Homework 1| Bass Model

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From TIME's provided best inventions of 2023, this paper discusses the most innovative smartwatch, which is the Apple Watch Ultra 2, also its look-alike innovation from the past, estimated Bass Model parameters, predictions of the diffusion of the innovation, and the potential market share of the product.

With an Apple Watch, you can conduct some things that would normally require taking out your iPhone and spend less time staring at your phone. It also gives you rapid access to essential information. Viewing and replying to iMessages, paying for purchases at a variety of stores (or, in some cases, paying for a train or bus ride), displaying your boarding pass at an airport, turning on and off smart lighting, receiving directions, pinging an iPhone you left under a pillow, and, of course, checking the time are all made simple with an Apple Watch. (McGarry,2024)

One of the innovations in this industry is the most innovative smartwatch – the Apple Watch Ultra 2. This watch allows consumers to just tap their index finger and thumb together twice to answer the phone or snooze the alarm. Also, it is among Apple's first carbon–neutral products. (TIME, 2023)

A look–alike innovation to the Apple Watch Ultra 2 from the past is Apple Watch Series 5. They can be compared through several factors, such as battery life, max depth of water resistance, CPU type and so much more. In all the mentioned features the new model is leading cause its battery life is longer, the max depth of water resistance is 2 times more and CPU type for series 5 is S5 while for Ultra 2 is S9 SiP. (ProductInDetail, 2023)

It is also important that they have some common features such as the design and wearing style, SIM type, battery type, etc. (Apple, 2023)

For a look-like innovation, the data is taken from statista.com. The data represents the Apple Watch sales (in millions) worldwide from 2015 to 2022. Using this data, the codes below will estimate Bass model parameters, make predictions of the diffusion of the innovation, and estimate the potential market share of the product.

```r
library(readxl)
library(tidyr)
library(ggplot2)
library(ggpubr)
```

Data Manipulation

```r
df <- read_excel("applewatch_sales.xlsx")
```

```
## New names:
## * `` -> `...2`
```

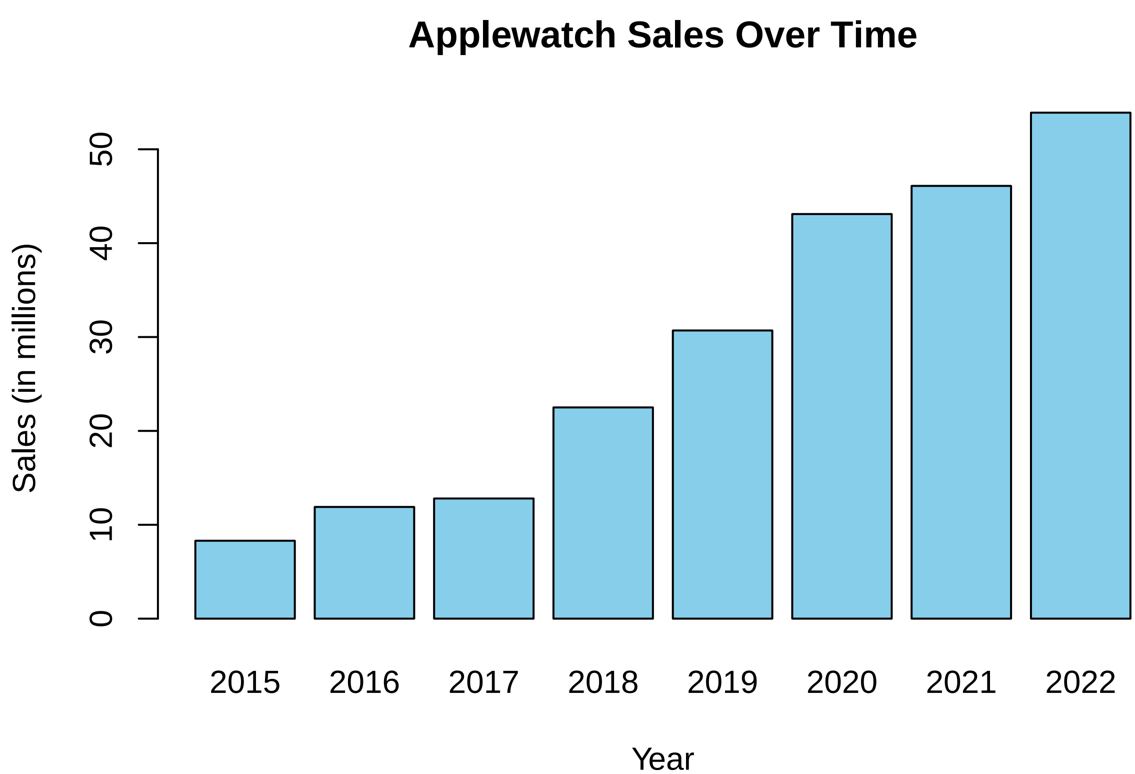
```r
colnames(df) <- c("Year", "Sales")
upd_df <- df
upd_df <- drop_na(upd_df)
upd_df
```

```
## # A tibble: 8 x 2
##    Year  Sales
```

```
##   <chr> <dbl>
## 1 2015    8.3
## 2 2016   11.9
## 3 2017   12.8
## 4 2018   22.5
## 5 2019   30.7
## 6 2020   43.1
## 7 2021   46.1
## 8 2022   53.9
```

Data Visualization

```r
barplot(upd_df$Sales,
        names.arg = upd_df$Year,
        col = "skyblue",
        main = "Applewatch Sales Over Time",
        xlab = "Year",
        ylab = "Sales (in millions)")
```



From the graph above we can see that each year the amount of sales has increased more and more.

Bass Model parameters

bass.f <- fraction of the total market that adopts at time t bass.F <- fraction of the total market that has adopted up to and including time t p <- innovation rate q <- imitation rate

```r
bass.f <- function(t, p, q) {
  ((p + q)^2/p) * exp(-(p + q) * t) / (1 + (q/p) * exp(-(p + q) * t))^2
}
```

```r
bass.F <- function(t, p, q) {
  (1 - exp(-(p + q) * t)) / (1 + (q/p) * exp(-(p + q) * t))
}
```

Parameter estimation using NLS

```r
upd_df$Year <- as.numeric(upd_df$Year)
rev <- upd_df$Sales
t <- 1:length(rev)

bass_model <- nls(rev ~ m * (((p + q)^2/p) * exp(-(p + q) * t)) /
                          (1 + (q/p) * exp(-(p + q) * t))^2,
                  start = c(m = sum(rev), p = 0.02, q = 0.4))

result <- summary(bass_model)$coefficients
m <- result[1, 1]
p <- result[2, 1]
q <- result[3, 1]

summary(bass_model)
```

```
##
## Formula: rev ~ 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 4.667e+02  6.806e+01   6.857 0.001008 **
## p 9.799e-03  1.094e-03   8.955 0.000290 ***
## q 4.412e-01  4.725e-02   9.336 0.000237 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.271 on 5 degrees of freedom
##
## Number of iterations to convergence: 6
## Achieved convergence tolerance: 5.508e-06
```

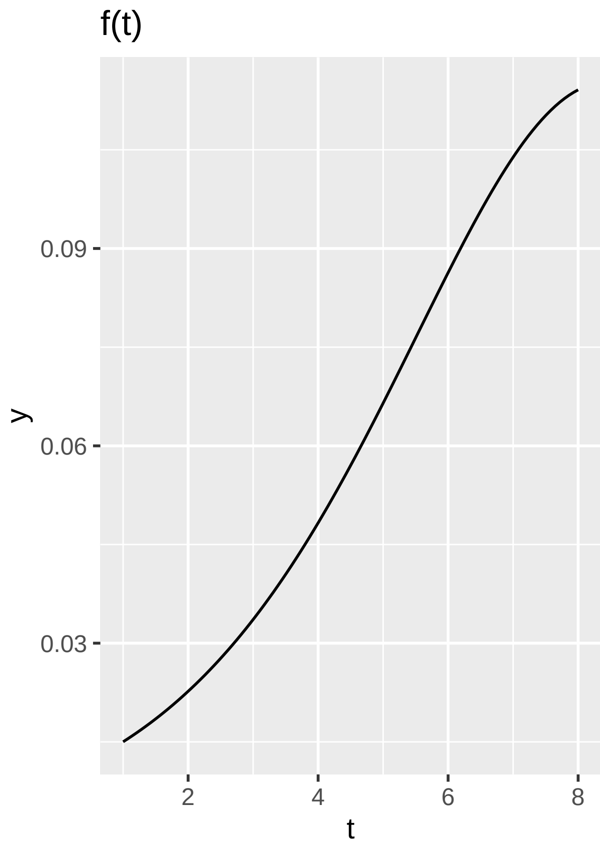
From the summary we can see that innovation rate, imitation rate and market potential are 9.799e-03 , 4.412e-01 and 4.667e+02, so we will use that values.

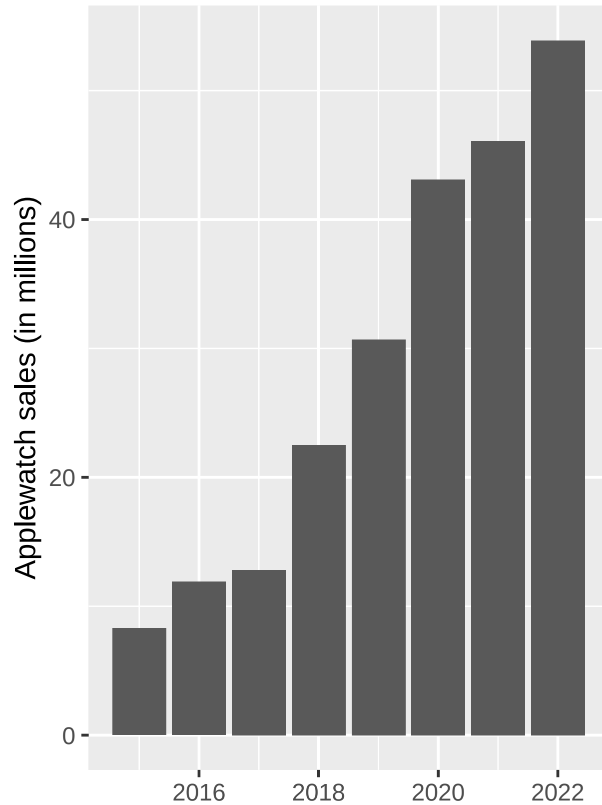
```r
time_ad <- ggplot(data.frame(t = c(1:8)), aes(t)) +
stat_function(fun = bass.f, args = c(p = 9.799e-03, q = 4.412e-01 )) +
labs(title = 'f(t)')

watch_s <- ggplot(upd_df, aes(x = Year, y = upd_df$Sales)) +
geom_bar(stat = 'identity') + labs(x = " ", y = "Applewatch sales (in millions)")

ggarrange(time_ad, watch_s)
```

```
## Warning: Use of `upd_df$Sales` is discouraged.
## i Use `Sales` instead.
```





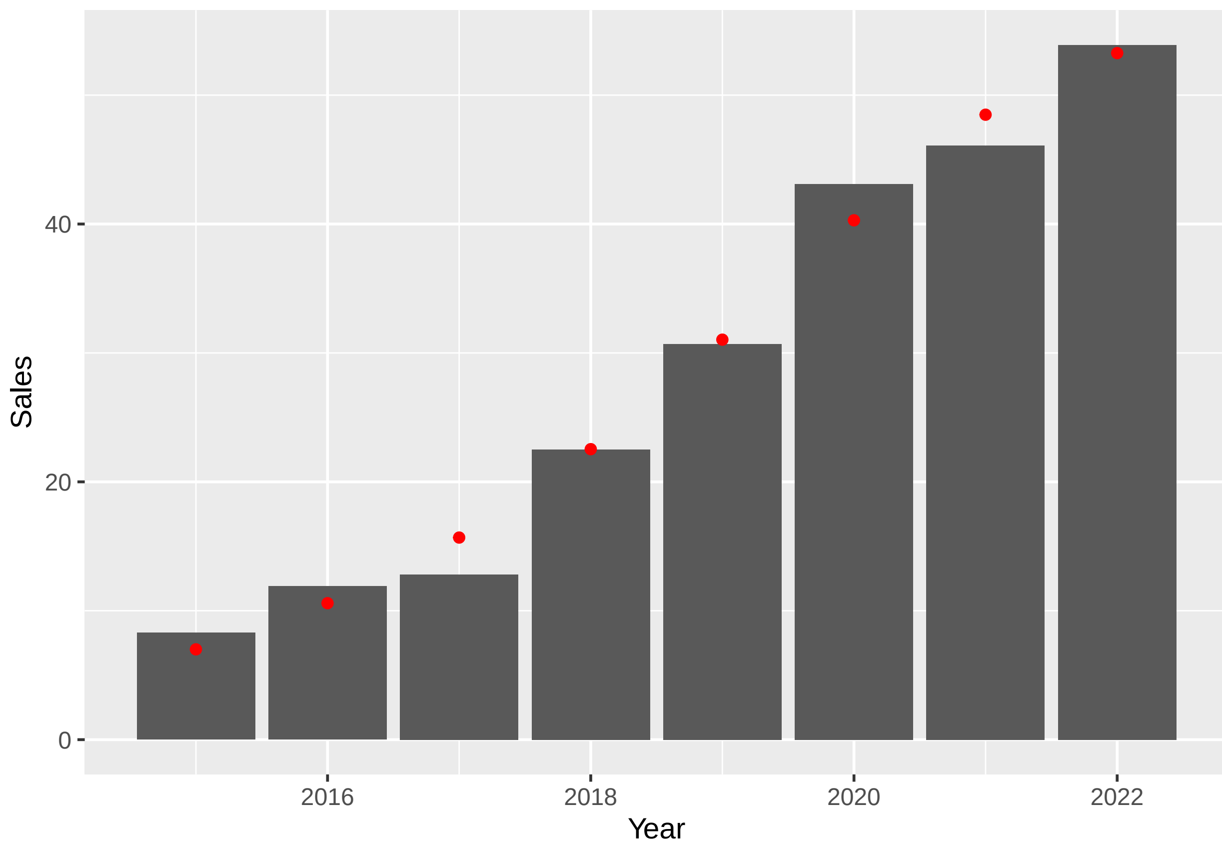
As we see we have increasing trend here

Estimating # of adopters by time

We calculate f(t) with the estimated rate of p and q, and then multiply by the predicted market potential. These are plotted as red dots on the graph. As our data is not scaled, we can freely use the market potential value.

```
upd_df$pred_sales <- bass.f(1:8, p = 9.799e-03, q = 4.412e-01) * 4.667e+02

ggplot(data = upd_df, aes(x = Year, y = Sales)) +
  geom_bar(stat = 'identity') +
  geom_point(mapping = aes(x = Year, y = pred_sales), color = 'red')
```



As we see, overall the trend is correct, more or less is accurate. In some years the difference is more accurate, in some a little bit less accurate, but in general we can say that the trend is correct(increasing) and it deviates a little.

Sources

Innovation : - The Most Innovative Smart Watch Apple Watch Ultra 2 https://time.com/collection/best-inventions-2023/6324040/apple-watch-ultra-2/ - (Caitlin McGarry, 2024) The Apple Watch Is the Best Smartwatch for iPhone Owners https://www.nytimes.com/wirecutter/reviews/best-smartwatch-iphone/

Look-alike innovation:

- Apple Watch Series 5 (GPS) vs. Apple Watch Ultra 2 https://www.productindetail.com/ch/comparison-apple-watch-series-5-gps-vs-apple-watch-ultra-2#google_vignette
- Apple Watch models https://www.apple.com/watch/compare/