BR2211 Store Sales Forecasting

Group 5

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QEUXKH

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04

Learn *more*

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Corporación Favorita

- Established since 1952
- A large grocery retailer based in Ecuador
- Subsidiaries in Colombia, Costa Rica, Chile, Panamá, Paraguay and Perú
- Sells a vast range of product families

CORPORACION FAVORITA

01

Exploratory Data Analysis

Structure, Granularity,
Accuracy, Temporality, Scope

CSVs

1. Train
2. Test
3. Store
4. Transactions
5. Holidays and Events
6. Daily Oil Price

Train Data

train

id	date	store_nbr	family	sales	onpromotion
0	2013-01-01	1	AUTOMOTIVE	0.0	0
1	2013-01-01	1	BABY CARE	0.0	0
2	2013-01-01	1	BEAUTY	0.0	0
3	2013-01-01	1	BEVERAGES	0.0	0
4	2013-01-01	1	BOOKS	0.0	0
5	2013-01-01	1	BREAD/BAKERY	0.0	0
6	2013-01-01	1	CELEBRATION	0.0	0
7	2013-01-01	1	CLEANING	0.0	0
8	2013-01-01	1	DAIRY	0.0	0
9	2013-01-01	1	DELI	0.0	0
10	2013-01-01	1	EGGS	0.0	0

- 01/01/2013 - 15/08/2017
- store_nbr: 1-54 stores
- family: type of product
- sales: product family's total sales each day for each store
- onpromotion: number of items in a product family on promotion each day

Stores Data

- Information about Corporación Favorita's 54 stores
- Location (city and state)
- Type and cluster (grouping of similar stores)

stores

store_nbr	city	state	type	cluster
1	Quito	Pichincha	D	13
2	Quito	Pichincha	D	13
3	Quito	Pichincha	D	8
4	Quito	Pichincha	D	9
5	Santo Domingo	Santo Domingo de los Tsachilas	D	4
6	Quito	Pichincha	D	13
7	Quito	Pichincha	D	8
8	Quito	Pichincha	D	8
9	Quito	Pichincha	B	6
10	Quito	Pichincha	C	15

Transactions Data

- Number of transactions made in each store from 01/01/2013 to 15/08/2017

transactions

date	store_nbr	transactions
2013-01-01	25	770
2013-01-02	1	2111
2013-01-02	2	2358
2013-01-02	3	3487
2013-01-02	4	1922
2013-01-02	5	1903
2013-01-02	6	2143
2013-01-02	7	1874
2013-01-02	8	3250
2013-01-02	9	2940
2013-01-02	10	1293

Holidays and Events Data

holidays_events

date	type	locale	locale_name	description	transferred
2012-03-02	Holiday	Local	Manta	Fundacion de Manta	FALSE
2012-04-01	Holiday	Regional	Cotopaxi	Provincializacion de Cotopaxi	FALSE
2012-04-12	Holiday	Local	Cuenca	Fundacion de Cuenca	FALSE
2012-04-14	Holiday	Local	Libertad	Cantonizacion de Libertad	FALSE
2012-04-21	Holiday	Local	Riobamba	Cantonizacion de Riobamba	FALSE
2012-05-12	Holiday	Local	Puyo	Cantonizacion del Puyo	FALSE
2012-06-23	Holiday	Local	Guaranda	Cantonizacion de Guaranda	FALSE
2012-06-25	Holiday	Regional	Imbabura	Provincializacion de Imbabura	FALSE
2012-06-25	Holiday	Local	Latacunga	Cantonizacion de Latacunga	FALSE
2012-06-25	Holiday	Local	Machala	Fundacion de Machala	FALSE
2012-07-03	Holiday	Local	Santo Domingo	Fundacion de Santo Domingo	FALSE
2012-07-03	Holiday	Local	El Carmen	Cantonizacion de El Carmen	FALSE
2012-07-23	Holiday	Local	Cayambe	Cantonizacion de Cayambe	FALSE
2012-08-05	Holiday	Local	Esmeraldas	Fundacion de Esmeraldas	FALSE
2012-08-10	Holiday	National	Ecuador	Primer Grito de Independencia	FALSE
2012-08-15	Holiday	Local	Riobamba	Fundacion de Riobamba	FALSE

- Information about dates that are holidays
- Metadata about the holiday and event
- Information about holidays that were transferred

Daily Oil Price Data

oil

date	dcoilwtico
2013-01-01	
2013-01-02	93.14
2013-01-03	92.97
2013-01-04	93.12
2013-01-07	93.2
2013-01-08	93.21
2013-01-09	93.08
2013-01-10	93.81
2013-01-11	93.6
2013-01-14	94.27
2013-01-15	93.26
2013-01-16	94.28
2013-01-17	95.49
2013-01-18	95.61
2013-01-21	

- Daily oil price from 01/01/2013 to 31/08/2017
- West Texas Intermediate - Cushing Oklahoma (dcoilwtico)
- Contains some missing values
- Ecuador is an oil-dependent country
  - drastic changes in oil prices may influence economy
  - unusual fluctuations can affect sales

Test Data

test

id	date	store_nbr	family	onpromotion
3000888	2017-08-16	1	AUTOMOTIVE	0
3000889	2017-08-16	1	BABY CARE	0
3000890	2017-08-16	1	BEAUTY	2
3000891	2017-08-16	1	BEVERAGES	20
3000892	2017-08-16	1	BOOKS	0
3000893	2017-08-16	1	BREAD/BAKERY	12
3000894	2017-08-16	1	CELEBRATION	0
3000895	2017-08-16	1	CLEANING	25
3000896	2017-08-16	1	DAIRY	45
3000897	2017-08-16	1	DELI	18
3000898	2017-08-16	1	EGGS	1
3000899	2017-08-16	1	FROZEN FOODS	1
3000900	2017-08-16	1	GROCERY I	64
3000901	2017-08-16	1	GROCERY II	0
3000902	2017-08-16	1	HARDWARE	0
3000903	2017-08-16	1	HOME AND KITCHEN I	2
3000904	2017-08-16	1	HOME AND KITCHEN II	6

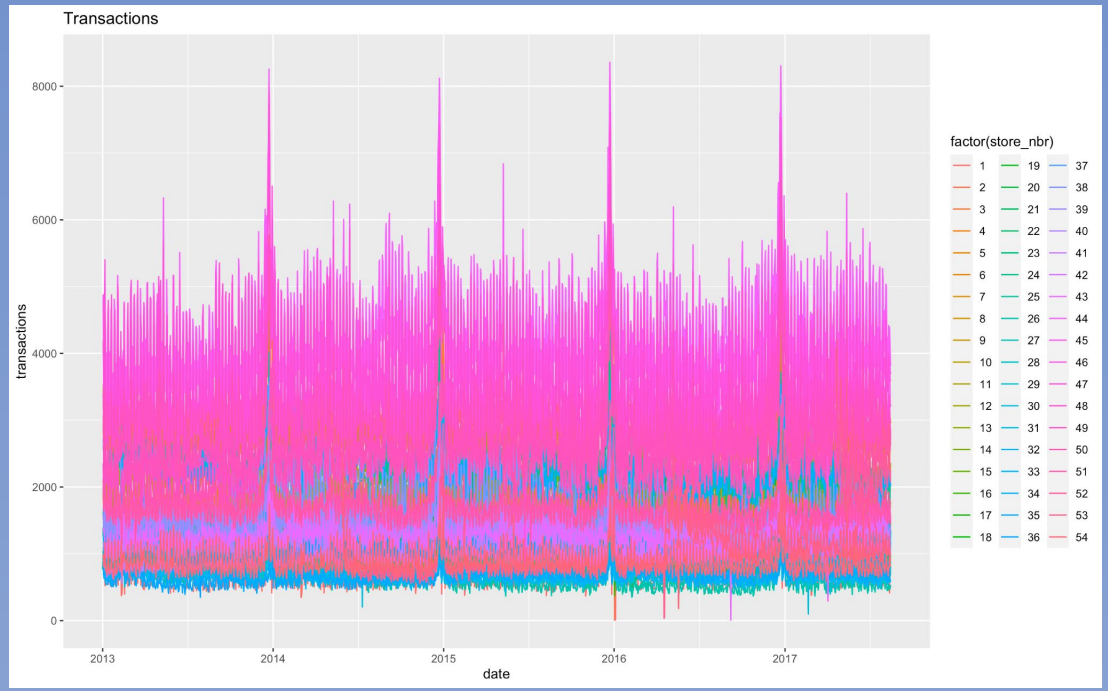
- 16/08/2017 to 31/08/2017
- Columns store_nbr, family and onpromotion like train data
- **Aim**: predict sales for next 15 days

02

Transactions

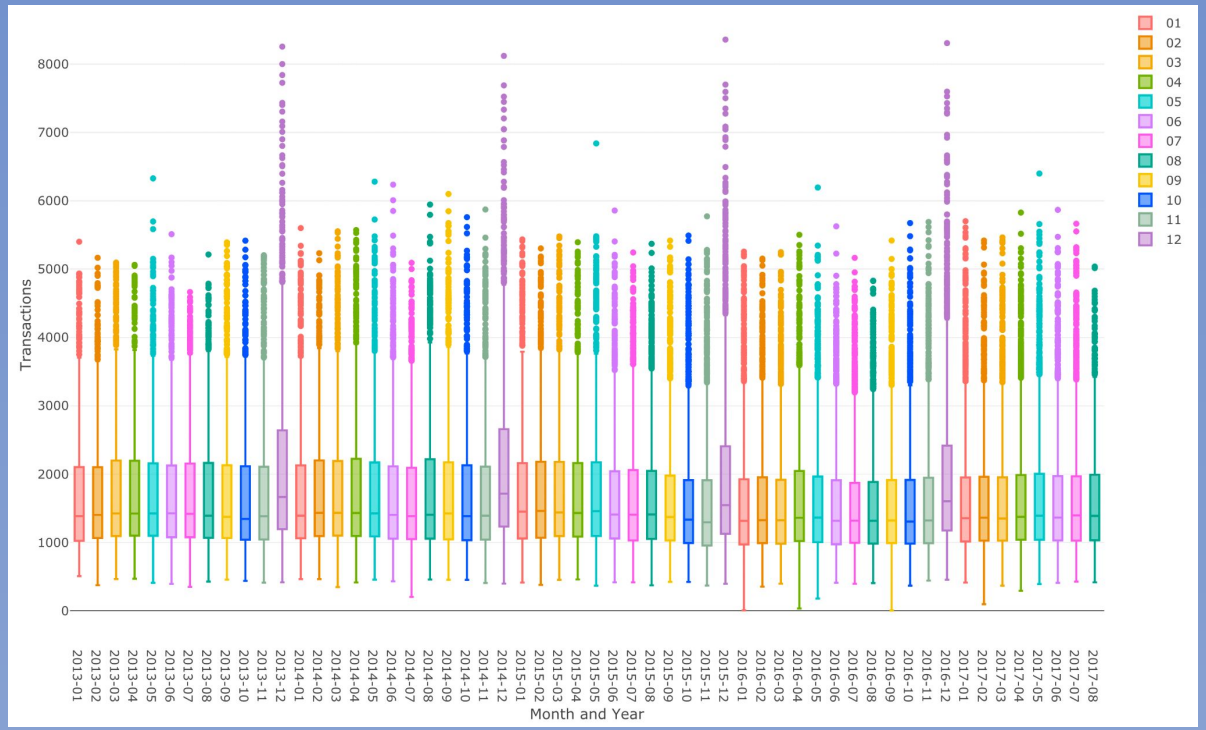
Daily Transactions

```
[1] "Spearman Correlation: 0.817464435501645"
```

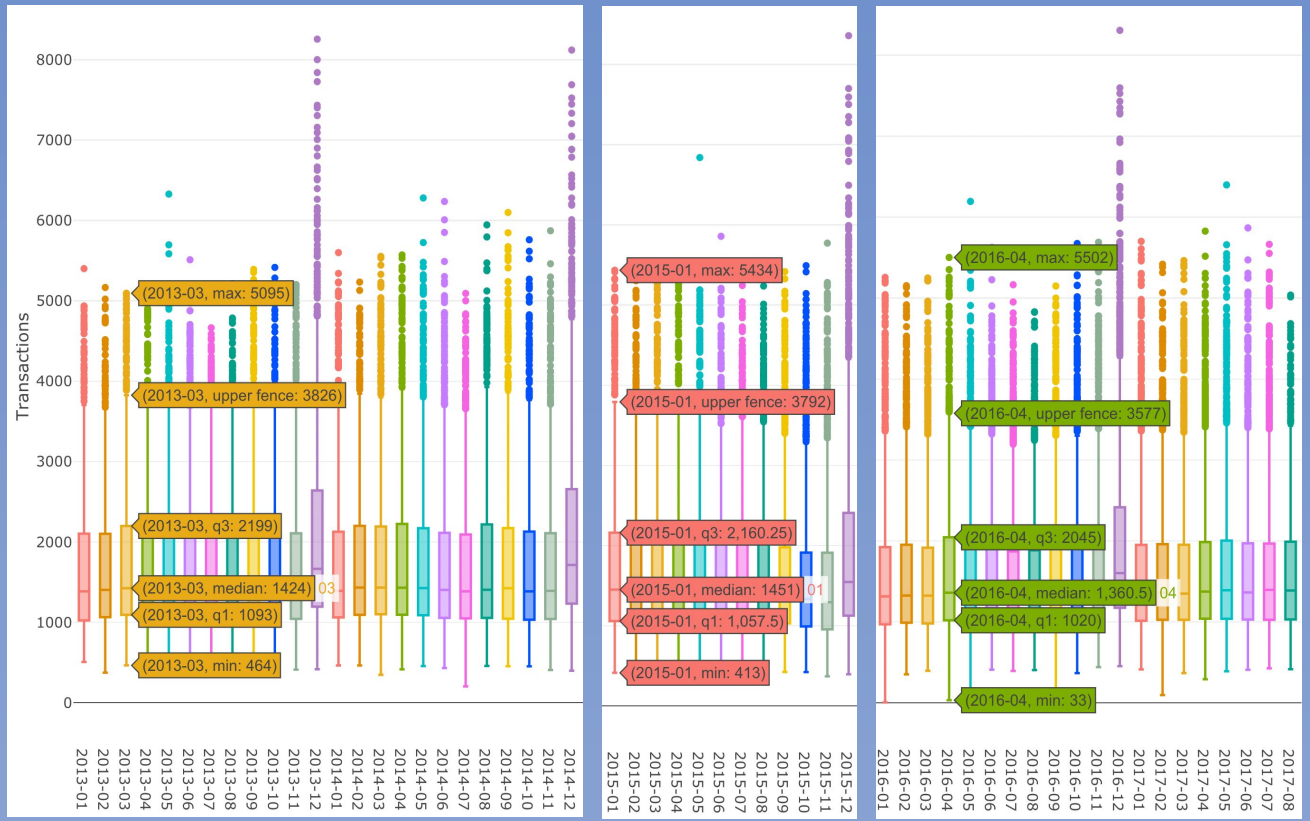


- High correlation between daily transactions and total sales
- Similar pattern each year
- Highest peaks at year ends

Boxplot: Monthly Median Transactions



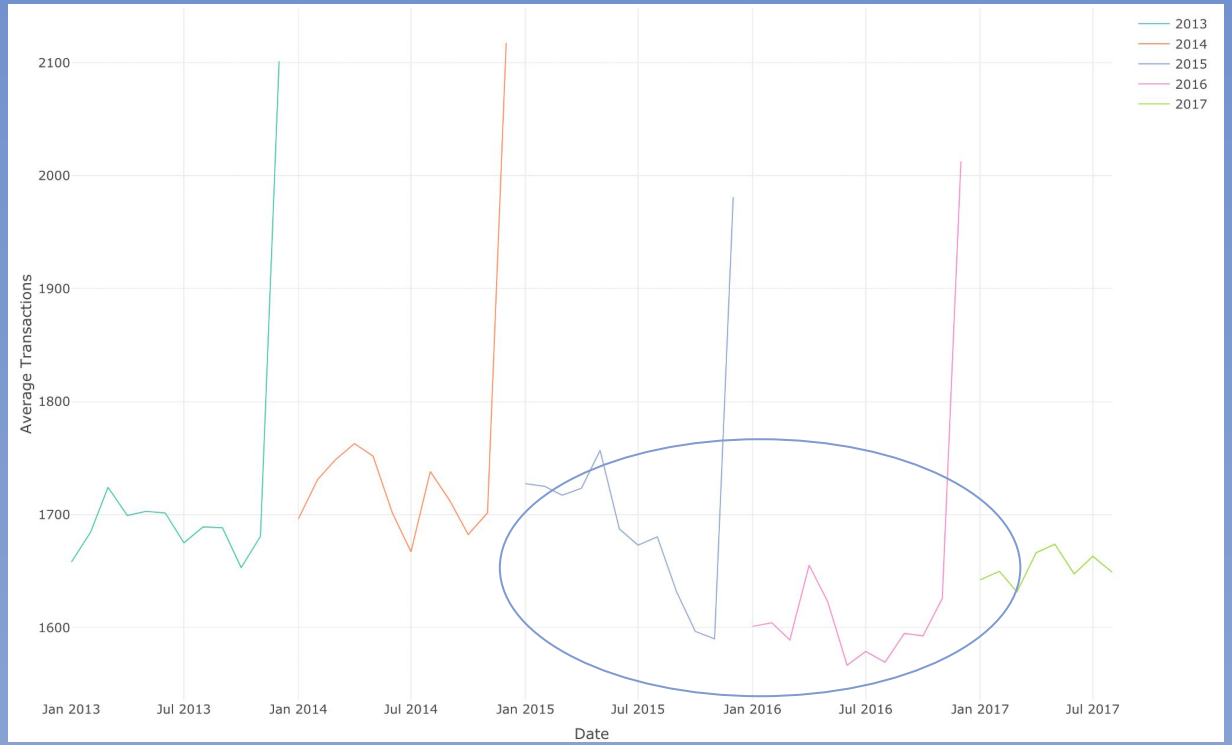
- Stable pattern in monthly transactions
- Peaks in December



Monthly Median Transactions

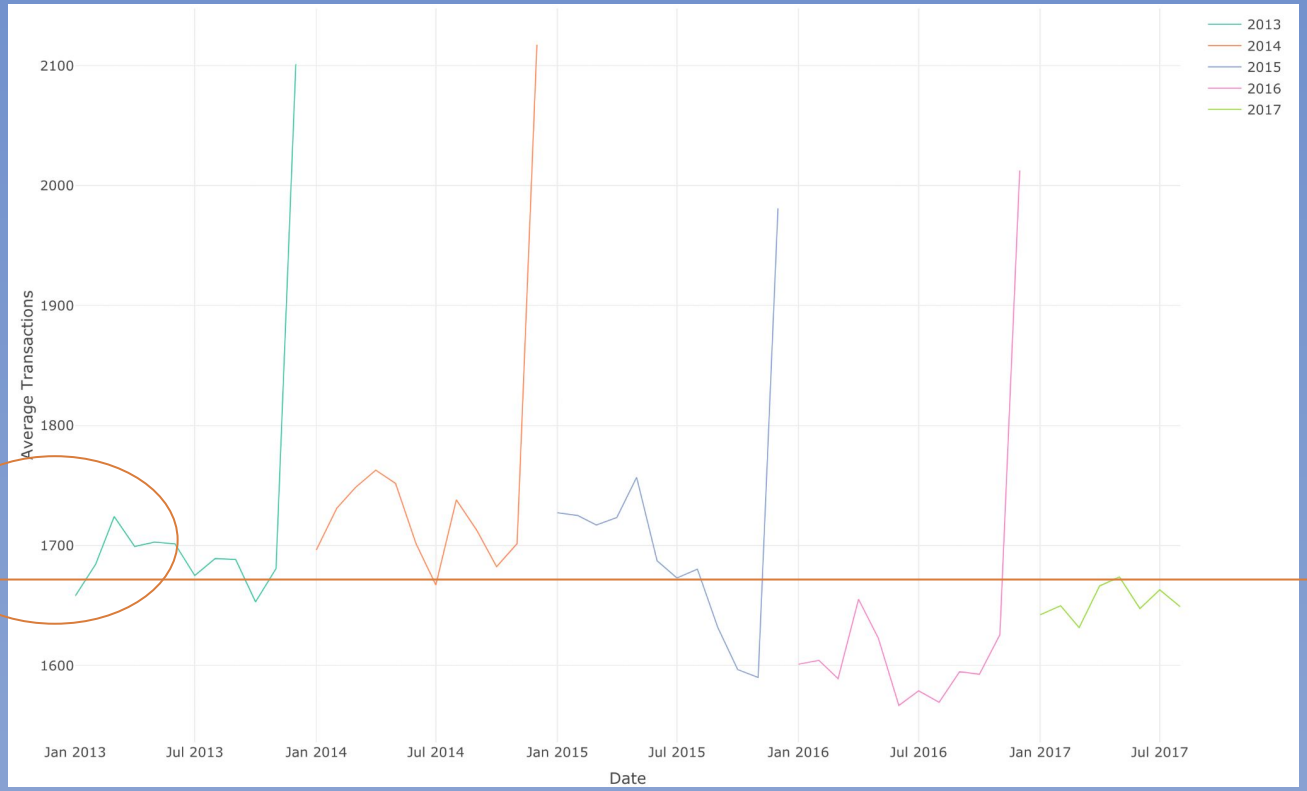
- 2013 to 2014: 1,380 to 1,420
- 2015 (Jan-May): 1,430 to 1,460
- 2015 (Jun-Dec): 1,295 to 1,400
- 2016-2017: 1,310 to 1,390

Monthly Average Transactions



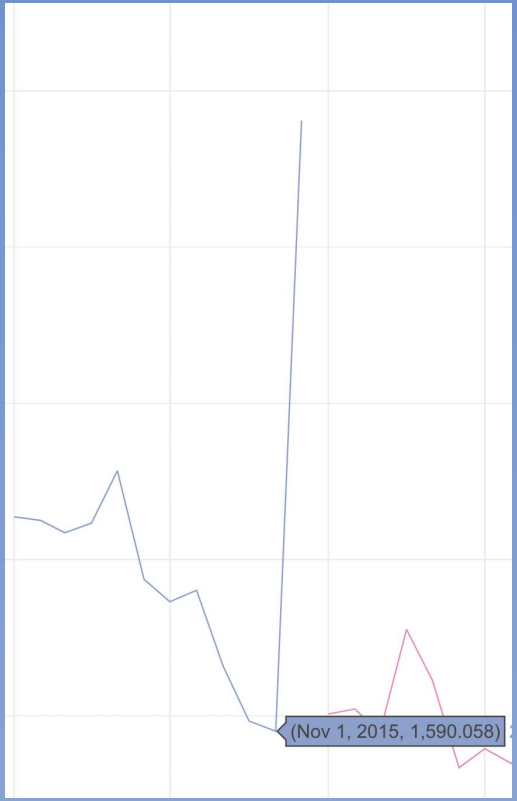
- Consistent peaks in December
- Decreased average transactions for second half of 2015
- Lower average transactions in 2016

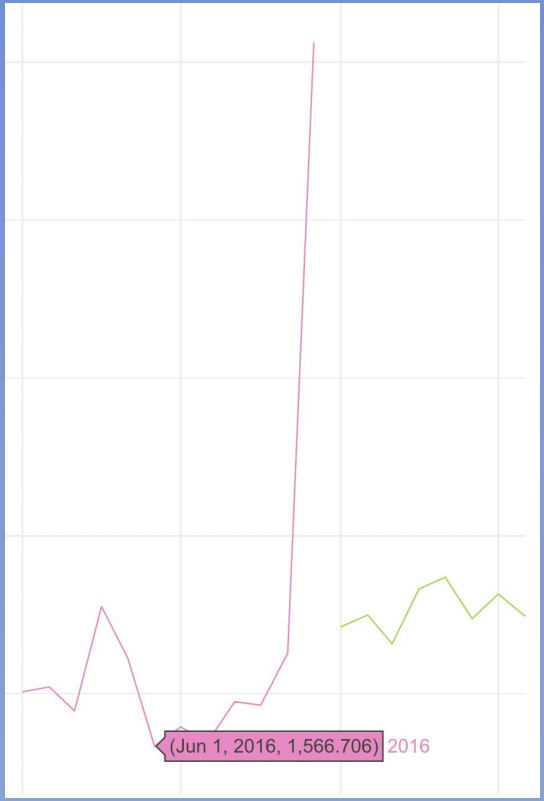
Monthly Average Transactions



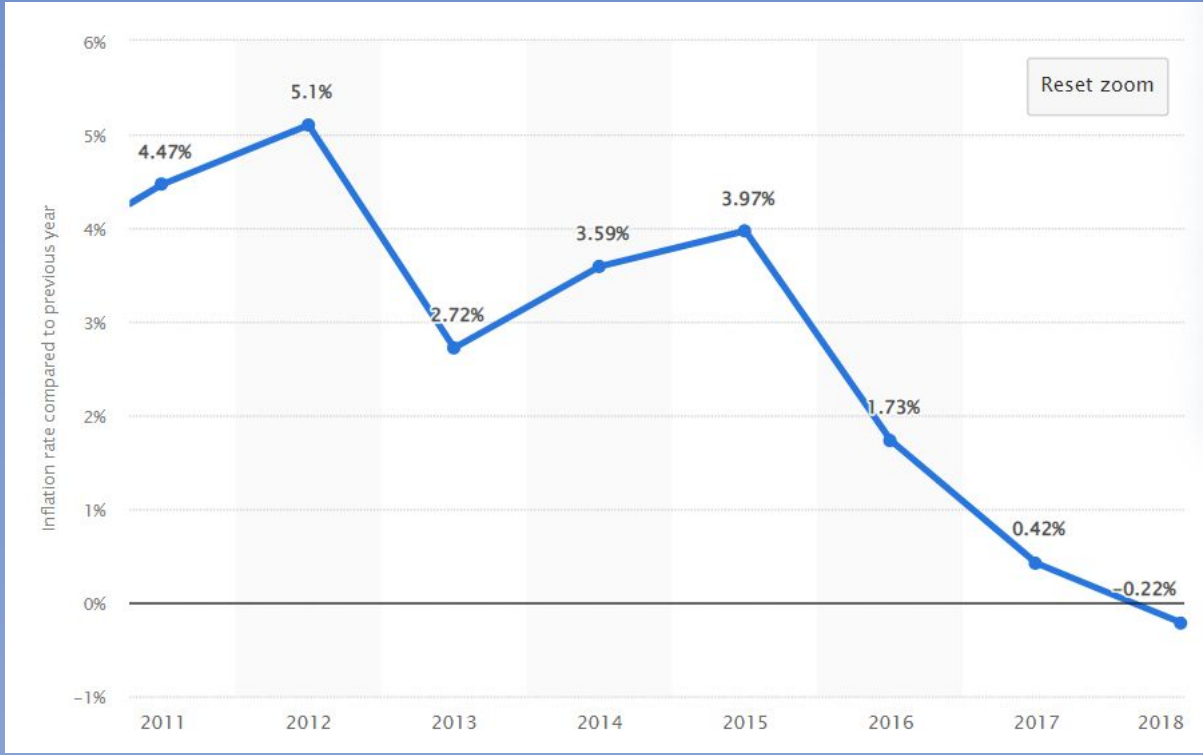
Monthly Average Transactions

- 2015 lowest: November, 1,590.058
- Increase until April 2016, followed by decrease until November
- 2016 lowest: June, 1,566.706
- More stable in 2017



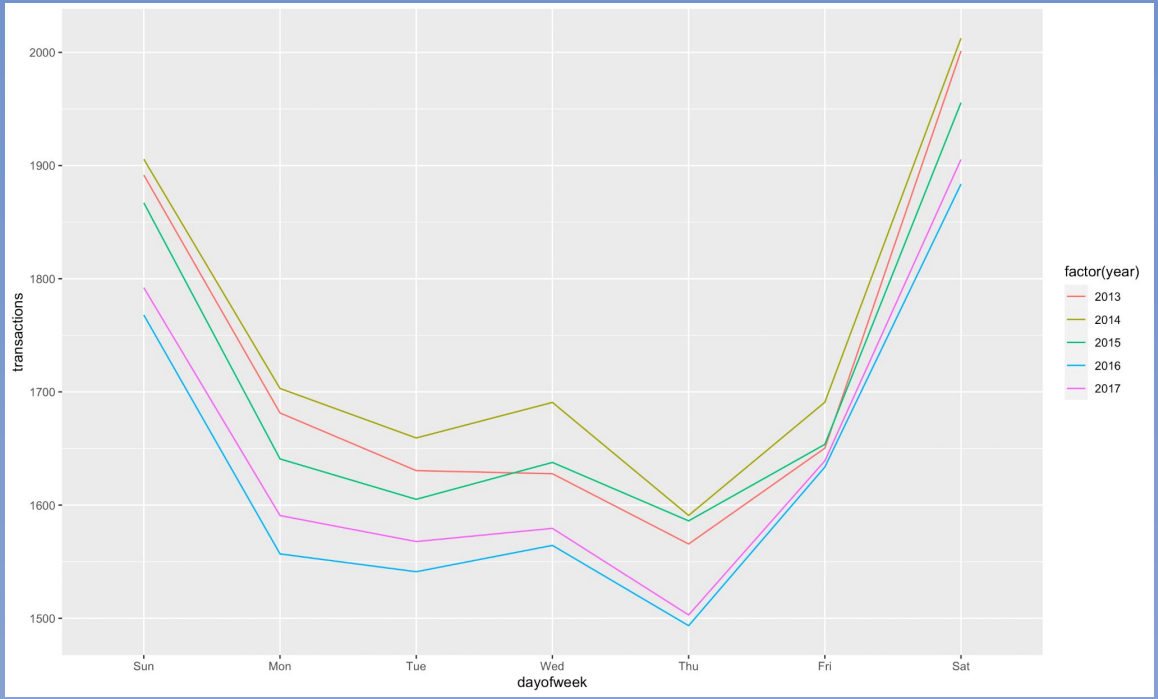


Inflation Rate



Average Transactions Days of the Week

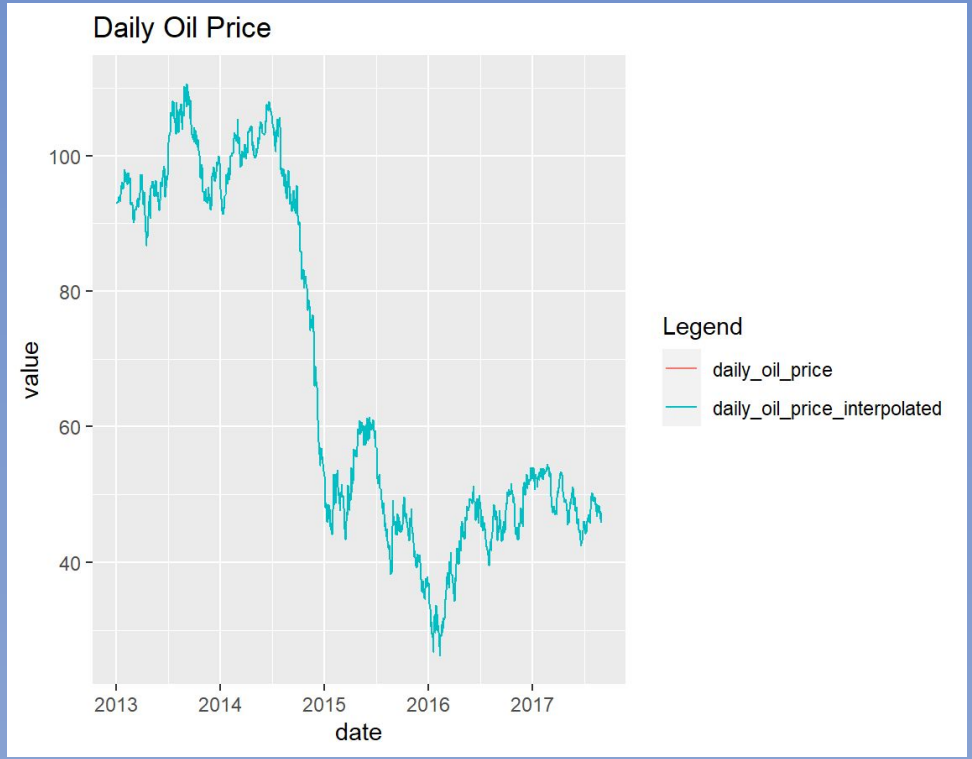
- Same pattern each year
- Higher transactions towards weekends
- Decreasing transactions from Sat to Thurs
- Highest on Sat
- Lowest on Thurs



03

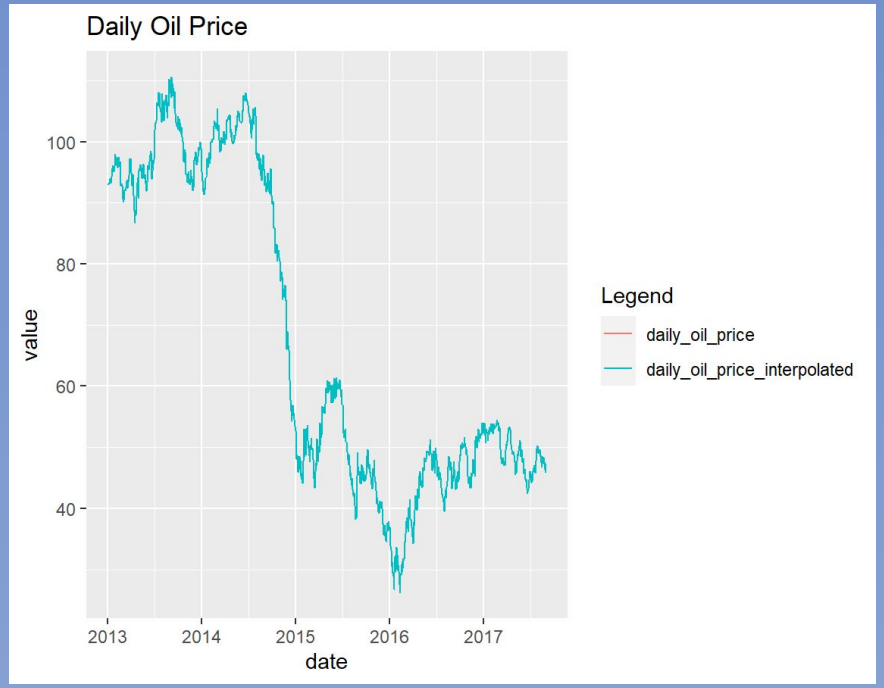
Oil Price vs Sales

Oil Price vs Sales



Oil. csv

- Correlation between daily oil price and transactions: **0.03764688**
- Correlation between daily oil price and sales: **-0.1800813**
- Not much correlation



Reasons for low correlation

1) Govt subsidies :Gasoline subsidies for vehicles accounted for some 49% of the subsidy budget, while household gas accounted for 38% (Reuters)

2) Economic diversification

3) Regional differences

4) Consumer preferences

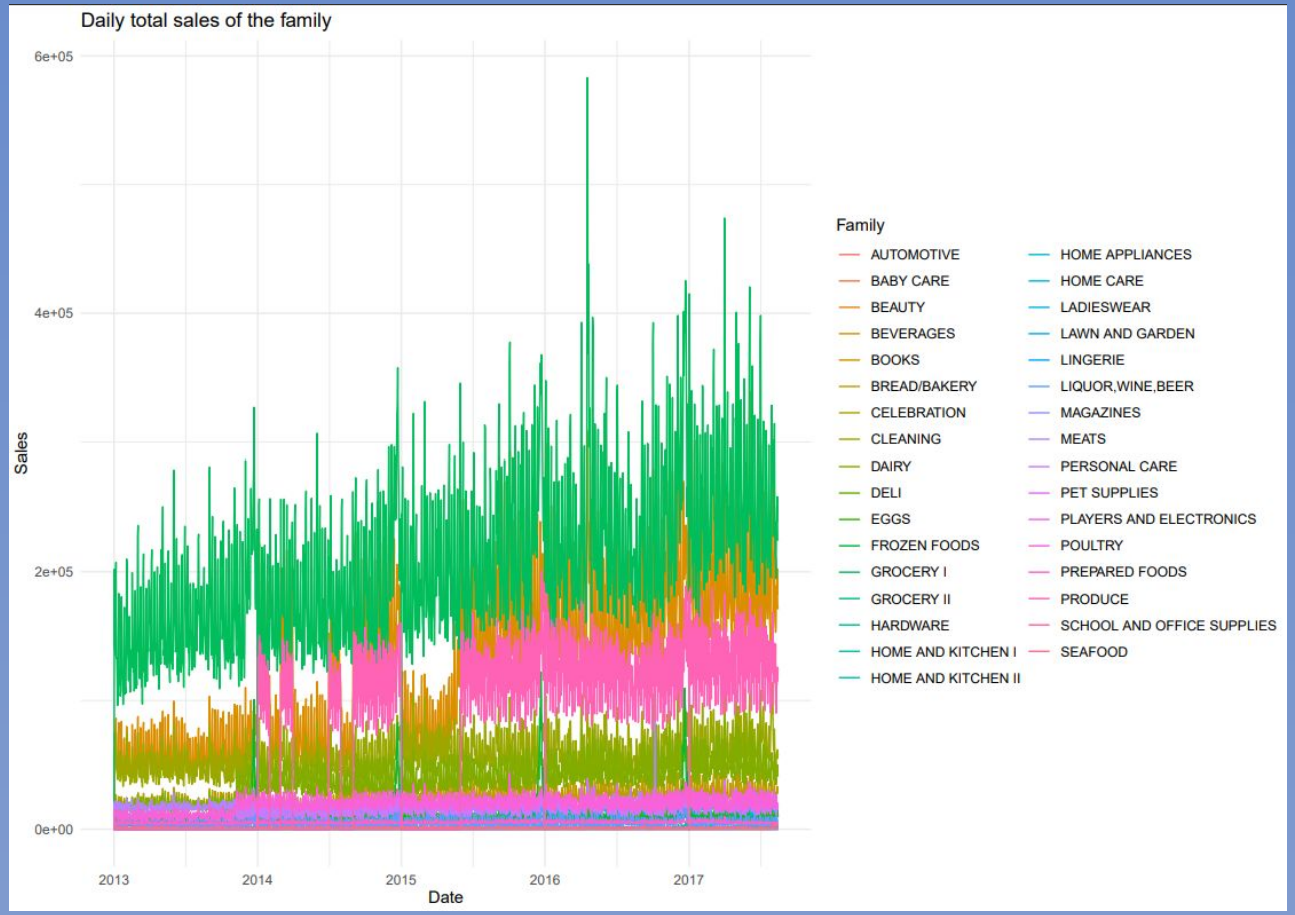
04 Holidays

Holiday Events

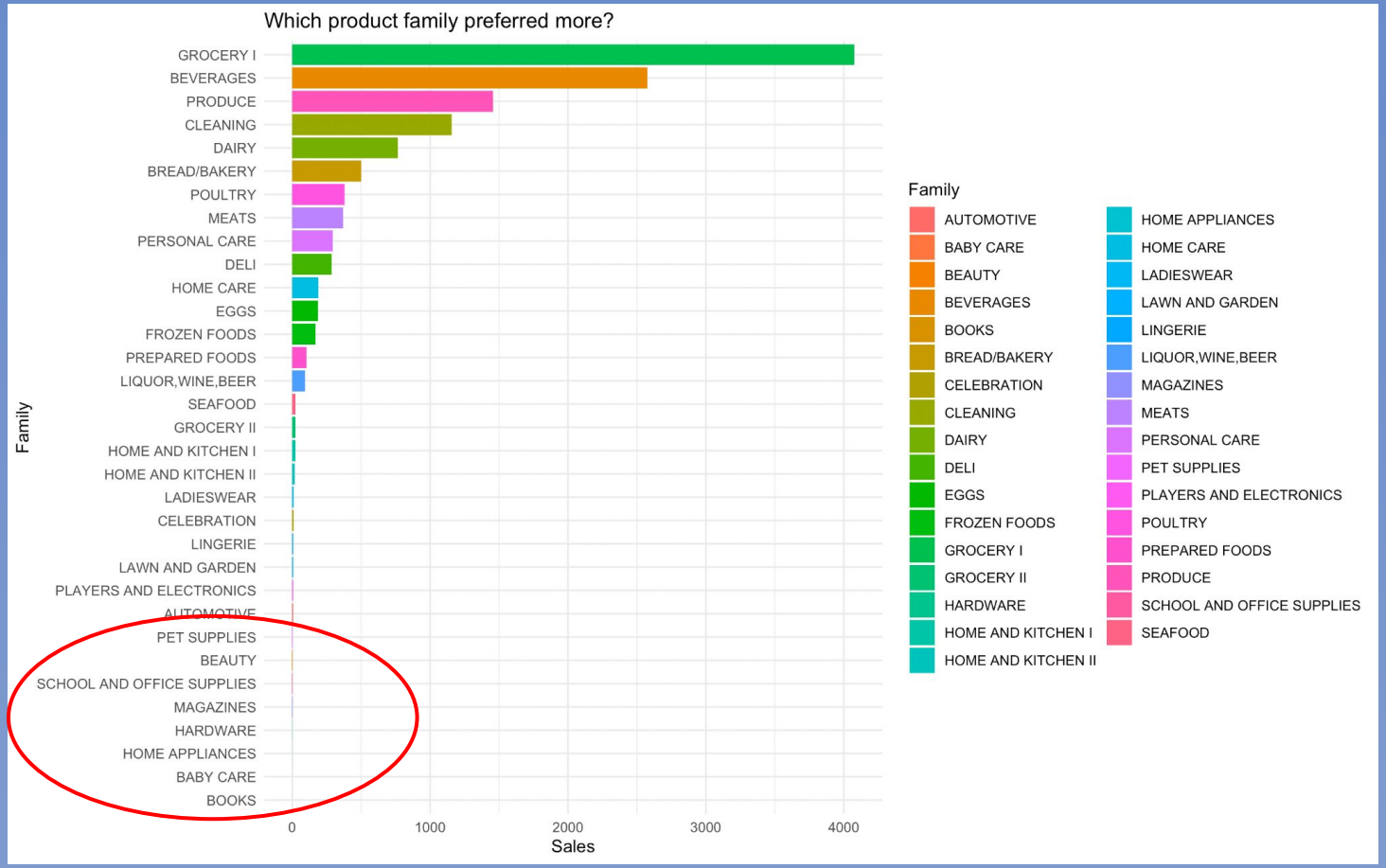
- Weekend (Blue line)
- Weekday (Red line)
- Holiday (Green line)

05 Sales

Total Sales by Family graph



Total Sales by Family graph



Zero forecasting

1. Group by store_nbr and family, then calculate the sum of sales
2. Anti Join function
3. Create zero_prediction data frame
4. Print the zero_prediction data frame

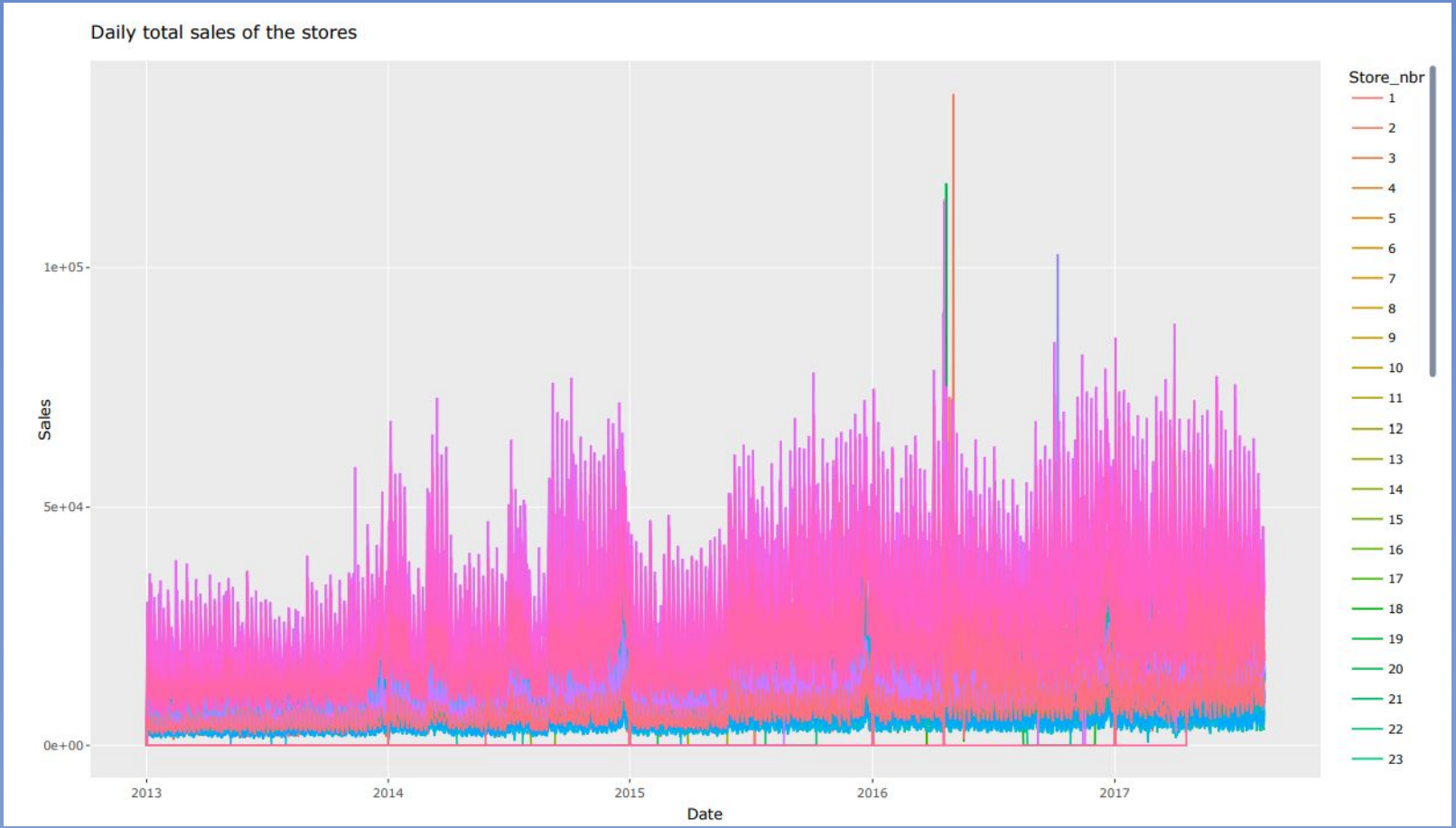
	date	store_nbr	family	sales
0	2017-08-16	1	BABY CARE	0
1	2017-08-17	1	BABY CARE	0
2	2017-08-18	1	BABY CARE	0
...	...	...	...	...
847	2017-08-30	54	LAWN AND GARDEN	0
848	2017-08-31	54	LAWN AND GARDEN	0

Does Ongoing Promotion Affect the Sales?

```
> cat("Spearman Correlation between Sales and Onpromotion:", format(spearman_correlatio
n, digits = 4), "\n")
Spearman Correlation between Sales and Onpromotion: 0.5304
```

Ongoing promotions have a moderate impact on sales

Total Sales by Stores graph

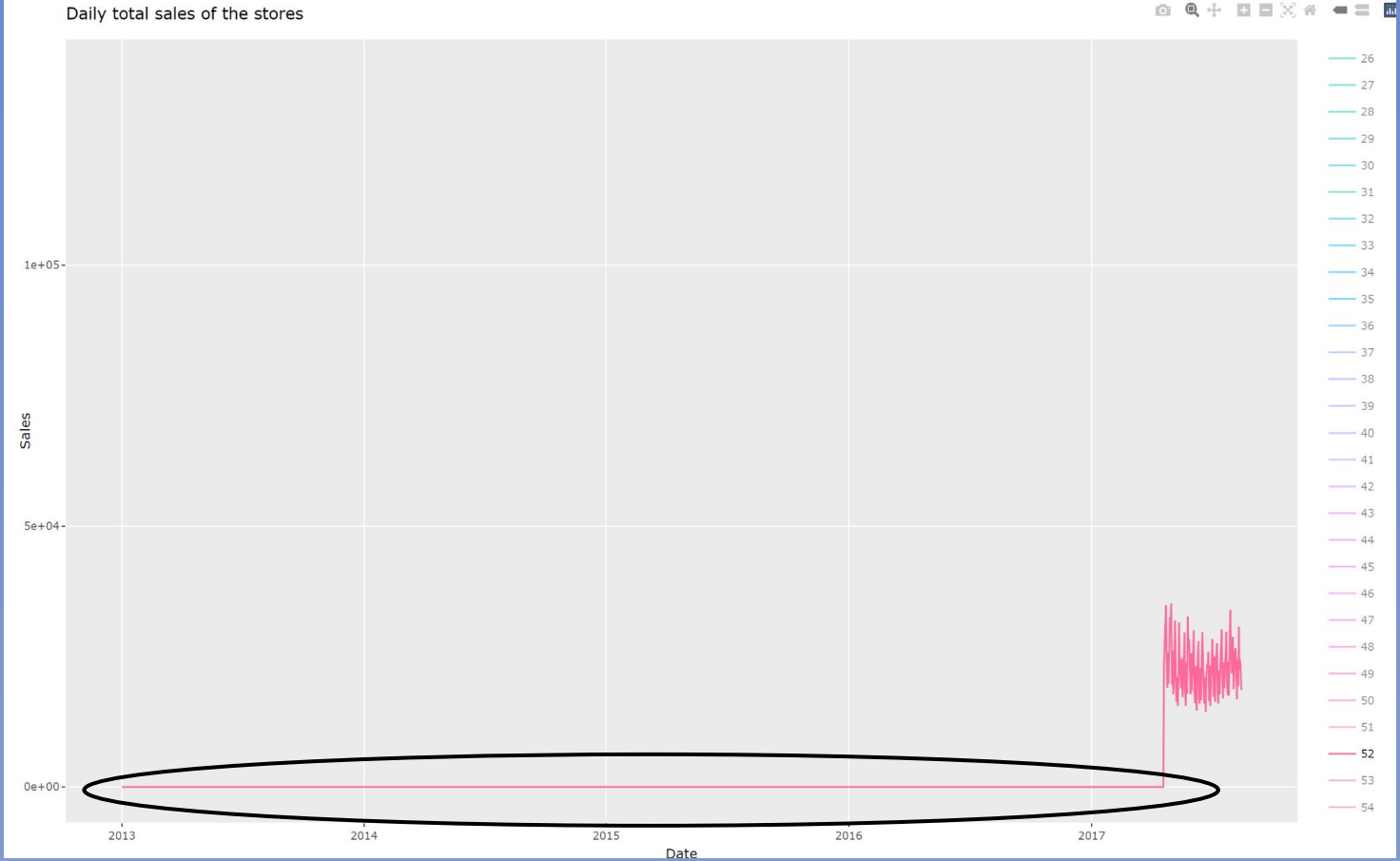


Total Sales by Stores graph

Total Sales by Stores graph

Anything abnormal?

Total Sales by Stores graph



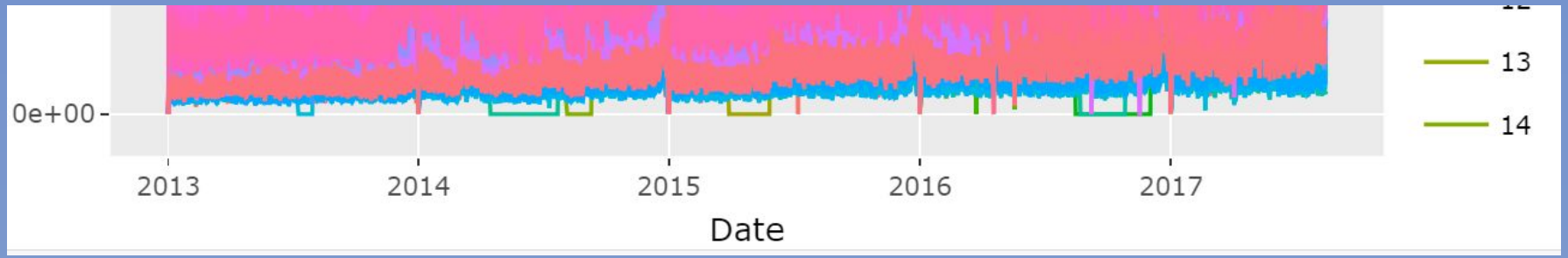
Data Cleaning: Removal of Sales before Store Opening

```
> # Print the shape of the train data frame
> cat("Shape of the train data frame before removing rows:", dim(train), "\n")
Shape of the train data frame before removing rows: 3000888 6
```

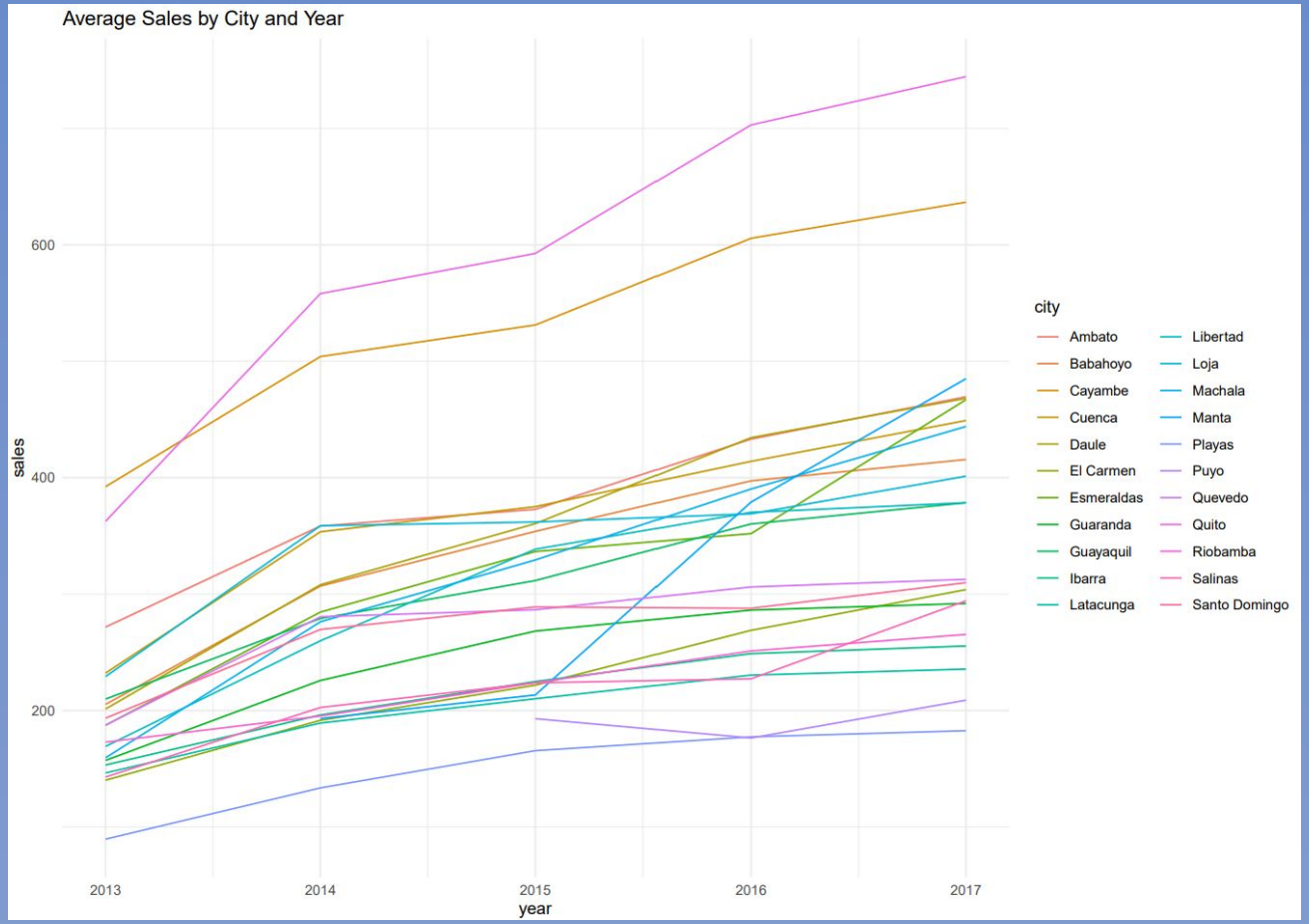
```
# Remove unnecessary rows
train <- train[!((train$store_nbr == 52) & (train$date < "2017-04-20")), ]
train <- train[!((train$store_nbr == 22) & (train$date < "2015-10-09")), ]
train <- train[!((train$store_nbr == 42) & (train$date < "2015-08-21")), ]
train <- train[!((train$store_nbr == 21) & (train$date < "2015-07-24")), ]
train <- train[!((train$store_nbr == 29) & (train$date < "2015-03-20")), ]
train <- train[!((train$store_nbr == 20) & (train$date < "2015-02-13")), ]
train <- train[!((train$store_nbr == 53) & (train$date < "2014-05-29")), ]
train <- train[!((train$store_nbr == 36) & (train$date < "2013-05-09")), ]
```

Data Cleaning: Removal of Sales before Store Opening

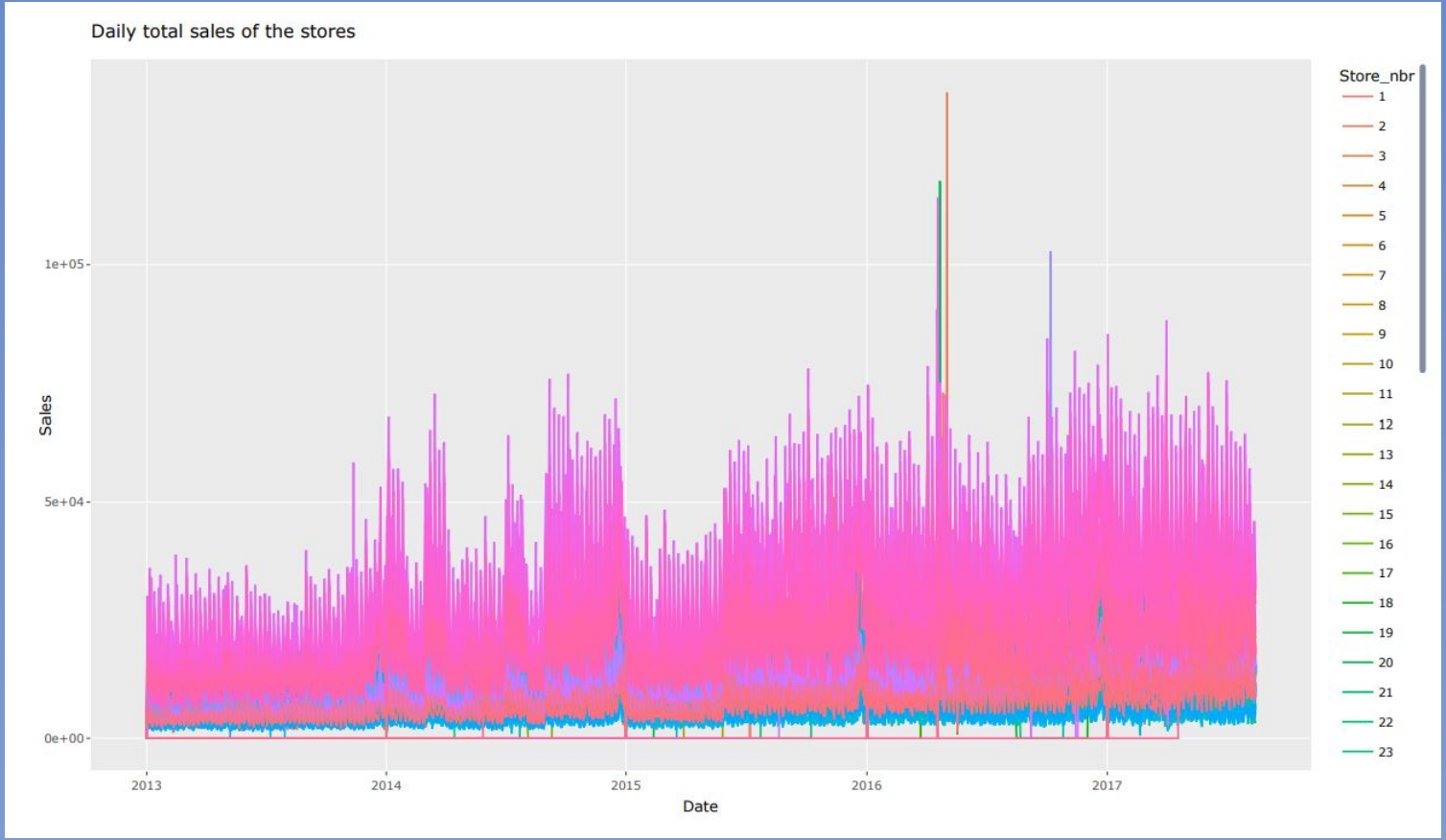
```
> # Print the shape of the train data frame after removing rows
> cat("Shape of the train data frame after removing rows:", dim(train), "\n")
Shape of the train data frame after removing rows: 2780316 6
```



Average Sales by City graph



Total Sales Graph by stores

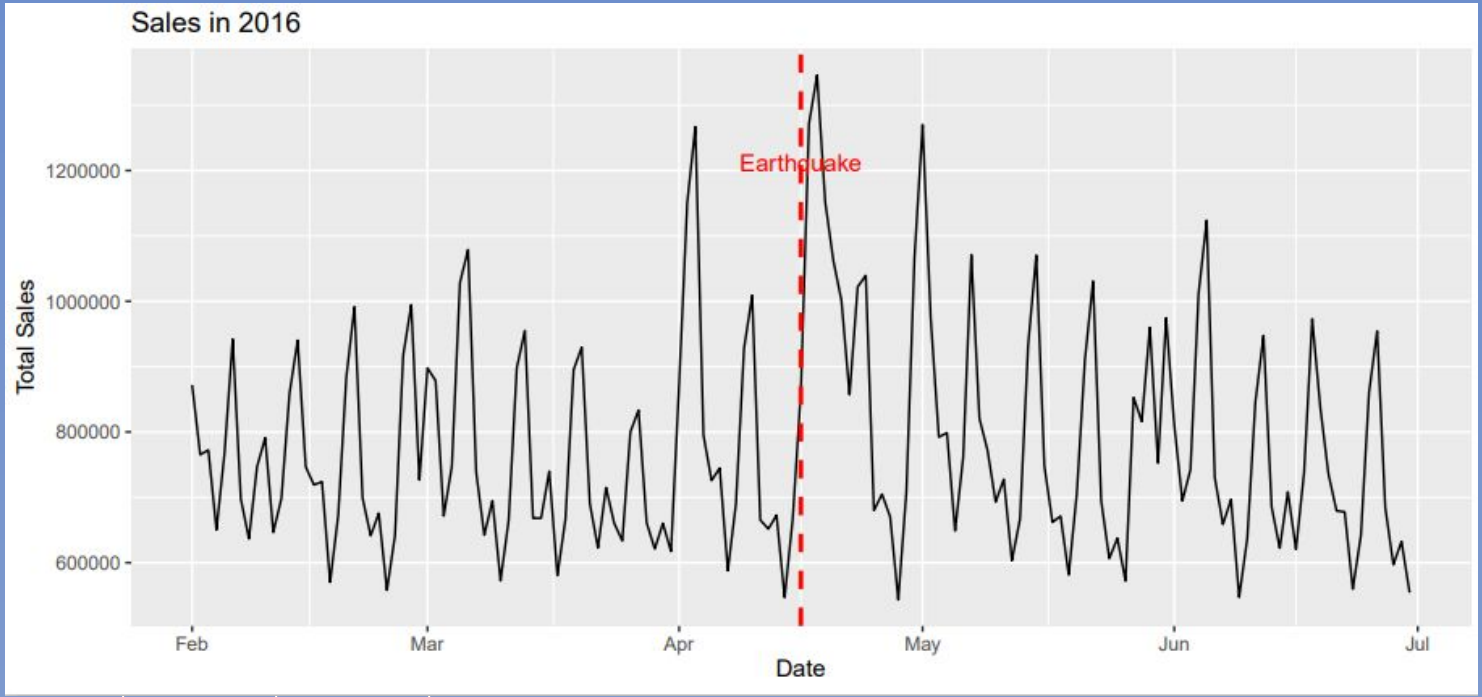


06 Additional Info

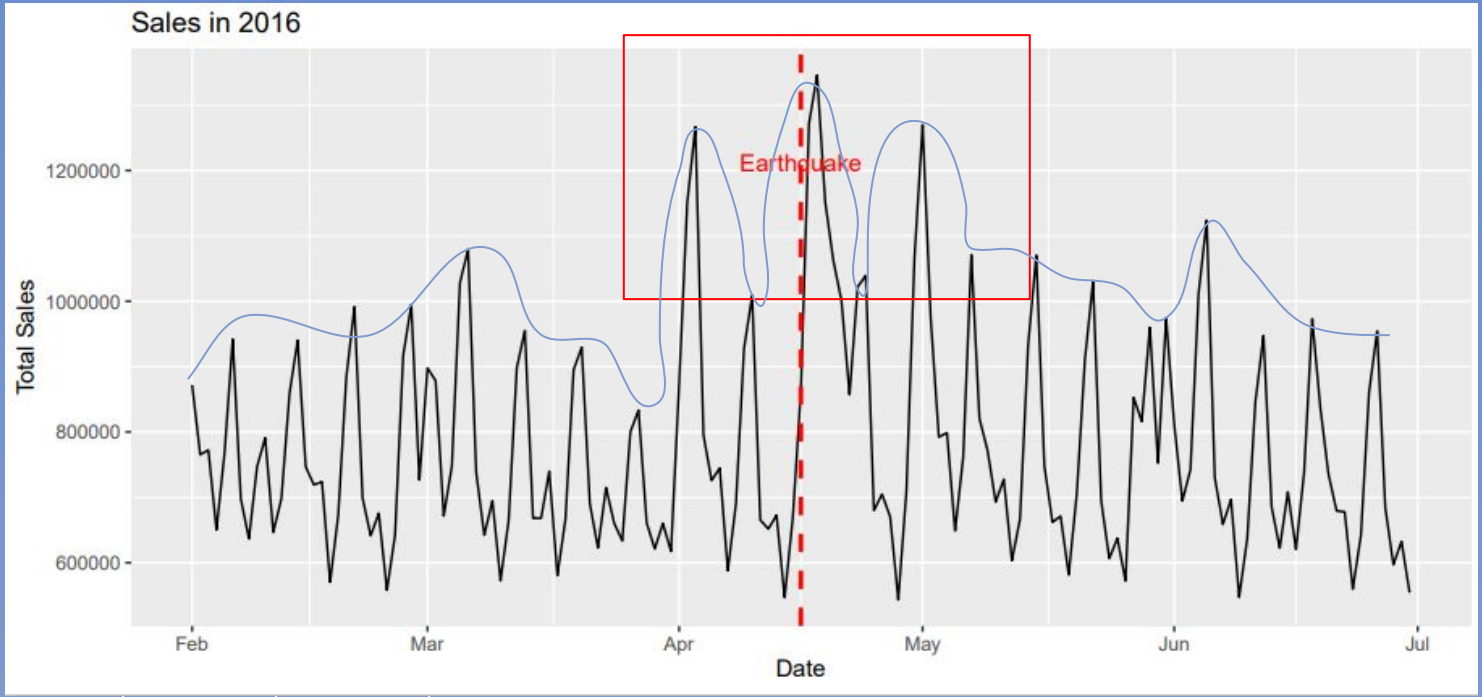
Earthquake

A magnitude 7.8 earthquake struck Ecuador on April 16, 2016.

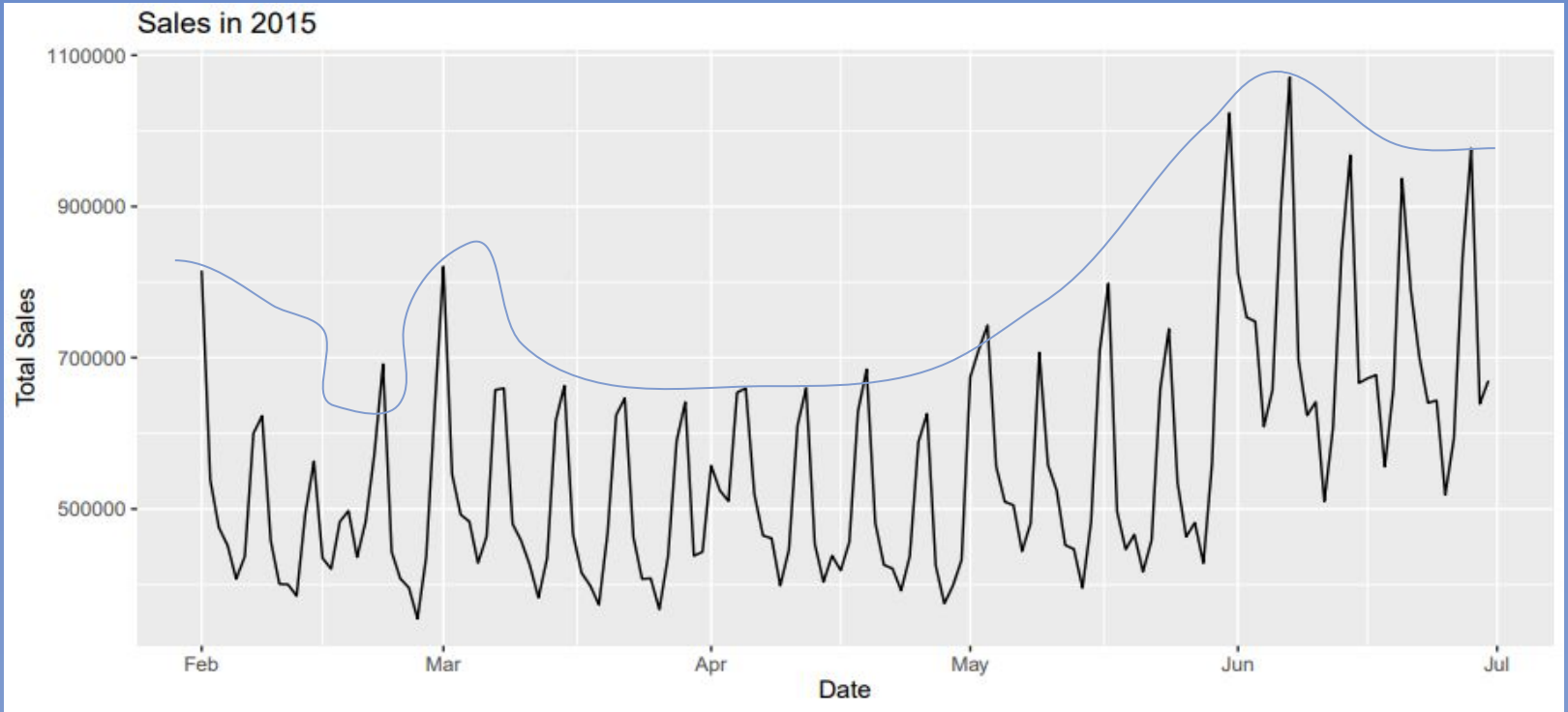
Total Sales Trend in 2016



Total Sales Trend in 2016



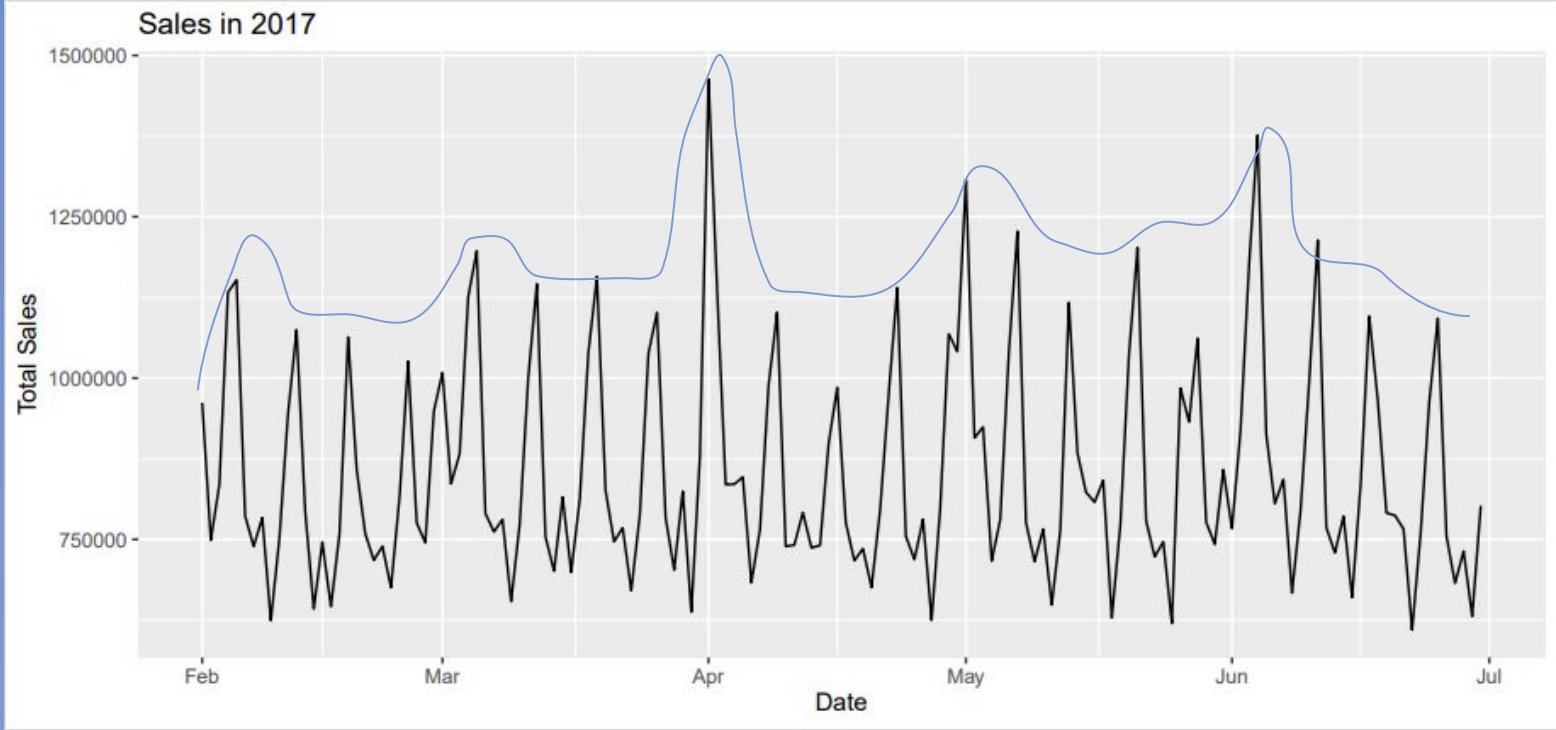
Total Sales Trend in 2015



Holiday Events

- Weekend (Blue line)
- Weekday (Red line)
- Holiday (Green line)

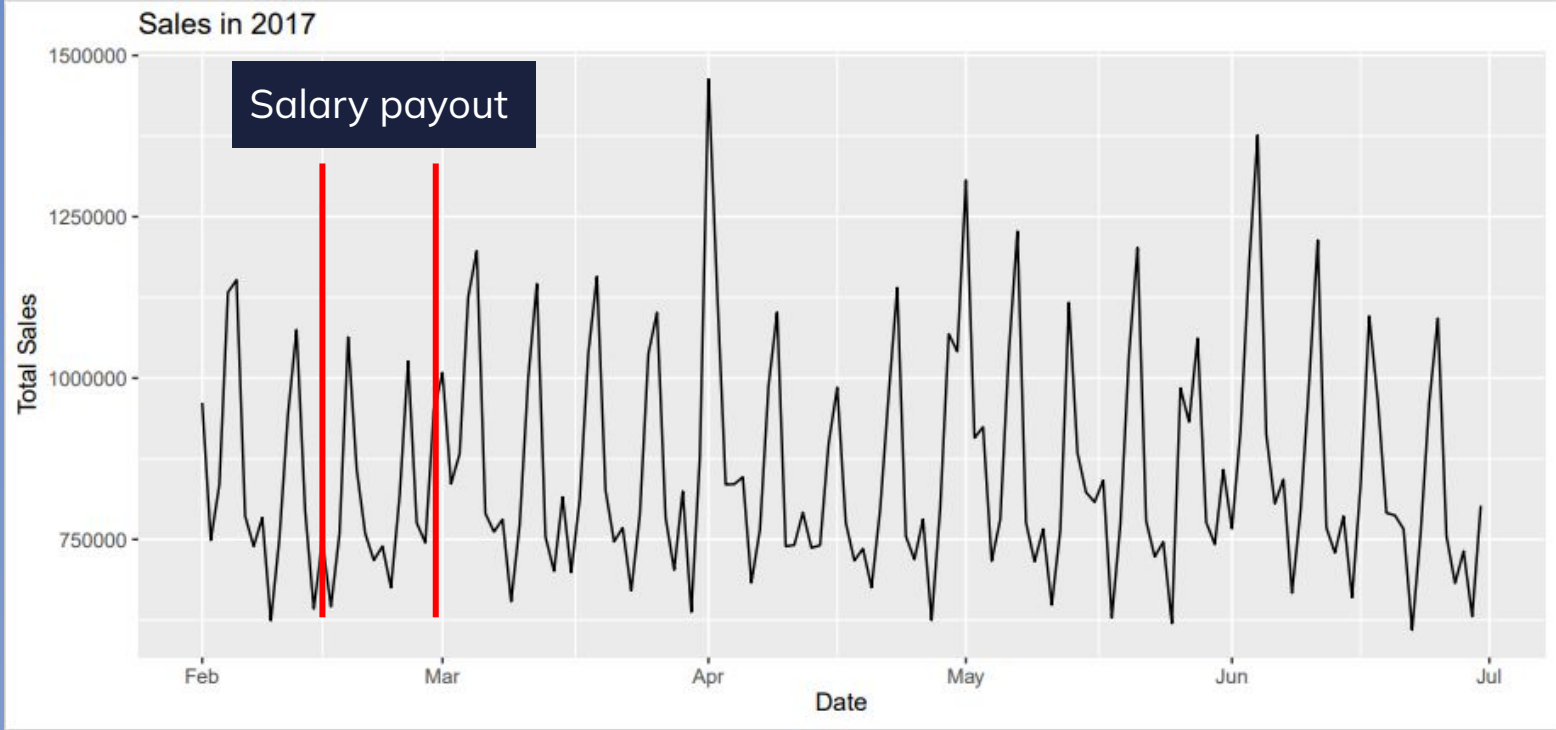
Total Sales Trend in 2017



Salary Payout

Wages in the public sector are paid every two weeks on the 15th and on the last day of the month

Total Sales Trend in 2017



08

Data Modelling

You can enter a subtitle here if you need it

Train Test Split

- Split 95-5
- Capture seasonality
- Small data set (4 years only)
-

Observing ACF and PACF

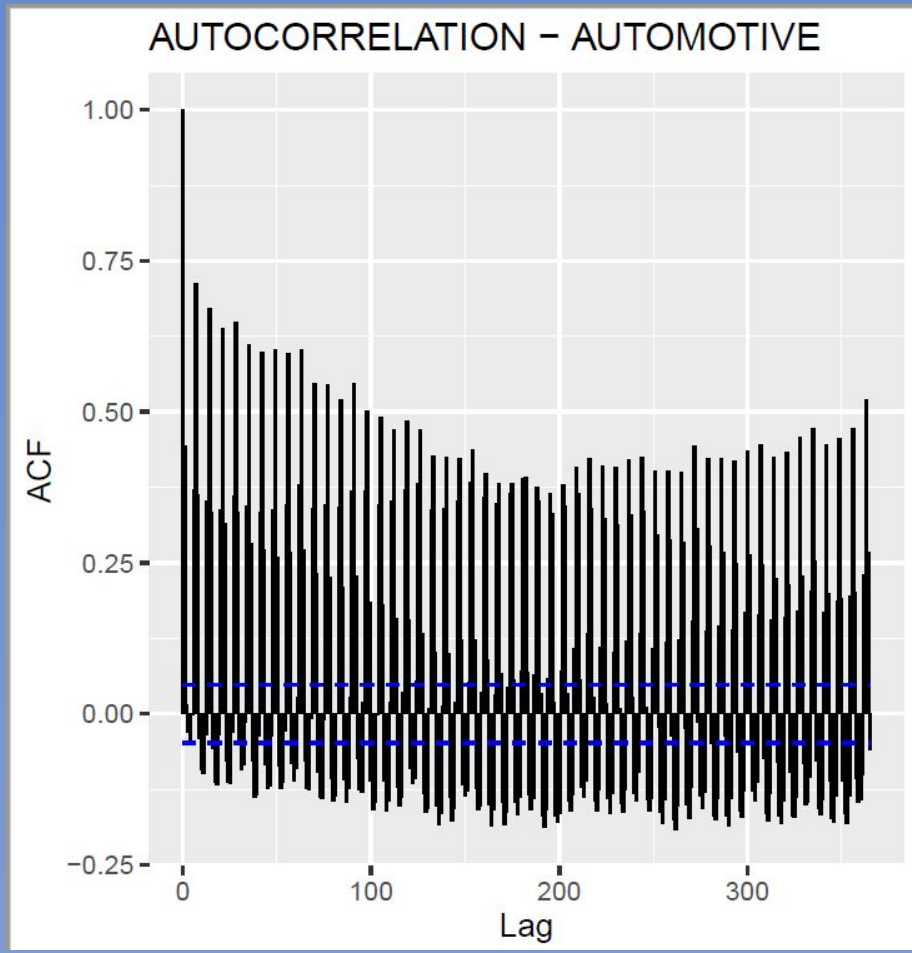
Looking at the ACF and PACF can help us decide on which timeseries model to use

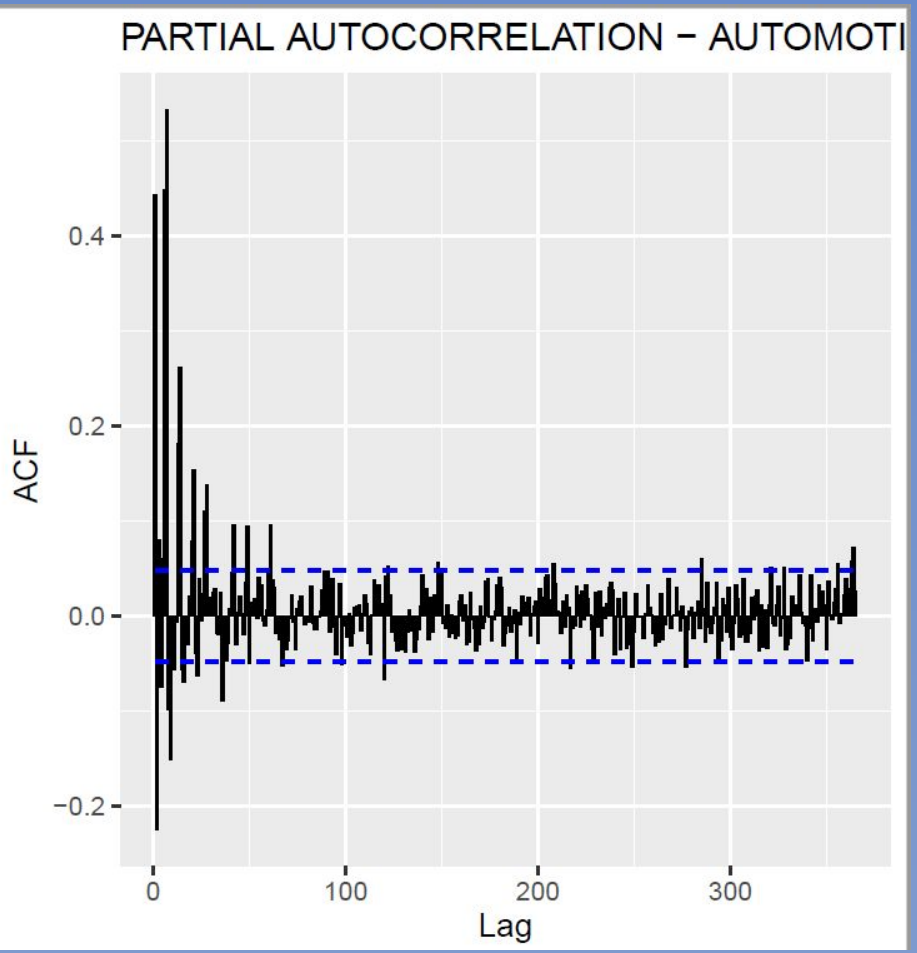
Manual Model Selection

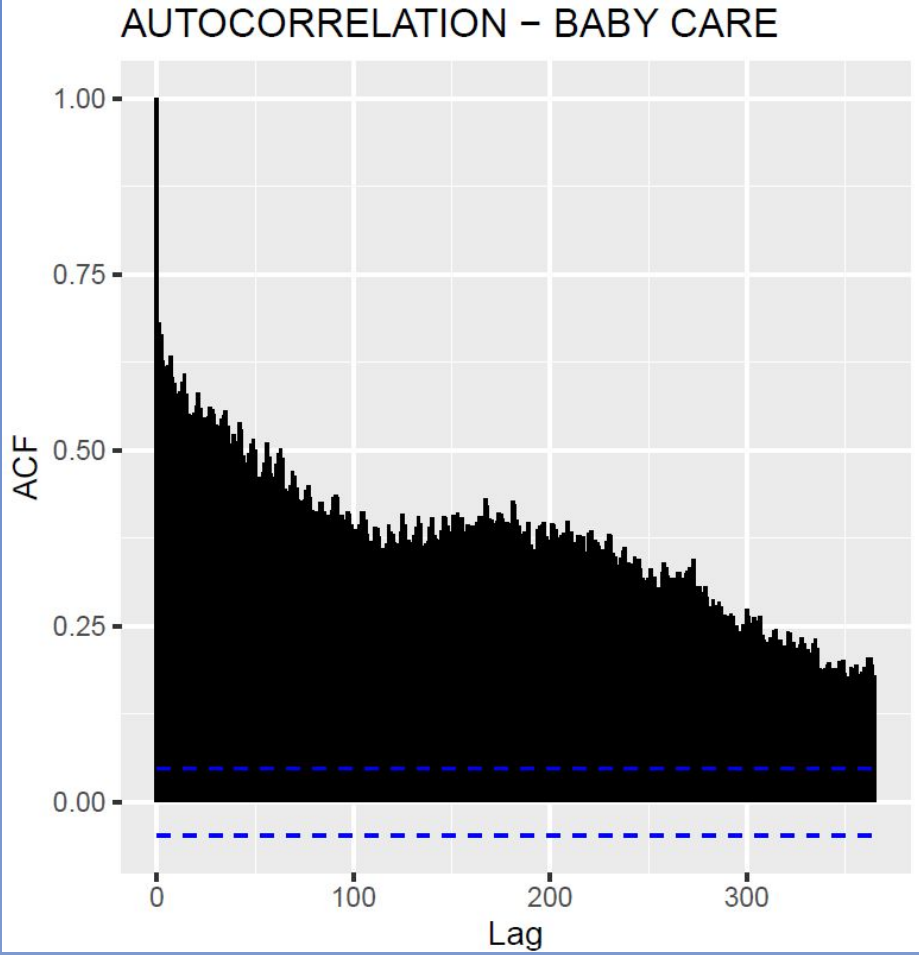
AR/MA/ models:

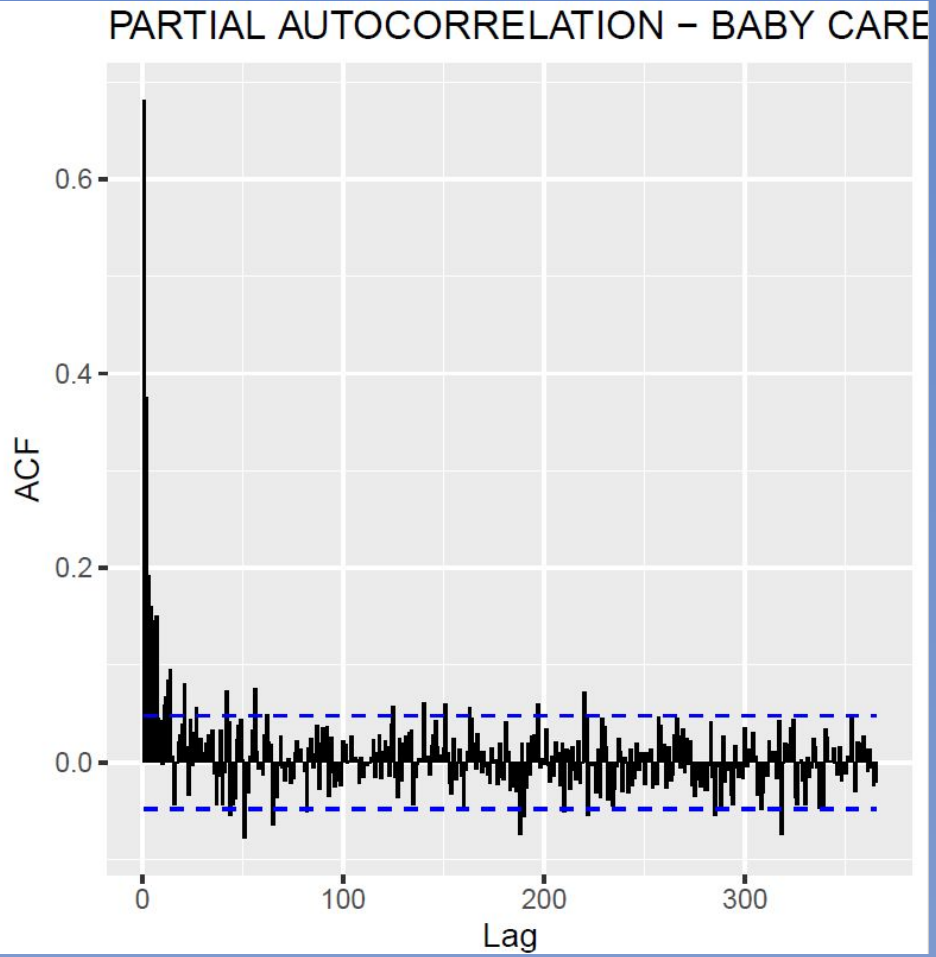
- Select based on shape of ACF and PACF curves

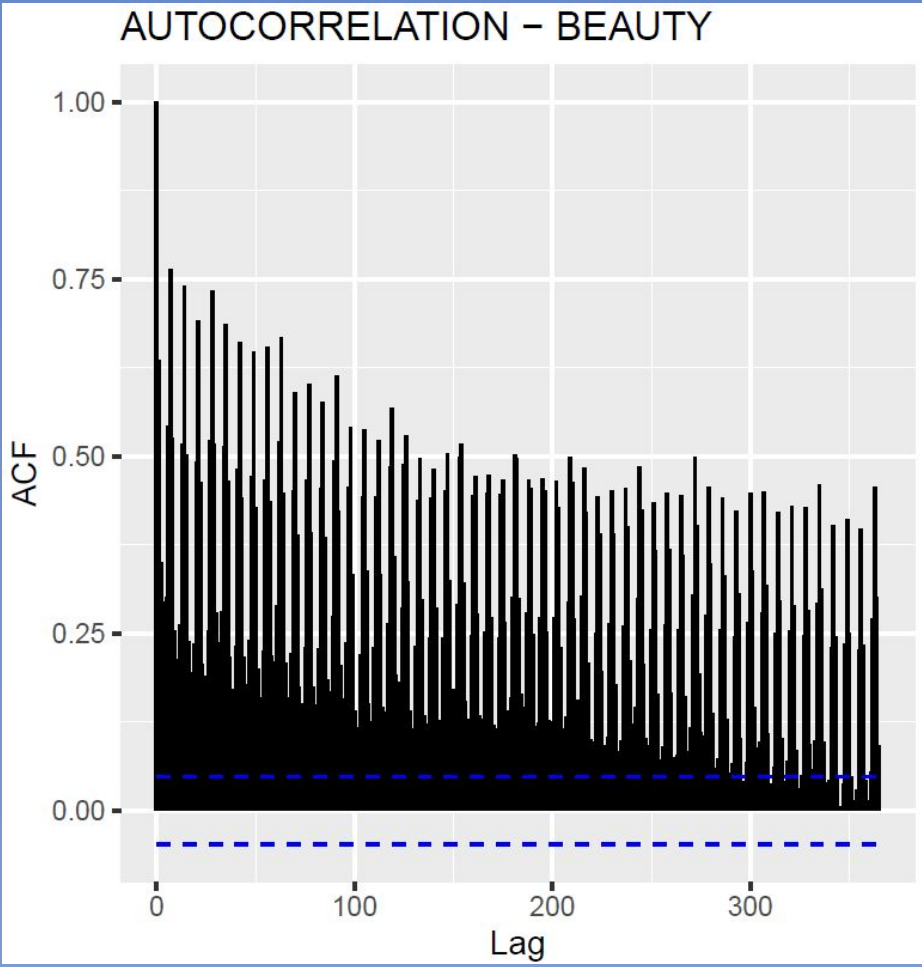
	AR(p)	MA(q)	ARMA(p,q)
ACF	Tails off	Cuts off after lag q	Tails off
PACF	Cuts off after lag p	Tails off	Tails off

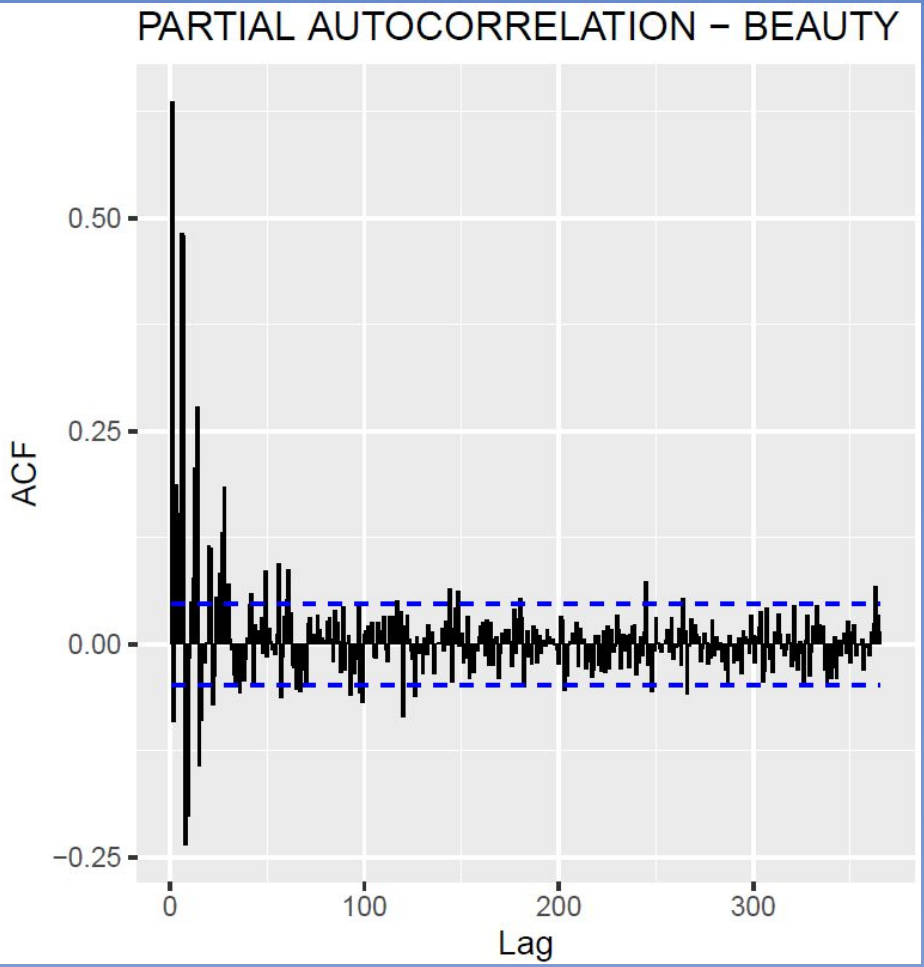

AUTOCORRELATION − AUTOMOTIVE
ACF
1.00
0.75
0.50
0.25
0.00
−0.25
0
100
200
300
Lag

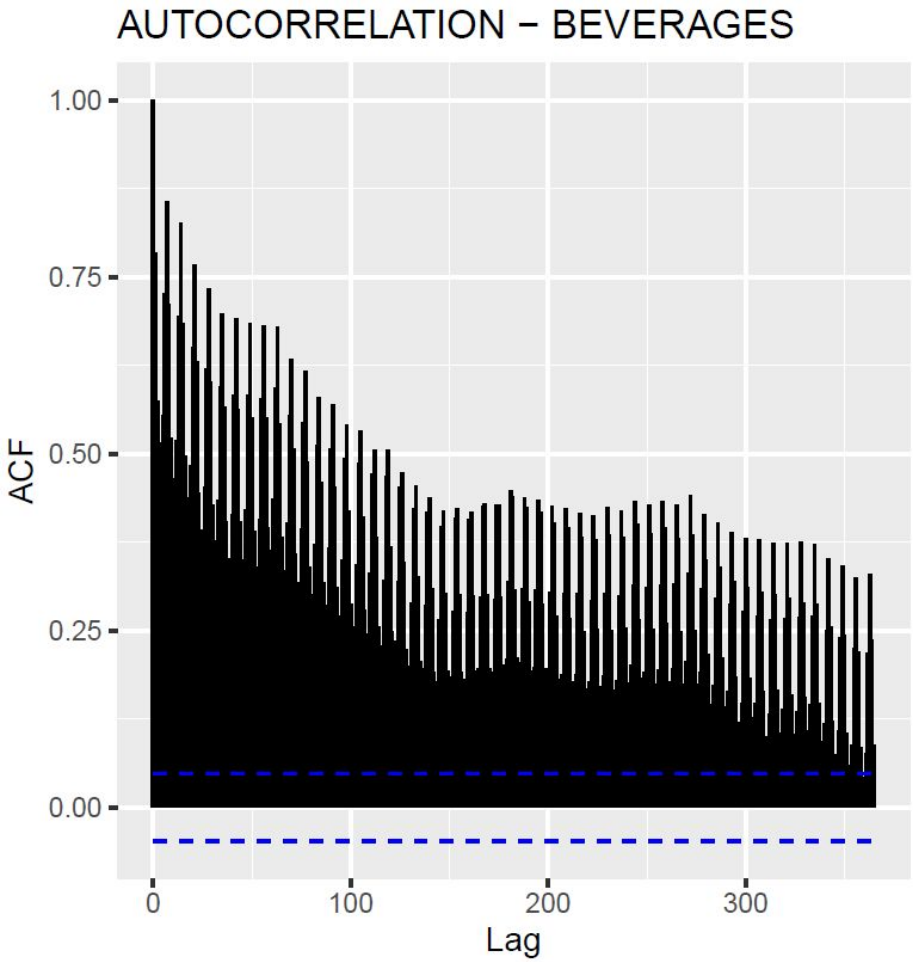

PARTIAL AUTOCORRELATION − AUTOMOTI
ACF
0.4
0.2
0.0
−0.2
0
100
200
300
Lag

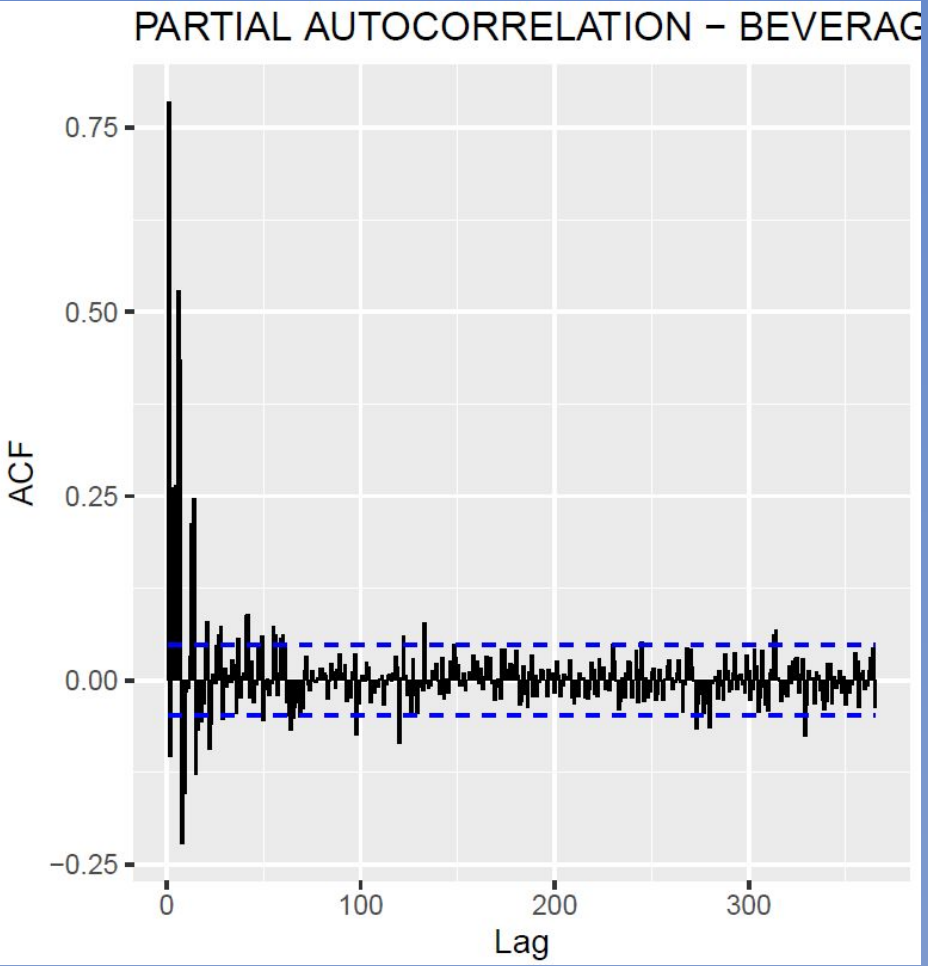

AUTOCORRELATION − BABY CARE
1.00
0.75
0.50
0.25
0.00
ACF
0
100
200
300
Lag

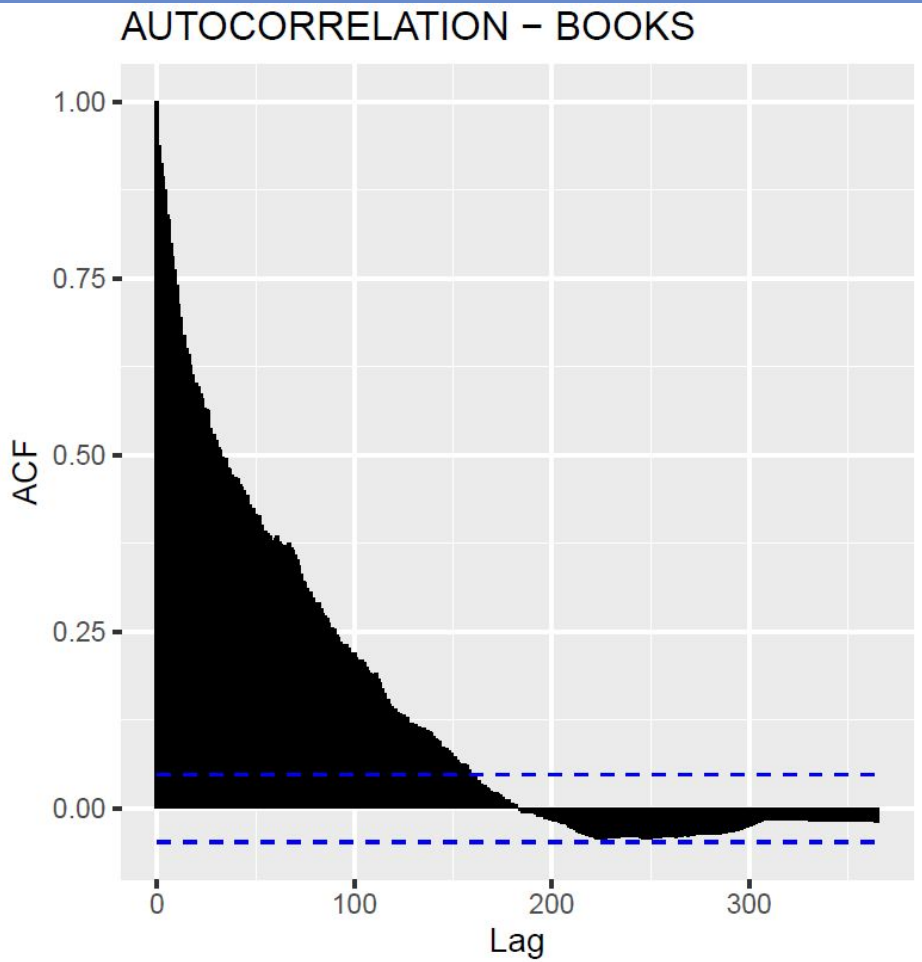

PARTIAL AUTOCORRELATION − BABY CARE
0.6
0.4
0.2
0.0
ACF
0
100
200
300
Lag

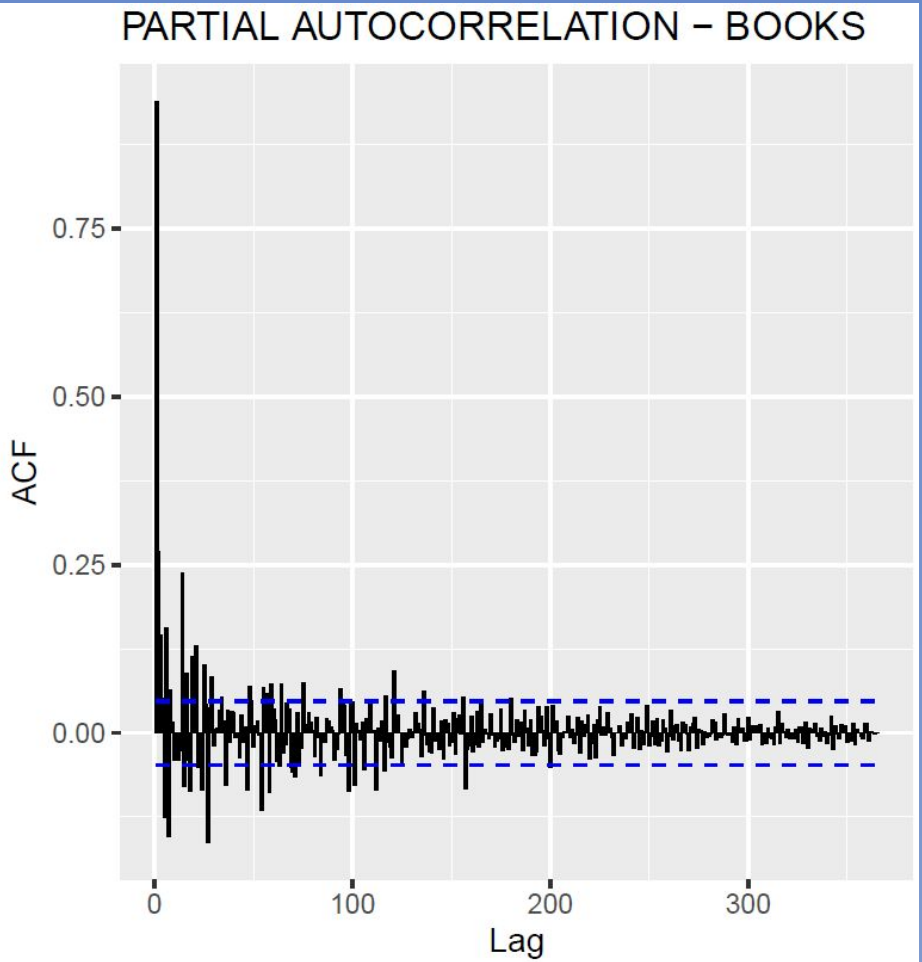

AUTOCORRELATION − BEAUTY
1.00
0.75
0.50
0.25
0.00
ACF
0
100
200
300
Lag


PARTIAL AUTOCORRELATION − BEAUTY
0.50
0.25
0.00
−0.25
ACF
0
100
200
300
Lag


AUTOCORRELATION − BEVERAGES
ACF
1.00
0.75
0.50
0.25
0.00
0
100
200
300
Lag


PARTIAL AUTOCORRELATION − BEVERAG
ACF
0.75
0.50
0.25
0.00
−0.25
0
100
200
300
Lag

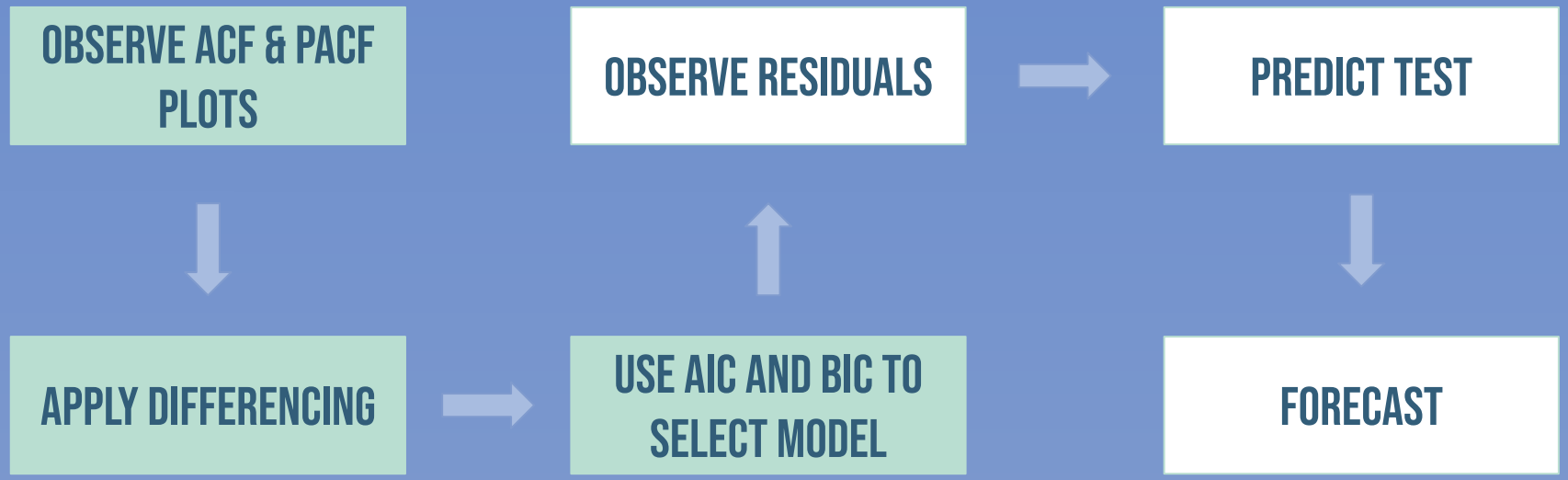

AUTOCORRELATION − BOOKS
1.00
0.75
0.50
0.25
0.00
ACF
0
100
200
300
Lag


PARTIAL AUTOCORRELATION − BOOKS
0.75
0.50
0.25
0.00
ACF
0
100
200
300
Lag

AUTO.ARIMA

- Function in R
- Automatically fits ARIMA
- Selects best set of p, d and q
  - p = number of autoregressive terms
  - d = number of non seasonal differences needed for stationarity (number of differencing)
  - q = number of lagged forecast errors in the prediction equation.
- Selects by minimising the following:
  - Akaike information criterion (AIC)
  - Corrected AIC (AICc)
  - Bayesian information criterion (BIC)
- Helps to reduce overfitting

AUTO.ARIMA


OBSERVE ACF & PACF PLOTS
APPLY DIFFERENCING
USE AIC AND BIC TO SELECT MODEL
OBSERVE RESIDUALS
PREDICT TEST
FORECAST

Results

```
[1] "ARIMA Model for AUTOMOTIVE"
Series: temp_ts
ARIMA(5,1,1)

Coefficients:
          ar1      ar2      ar3      ar4      ar5      ma1
      -0.0858  -0.5244  -0.3347  -0.3264  -0.5174  -0.5070
s.e.   0.0260   0.0200   0.0237   0.0199   0.0226   0.0239

sigma^2 = 2.087:  log likelihood = -3005.98
AIC=6025.97   AICc=6026.03   BIC=6063.97

Training set error measures:
                     ME     RMSE      MAE       MPE    MAPE      MASE       ACF1
Training set 0.01305924 1.441737 1.069434 -44.44319 57.6048 0.4595702 -0.0940294
```

Results

```
[1] "ARIMA Model for BEAUTY"
Series: temp_ts
ARIMA(5,1,1)

Coefficients:
          ar1      ar2      ar3      ar4      ar5      ma1
      -0.0915  -0.4884  -0.3215  -0.3068  -0.4997  -0.4049
s.e.   0.0275   0.0204   0.0237   0.0203   0.0227   0.0255

sigma^2 = 1.283:  log likelihood = -2596.21
AIC=5206.41   AICc=5206.48   BIC=5244.41

Training set error measures:
                     ME     RMSE       MAE       MPE     MAPE      MASE        ACF1
Training set 0.01243027 1.130373 0.7889472 -23.23123 38.30125 0.4634453 -0.08072335
```

Results

```
[1] "ARIMA Model for BABY CARE"
Series: temp_ts
ARIMA(2,1,1)

Coefficients:
         ar1     ar2      ma1
      0.1444  0.1023  -0.9139
s.e.  0.0289  0.0279   0.0147

sigma^2 = 0.01467:  log likelihood = 1165.37
AIC=-2322.74   AICc=-2322.71   BIC=-2301.02

Training set error measures:
                       ME      RMSE        MAE  MPE MAPE      MASE          ACF1
Training set 0.001153815 0.1209867 0.05902519 -Inf  Inf 0.4191347 -0.0002685704
```

Results

```
[1] "ARIMA Model for BOOKS"
Series: temp_ts
ARIMA(3,1,4) with drift

Coefficients:
          ar1      ar2      ar3     ma1     ma2      ma3      ma4   drift
      -2.0968  -1.8444  -0.7089  1.8449  1.1816  -0.0364  -0.2731  0.0000
s.e.   0.0622   0.0587   0.0423  0.0708  0.0695   0.0862   0.0425  0.0025

sigma^2 = 0.02469:  log likelihood = 730.04
AIC=-1442.08   AICc=-1441.97   BIC=-1393.22

Training set error measures:
                       ME      RMSE        MAE MPE MAPE      MASE        ACF1
Training set 1.944065e-06 0.1567244 0.03886142 NaN  Inf 0.2070074 -0.01084568
```

Observing Residuals

```
> # Calculate the mean of the residuals to check if they are centered around zero:
> mean(combined_residuals)
[1] -1.383473
>
```

Observing mean of residuals

- Mean should be 0, with residuals scattered around 0
- Not near 0
- Residuals may not be random
- There could be something the model is not accounting for

Observing Residuals

```
> # Perform the Ljung-Box test to check for autocorrelation in the residuals:
> library(lmtest)
> Box.test(combined_residuals, lag = 10, type = "Ljung-Box")

        Box-Ljung test

data:  combined_residuals
X-squared = 1084.9, df = 10, p-value < 2.2e-16
```

Box test on residuals

- P value is small

Which to Reject If p-value Is Small?

Here are the basics of the Ljung-Box test:

Hypotheses

The Ljung-Box test uses the following hypotheses:

H_0: The residuals are independently distributed.

H_A: The residuals are not independently distributed; they exhibit serial correlation.

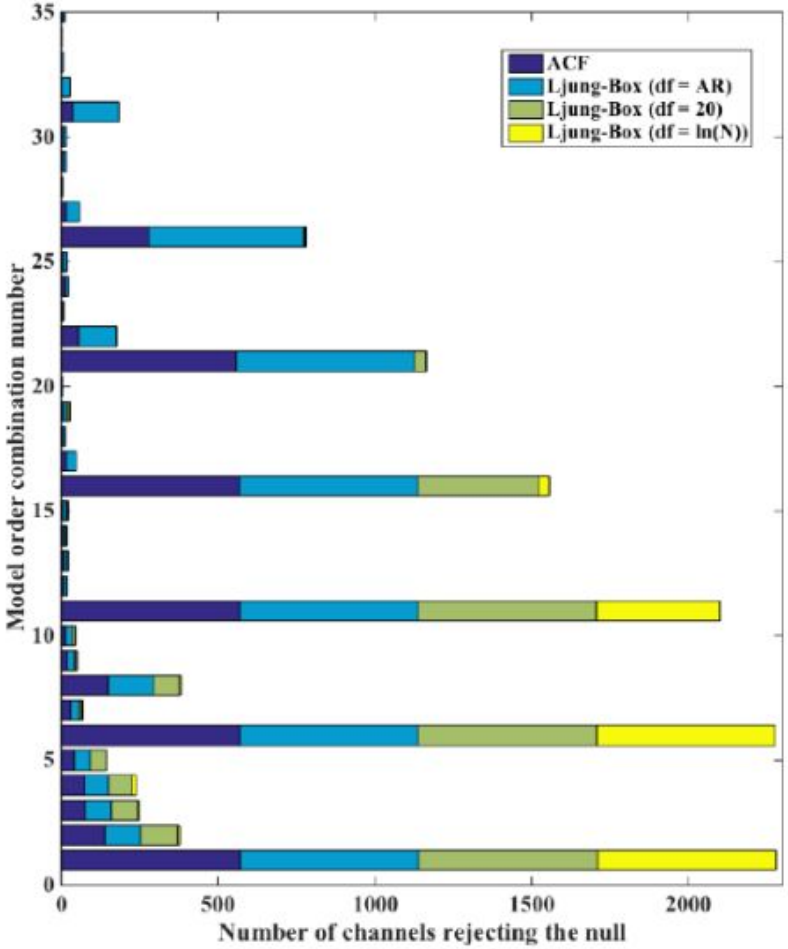


Fig. 5: ACF and Ljung-Box Attributes Compared

Disparity in conclusions?

What degree of freedom should we use?

Source: (Mahan et al., 2015)

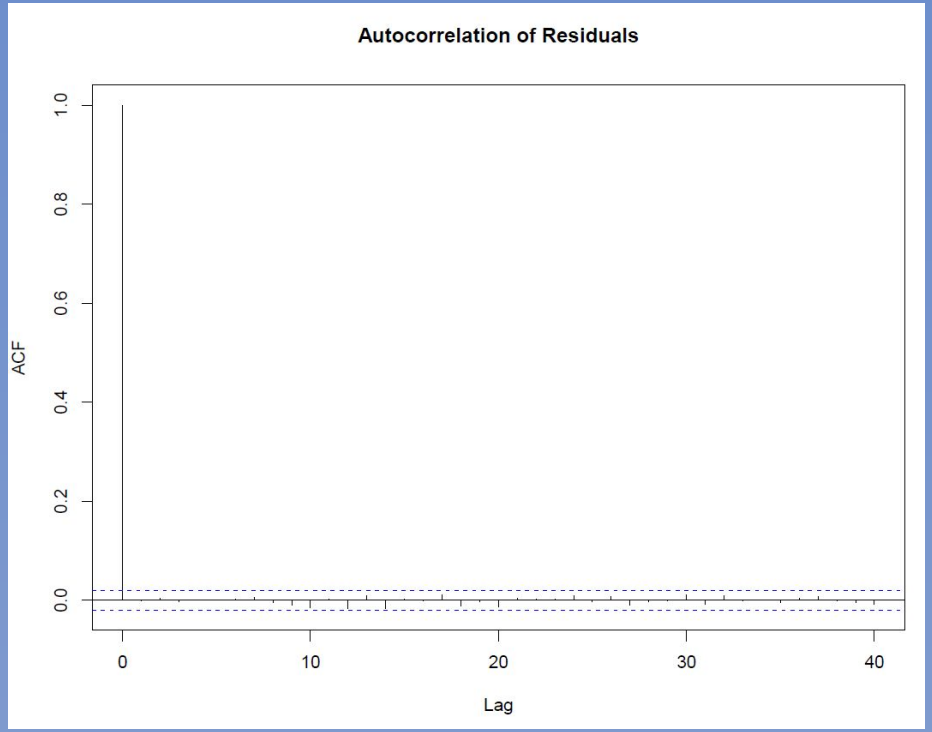
the Ljung-Box, showed similar results. It can be seen that the Ljung-Box corresponds well to our ACF thresholding when the df equal the AR order but fails to identify autocorrelation using either of the suggested df. Finally, the Breusch-Godfrey and Ljung-Box statistics are compared in terms of the percent of residual series failing each statistic (Table 4).

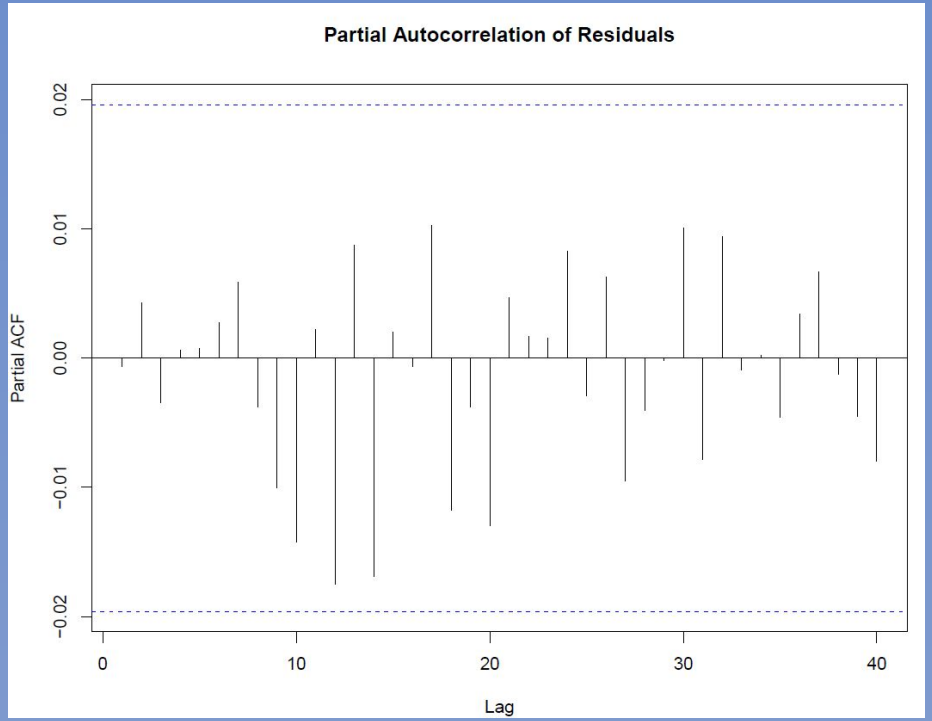
```
> print(ljung_box_test)

        Box-Ljung test

data:  combined_initial_residuals$x
X-squared = 243.07, df = 5, p-value < 2.2e-16
```

Determining Degrees of Freedom

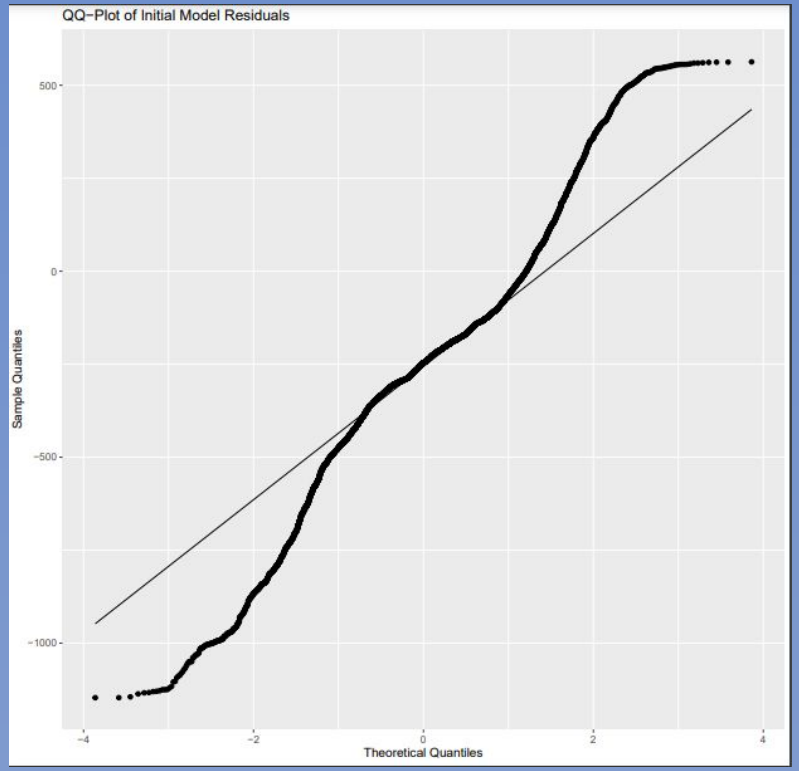
- Lags = df + parameters estimated
- ARIMA(5,1,1) has 7 parameters
- Lags = 12, df = 5

Observe Residuals





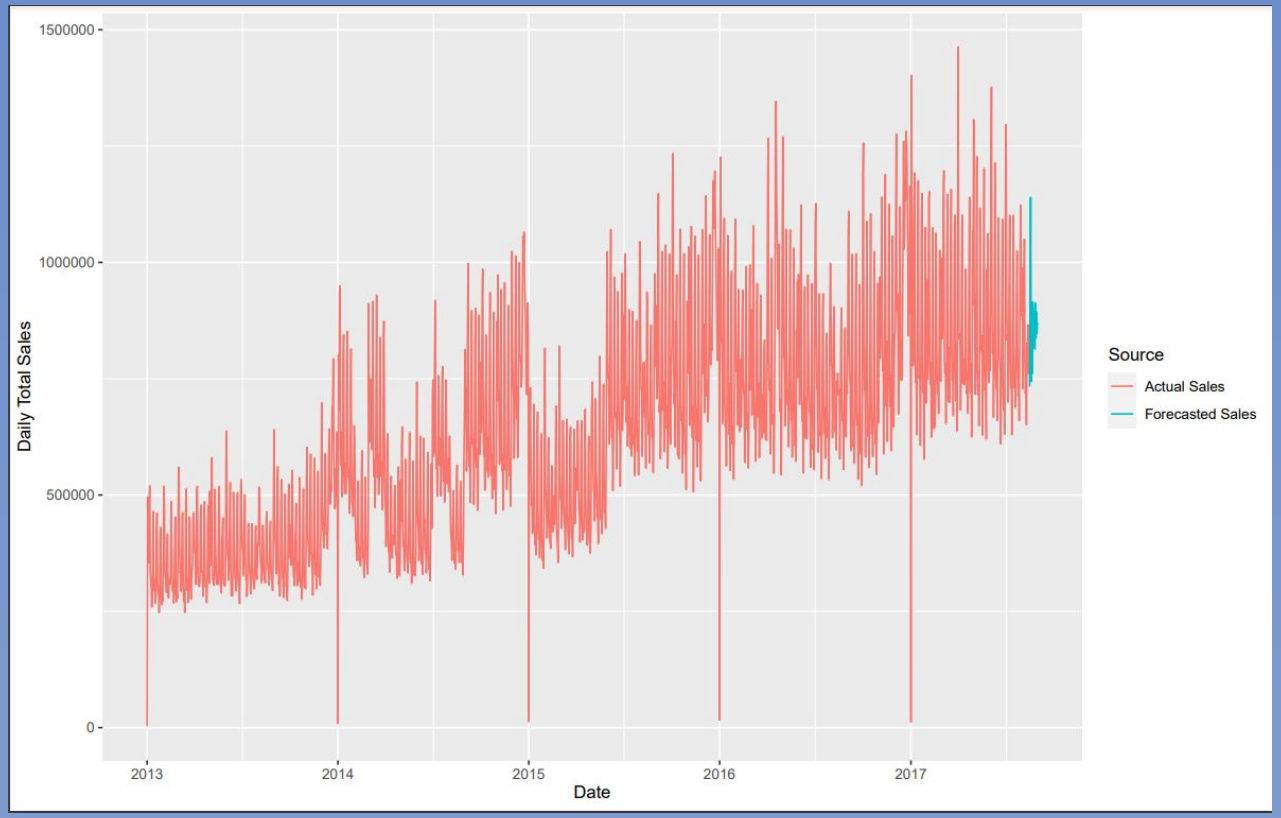
Observe Residuals



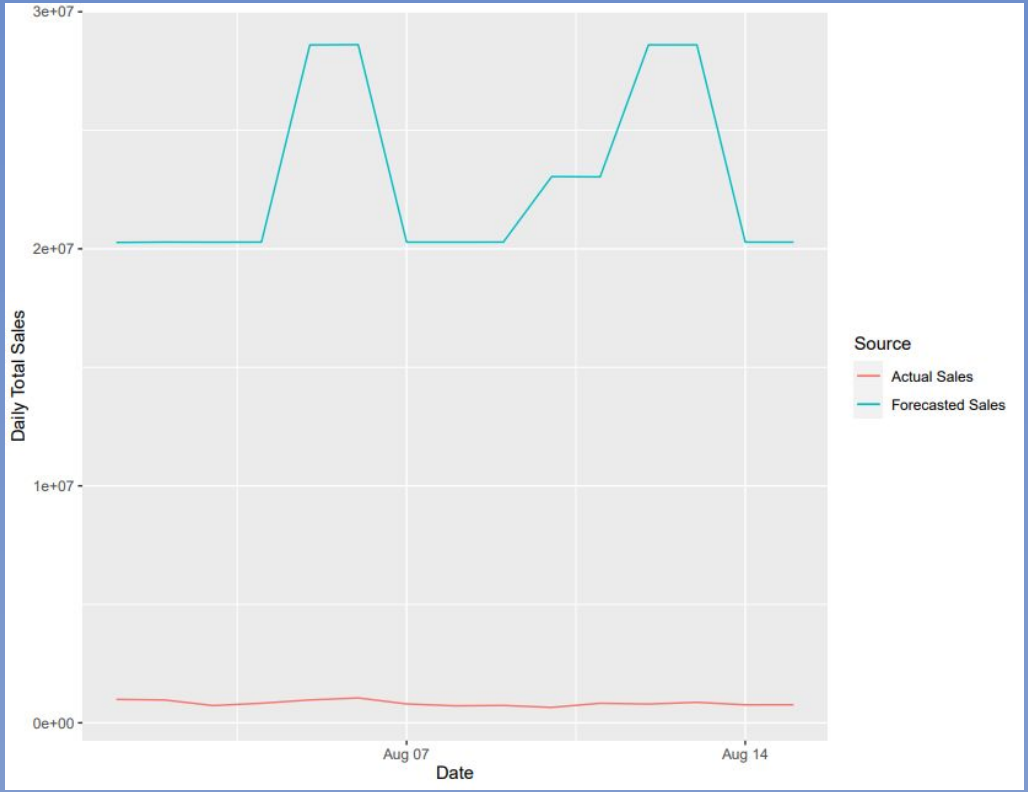
Is this normal?

- Normal should lie on the straight line
- Bimodal qq plot?
- Light tailed?
- **Not normal, residuals are not white noise**

Forecasting



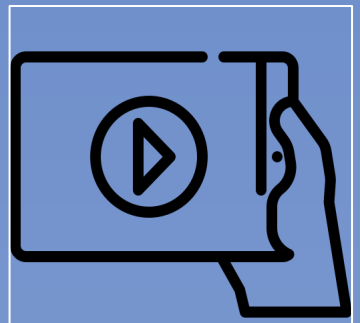
Check Test Against Forecasted



Improving Model

Log Transformation

- Stabilize variances
- Normalize data
- Improve interpretability



Before:

```
> mean(combined_residuals)
[1] -1.383473
```

```
        Box-Ljung test

data:  combined_initial_residuals$x
X-squared = 243.07, df = 5, p-value < 2.2e-16
```

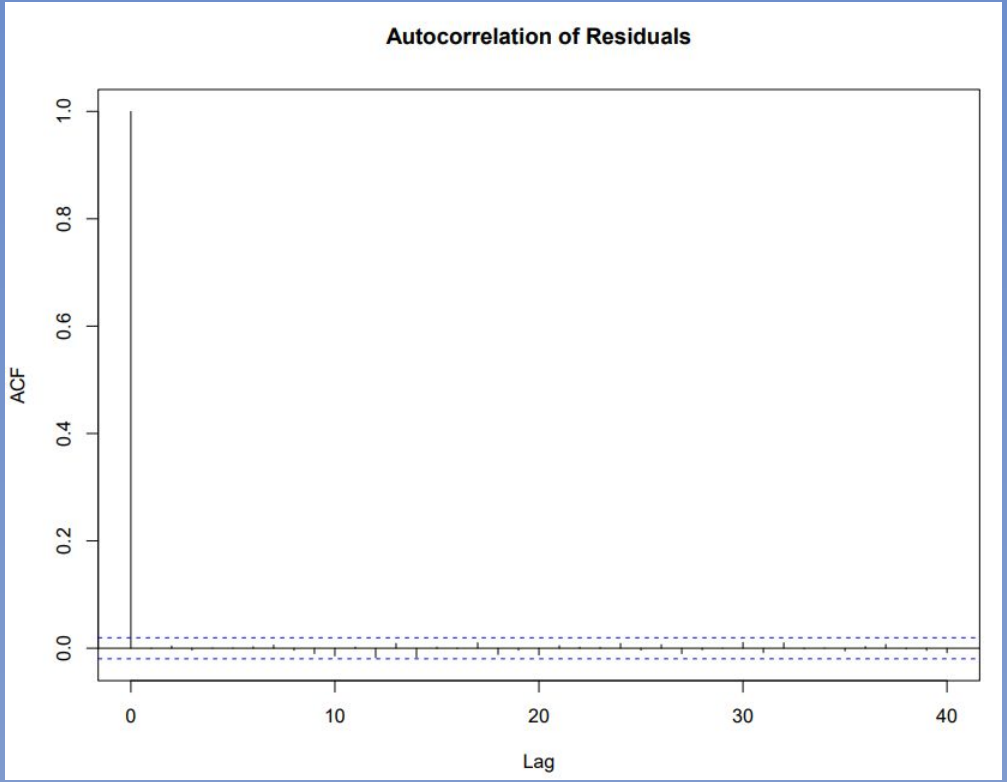
After:

```
> mean(combined_new_residuals$x)
[1] -0.008462333
```

```
        Box-Ljung test

data:  combined_new_residuals$x
X-squared = 4.8984, df = 2, p-value = 0.08636
```

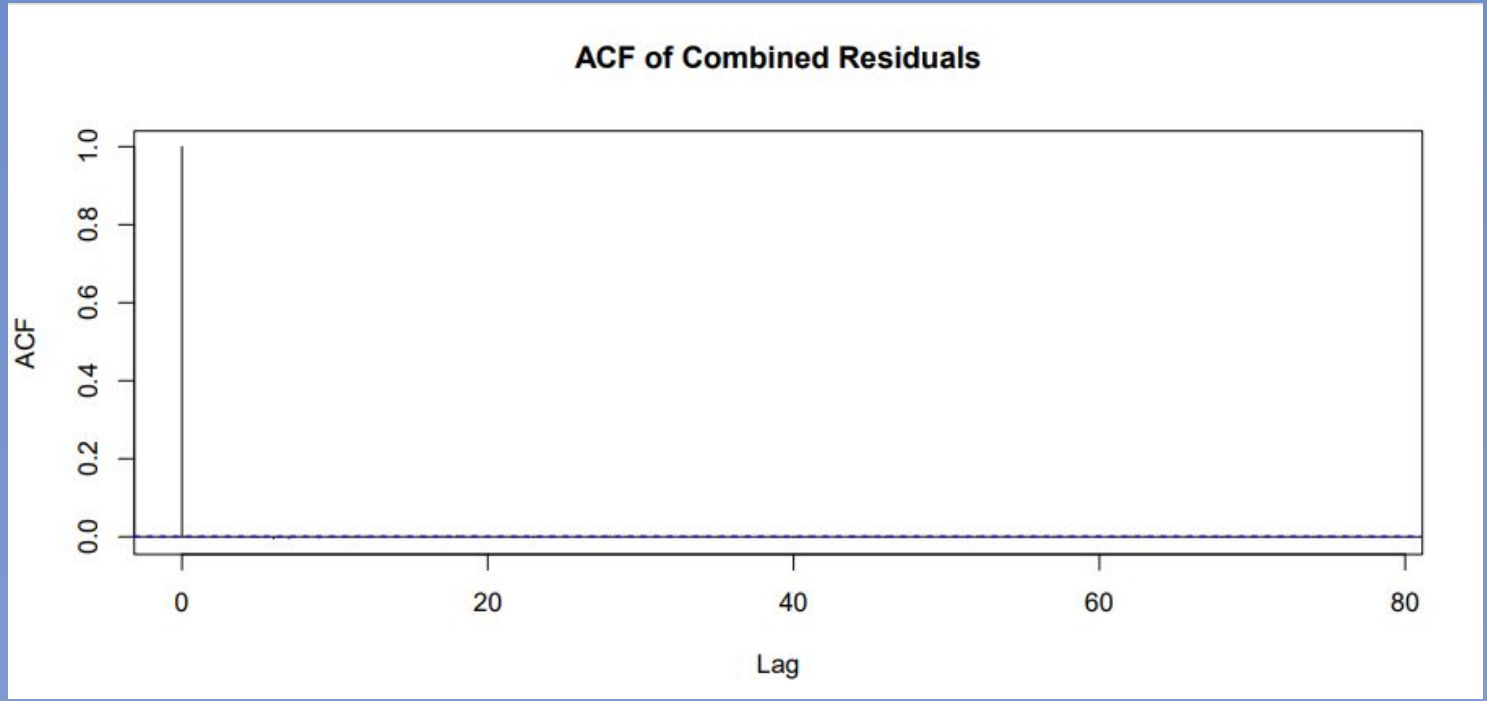
Comparing ACF

Initial Model



Comparing ACF

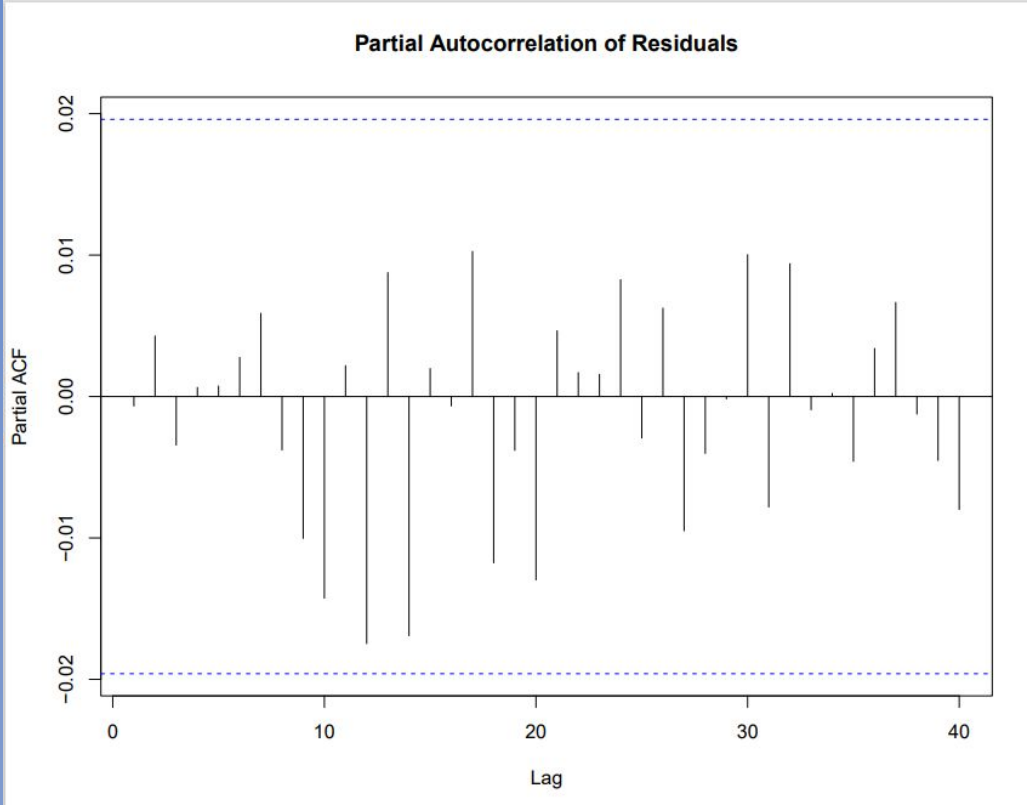
New Model



More stationary

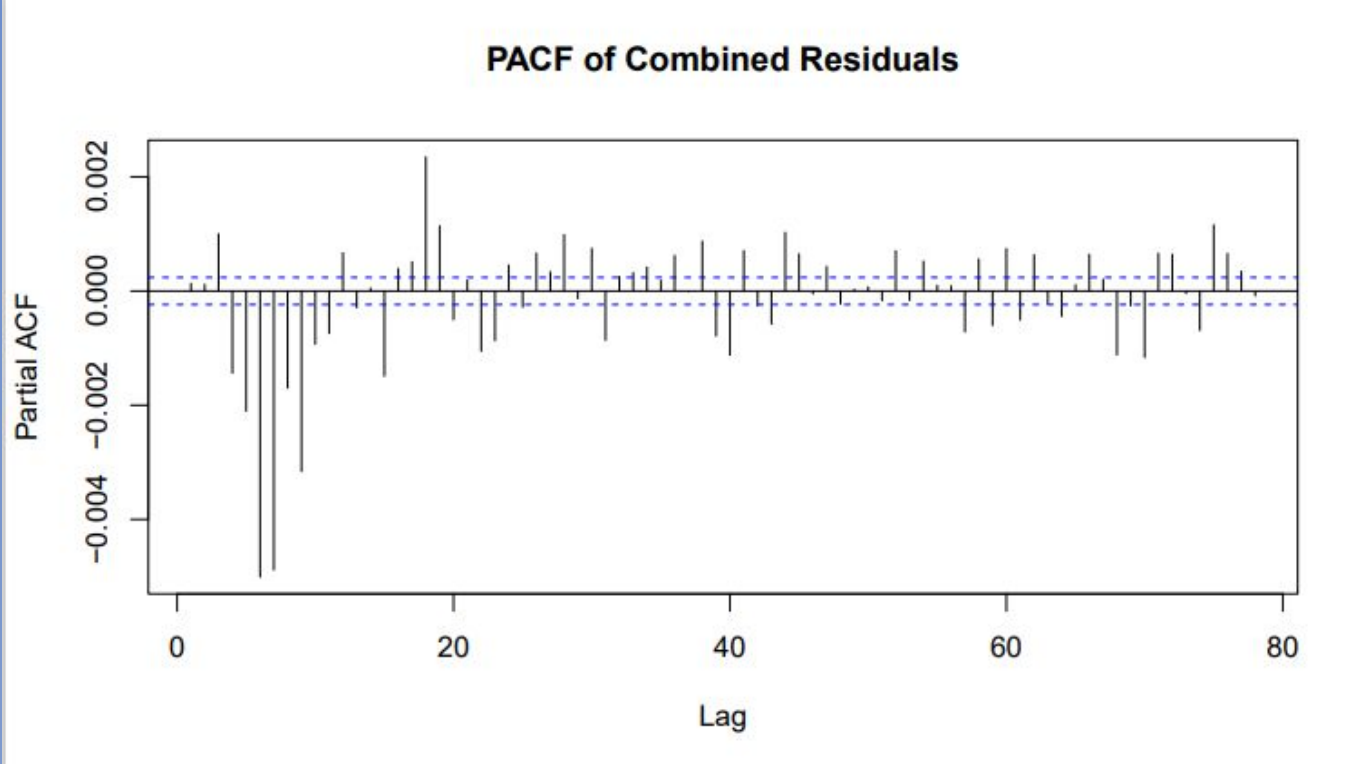
Comparing PACF

Initial Model



Comparing PACF

New Model



Reduced partial autocorrelation

Improved Model?

Lower Mean of Residuals

- Closer to zero
- Positive sign
- Model not systematically over or underpredicting

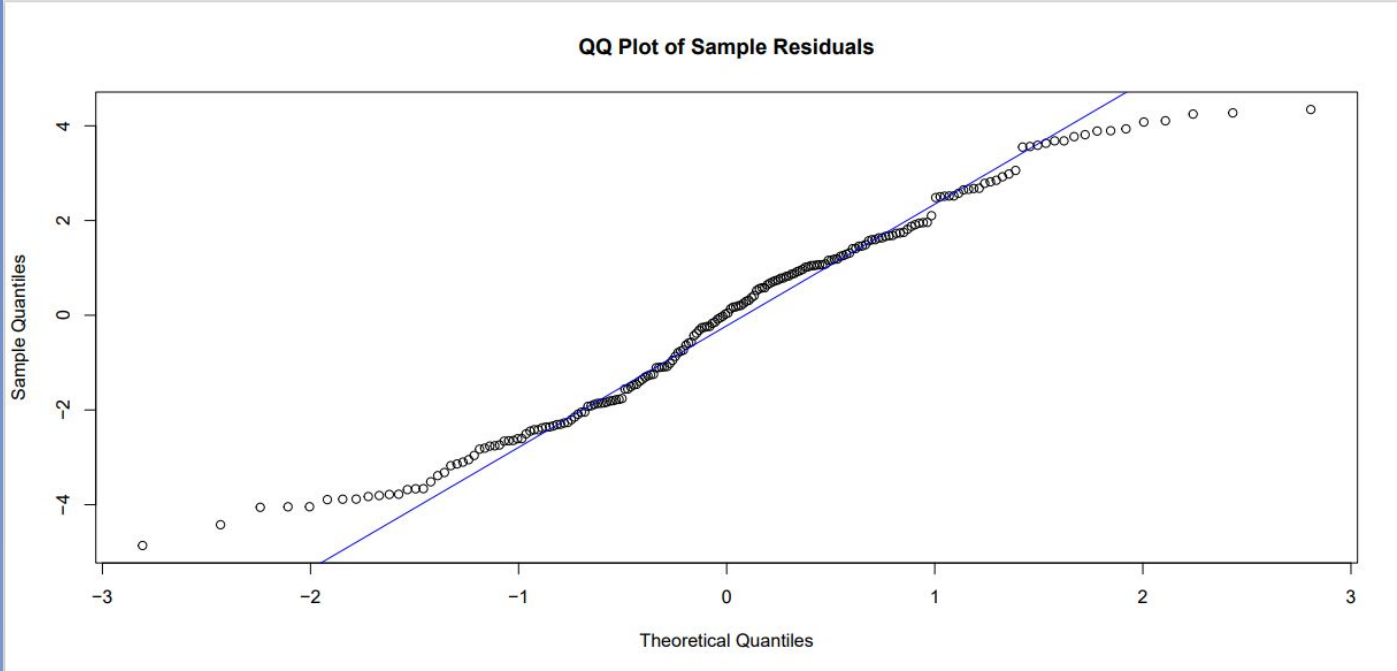
Lower ACF Values

- Less dependency between observations at various lags
- Stabilized variance

Better PACF

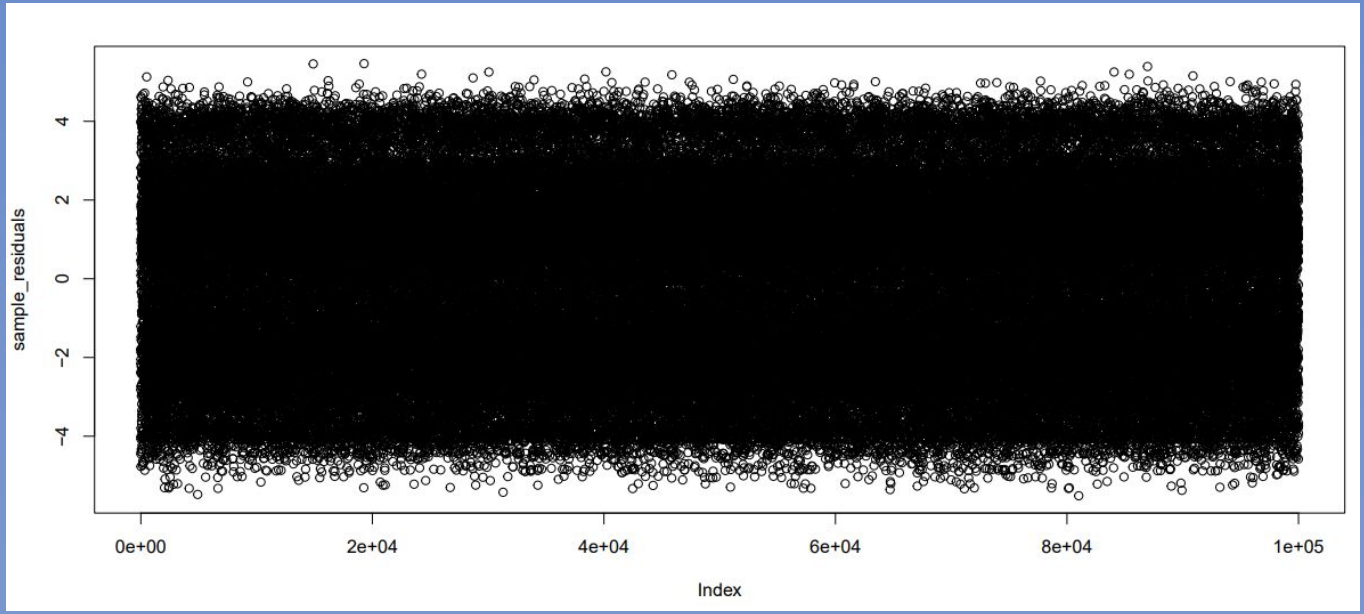
- Log transformation reduced the autocorrelation to some extent
- Improved the quality of the data for modeling

QQPlot of Residuals



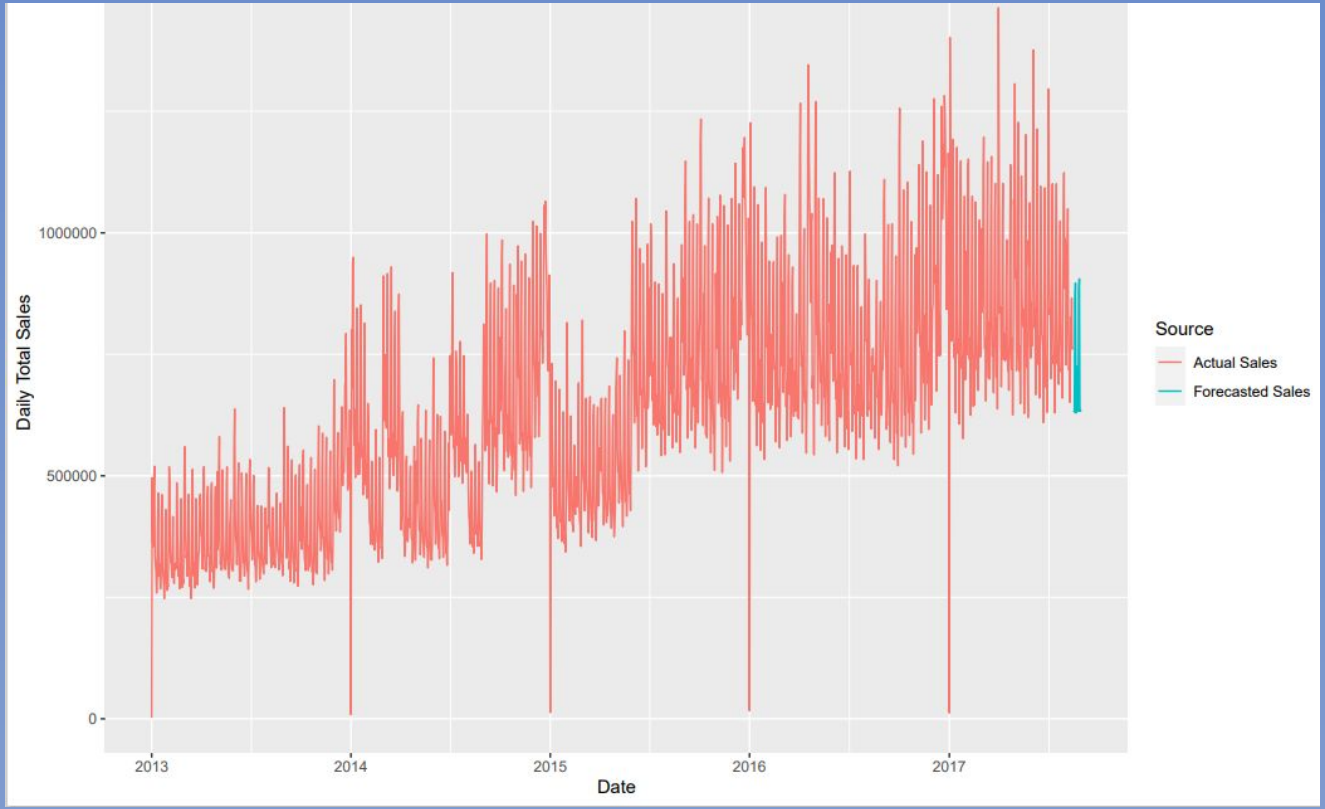
- Generally -> 45-degree line
- Some deviation is acceptable as long as it is not excessive

Scatter Plot of Residuals

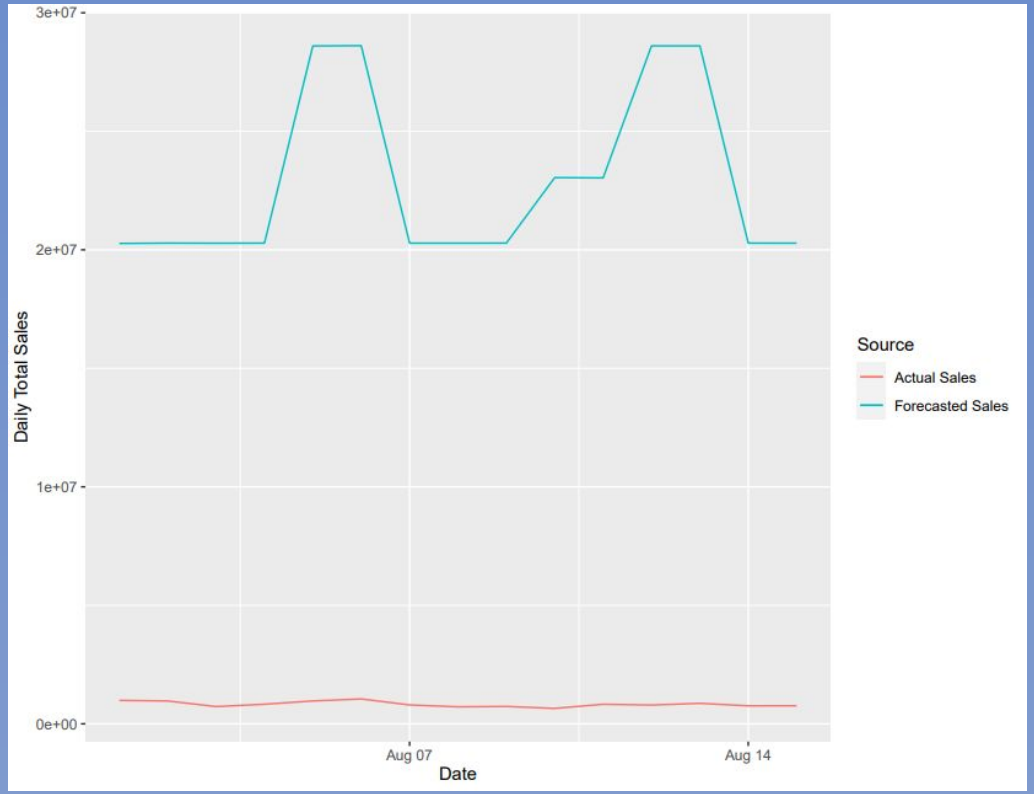


- Evenly scattered around the horizontal line of zero
- No discernable pattern
- No systematic bias

New Forecast Data

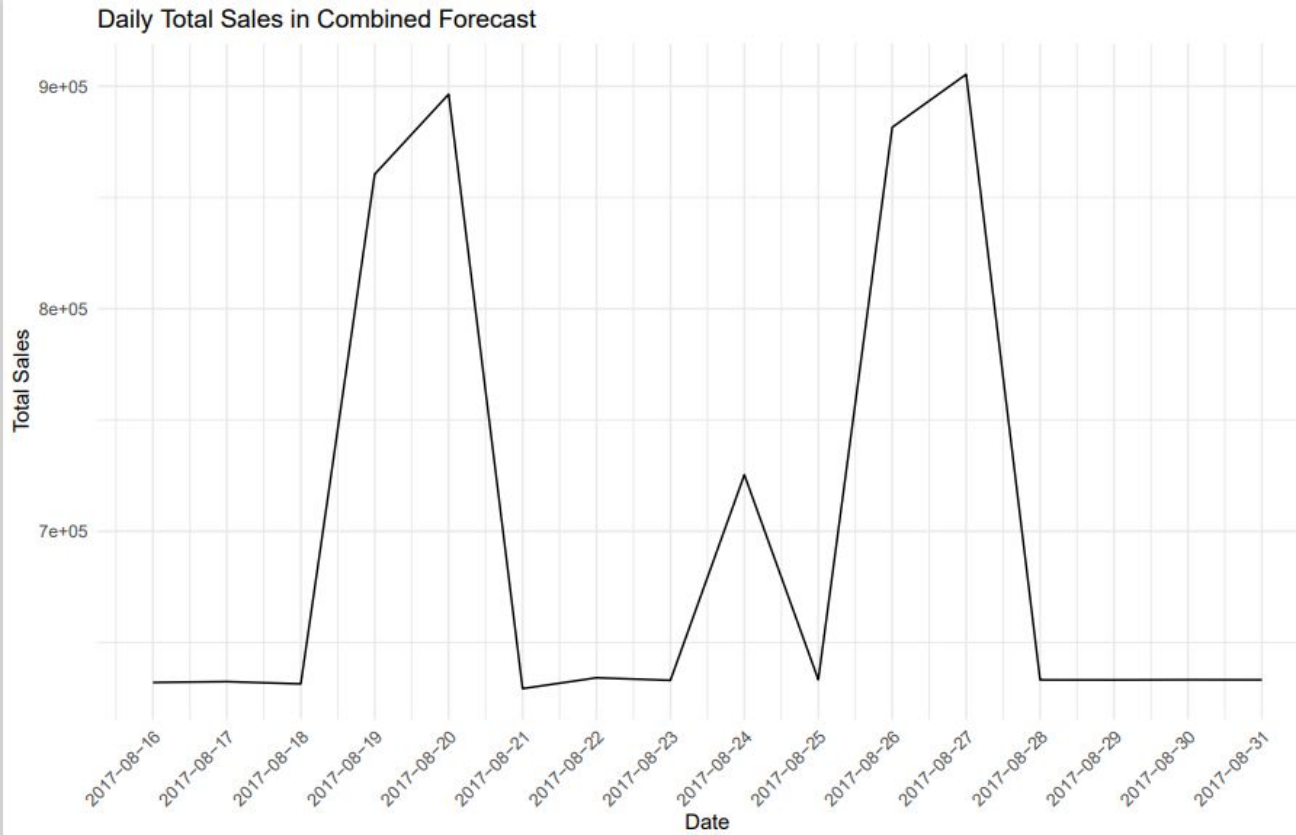


Initial Model



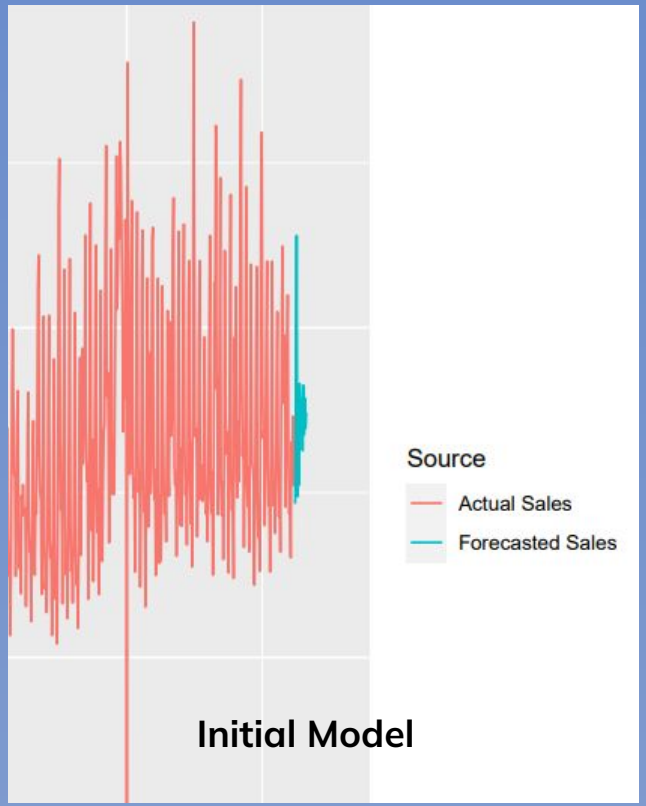
Forcased too high for actual sales

New Forecast Data

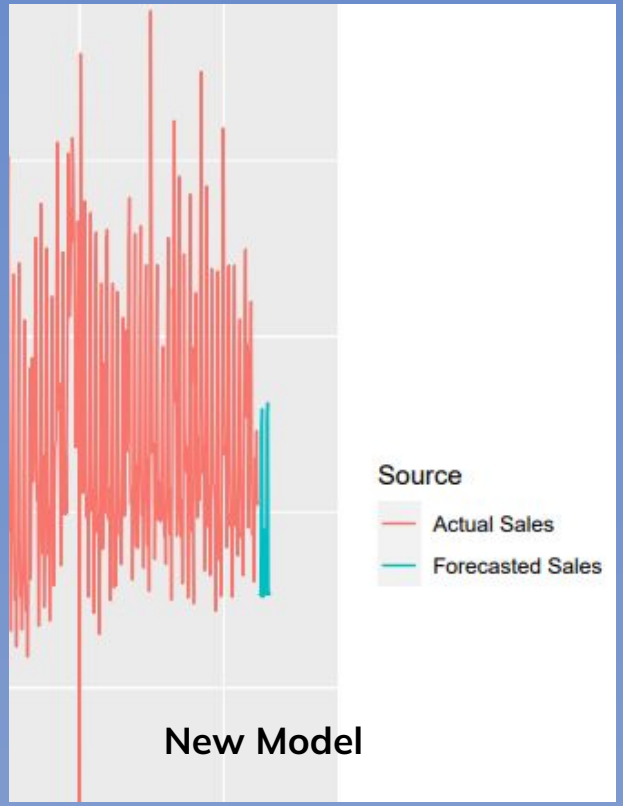


Better!

New Forecast Data



Initial Model



New Model

09

Key Takeaways

Key Takeaways

Be Curious

Importance of EDA
Suspect the Data
Keep exploring

Be Calm and Patient

Debug takes time :)
And also the forecasting loop :)

Be Resourceful

ChatGPT :)
Find References

"No Model is Perfect. Confusion is Part of Programming :)"

Thanks!

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References

1. Mahan, M., Chorn, C., & Georgopoulos, A. (2015). White Noise test: Detecting autocorrelation and nonstationarities in long time series after Arima modeling. *Proceedings of the 14th Python in Science Conference*. https://doi.org/10.25080/majora-7b98e3ed-00f
2.

Strategic *actions*

Sector	Strategy	Description
Marketing	A	Mercury is a small planet
Creative content	B	Venus has a beautiful name
Graphic design	C	Neptune is very far away from us
Data analysis	D	Earth is the planet with life
Community manager	E	Mars was named after a god

Data *storytelling reporting*

Neptune Jupiter

In *2020*

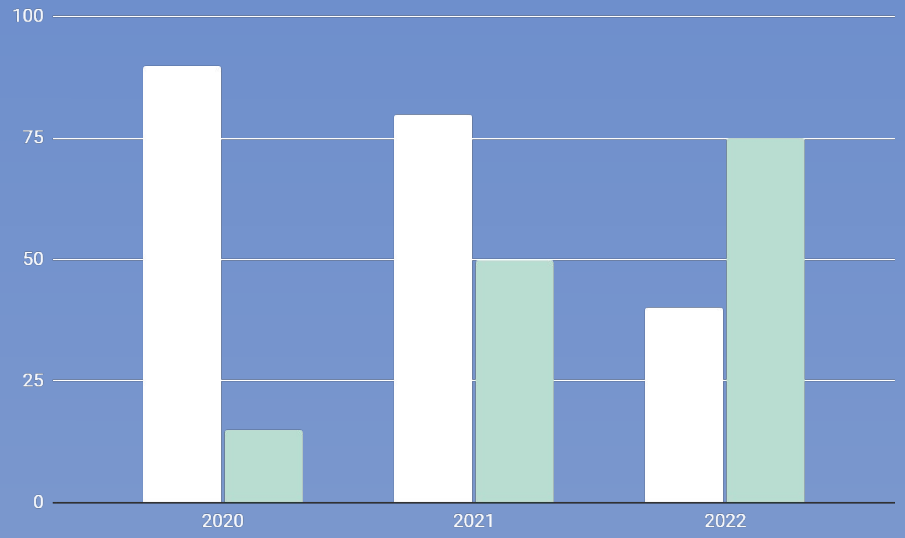
Mercury is very small

In 2021

Venus is a hot planet

In *2022*

Mars is a cold planet



Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

Our *conclusions*

Venus has a beautiful name and is the second planet from the Sun. It’s terribly hot, even hotter than Mercury, and its atmosphere is extremely poisonous. It’s the second-brightest natural object in the night sky after the Moon

Icon *pack*

Alternative *resources*

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- Hand drawn flat design innovation concept I
- Hand drawn flat design innovation concept II
- Hand drawn flat design business planning concept

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- Icon Pack: Charts and diagrams | Lineal

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- Hand drawn flat design business strategy concept I
- Hand drawn flat design business strategy concept II
- Hand drawn flat design gathering data business concept I
- Hand drawn flat design gathering data business concept II
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- Hand drawn business communication concept II
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#95b8d1	#b9ded1	#d5eadf	#f5f0bb

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Pana

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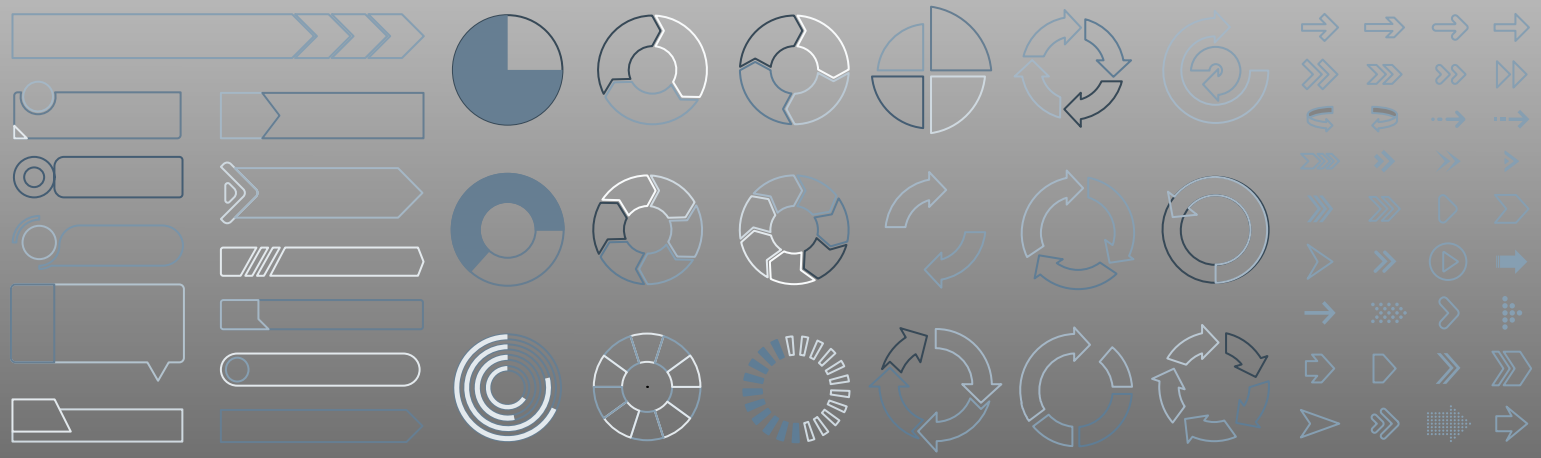
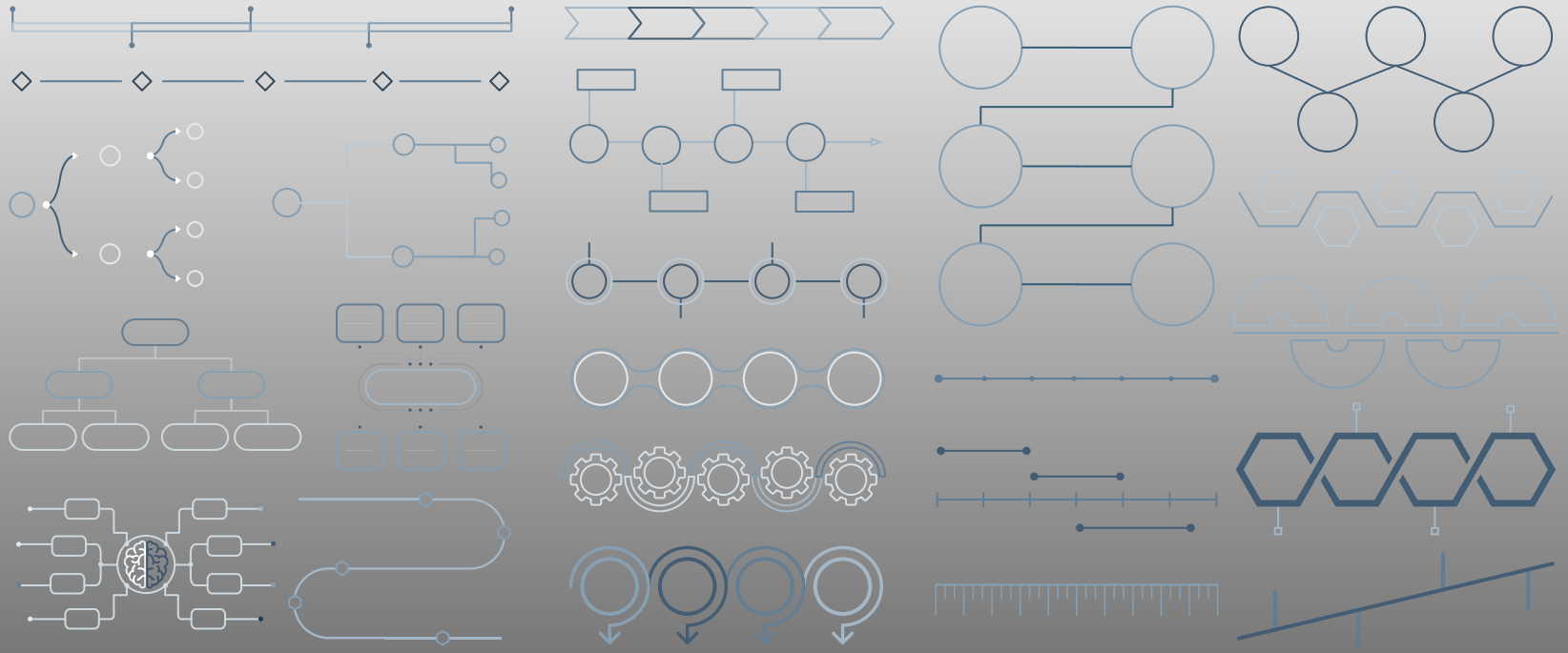
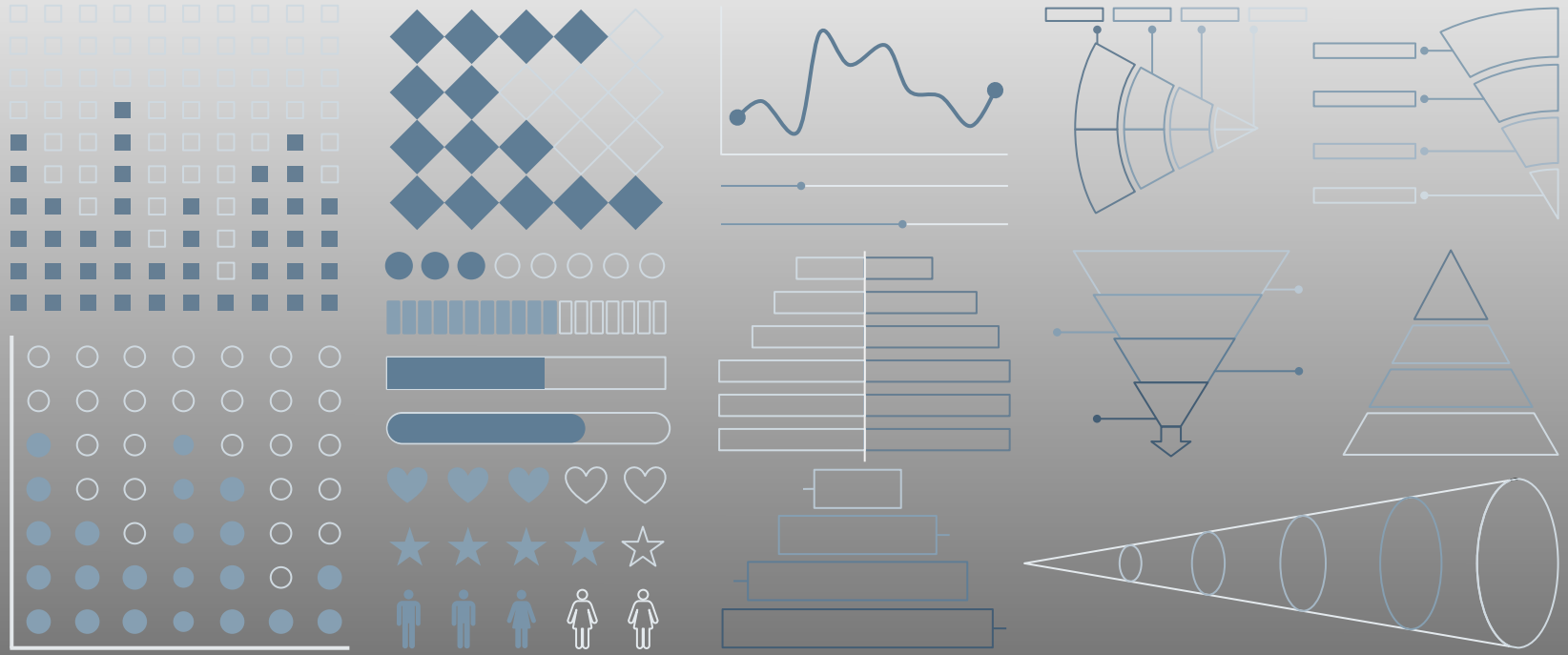




JANUARY
FEBRUARY
MARCH
APRIL
PHASE 1
Task 1
Task 2



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Medical Icons

Business Icons

Teamwork Icons

Help & Support Icons

Avatar Icons

Creative Process Icons

Performing Arts Icons

Nature Icons

SEO & Marketing Icons

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