

Analysis to Predict Closing Stock Prices from Company AT&T

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Abstract

In our project, we are trying to determine if we are capable of developing a suitable model using regression analysis that allows for trades in the market to be fully automated. Mentioned under the data's context on Kaggle, roughly 30% of the trades are already automated. We gathered the data from the company AT&T from the years 2013-2016 and added in the yearly fundamental data. Furthermore, we used visual graphs to analyze the residuals to help identify any underlying problems we came across when developing our model. By data-splitting, we acquired a model that was capable of predicting the closing prices roughly 69% of the time. The overall analysis of the model helped us subset and distinguish the effectiveness of each regressor we found to the response variable, however we were expecting our model to have a higher percentage predicting closing stock price of AT&T.

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1 Introduction

The telecommunication industry is growing inevitably, and it is highly dependent on the rapid advancement of technology. The telecommunication industry is a key element for businesses and individuals to collaborate from anywhere across the world. As a result, there will be investment opportunities present, however it is not risk free. In our analysis, we designate our efforts toward one of the most well-known telecommunication companies around the world, AT&T.

2 Data Description

We are using three datasets: `securities.csv`, `fundamentals.csv`, and `prices-split-adjusted.csv`.

`Securities.csv` contains information on the stock companies such as the company's name and ticker symbol, the type of sector they are in, location of headquarters and others.

`Fundamentals.csv` contains information of yearly reports of fundamental information of each company such as `total revenue`, `accounts payable`, `liabilities` and many more.

`Prices-split-adjusted.csv` contains information of the stocks adjusted prices after splitting. The columns included are the `date`, `ticker symbol`, `close`, `open`, `low`, `high`, and `volume`.

For our linear regression model, we have selected to predict close prices of AT&T's stock. Our regressor variables are `volume` from the `prices-split-adjusted.csv` and `capital surplus`, `gross margin`, and `liabilities` from the `fundamentals.csv`. See Equation (1)

$$close = \beta_0 + \beta_1(volume) + \beta_2(CapitalSurplus) + \beta_3(GrossMargin) + \beta_4(Liabilities) + \epsilon \quad (1)$$

Since the data from the `fundamentals.csv` is annual, we merged the previous year's dataset with the following year's `prices-split-adjusted.csv` data of AT&T to form the full dataset. For example, if the `total revenue` for 2013 is \$1,000,000 so we made a column for total revenue and made every row that is in 2014 to be \$1,000,000. We ran a nested for loop to apply this for all years and columns. `Tprices` is the DataFrame with the columns of interest for our linear model. See Table 1.

Table 1: Column Names of DataFrame Tprices

Columns
close
volume
date
year
Capital.Surplus
Gross.Margin
Liabilities

`Close` corresponds to the price of the stock when the market closes on that day.

`Volume` is the number of trades that occurred that day.

`Date` is the date of the trading day.

`Year` is the year of the trading day.

`Capital.surplus` or share premium, most commonly refers to the surplus resulting after common stock is sold for more than its par value.

Gross.margin is a company's net sales revenue minus its cost of goods sold. The higher the gross margin, the more capital a company retains on each dollar of sales, which it can then use to pay other costs or satisfy debt obligations.

Liabilities are the debts and obligations of a company.

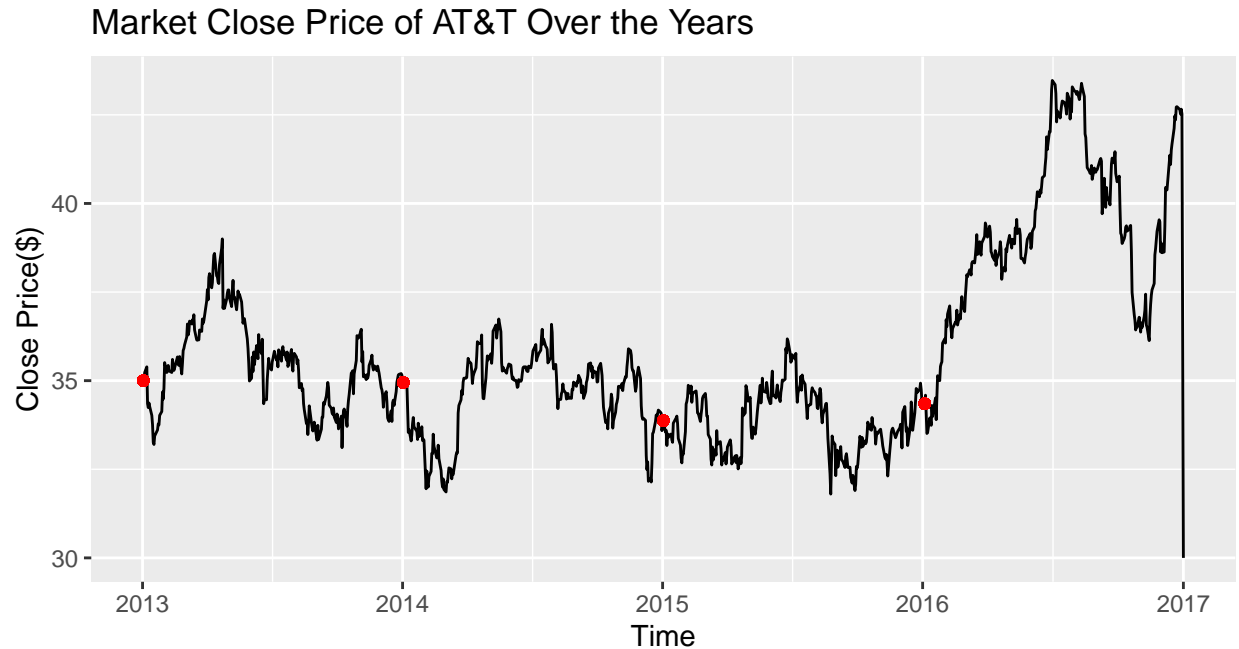


Figure 1: Daily Market Close Price of AT&T

Figure 1 represents the market closing price of the stock for AT&T over the span of 2013 to 2017. The red points on the line mark as an indication when the year begins. We notice that 2013 and 2014 closing prices both started around \$35. Around spring of 2013, the stock shot up to about \$39 which is the highest closing price until 2016. The stock drops to about \$32 in the beginning of the year and before 2015. In 2016, the stock was starting to rise and in mid 2016, the stock got a new record of about \$43.

##	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
##	30.00	33.96	35.10	35.77	36.74	43.47

In the five number summary of the close prices, the minimum is our added observation of \$30 . Without the added observation, the lowest is \$31.80. The max close price is \$43.47. The mean close price is \$35.77.

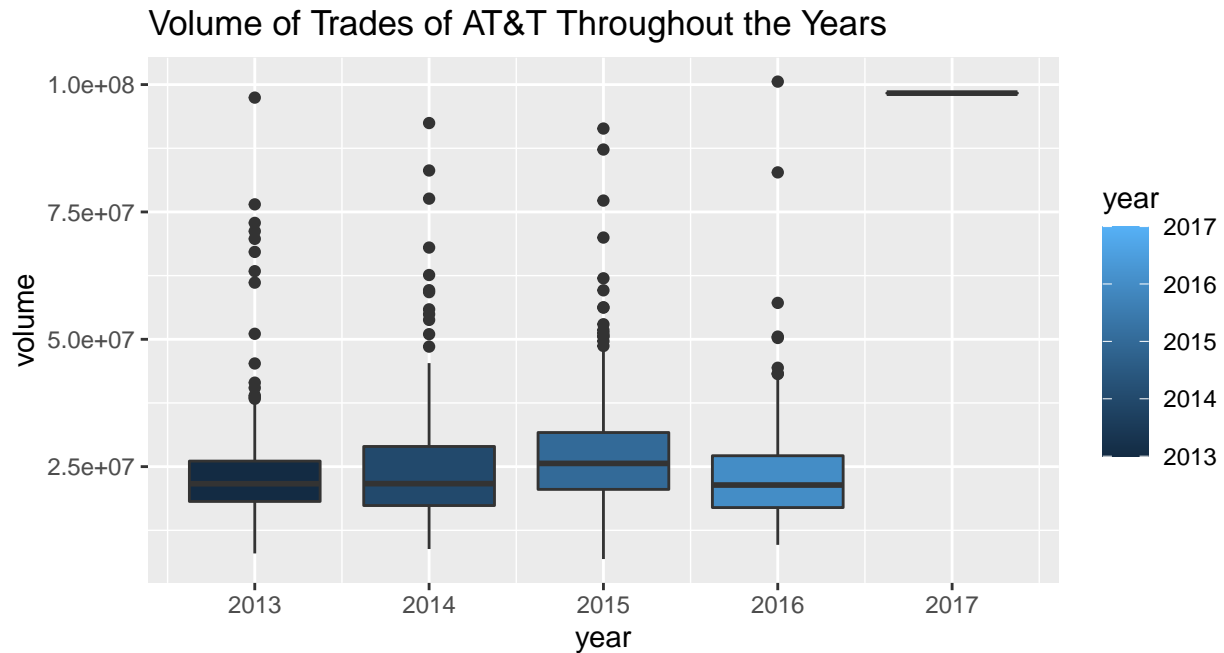


Figure 2: Daily Volume Traded of ATNT

Figure 2 shows the volume traded each year. The mean volume traded yearly is roughly the same except for 2015. The dots on the boxplot represent the outliers from that given year. There are days where the stock is traded more often than usual which could be caused by good news, low stock prices, etc. On the other hand, there are also days where volume is lower than usual since the stock price is higher causing people who own the stock to hold or the price being too high that does not incentivize buyers, etc.

```
## [1] "Summary of Volume in 2013"
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 7960000 18167000 21646500 23940484 26088200 97444100
```

```
## [1] "Summary of Volume in 2014"
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 8831900 17360725 21657950 24690541 28960075 92453000
```

```
## [1] "Summary of Volume in 2015"
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 6862400 20536525 25633950 28282645 31696250 91372900
```

```
## [1] "Summary of Volume in 2016"
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 9645400 16962575 21388750 23596375 27142400 100586200
```

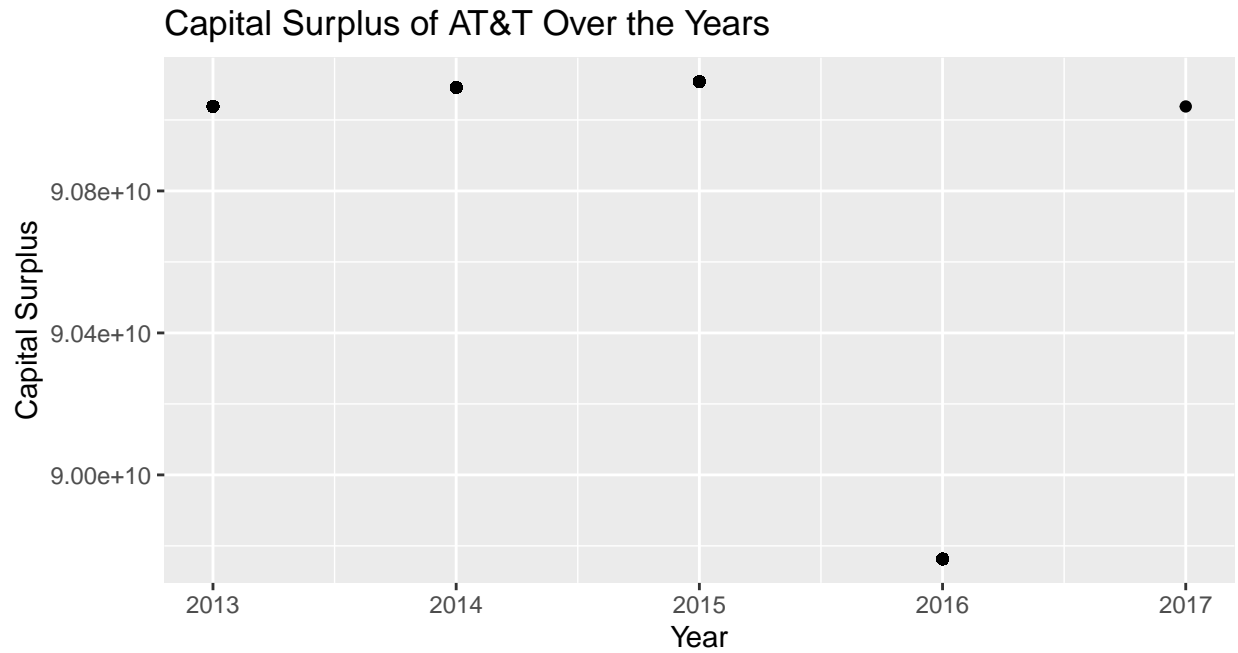


Figure 3: Capital Surplus of ATNT 2013-2016

Figure 3 shows the capital surplus of each year. It was rising up until 2016 where it dropped by significantly.

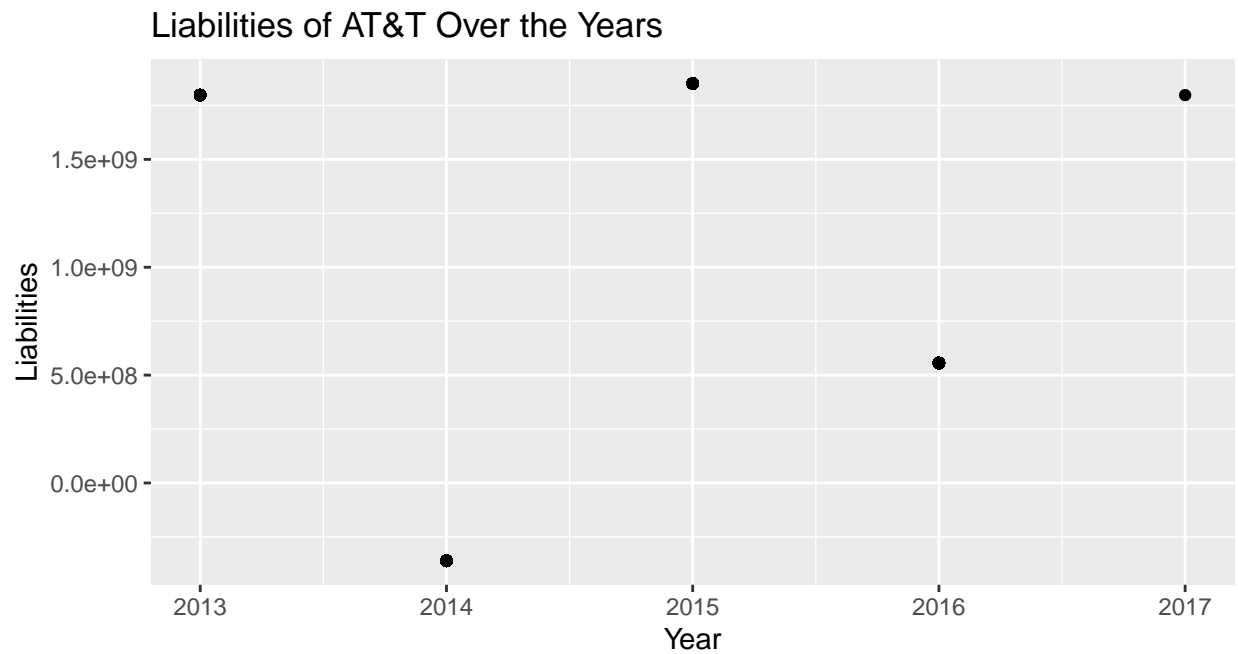


Figure 4: Liabilities of ATNT 2013-2016

Figure 4 shows the liabilities of each year. In 2013 and 2015, AT&T had the highest liabilities. In 2014, they had the lowest. In 2016, it was between the highest and lowest liabilities.

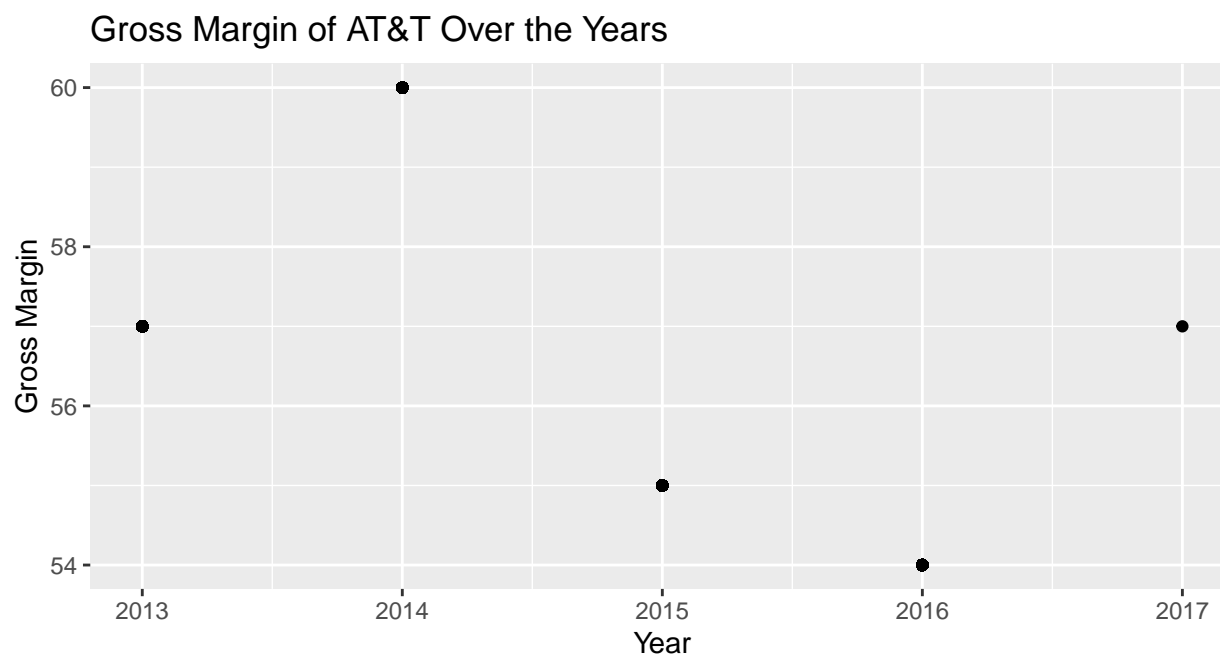


Figure 5: Gross Margin of ATNT 2013-2016

Figure 5 shows the gross margin of each year. From 2013 to 2014, it rose up to the highest of 60. In 2015 it fell down to 55 and 2016 dropped to 54.

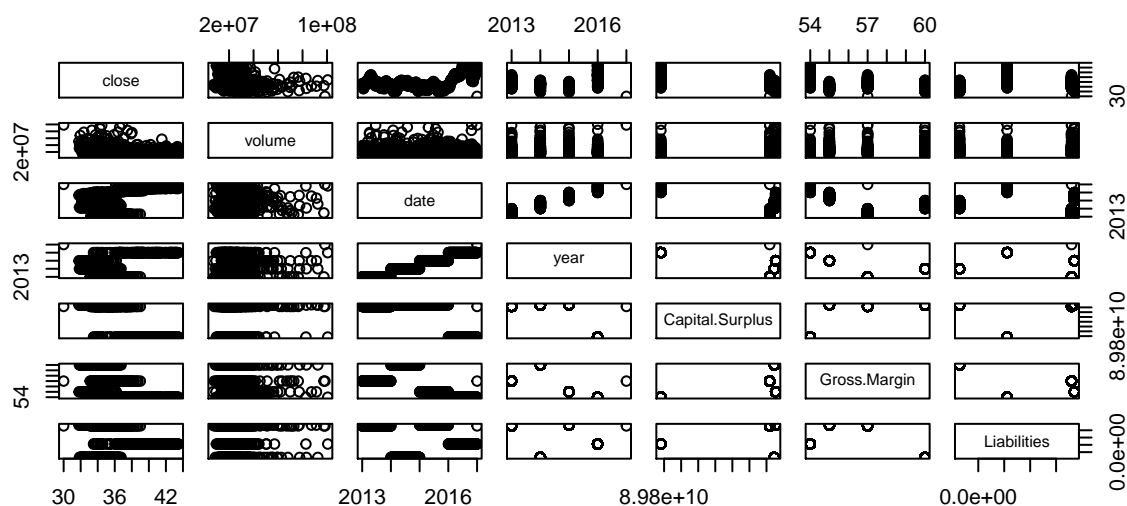


Figure 6: Pairs Plot of Columns of Tprices

Figure 6 shows the columns plotted against each other. Since the columns from the fundamentals.csv is yearly data, when plotted against other columns, they are shown as separate lines due to the values being the same daily for the year.

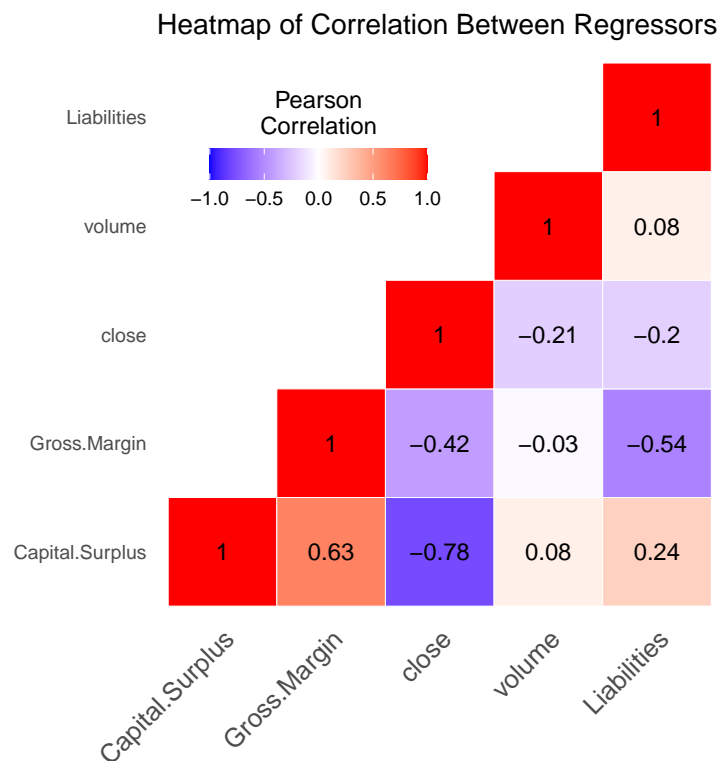


Figure 7: Correlation Between Variables

Figure 7 shows the correlation between each column.

3 Methods

3.1 Datasets

To begin, we chose to combine two of the four datasets offered, “Price-split-adjusted” (PSA) and “Fundamentals” (Fund). The PSA dataset accounts for all stocks traded in the NYSE daily from 2010-2016 and the Fund dataset accounts for the 10-K filing from 2012-2016, an annual comprehensive report required by the U.S. Securities and Exchanges Commission (SEC). Since the dates in the datasets varies from daily in PSA and annually in Fund, we attach the previous year’s filing of the 10-K report to help predict the next year over.

3.2 Choosing Regressors

When first developing the model, we included open as one of the predictors for close. As a result, the correlation of our model increased to 99%, this is because if a stock were to open higher than the average, it is most likely going to close higher than the average. Also, if other predictors were to be added with open, the variance inflation factor will be increased to a level where there are clear violations of multicollinearity. In the end, we decided not to include open as part of our model because it is unrealistic to be able to predict the model with 99% accuracy.

##

```
## Call:
## lm(formula = close ~ open + low + high + volume, data = ogdf)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.54358 -0.08214  0.00559  0.08498  0.83460
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3.348e-02  2.835e-02   1.181  0.2377
## open        -4.845e-01  1.966e-02 -24.647 <2e-16 ***
## low          6.656e-01  2.036e-02  32.690 <2e-16 ***
## high         8.180e-01  2.164e-02  37.797 <2e-16 ***
## volume      -8.001e-10  3.212e-10  -2.491  0.0128 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.132 on 1757 degrees of freedom
## Multiple R-squared:  0.999, Adjusted R-squared:  0.999
## F-statistic: 4.401e+05 on 4 and 1757 DF, p-value: < 2.2e-16
```

This is the summary of our first model.

```
##      open      low      high      volume
## 676.47197 723.77829 828.08043  1.48055
```

These are the variance inflation factors. `Open`, `low`, and `high` have values vastly greater than 10, thus this model suffers from severe multicollinearity.

3.3 Subsetting Dataset

Since our datasets covers different years, we kept only the years that overlap in both datasets, 2013-2016. Lastly, we removed all companies other than our company of focus, AT&T. With 76 columns in `fundamentals.csv` that were added into `tprices` DataFrame, we ran into issues with fitting the model with all the columns. The error that came up was due to singularities with the columns. The singularities are due to the fact that many of the variables are dependent of each other. The model would fit up to four variables and the other coefficients would be NA. Due to this, we handpicked the variables `Capital.Surplus`, `Liabilities`, and `Gross.Margins`. We subsetting the DataFrame to just include `close`, `volume`, `date`, `year`, `year`, `Capital.Surplus`, `Gross.Margin`, and `Liabilities`. Table 2 presents the subsetting data.

Table 2: First five rows of `tprices` DataFrame

close	volume	date	year	Capital.Surplus	Gross.Margin	Liabilities
35.00	38323500	2013-01-02	2013	9.1038e+10	57	1.798e+09
35.02	28932700	2013-01-03	2013	9.1038e+10	57	1.798e+09
35.23	21136600	2013-01-04	2013	9.1038e+10	57	1.798e+09
35.39	27500500	2013-01-07	2013	9.1038e+10	57	1.798e+09
34.35	29210300	2013-01-08	2013	9.1038e+10	57	1.798e+09

3.4 Model Adequacy

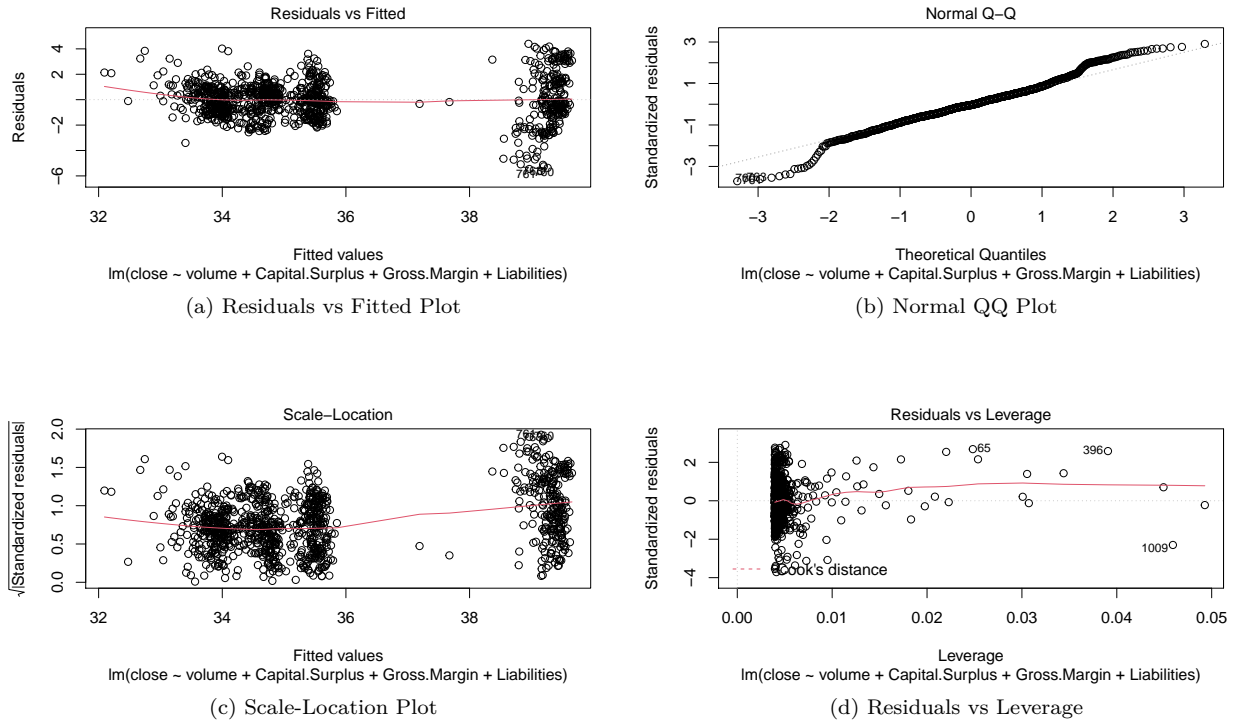


Figure 8: Model Adequacy Plots

Checking model adequacy is an important step to measure the accuracy of the model. **The Residuals vs. Fitted values** in Figure 8(a) shows whether the residuals have a relationship with each other. Ideally, the points would be randomly scattered about zero with no patterns. In our plot, the spaces in between the four groups represent the four different years ranging from 2013-2016. When observing the residuals vs fitted, it seems as though the points are scattered randomly about zero, starting with a negative relationship into a more stable relationship as the plot moves from left to right. We also see that the scatter on the far right is more spread out which could point out to potential problems down the line.

The **normal Q-Q plot** in Figure 8(b) shows whether the errors are normally distributed. If the errors were normally distributed, points are expected to rest on the line with minimum gaps. Our plot has noticeable gaps on both ends labeling point 761 and 763 as potential outliers. The plot seems to be light tailed but nonetheless the plot is about normal due to the amount of observations.

The **scale-location plot** in Figure 8(c) shows whether the residuals are spread equally among the predictors and whether the assumption of constant variance is met. Ideally, the plot show has points scattered equally horizontally. In our plot, we see that there are four groups of points, the first three groups (from left to right) seem to follow constant variance but the points in the rightmost group have a wider spread compared to the previous three. The residuals in the plot do not meet constant variance assumption. Our plot points out point 761 and 763 as potential outliers.

The **residuals vs leverage plot** in Figure 8(d) points out the influential observations within our dataset. The dotted line represents the cook's distance and any points that fall outside of the dotted red line signifies a highly influential point to the regression results. If we were to exclude these observations, our regression will change and improve. In our case, no points fall outside of the cook's distance, this may be due to the

large number of observations included in the data. The plot did highlight point 65, 396, and 1009 (our added point) as potential outliers.

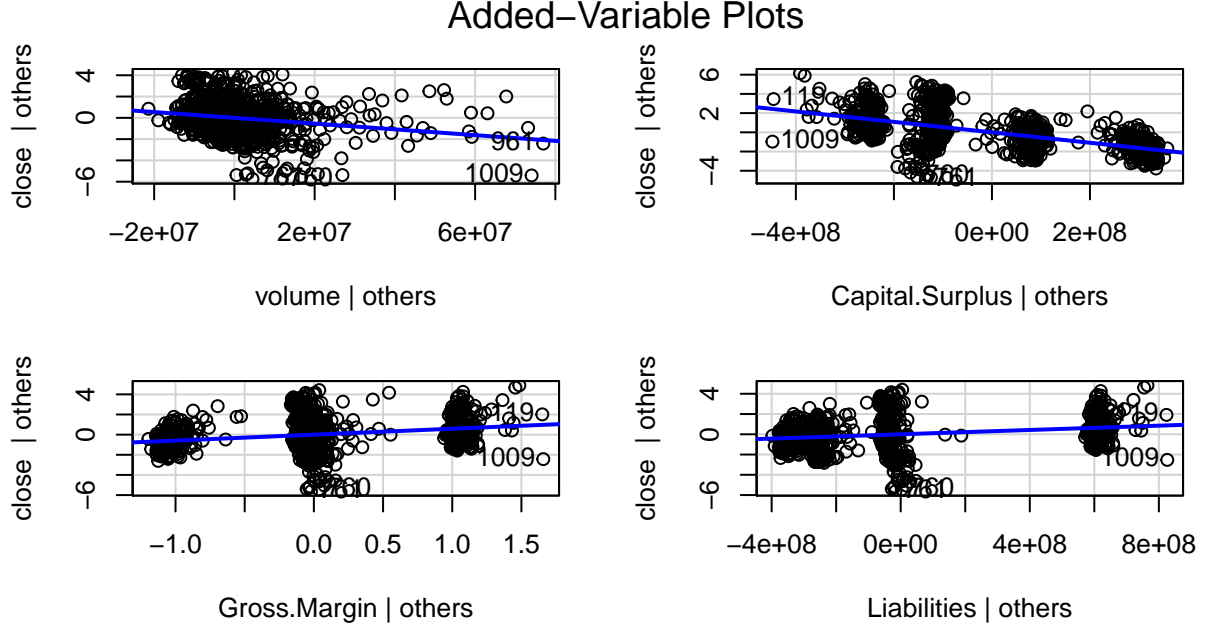


Figure 9: Added Variable Plot of Model

The Added Variable Plots in Figure 9 aim to compare each regressor against the response variable while controlling the presence of the other regressors. Since the variables in the fundamental dataset are presented annually and are merged with daily data, the variable-plot consists of grouping points.

We also investigated the leverage and influential points. A leverage point is when $h_{ii} > 2p/n$, where p is the number of predictors and n is the number of rows of the dataset. h_{ii} comes from the diagonal elements of the hat matrix((2)):

$$H = X(X'X)^{-1}X \quad (2)$$

The high leverage points are sorted here. Data point 1009 is the one data point that we added in. Measuring for leverage points caught this point.

```
##          961          1009          119          396          581          960
## 0.049278243 0.045912513 0.044922337 0.039068133 0.034394745 0.030729741
##          645          271          347          65          666          64
## 0.030548797 0.030082971 0.025373101 0.024825409 0.022283334 0.022020309
##          120          192          274          121          623          193
## 0.020827655 0.019769046 0.018313347 0.018034662 0.017253045 0.015659610
##          306          78          329          489          658          877
## 0.014963038 0.014356594 0.013304578 0.013100958 0.012645405 0.012572914
##          598          457          291          308          524          610
## 0.011471124 0.011403934 0.010954989 0.010447714 0.009960494 0.009934028
##          768          51          773          307          647          451
## 0.009513285 0.009460517 0.009404053 0.009260503 0.008619798 0.008323023
##          643          748
## 0.008194445 0.007988696
```

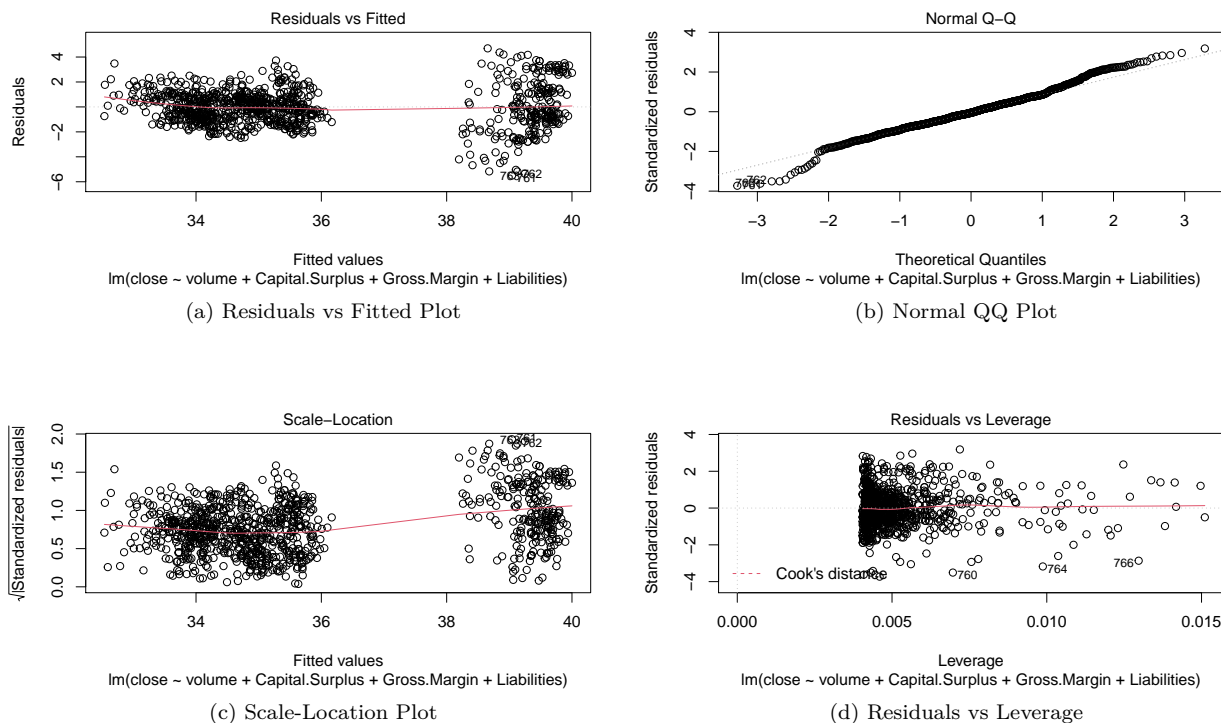


Figure 10: Model Adequacy Plots

By removing the leverage points, the model adequacy plots in Figure 10 improve as the grouping of the points are less evident in all plots. There seems to be less clustering of points without the leverage points and for the residuals vs leverage plot in Figure 10(d), the data points look more spread out.

```
##
## Call:
## lm(formula = close ~ volume + Capital.Surplus + Gross.Margin +
##     Liabilities, data = newdata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.5033 -0.9369 -0.0740  0.8264  4.6954
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.889e+02  1.700e+01  28.756 < 2e-16 ***
## volume       -5.186e-08  6.433e-09  -8.063 2.20e-15 ***
## Capital.Surplus -5.330e-09  2.253e-10 -23.654 < 2e-16 ***
## Gross.Margin    5.465e-01  6.445e-02   8.480 < 2e-16 ***
## Liabilities     9.943e-10  1.274e-10   7.805 1.54e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.479 on 966 degrees of freedom
## Multiple R-squared:  0.6832, Adjusted R-squared:  0.6819
## F-statistic: 520.9 on 4 and 966 DF, p-value: < 2.2e-16
```

By removing the leverage points, the R^2 improves from 0.6638 to 0.6832.

Here we checked the Variance Inflation Factor(VIF),

```
##           volume Capital.Surplus   Gross.Margin   Liabilities
##      1.025562      7.137102      9.378354      6.024813
```

The VIF for Capital.Surplus, Gross.Margin, and Liabilities are pretty high but they are less than 10 so they are acceptable.

3.5 Model Selection

By performing stepwise selection with our model, we discovered that our current model is the best for predicting closing stock price for AT&T therefore no variables need to be removed. See Equation (1) above.

```
## Start:  AIC=765.33
## close ~ volume + Capital.Surplus + Gross.Margin + Liabilities
##
##           Df Sum of Sq    RSS    AIC
## <none>                 2113.7  765.33
## - Liabilities      1    133.31 2247.1  822.72
## - volume           1    142.24 2256.0  826.57
## - Gross.Margin     1    157.34 2271.1  833.05
## - Capital.Surplus  1   1224.33 3338.1 1207.01

##
## Call:
## lm(formula = close ~ volume + Capital.Surplus + Gross.Margin +
##     Liabilities, data = newdata)
##
## Coefficients:
##      (Intercept)           volume   Capital.Surplus   Gross.Margin
##      4.889e+02      -5.186e-08      -5.330e-09      5.465e-01
##      Liabilities
##      9.943e-10
```

3.6 Model Validation

After assessing the model adequacy, we go on to validate our model to see if it can function properly and successfully for the intended user. To do this, we sampled 80% of the AT&T data to form the training dataset, leaving 20% to be the testing set. The model and results will be shown in the following section.

4 Result

This is the summary of fitting a model on the training data.

```
##
## Call:
## lm(formula = close ~ volume + Capital.Surplus + Gross.Margin +
##     Liabilities, data = train_data)
```

```
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.3926 -0.9254 -0.0857  0.8235  4.4956
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   4.745e+02  1.882e+01  25.217 < 2e-16 ***
## volume        -5.709e-08  7.008e-09  -8.146 1.51e-15 ***
## Capital.Surplus -5.149e-09  2.497e-10 -20.622 < 2e-16 ***
## Gross.Margin    5.121e-01  7.164e-02   7.148 2.05e-12 ***
## Liabilities     9.177e-10  1.418e-10   6.472 1.72e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.459 on 772 degrees of freedom
## Multiple R-squared:  0.6828, Adjusted R-squared:  0.6811
## F-statistic: 415.4 on 4 and 772 DF,  p-value: < 2.2e-16
```

This is the summary of the full model without the leverage points.

```
##
## Call:
## lm(formula = close ~ volume + Capital.Surplus + Gross.Margin +
##      Liabilities, data = newdata)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.5033 -0.9369 -0.0740  0.8264  4.6954
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   4.889e+02  1.700e+01  28.756 < 2e-16 ***
## volume        -5.186e-08  6.433e-09  -8.063 2.20e-15 ***
## Capital.Surplus -5.330e-09  2.253e-10 -23.654 < 2e-16 ***
## Gross.Margin    5.465e-01  6.445e-02   8.480 < 2e-16 ***
## Liabilities     9.943e-10  1.274e-10   7.805 1.54e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.479 on 966 degrees of freedom
## Multiple R-squared:  0.6832, Adjusted R-squared:  0.6819
## F-statistic: 520.9 on 4 and 966 DF,  p-value: < 2.2e-16
```

When comparing the coefficients and p values from the two models, the coefficients remain similar and the regressors that were previously found to be significant are still significant.

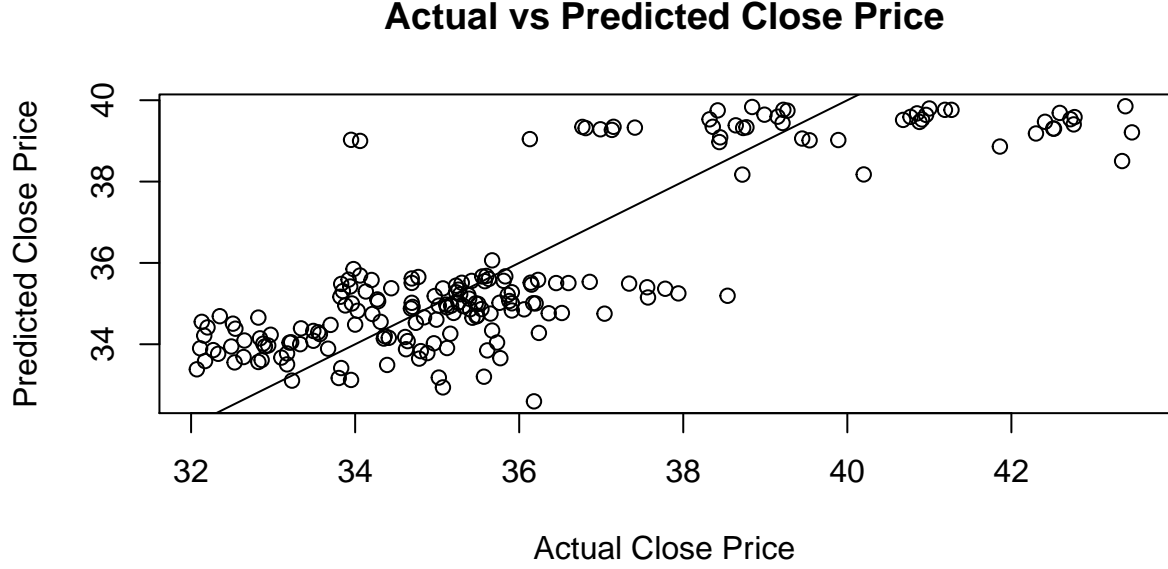


Figure 11: Predicted Values Plotted with Actual Values With $y=x$ Line

Figure 11 shows the relationship between predicted close price (y-axis) versus actual close price (x-axis). We notice that the fitted line provides a positive slope across the plot indicating that there is a positive linear relationship between the predicted and actual close price. In addition, the points are evenly scattered around the fitted line which is a sign of constant variance. However, the points do not rest directly on the line which means that our model is not capable of perfectly predicting closing price. Although the two points on the top left of the plot could be potential outliers, removing them will not make a significant difference in the overall pattern so we can leave it as is.

Table 3: Table containing $R^2_{Prediction}$, Root Mean Square Prediction Error, Mean Absolute Prediction Error, Normalized Standard Error

R2	RMSPE	MAPE	NSE
0.6860785	1.563026	1.214033	0.5630319

In Table 3, we generated the $R^2_{Prediction}$, Root Mean Square Prediction Error, Mean Absolute Prediction Error and Normalized Standard Error. After sampling 80% of the data, $R^2_{Prediction}$ uses the same regressors as the original model but uses the sampled data (train dataset) instead of the full data. By calling the summary using the predicted linear model, we can observe the correlation between regressors and response of the train dataset. The sampled data is capable of predicting the remaining 20% of the data 69% of the time.

The Root Mean Square Prediction Error (Equation (3)) is the standard deviation of the residuals. It is a measure of how far the data points deviate from the regression line.

$$RMSPE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2} \quad (3)$$

The Mean Absolute Prediction Value measures the average magnitude of the data points that deviate from

the fitted line. See Equation (4).

$$MAPE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i| \quad (4)$$

The Normalized Standard Error(Equation (5)) is the normalized Root Mean Square Prediction Error. Normalizing it tells us if the Root Mean Square Prediction Error value is a low value or not. It tells us how much variability we have explained. For example, a value of 1 says the model explains none of the variability.

$$NSE = \frac{RMSPE}{\sigma_{test}} \quad (5)$$

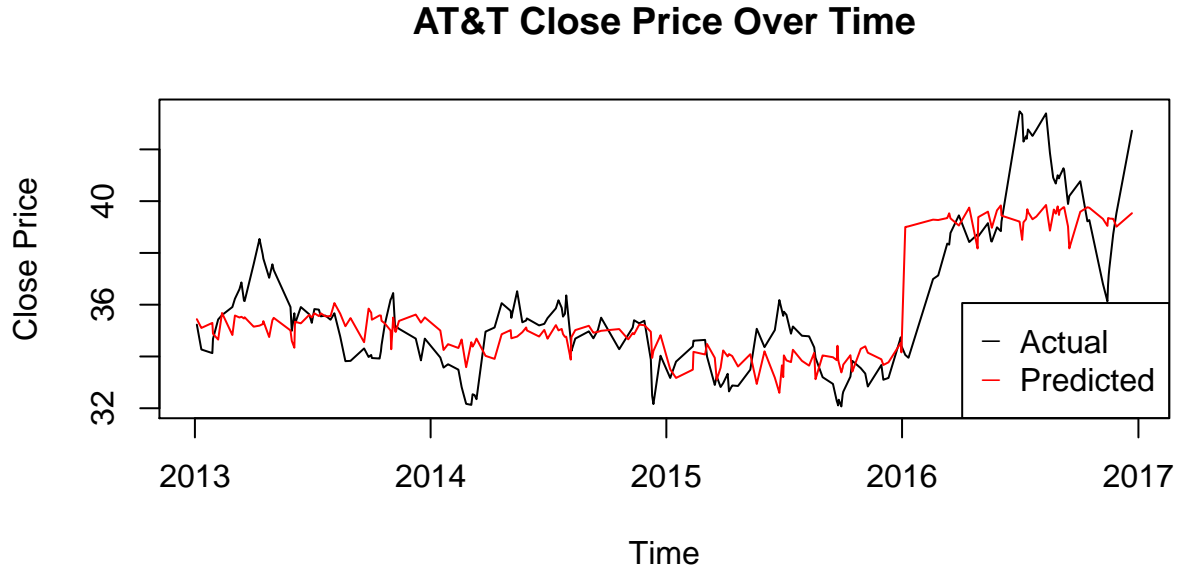


Figure 12: Time Series Plot of Actual Close Price and Predicted Close Price

Figure 12 shows the overall pattern of close prices of AT&T stocks over years 2013 to 2016 with the one data point that we added for 2017. This plot gives a visual representation of the difference between the predicted closing price (labelled in red) versus the actual closing price (labelled in black). We see that our predicted prices are generally more stable than the actual prices meaning that there are some variations between what we predicted versus what the actual price of the closing stock is at a certain point in time. From the results we see our prediction is not 100% accurate but it does show that it is not completely off as it provides similar patterns to the actual closing price which the 0.69 from the R^2 prediction explains. Furthermore, we also notice a large shift in the pattern from the beginning to the end of 2016 where the closing price has been the highest since recent years. This is an indication that the value of the company has grown.

5 Conclusion

In conclusion, our prediction model used 80% of the training data to predict the testing data with 69% accuracy. Although this is not perfect, the 69% accuracy is tolerable considering that we only have 4 predictors to the model.

Some of the limitations of the data presented in this case includes not being able to use the data prior to 2013 because the fundamental dataset lacked the years 2010-2012, not having more information on day to day stock activities that can help better predict how volatile the stocks are, and how well the company's did in the earnings report.

Listed below are some of the examples of better predictors of stock price excluding the ones already included in the dataset.

1. **Price to Earnings Ratio** – determines market value of stock compared to the company's reported earnings.
2. **Market Capitalization** – refers to the total value of all the company's shares in stock. Market capitalization is the total from (number of common shares * stock price).
3. **Earnings per Share** – how much a company earns per share, higher EPS means stock has higher value than those in the same industry.

By having quarterly information on the earnings reports of AT&T, the user of the dataset would have been able to better predict how the stock would react in the following days after the earnings report is released. For context, if AT&T's earning report were to beat the expectations, the stock would perform better on the following days. In conjunction with adding extra predictors listed above, the predictive power of the model would most likely increase.

Although the dataset on Kaggle highlights that roughly 30% of daily trades are performed by machine, the results of and the limitations of our study points towards the complexity of the stock market that must be considered to make an accurate forecast model.

6 Appendix

6.1 URL:

Repository containing all files

6.2 Data Files:

fundamentals.csv
prices-split-adjusted.csv
securities.csv

6.3 Raw Code:

rawcode.Rmd

6.4 Report:

atntReport.Rmd
atntReport.pdf

6.5 Text Files:

README.md
my_header.tex

6.6 Required Libraries:

```
lubridate  
tidyverse  
faraway  
caret  
reshape2  
car  
knitr  
bookdown
```