Bass Model Analysis for Apple Watch Ultra 2

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Introduction

This report presents a Bass Model Analysis for the **Apple Watch Ultra 2**. To estimate the diffusion of this new model, I used historical sales data from previous Apple Watch models (2015-2023). The goal is to predict the potential adoption of Apple Watch Ultra 2 from 2024-2033. For this analysis, I use two methods: Non-linear Least Squares (nls) and the `diffusion` package. The parameters `p`, `q`, and `m` from the Bass Model will help forecast future adoption trends.

The data was sourced from Business of Apps.

Loading Necessary Libraries

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.3.2
```

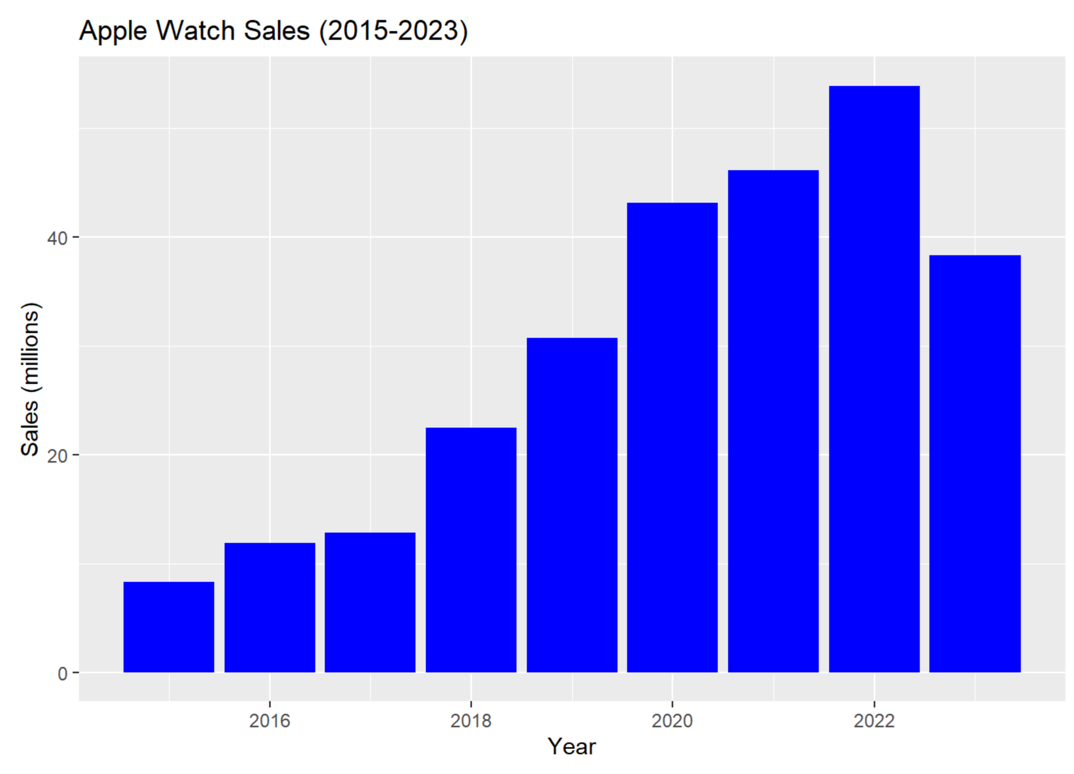
```
library(diffusion)
```

```
## Warning: package 'diffusion' was built under R version 4.3.3
```

Sales Data (2015-2023)

I am using the sales data of Apple Watches from 2015 to 2023. The time variable `t` represents the number of years since 2015, which helps us model the diffusion over time.

```
# Apple Watch Sales Data (2015-2023)
sales_data <- data.frame(
  year = c(2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023),
  sales = c(8.3, 11.9, 12.8, 22.5, 30.7, 43.1, 46.1, 53.9, 38.3)
)

# Add a numeric time variable (t)
sales_data$t <- 1:nrow(sales_data)

# Visualize the sales data
ggplot(data = sales_data, aes(x = year, y = sales)) +
  geom_bar(stat = 'identity', fill = 'blue') +
  ggtitle('Apple Watch Sales (2015-2023)') +
  xlab('Year') + ylab('Sales (millions)')
```



Bass Model Parameters Estimation

I used two methods to estimate the Bass Model parameters: Non-linear Least Squares (nls) and the `diffusion` package. The parameters are: - **p (innovation rate)**: This represents the proportion of people who adopt the product based on external information (advertising, etc.). - **q (imitation rate)**: This reflects how much of the product's adoption is driven by social influence. - **m (market potential)**: This is the total number of potential adopters.

Estimation using Non-linear Least Squares (nls)

```
# Estimate Bass Model parameters using Non-linear Least Squares (nls)
bass_model <- nls(sales ~ m * (((p + q)^2 / p) * exp(-(p + q) * t)) /
                    (1 + (q / p) * exp(-(p + q) * t))^2,
                  data = sales_data,
                  start = list(m = sum(sales_data$sales), p = 0.03, q = 0.4))

# Summary of the nls model
summary(bass_model)
```

```
##
## Formula: sales ~ m * (((p + q)^2/p) * exp(-(p + q) * t))/(1 + (q/p) *
##     exp(-(p + q) * t))^2
##
## Parameters:
##    Estimate Std. Error t value Pr(>|t|)
## m 3.555e+02  2.579e+01  13.785 9.07e-06 ***
## p 9.059e-03  1.925e-03   4.705  0.00331 **
## q 5.381e-01  5.075e-02  10.603 4.14e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.441 on 6 degrees of freedom
##
## Number of iterations to convergence: 7
## Achieved convergence tolerance: 3.234e-06
```

```
# Extract parameters from the nls model
nls_params <- summary(bass_model)$coefficients
p_nls <- nls_params["p", "Estimate"]
q_nls <- nls_params["q", "Estimate"]
m_nls <- nls_params["m", "Estimate"]

cat("Estimated p (innovation rate) from nls:", p_nls, "\n")
```

```
## Estimated p (innovation rate) from nls: 0.009058541
```

```
cat("Estimated q (imitation rate) from nls:", q_nls, "\n")
```

```
## Estimated q (imitation rate) from nls: 0.5381083
```

```
cat("Estimated m (market potential) from nls:", m_nls, "\n")
```

```
## Estimated m (market potential) from nls: 355.4789
```

Estimation using `diffusion` Library

```
# Estimate Bass Model parameters using the diffusion package
diffusion_model <- diffusion(sales_data$sales)
diff_params <- diffusion_model$w

m_diff <- round(diff_params[1], 4)
p_diff <- round(diff_params[2], 4)
q_diff <- round(diff_params[3], 4)

cat("Estimated p (innovation rate) from diffusion package:", p_diff, "\n")
```

```
## Estimated p (innovation rate) from diffusion package: 0.0139
```

```
cat("Estimated q (imitation rate) from diffusion package:", q_diff, "\n")
```

```
## Estimated q (imitation rate) from diffusion package: 0.4647
```

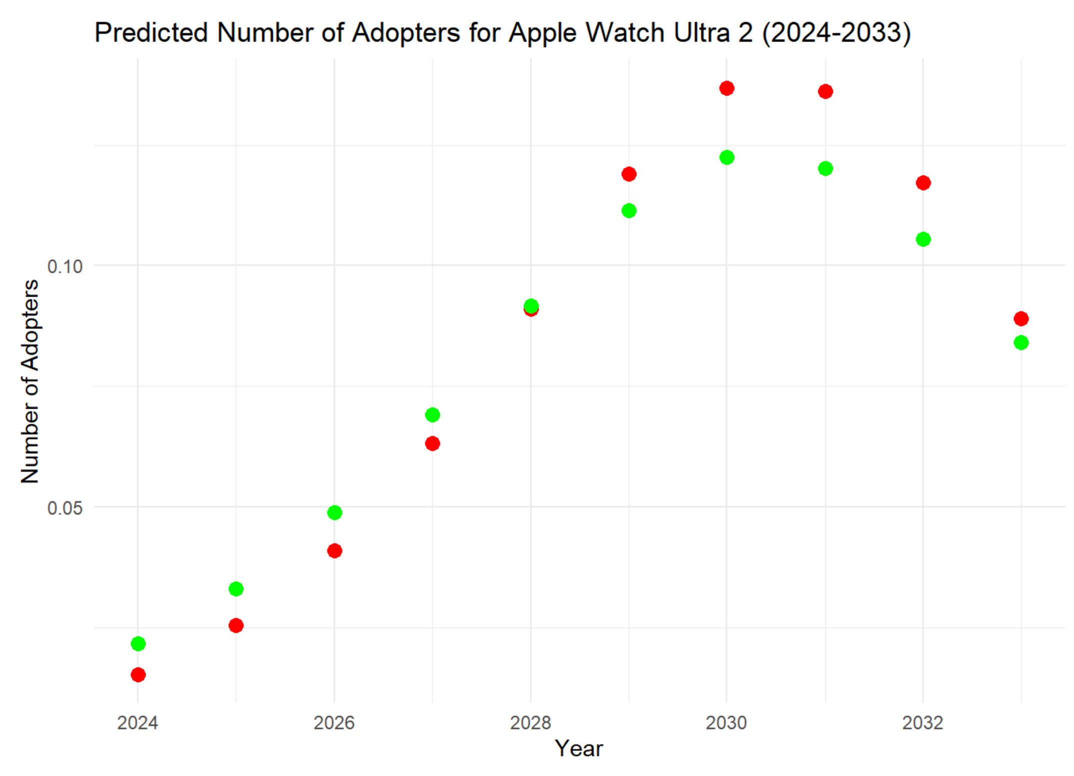
```
cat("Estimated m (market potential) from diffusion package:", m_diff, "\n")
```

```
## Estimated m (market potential) from diffusion package: 396.6552
```

Forecasting Apple Watch Ultra 2 (2024-2033)

Using the estimated Bass Model parameters, I predicted the adoption of Apple Watch Ultra 2 from 2024-2033. Both `nls` and `diffusion` methods were used for comparison.

```
# Bass model function for f(t)
bass_f <- function(t, p, q) {
  ((p + q)^2 / p) * exp(-(p + q) * t) / (1 + (q / p) * exp(-(p + q) * t))^2
}

# Create a data frame for future predictions (2024-2033)
future_years <- data.frame(
  year = 2024:2033,
  t = 1:10 # time periods for future predictions
)

# Using the parameters from the nls model to predict
future_years$predicted_adopters_nls <- bass_f(future_years$t, p_nls, q_nls)

# Using the parameters from the diffusion package to predict
future_years$predicted_adopters_diff <- bass_f(future_years$t, p_diff, q_diff)

# Plotting the predictions for Apple Watch Ultra 2 (2024-2033)
ggplot(future_years, aes(x = year)) +
  geom_point(aes(y = predicted_adopters_nls), color = 'red', size = 3) +
  geom_point(aes(y = predicted_adopters_diff), color = 'green', size = 3) +
  ggtitle('Predicted Number of Adopters for Apple Watch Ultra 2 (2024-2033)') +
  ylab('Number of Adopters') + xlab('Year') +
  theme_minimal()
```




```
# Print the predicted data for review
print(future_years)
```

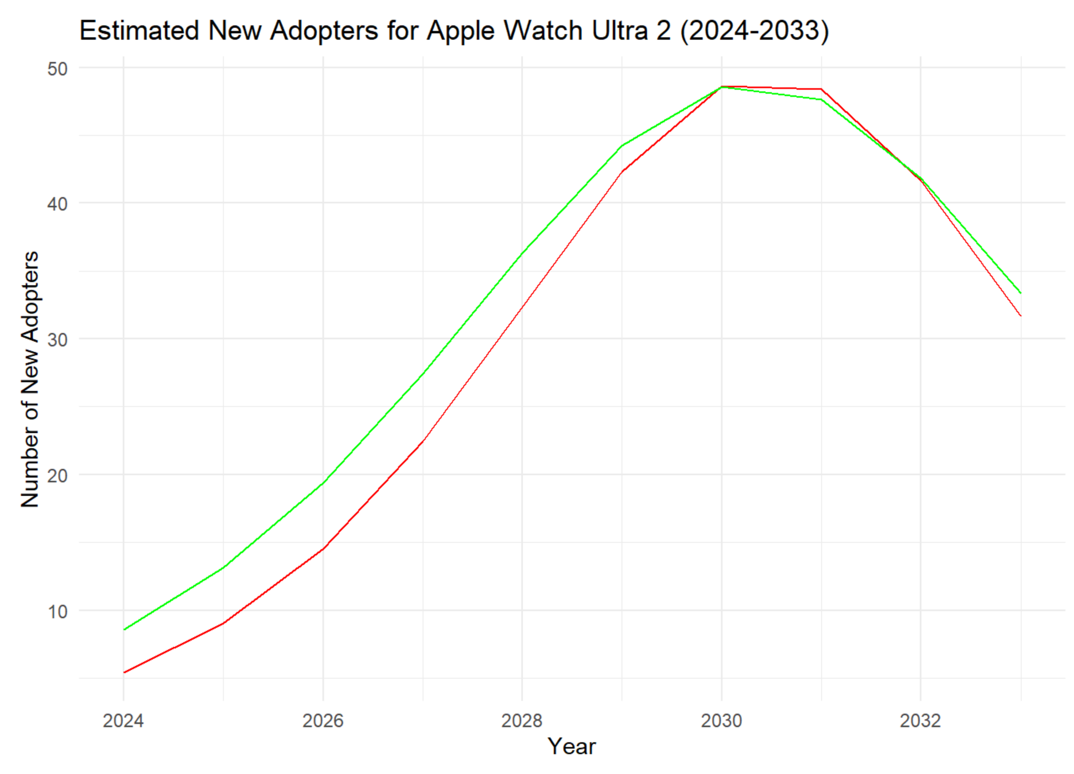
```
##    year  t predicted_adopters_nls predicted_adopters_diff
## 1  2024  1             0.01528548              0.02165311
## 2  2025  2             0.02536331              0.03304935
## 3  2026  3             0.04093207              0.04890065
## 4  2027  4             0.06317223              0.06911592
## 5  2028  5             0.09104031              0.09159316
## 6  2029  6             0.11895353              0.11149651
## 7  2030  7             0.13687175              0.12245043
## 8  2031  8             0.13615173              0.12014074
## 9  2032  9             0.11717264              0.10552365
## 10 2033 10             0.08896585              0.08407120
```

Estimating Yearly and Cumulative Adopters

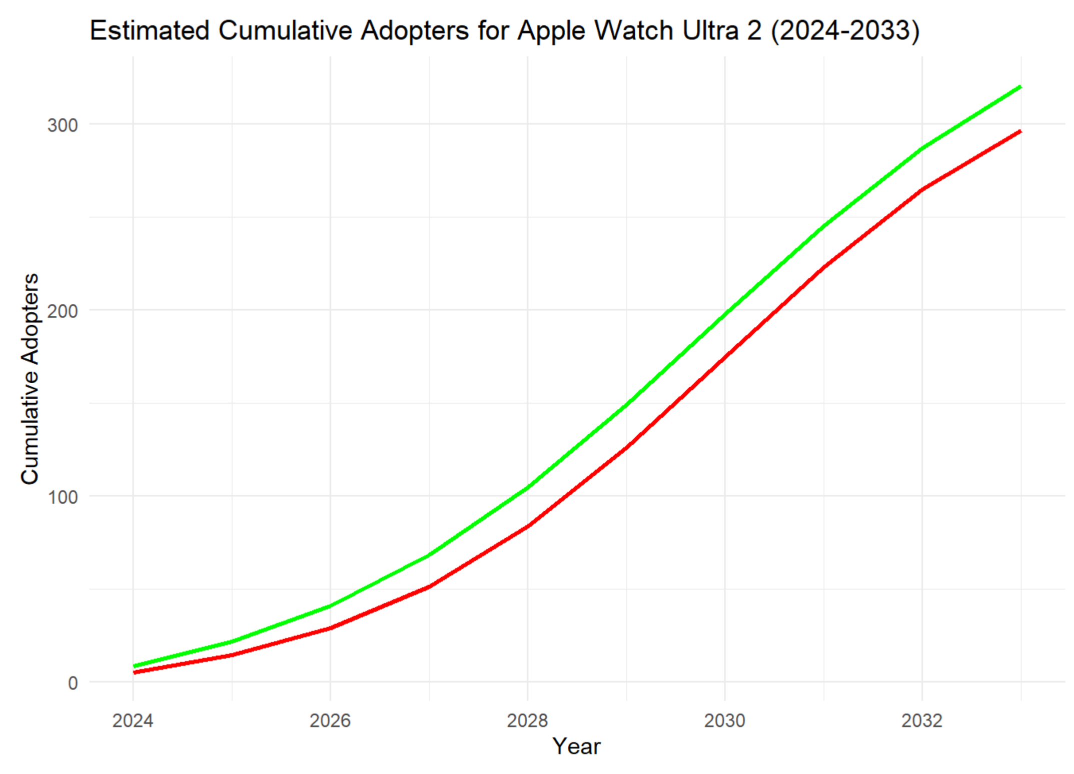
I analyze the diffusion worldwide as my data is for the whole sales worldwide and not in a specific country.

Finally, I estimated the number of new adopters each year, as well as the cumulative number of adopters over time.

```
# Number of adopters at each time period using nls parameters
future_years$new_adopters_nls <- bass_f(future_years$t, p_nls, q_nls) * m_nls

# Number of adopters at each time period using diffusion package parameters
future_years$new_adopters_diff <- bass_f(future_years$t, p_diff, q_diff) * m_diff

# Cumulative adopters
future_years$cumulative_adopters_nls <- cumsum(future_years$new_adopters_nls)
future_years$cumulative_adopters_diff <- cumsum(future_years$new_adopters_diff)

# Plot the estimated yearly new adopters
ggplot(future_years, aes(x = year)) +
  geom_line(aes(y = new_adopters_nls), stat = 'identity', color = 'red') +
  geom_line(aes(y = new_adopters_diff), stat = 'identity', color = 'green') +
  ggtitle('Estimated New Adopters for Apple Watch Ultra 2 (2024-2033)') +
  ylab('Number of New Adopters') + xlab('Year') +
  theme_minimal()
```




```
# Plot the estimated cumulative adopters
ggplot(future_years, aes(x = year)) +
  geom_line(aes(y = cumulative_adopters_nls), color = 'red', linewidth = 1) +
  geom_line(aes(y = cumulative_adopters_diff), color = 'green', linewidth = 1) +
  ggtitle('Estimated Cumulative Adopters for Apple Watch Ultra 2 (2024-2033)') +
  ylab('Cumulative Adopters') + xlab('Year') +
  theme_minimal()
```



Conclusion

In this analysis, I used historical sales data of Apple Watches from 2015-2023 to estimate the Bass Model parameters. Using these parameters, I have forecasted the diffusion of Apple Watch Ultra 2 from 2024-2033. Both methods (`nls` and `diffusion`) provided slightly different predictions, but overall, the analysis shows that the Apple Watch Ultra 2 has strong market potential, with adoption driven largely by social factors (high imitation rate).