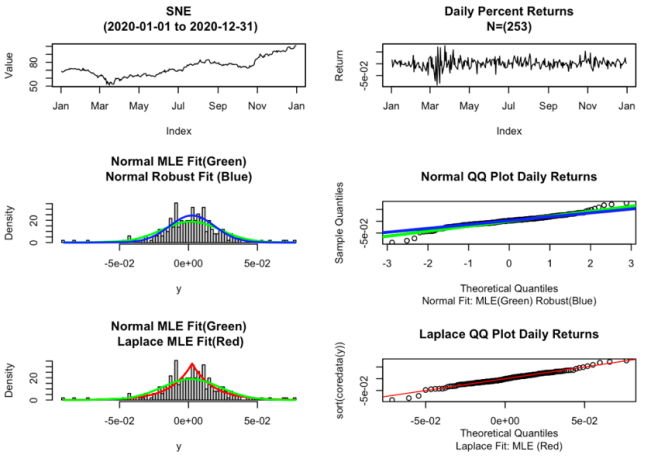

Fig. 23. SNE: Period four.

4) Period Four (2020-01-01 to 2020-12-31)

The fourth period is exactly the time that covid-19 outbreaks. It contains representative data that can directly show how different companies react to the crisis and how the stock price is doing under the pressure of covid and new policy from government. There are 253 daily observations overall. On the left side, similar with third period, the histogram graph of daily percent returns appears to be a standard bell-shaped with only a number of outliers in the

middle and skewed towards center. As we can see, the blue line in general does a good job in describing the behavior of the histogram. Red line accounts more for the middle part where numbers seem to be extremely high. Green line presents poorly in the graph. In QQ plot, both blue and green lines poorly describe the behavior of the upper and lower level of dotted line. The red line closely to the upper level but less close to the dotted points on lower ends where blue and green lines miss them. We make our initial finding that perhaps Laplace MLE model is the best fit.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

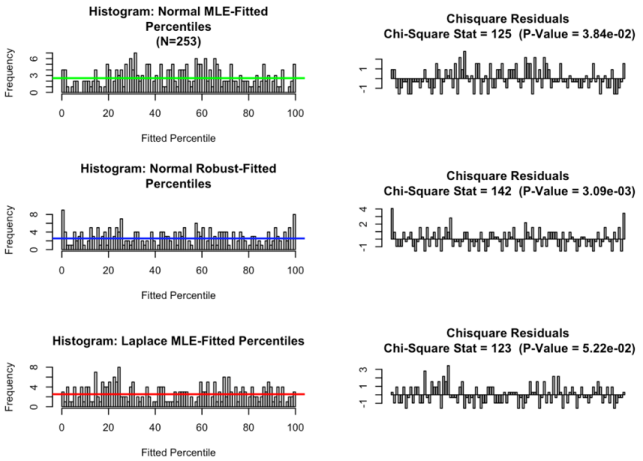

Fig. 24. SNE: Percentile and residuals plot.

From histogram on the left side, we notice that Laplace MLE Fit in general fits good on the 0% percentile and less well on 99% or the middle part. While Robust Fit does poorly on both ends but presents well in the middle percentile. Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. On the right-side chi-square residual plot, we reject Normal MLE (p-value 3.84e-02) and Normal Robust Model (p-value 3.09e-03) as their p-value tend to be way smaller than 5% significant level. None of these two models fit our data well. However, Laplace MLE model has the smallest chi-square statistic of 106 and largest p-value of 5.22e-02. This p-value is greater than alpha, in this way we fail to reject the null hypothesis. There is 5.22% chance that the chi-square test statistic is 123 or larger, assuming the Laplace MLE fit is the true model. With such p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model.

Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during fourth period for Sony Corporation.

5) Period Five (2021-01-01 to 2021-04-22)

The fifth period is the afterwards of covid-19 where the pandemic has been largely under control. Since the period only covers the first half years of 2021, there is only about 76 daily observations. Due to this limited amount of data, the result we gain may not be fully accurate and can be biased. We will look at this data in a critical way.

As mentions before, the data may not be accurate. On the left side, we notice the general trend of histogram is unclear. It looks like a bell-shaped curve that skewed left, but there are a great number of outliers where density is high at y=0 or before. We find out that none of the model truly fits the data well but Robust Model and Laplace MLE model tend to fit better compare with Normal MLE model. In the QQ plot return, it shows the three lines seem to overlap with the dotted line, but none of these models do a good job in describing the lower end of the dotted line. In such, we make our initial finding that perhaps Laplace MLE model and Robust Model fits this period a bit better.

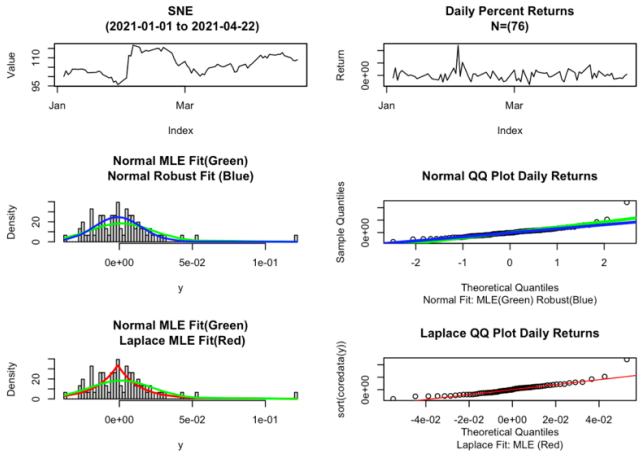

Fig. 25. SNE: Period five.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

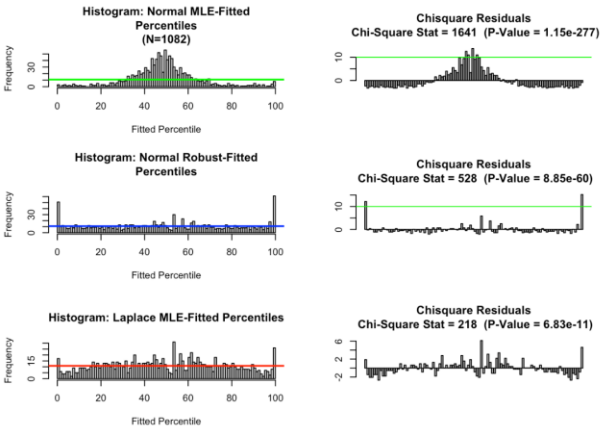

Fig. 26. SNE: Percentile and residuals plot.

This time it is hard to tell the difference between which graph performs better by looking at percentiles' histogram on the left side. Although they look rather similar, still we can tell the red and blue line fit better with most of the data below the line, on the right side, due to our limited sample size, we reduce the number of bins from 100 to 25 to prevent any empty bins in the chi-square goodness of fit. Under such, we do not reject any of the model since all p-values are way greater than 0.05. The Robust model has the smallest chi-square statistic of 12 and largest p-value of 8.67e-01. There is a 86.7% chance that the chi-square test statistic is 12 or larger, assuming the Robust Model is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Robust model is the true model. But due to our limited sample size and accuracy of data, this result we get will not be that statistically significant.

In such, we draw the conclusion that **Robust Model** is the best fit model during final period for Sony Corporation, but we'll only use this result as a reference to other periods.

*Conclusion***:** From first to fourth period, we find out that the best fit model is Laplace MLE Model. In fifth period, the best fit model is Robust Model. But since there is limited data, the result we have on fifth period is less statistically significant. Hence combining with our conclusions with five different periods, we draw our conclusion that the best fit stock model overall for Sony Corporation is **Laplace MLE Model.**

C. AMC Entertainment (AMC)

1) Period One (2017-01-03 to 2021-04-22)

This is the overall time span of our stock market. It has 1082 daily observations. The histogram graph of daily percent returns seems to be bell-shaped and extremely skewed left, and the reason behind should be due to the extreme slump of AMC stock. But clearly, blue line and red line fits the general trend of histogram while green line performs poorly. In the QQ plot return, it shows the three lines seem to overlap with lower bound of the dotted line, but none of these models do a good job in describing the upper end of the dotted line. In such, we make our initial finding that perhaps Laplace MLE model and Robust Model fits this period a bit better. Also, since the general graph appears to be a bit blurry in the middle part, our daily observation may contain certain bias.

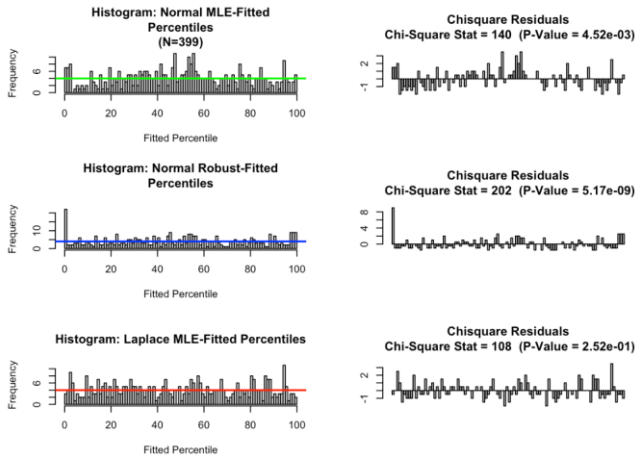

Fig. 27. AMC: Period one.

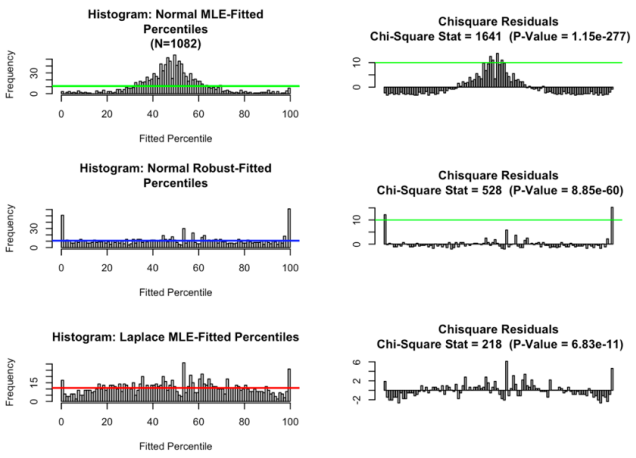

Fig. 28. AMC: Percentile and residuals plot.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

From histogram on the left side, we notice that Robust Fit in general fits good very well with the original data especially well except at 1% or 99%. Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. While Laplace MLE fit seems to be the second-best fit. On the right-side chi-square residual plot, we reject all three models. Normal MLE (p-value 1.15e-277), Normal Robust Model (p-value 8.85e-60) and Laplace MLE (p-value 6.83e-11) tend to be way smaller than 5% significant level. None of these three models fit our data well. However, Laplace MLE model has the smallest chi-square statistic of 218 and largest p-value. Hence we can tell compare with other models, Laplace MLE model seem to fit the general trend a bit better. However since, on the left-hand side, Normal Robust Fit the histogram better. We can combine these two models.

Finally, we draw the conclusion that **Laplace MLE Model combined with Normal Robust Model** is the best fit model during first period for AMC Entertainment.

2) Period Two (2017-02-01 to 2018-05-31)

The second period is just a normal period where we can look at general performances of company on a regular basis. There are 335 daily observations overall. The histogram graph of daily percent returns tends to be bell-shaped and extremely skewed right. Clearly, blue line and red line fits the general trend of histogram while green line performs poorly. The green line fails to consider the max point at y=0. In the QQ plot return, it shows the three lines seem to overlap the dotted line quite well. All of these models do a good job in describing both upper end and lower end of the dotted line, except maybe blue line behaves a bit less well on the lower end. Overall, we make our initial finding that perhaps Laplace MLE model and Robust Model fits this period a bit better.

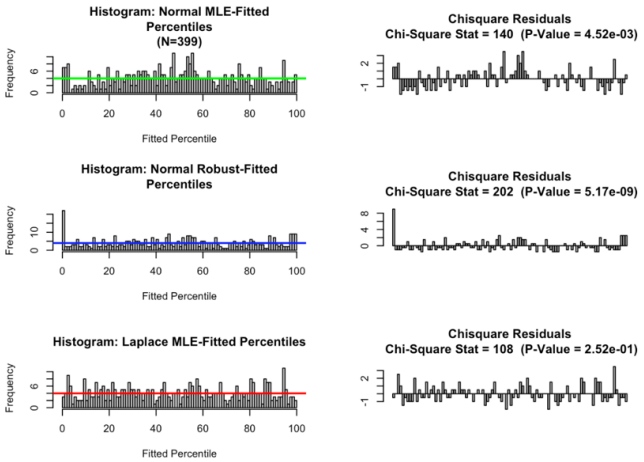

Fig. 29. AMC: Period two.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

From histogram on the left side, we notice that Normal Robust Fit and Laplace MLE Fit fits well in the middle part but not so well on the 1% and 99% percentile. Normal MLE compare with other two models fit less well. On the right-side chi-square residual plot, we reject both Normal MLE

(p-value 4.52e-03) and Normal Robust Model (p-value 5.19e-09) as their p-value tend to be way smaller than 5% significant level. None of these two models truly fit our data well. However, Laplace MLE model has the smallest chi-square statistic of 108 and largest p-value of 2.52e-01. There is a 25.2% chance that the chi-square test statistic is 108 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model.

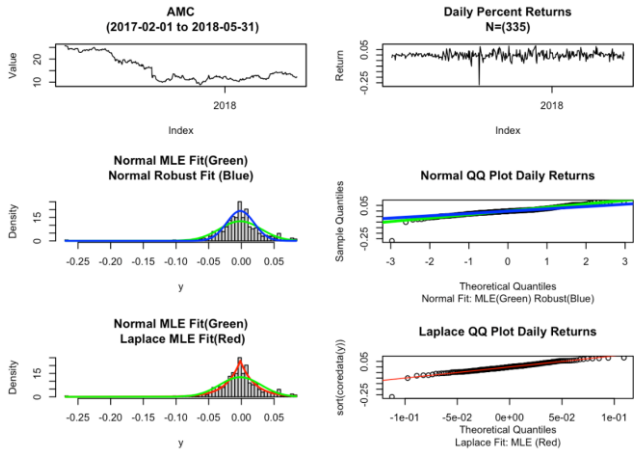

Fig. 30. AMC: Percentile and residuals plot.

Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during second period for AMC Entertainment.

3) Period Three (2018-06-01 to 2019-12-31)

The third period is years right before the outbreak of covid-19 and serves as the comparison group with later on. It has 399 daily observations overall. On the left side, the histogram graph of daily percent returns continues to be a standard bell-shaped with only a few outliers and skewed towards center. As we can see, the blue and red line in general do a good job in describing the behavior of the histogram. They account and includes most of the histogram in their curve. But red line does a better job in including the maximum points at y=0. In QQ plot, both blue and green lines poorly describe the behavior of the upper level of dotted line. The red line closely overlaps with dotted points on two ends where blue and green lines miss them. We make our initial finding that perhaps Laplace MLE model is the best fit.

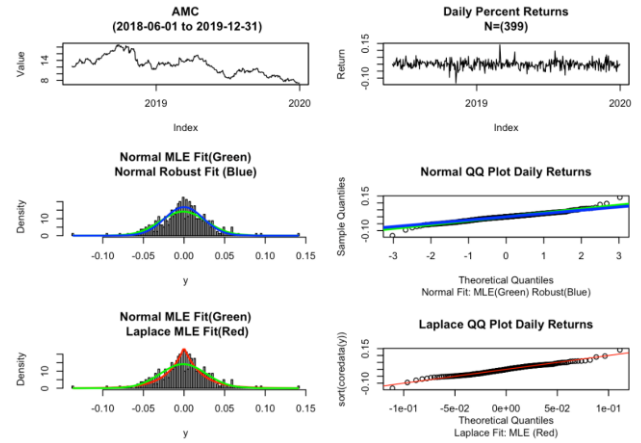

Fig. 31. AMC: Period three.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

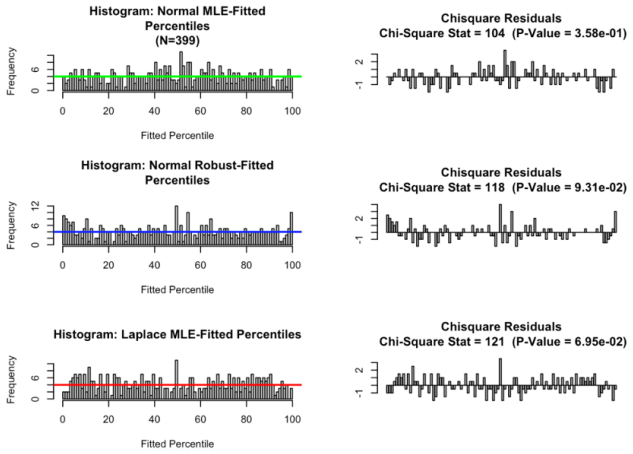

Fig. 32. AMC: Percentile and residuals plot.

From histogram on the left side, we notice that all three models fit generally well in the middle part but not so well on the 0 and 99% percentile. On the right-side chi-square residual plot, we fail to reject all three models, Normal MLE (p-value 3.58e-01), Normal Robust Model (p-value 9.31e-02) and Laplace MLE (p-value 6.95e-02) as all p-value are bigger than 5% significant level. They fit behaviors of data on certain level. However, Normal MLE model has the smallest chi-square statistic of 104 and largest p-value of 3.58e-01. There is a 35.8% chance that the chi-square test statistic is 104 or larger, assuming the Normal MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Normal MLE model is the true model.

Finally, we draw the conclusion that **Normal MLE Model** is the best fit model during third period for AMC Entertainment.

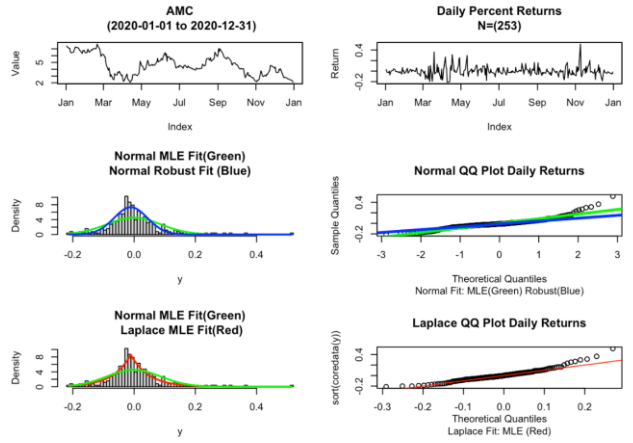

Fig. 33. AMC: Period four.

4) Period Four (2020-01-01 to 2020-12-31)

The fourth period is exactly the time that covid-19 outbreaks. It contains representative data that can directly show how different companies react to the crisis and how the stock price is doing under the pression of covid and new policy from government. It contains 253 daily observations overall. The second period's distribution graph is very similar with first period. The histogram graph of daily

percent returns is a very standard bell-shaped curve and skewed towards left, and also the blue line and red line seem to better describe the general trend of stock than green line. This daily observation is further proved in QQ plot daily returns. Although all lines fit less well on the upper end of dotted line, red line and blue line seems to be more closely to the original dots. Hence, we can draw the finding that Normal Robust Fit (Blue) and Laplace MLE model fits this period a bit better.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

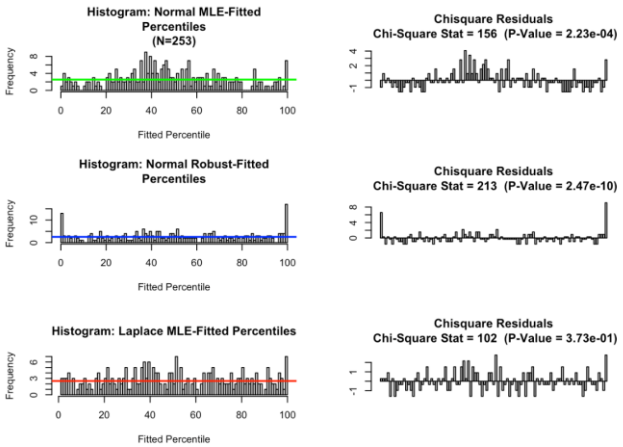

Fig. 34. AMC: Percentile and residuals plot.

From histogram on the left side, we notice that Robust Fit in general fits extremely well with the original data especially well except at 0% or 99%. Robust Fit Percentile seems to contain merely no frequencies that go above the limits as most of the data remain below the line. While Laplace MLE and Normal MLE fit seem to be the second-best fit. On the right-side chi-square residual plot, we reject both Normal MLE and Robust models. Normal MLE (p-value 2.34e-04) and Normal Robust Model (p-value 2.47e-10). Their p-vlaues tend to be way smaller than 5% significant level. However, Laplace MLE model has the smallest chi-square statistic of 102 and largest p-value of 3.73e-01. We fail to reject Laplace MLE Model. Hence, we can tell compare with other models, Laplace MLE model seem to fit the general trend a bit better. But since on the left side, Normal Robust Fit the histogram really well, we decide to combine these two models.

Finally, we draw the conclusion that **Laplace MLE Model combined with Normal Robust Model** is the best fit model during fourth period for AMC Entertainment.

5) Period Five (2021-01-01 to 2021-04-22)

The fifth period is the afterwards of covid-19 where the pandemic has been largely under control. Since the period only covers the first half years of 2021, there is only about 76 daily observations. Due to this limited amount of data, the result we gain may not be fully accurate and can be biased. We will look at this data in a critical way.

AMC stock seem to experience extreme upraise during this time. On the left side, we notice the graph is a bell-shaped curve that skewed extremely to left. We find out that Robust Model and Laplace MLE model tend to fit better compare with Normal MLE model. In the QQ plot return, it shows the three lines all seem to overlap with the dotted line at some point, but Laplace MLE Model does a better job in describing the behaviors dotted line on both ends. In such, we make our initial finding that perhaps Laplace MLE model fits this period a bit better.

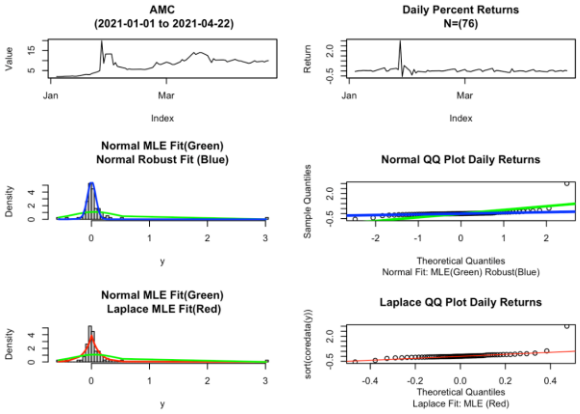

Fig. 35. AMC: Period five.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

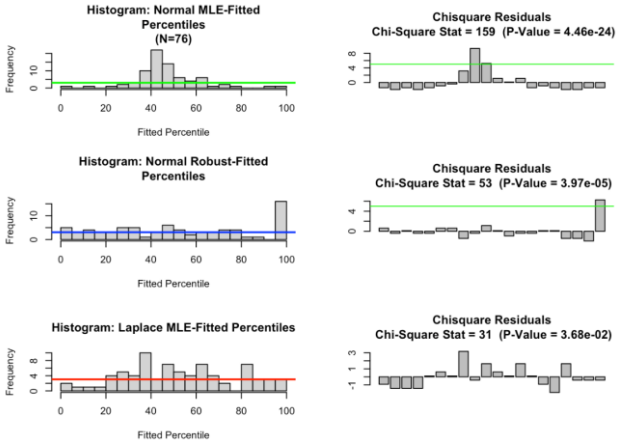

Fig. 36. AMC: Percentile and residuals plot.

This time it is hard to tell the difference between which graph performs better by looking at percentiles' histogram on the left side. They all look rather similar. But still we can tell Laplace and Normal Robust Fit are better fitted compare with Normal MLE fit. On the right side, due to our limited sample size, we reduce the number of bins from 100 to 25 to prevent any empty bins in the chi-square goodness of fit. Based of that, we reject both Normal MLE (p-value 4.46e-24) and Normal Robust Model(p-value 3.97e-05) since all p-values are way smaller than 0.05. Laplace MLE model has the smallest chi-square statistic of 31 and largest p-value of 3.68e-02. There is a 3.68% chance that the chi-square test statistic is 31 or larger, assuming the Laplace MLE fit is the true model. With such a p-value greater than 0.05, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. But due to our limited sample size and accuracy of data, this result we get will not be that statistically significant. Since 76 is smaller than 100, there will be several empty bins in the chi-square goodness of fit.

In such, we draw the conclusion that **Laplace MLE Model** is the best fit model during final period for AMC Entertainment, but we'll only use this result as a reference to other periods.

Conclusion: In the first and fourth period, we find out that

the best fit model is a combination of Robust and Laplace MLE Model. In the third period, Normal MLE model seems to be the best fit. And in third and fifth period, Laplace MLE model fits better. But since the limited amount of data in fifth period, the result is less statically significant. We only use the result as a reference. In short, we draw our conclusion that the best fit stock model overall for AMC Entertainment is **a combination of Normal Robust Model and Laplace MLE Model.**

D. International Business Machines Corporation (IBM)

1) Period One (2017-01-03 to 2021-04-22)

This is the overall time span of our stock market. It has 1082 daily observations. The stock of IBM in general goes through a lot of fluctuations. There is very typically of extremely matured business. The graph is a very standard bell-shaped curve and symmetrically along center. Both the blue line and red line seem to better describe the general trend of stock than green line. In QQ plot daily returns, all lines fit the dotted line in general. But on the upper and lower end of dotted line, none of the models appear to be a hundred percent overlap with the small circles. Under such condition, we can draw the finding that Normal Robust Fit (Blue) and Laplace MLE model(Red) fits this period a bit better.

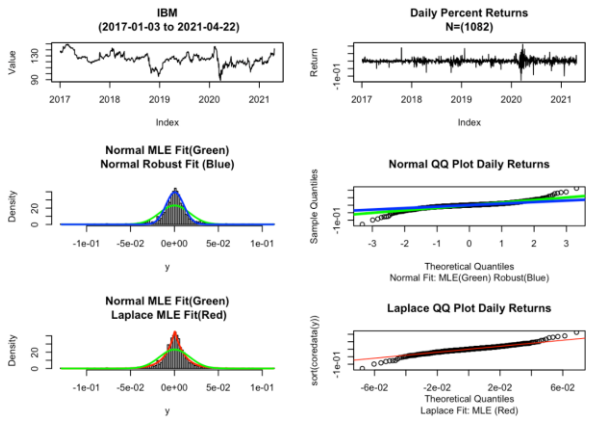

Fig. 37. IBM: Period one.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

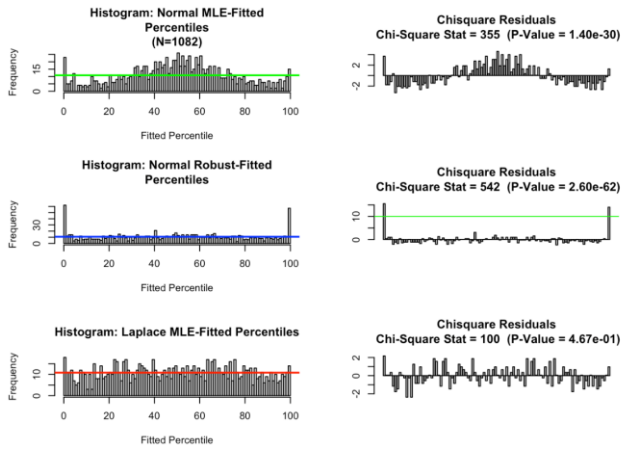

Fig. 38. IBM: Percentile and residuals plot.

From histogram on the left side, we notice that Robust Fit in general fits good very well with the original data especially well except at 0% or 99%. Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. While Laplace MLE fit seems to be the second-best fit. On the right-side chi-square residual plot, we reject both Normal MLE (p-value 1.40e-30) and Normal Robust Model (p-value 2.60e-62). Their p-value tend to be way smaller than 5% significant level. However, Laplace MLE model has the smallest chi-square statistic of 100 and largest p-value of 4.67e-01, hence we can tell Laplace MLE model seem to fit the general trend a bit better. There is a 46.7% chance that the chi-square test statistic is 100 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. But since our Normal Robust curve fits well with the percentile graph on the left, we decide to combine these two models.

Finally, we draw the conclusion that **Laplace MLE Model combined with Normal Robust Model** is the best fit model during first period for IBM.

2) Period Two (2017-02-01 to 2018-05-31)

The second period is just a normal period where we can look at general performances of company on a regular basis. It has 335 daily observations. Very similar to first period, the histogram graph of daily percent returns is a very standard bell-shaped curve and symmetrically along center. Both the blue line and red line seem to better describe the general trend of stock than green line. In QQ plot daily returns, blue and green lines fit the dotted line in general. But on the upper and lower end of dotted line, these two curves do not overlap much with the circle. The red line fits the upper end of dotted line but not so well on the lower end. Under such condition, we can draw the finding that Normal Robust Fit (Blue) and Laplace MLE model (Red) can potentially be the best fits for this period.

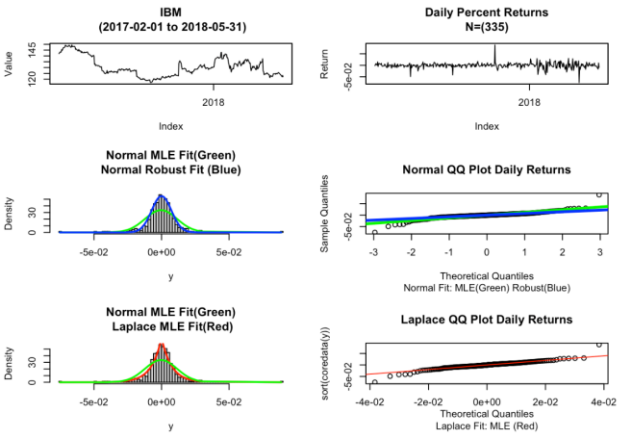

Fig. 39. IBM: Period two.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

From histogram on the left side, we notice that Robust Fit in general fits good very well with the original data especially well except at 1% or 99%. Robust Fit Percentile seems to contain less frequencies that go above the limits as most of the data remain below the line. While Laplace MLE fit seems to be the second-best fit. Compare with Robust Fit, Laplace fits better at 100% percentile, but less suitable for 1-99% percentile. On the right-side chi-square residual plot, we

reject both Normal MLE (p-value 4.28e-06) and Normal Robust Model (p-value 3.68e-10). Their p-value tend to be way smaller than 5% significant level. However, Laplace MLE model has the smallest chi-square statistic of 118 and largest p-value of 8.91e-02, hence we can tell Laplace MLE model seem to fit the general trend a bit better. There is a 8.91% chance that the chi-square test statistic is 118 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. But since our Normal Robust curve fits well with the percentile graph on the left, we decide to combine these two models.

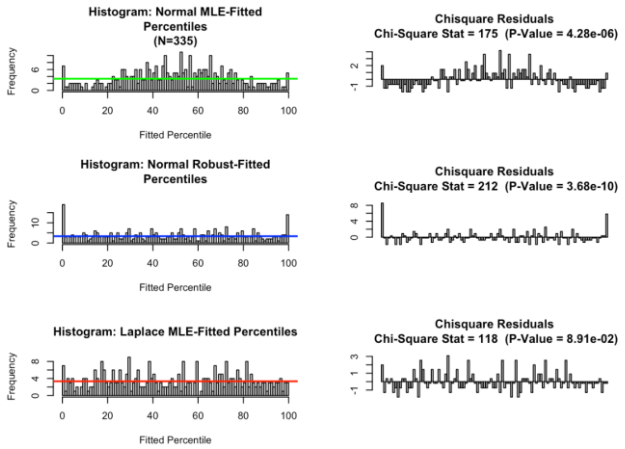

Fig. 40. IBM: Percentile and residuals plot.

Finally, we draw the conclusion that **Laplace MLE Model combined with Normal Robust Model** is the best fit model during second period for IBM.

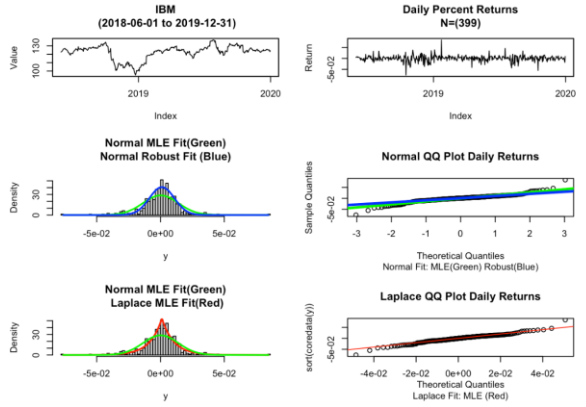

Fig. 41. IBM: Period three.

3) Period Three (2018-06-01 to 2019-12-31)

The third period is years right before the outbreak of covid-19 and serves as the comparison group with later on. There are 399 daily observations overall. Still, its histogram graph of daily percent returns is very similar to first and second period. It could be the typical characteristics of a matured corporation. The histogram graph of daily percent returns is a standard bell-shaped curve and symmetrically along center. Both the blue line and red line seem to better describe the general trend of stock than green line. The red line presents a bit better than blue since at y=0, the red curve reaches high enough to touch the max point. In QQ plot daily returns, blue and green lines fit the dotted line in general. Two lines almost overlap with each other. But on the upper and lower end of dotted line, these two curves do not overlap much with the circle. The red line fits the upper end of dotted line but not so well on the lower end. Under such condition, we can draw the finding that Normal Robust Fit (Blue) and Laplace MLE model (Red) can potentially be the best fits for this period.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

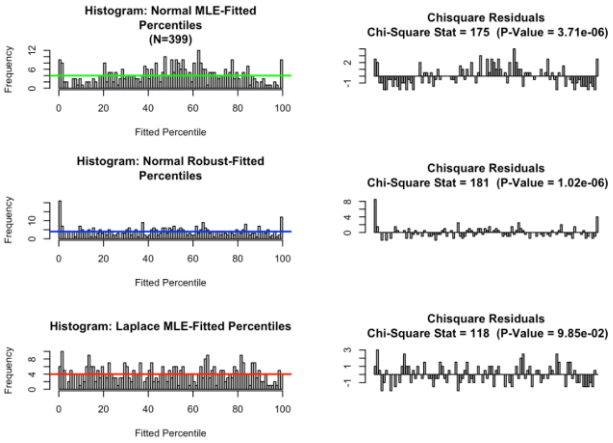

Fig. 42. IBM: Percentile and residuals plot.

From histogram on the left side, we notice that Robust Fit in general fits good very well with the original data especially well except at 1% or 99%. While Laplace MLE fit seems to be the second-best fit. Compare with Robust Fit, Laplace fits better at percentile of both ends, but less suitable for 0-99% percentile. On the right-side chi-square residual plot, we reject both Normal MLE (p-value 3.71e-06) and Normal Robust Model (p-value 1.02e-06). Their p-value tend to be smaller than 5% significant level. On the other hand, Laplace MLE model has the smallest chi-square statistic of 118 and largest p-value of 9.85e-02, hence we can tell Laplace MLE model seem to fit the general trend a bit better. There is a 9.85% chance that the chi-square test statistic is 118 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. But since our Normal Robust curve fits well with the percentile graph on the left, we decide to combine these two models.

Finally, we draw the conclusion that **Laplace MLE Model combined with Normal Robust Model** is the best fit model during third period for IBM.

4) Period Four (2020-01-01 to 2020-12-31)

The fourth period is exactly the time that covid-19 outbreaks. It contains representative data that can directly show how different companies react to the crisis and how the stock price is doing under the pressure of covid and new policy from government. There are 253 daily observations overall. On the left side, the graph still appears to be a standard bell-shaped but with a few numbers of outliers in the middle and symmetrically along center. As we can see, the blue line in general does a good job in describing the behavior of the histogram. Red line accounts more for the middle part where numbers seem to be extremely high. Green

line presents poorly in the graph. In QQ plot, both blue and green lines poorly describe the behavior of the upper and lower level of dotted line. The red line closely to the upper level but less close to the dotted points on lower ends where blue and green lines miss them. We make our initial finding that perhaps Laplace MLE model is the best fit.

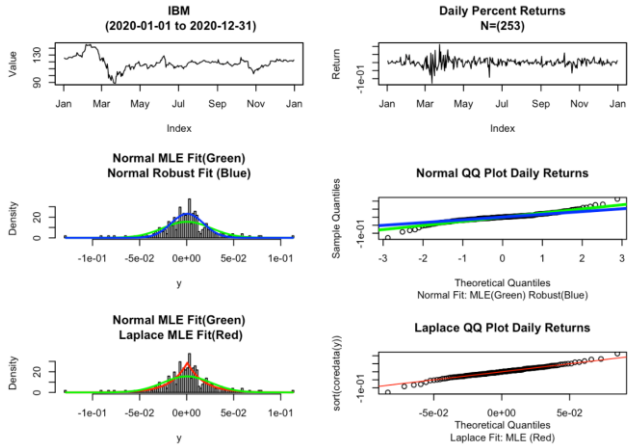

Fig. 43. IBM: Period four.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

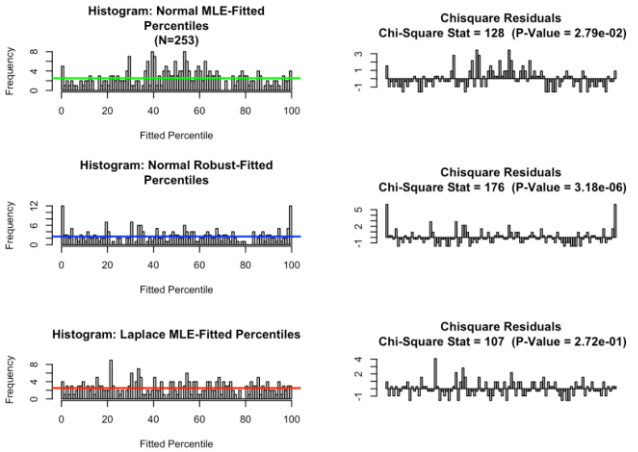

Fig. 44. IBM: Percentile and residuals plot.

From histogram on the left side, we notice that all three models fit generally well in the middle part but not so well on the 1 and 99% percentile. On the right-side chi-square residual plot, we reject both Normal MLE (p-value 2.79e-02), Normal Robust Model (p-value 3.18e-06) as their p-value are bigger than 5% significant level. These two models do not fit our data. However, Laplace MLE model has the smallest chi-square statistic of 107 and largest p-value of 2.72e-01. It has a p-value that's greater than alpha. There is a 27.2% chance that the chi-square test statistic is 107 or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. Finally, we draw the conclusion that **Laplace MLE Model** is the best fit model during fourth period for IBM.

5) Period Five (2021-01-01 to 2021-04-22)

The fifth period is the afterwards of covid-19 where the pandemic has been largely under control. Since the period only covers the first half years of 2021, there is only about 76 daily observations. Due to this limited amount of data, the result we gain may not be fully accurate and can be biased. We will look at this data in a critical way.

On the left side, we notice the general trend of histogram is unclear. It looks like a bell-shaped curve that skewed right, but there are a great number of outliers where density is high at y=0 or after. We find out that none of the model truly fits the data well but Robust Model and Laplace MLE model tend to fit better compare with Normal MLE model. In the QQ plot return, it shows all three lines seem to overlap with the dotted line, but none of these models do a good job in describing the lower end of the dotted line. In such, we make our initial finding that perhaps Laplace MLE model and Robust Model fits this period a bit better.

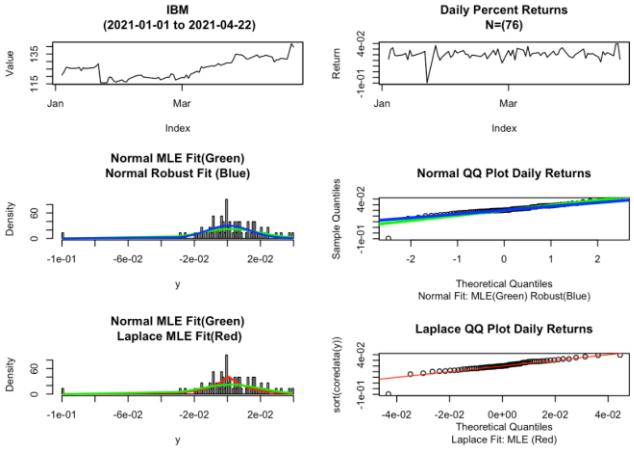

Fig. 45. IBM: Period five.

To determine best fit model among these two, we look at the chi-square residuals and histogram.

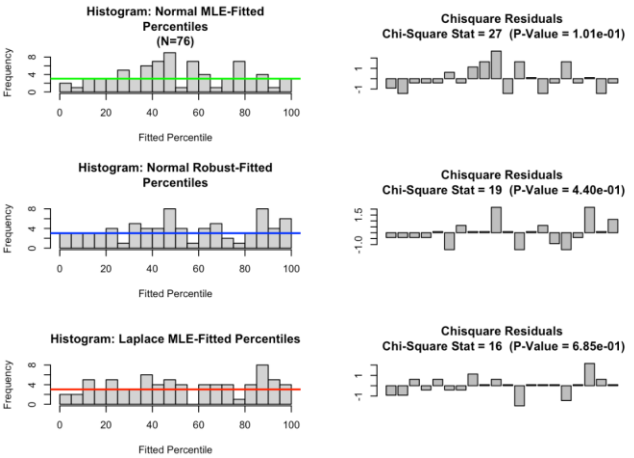

Fig. 46. IBM: Percentile and residuals plot.

This time it is hard to tell the difference between which graph performs better by looking at percentiles' histogram on the left side. Although they look rather similar, still we can tell the red line is a rather good fit with most of the data below the line, on the right side, due to our limited sample size, we reduce the number of bins from 100 to 25 to prevent any empty bins in the chi-square goodness of fit. Under such, we do not reject any of the model since all p-values are way greater than 0.05. The Laplace MLE model has the smallest chi-square statistic of 19 and largest p-value of 6.85e-01. There is a 68.5% chance that the chi-square test statistic is 19

or larger, assuming the Laplace MLE fit is the true model. With such a high p-value, there is no strong evidence against the null hypothesis that the Laplace MLE model is the true model. But due to our limited sample size and accuracy of data, this result we get will not be that statistically significant. Since 76 is smaller than 100, there will be several empty bins in the chi-square goodness of fit.

In such, we draw the conclusion that **Laplace MLE Model** is the best fit model during final period for IBM Corporation, but we'll only use this result as a reference to other periods.

*Conclusion***:** In the first, second, and third period, we find out that the best fit model is a combination of Robust and Laplace MLE Model. In the fourth and fifth period, Laplace MLE model seems to be the best fit. But since the limited amount of data in fifth period, the result is less statically significant. We only use the result as a reference. In short, as most period reflects, we draw our conclusion that the best fit stock model overall for IBM is **a combination of Normal Robust Model and Laplace MLE Model.**

V. Conclusion

As described in our analysis, we are able to draw two overall conclusions:

1. NTDOY and SNE are best modeled by the Laplace MLE Model.
2. AMC and IBM are best modeled by a combination of Robust Model and Laplace MLE Model.

To look back on our initial hypothesis, we find out that our Initial Hypothesis One corresponds to our Conclusion One. Initial Hypothesis Two and Three do not match with our Conclusion Two. It is very interesting to see that four different electronic corporations all seem to follow the Laplace MLE model (partially or fully). Under similar conditions, we project that in the future, the trends of these four stocks will still follow a Laplace model. To be more specific, we predict that as the economy recovers from the horrible strike of covid-19, NTDOY and SNE will continue to increase in the later quarters of 2021. There are a number of new games (eg. Monster Hunter Rise) or old games remake versions are ready to go on Nintendo Switch platform in the later time in 2021. Also, the same condition happens for Sony Corporation as more and more new games are ready to go on PS5 (eg. Final Fantasy VII Remake). These games will help to boost the two companies' stock to the next level. AMC is also looking good in later time of 2021. With the short squeeze of Reddit, the stock price already starts to go back up and with theatres opening back up, new movies or delayed movies will be on soon. The revenue is back.

However, this year is critical for IBM. As a multinational corporation that across multiple IT and software markets, IBM already has a very sophisticated business model and products. Their stock price is high but it's steady: not going up and not coming down significantly. To break free from this deadlock, the company needs innovations and investments in new projects. And just as the CEO describes that they intent to put more focus on hybrid cloud platform and artificial intelligence (AI), we should be able to see a raise in IBM stock price in next quarter of 2021.

Conflict of Interest

The author declares no conflict of interests.

Acknowledgment

I wish to present special thanks to Dr. Peter J. Kempthorne. He is the professor of MIT Math Department, specialize in financial mathematics and, he is an expert of R studio. We have had several discussions and communications about the choice of stock and the details of the contents. Dr. Kempthorne gave me precious suggestions towards the selection and helped me with grammar corrections. I thank him for his unconditional help, and I greatly appreciate it.

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Jialin Guo was born in Sichuan, China. She is a raising senior at Boston University, School of Arts and Science. She majors in applied mathematics and has some background in computer science.

She is currently an intern at the Investment Banking Division of Sinolink Securities since May 2021.