ESM204 Homework 4 - Social Cost of Carbon

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1. Estimate a quadratic function relating damages to temperature

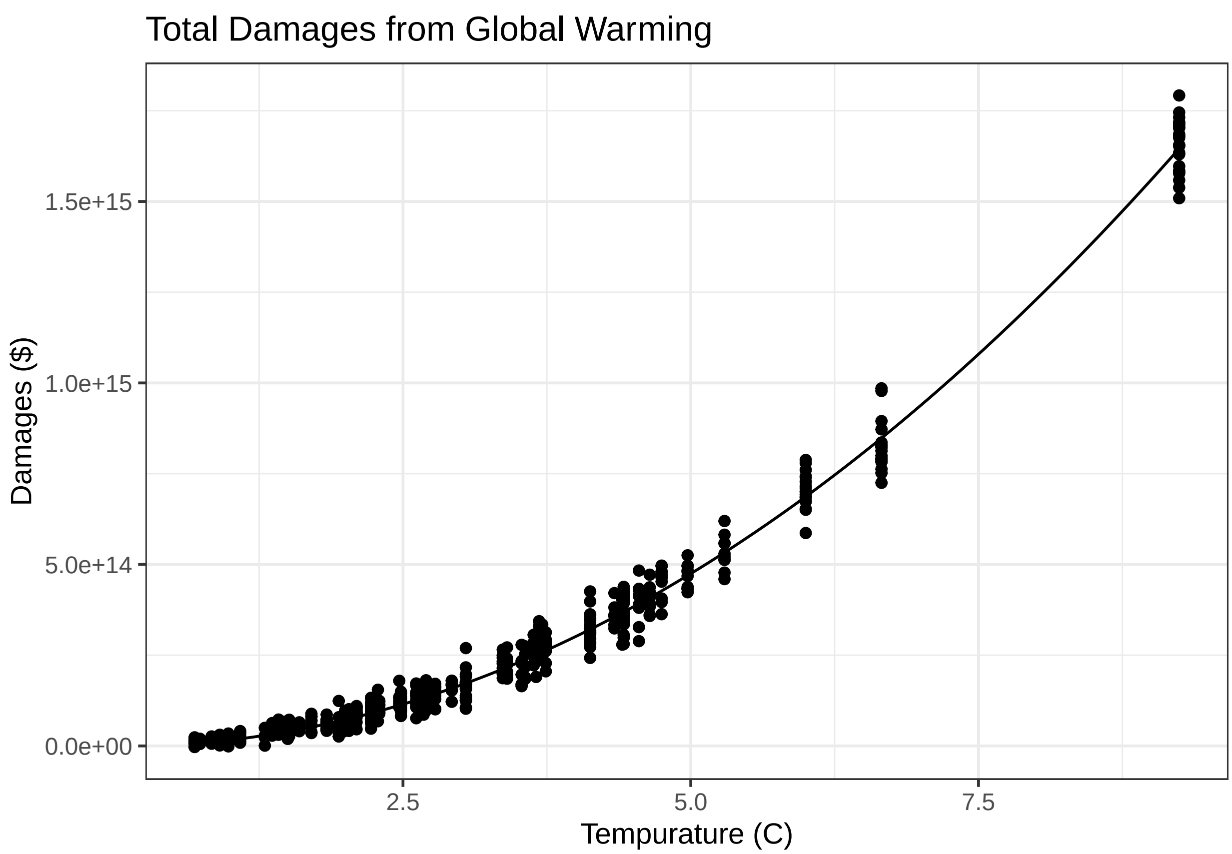
```
damages_data <- read_csv(here("data", "damages.csv")) %>% clean_names()

warming_data <- read_csv(here("data", "warming.csv")) %>% clean_names()

#ggplot(data = damages_data, aes(x = warming, y = damages))+
  #geom_point()+
  #theme_bw()
```

```
#Make the x variable exponential
damages_data$warming2 <- damages_data$warming^2

quadratic_model <-lm(damages ~ warming + warming2, data = damages_data)

summary(quadratic_model)
```

```
##
## Call:
## lm(formula = damages ~ warming + warming2, data = damages_data)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.410e+14 -1.620e+13 -4.180e+11  1.698e+13  1.422e+14
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  4.198e+12  4.968e+12   0.845    0.398
## warming     -3.019e+12  2.538e+12  -1.190    0.235
## warming2     1.959e+13  2.706e+11  72.378   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.467e+13 on 553 degrees of freedom
## Multiple R-squared:  0.9902, Adjusted R-squared:  0.9901
## F-statistic: 2.784e+04 on 2 and 553 DF,  p-value: < 2.2e-16
```

```
# Name coefficients we got from the above step
```

```r
a <- quadratic_model$coefficients[[3]]
b <- quadratic_model$coefficients[[2]]

#Write quadratic function using a and b
quadratic_function <- function(x) a*x^2 + b*x

#plot(quadratic_function)

ggplot(data = damages_data, aes(x = warming, y = damages))+
  stat_function(fun = quadratic_function)+
  geom_point()+
  theme_bw()+
  labs(
    y = "Damages ($)",
    x = "Tempurature (C)",
    title = "Total Damages from Global Warming"
  )
```

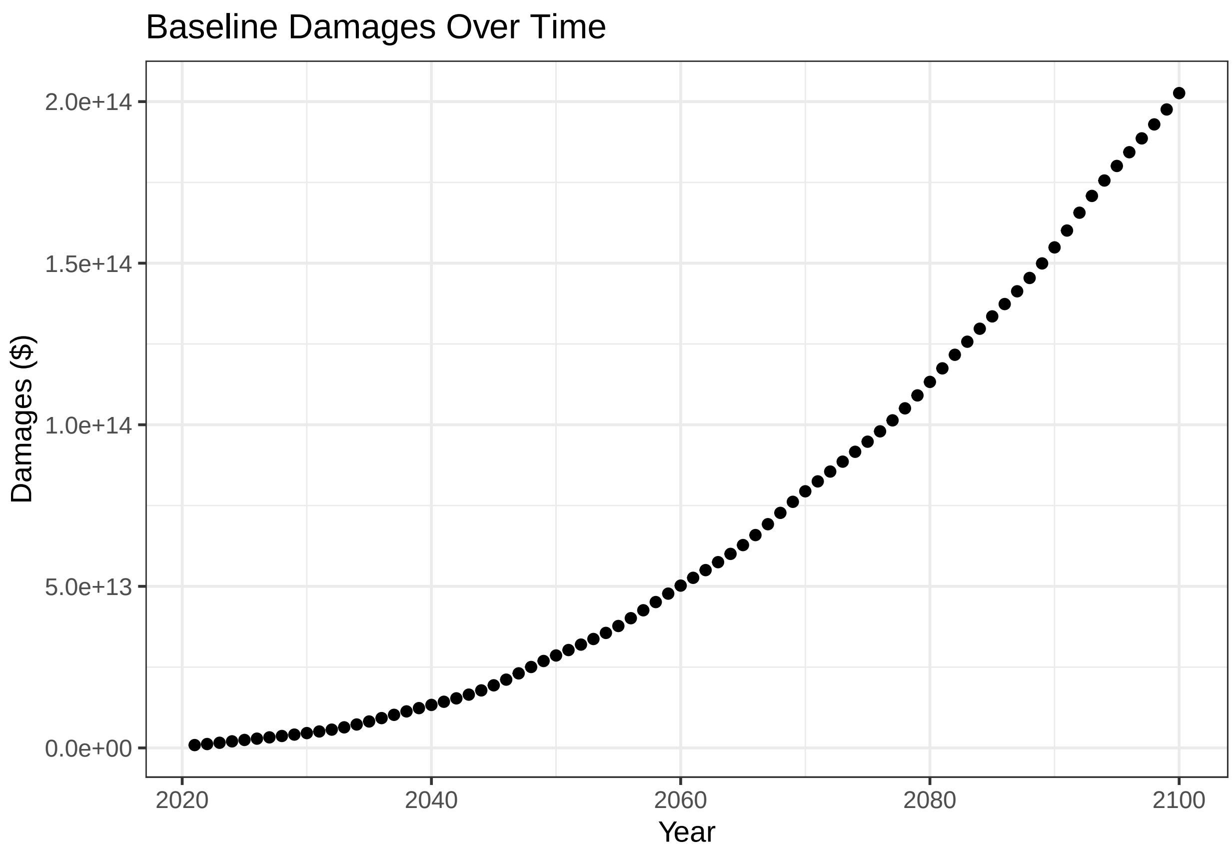


The quadratic damage function is y= $1.958902 \times 10^{13} x\hat{~}2$ $-3.0188563 \times 10^{12}$x.

2. Damages under baseline climate and pulse

a) Damages over time without pulse

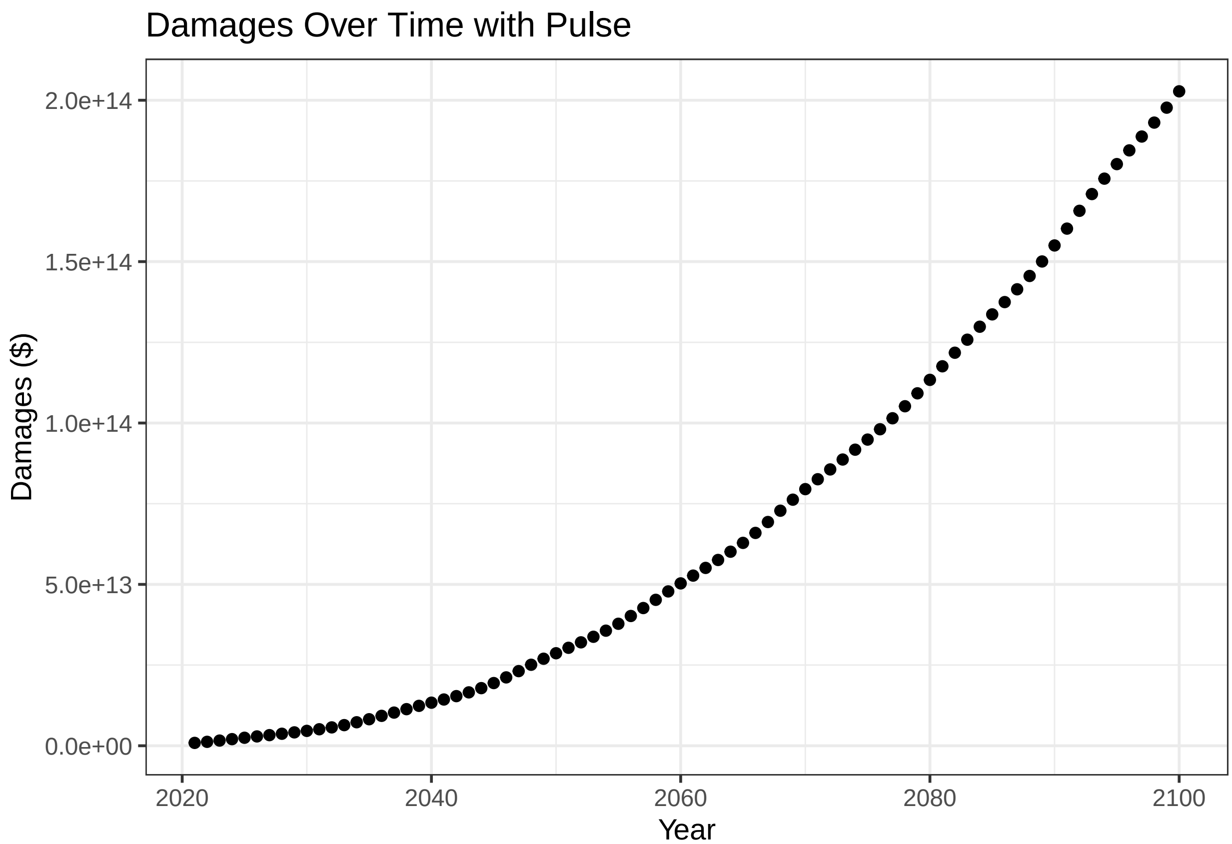
```
# Use the damages function to create a new column for the warming data set

warming_data$damage_baseline <- quadratic_function(warming_data$warming_baseline)

ggplot(data = warming_data, aes(x = year, y = damage_baseline))+
  geom_point()+
  theme_bw()+
  labs(
    y = "Damages ($)",
    x = "Year",
    title = "Baseline Damages Over Time")
```



b) Damages over time with pulse

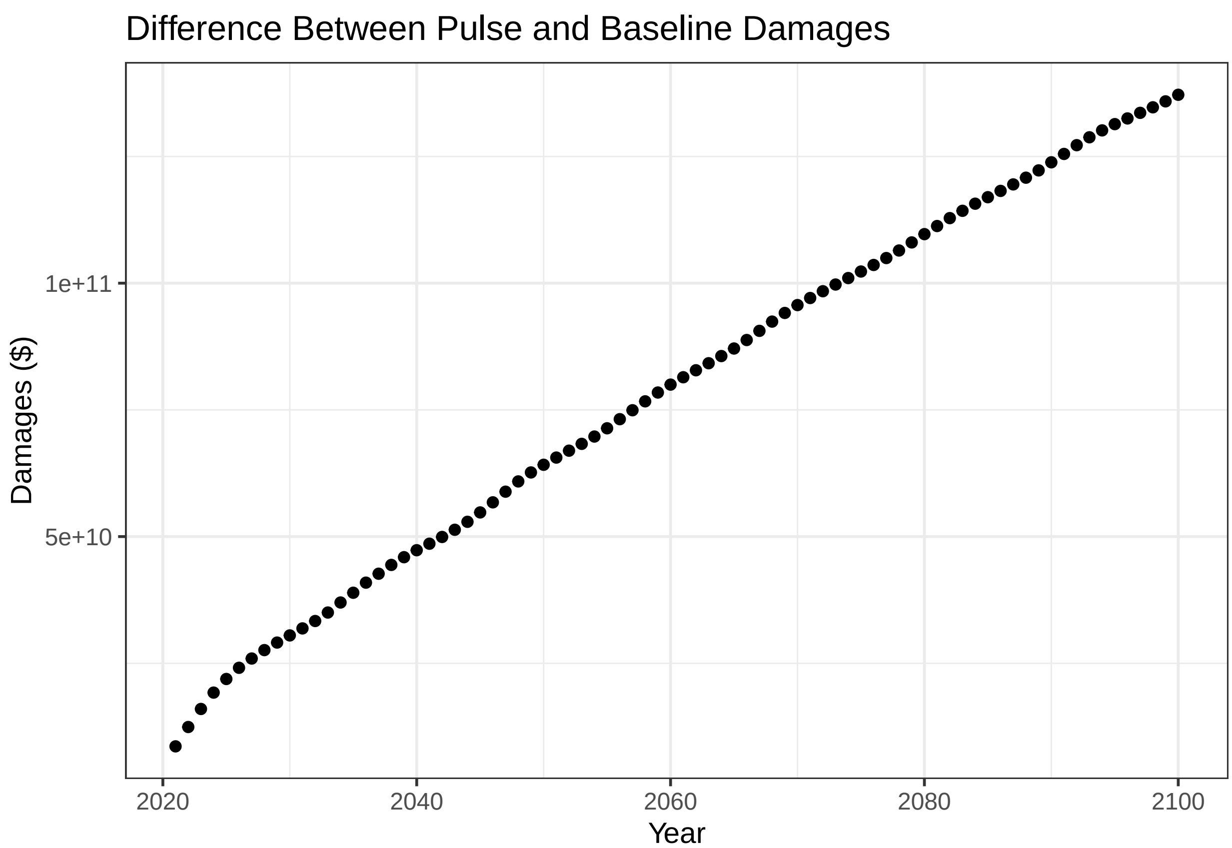
```
# Use damages function to create a new column for warming data set
warming_data$damage_pulse <- quadratic_function(warming_data$warming_pulse)

ggplot(data = warming_data, aes(x = year, y = damage_pulse))+
  geom_point()+
  theme_bw()+
  labs(
```

```
    y = "Damages ($)",
    x = "Year",
    title = "Damages Over Time with Pulse")
```



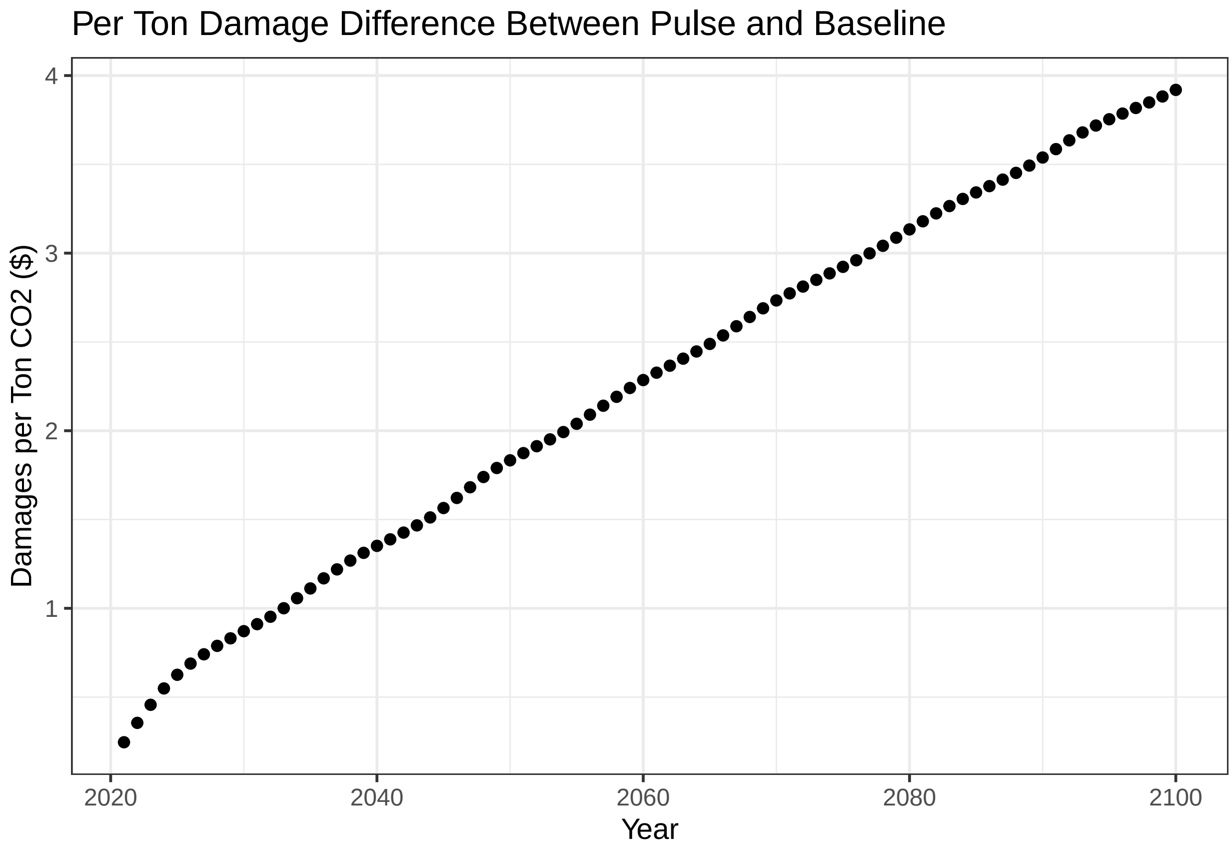
c) Difference in damages over time that arises from the pulse

```
warming_data$damage_difference <-(warming_data$damage_pulse - warming_data$damage_baseline)

ggplot(data = warming_data, aes(x = year, y = damage_difference))+
  geom_point()+
  theme_bw()+
  labs(
    y = "Damages ($)",
    x = "Year",
    title = "Difference Between Pulse and Baseline Damages")
```



d) Difference in damages over time per ton of CO2

```
warming_data$damage_diff_per_ton <-(warming_data$damage_difference/ 3.5e+10)

ggplot(data = warming_data, aes(x = year, y = damage_diff_per_ton))+
  geom_point()+
  theme_bw()+
  labs(
    y = "Damages per Ton CO2 ($)",
    x = "Year",
    title = "Per Ton Damage Difference Between Pulse and Baseline")
```

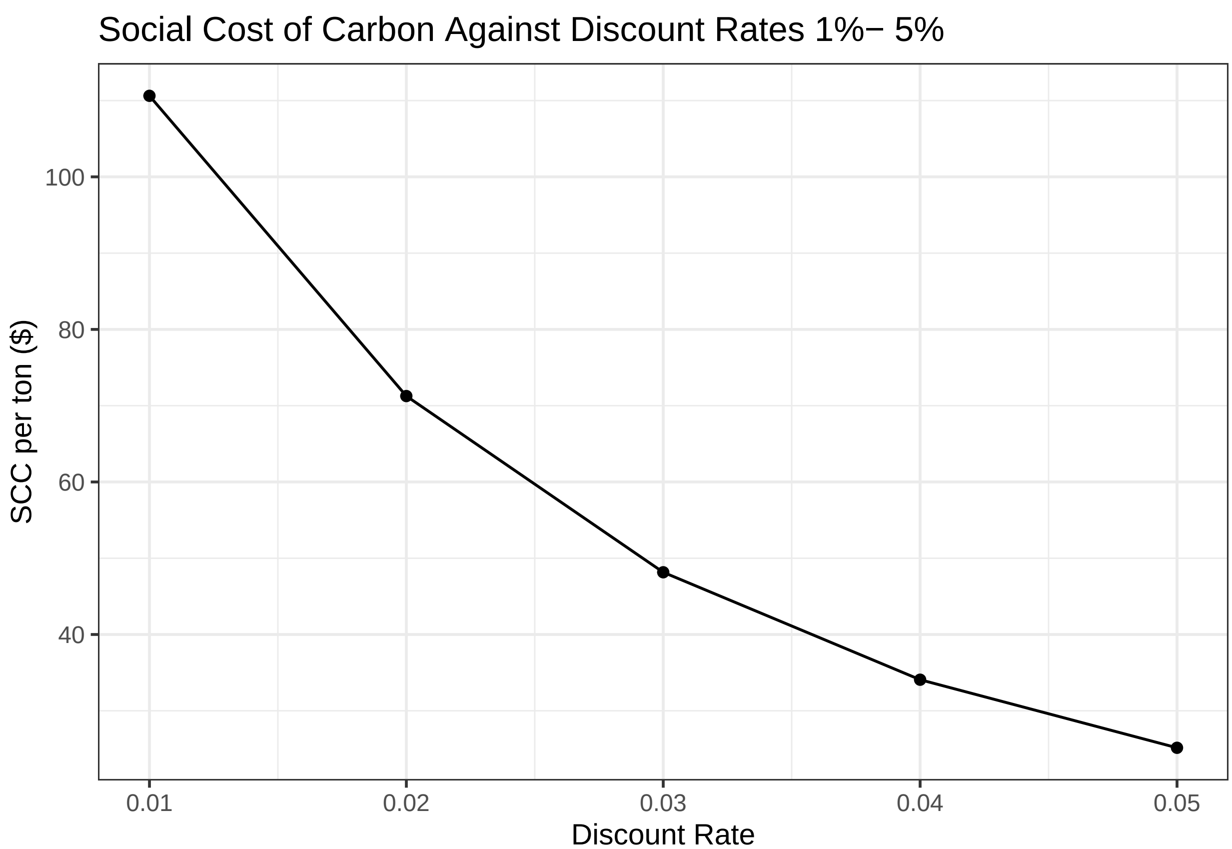


3. Social Cost of Carbon

```
# Write a function for the social cost of carbon (SCC) according to discount rate
scc <- function(r) warming_data$damage_diff_per_ton/((1+r)^warming_data$x1)

# Make new columns of different discount rates
warming_data$scc_1 <- scc(0.01)
warming_data$scc_2 <- scc(0.02)
warming_data$scc_3 <- scc(0.03)
warming_data$scc_4 <- scc(0.04)
warming_data$scc_5 <- scc(0.05)
```

```
scc_1_sum <- sum(warming_data$scc_1)

scc_2_sum <- sum(warming_data$scc_2)

scc_3_sum <- sum(warming_data$scc_3)

scc_4_sum <- sum(warming_data$scc_4)

scc_5_sum <- sum(warming_data$scc_5)

#make vectors
```

```r
damage_per_ton <- c(scc_1_sum,scc_2_sum, scc_3_sum, scc_4_sum, scc_5_sum )

r <- c(0.01, 0.02, 0.03, 0.04, 0.05)
scc_df<- data.frame(r,damage_per_ton)

ggplot(data= scc_df, aes(x= r, y=damage_per_ton)) +
  geom_point()+
  geom_line()+
  theme_bw()+
  labs(
    y = "SCC per ton ($)",
    x = "Discount Rate",
    title = "Social Cost of Carbon Against Discount Rates 1%- 5% ")
```



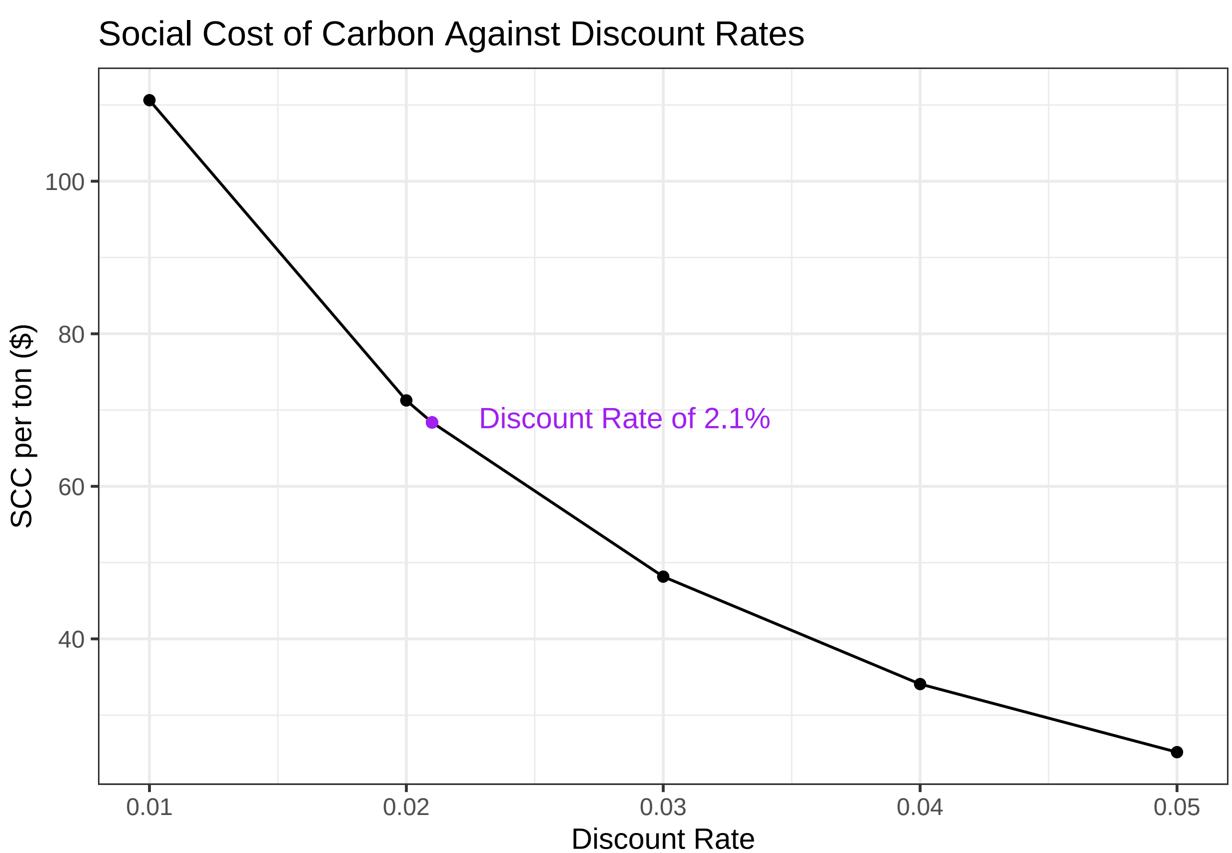
4. Ramsey Rule SCC calculation

```r
# Function for Ramsey Rule
ramsey_rule <- function(p, n, g) p + n*g

# Find the SCC for our given values
ramsey_rule(p = 0.001, n = 2, g = 0.01)
```

```
## [1] 0.021
```

Using the Ramsey Rule, we found the discount rule should be 2.1%.

```
# Make new column in our warming data of this discount rate
warming_data$scc_2.1 <- scc(0.021)
# Find the sum of damages at this SCC
scc_2.1_sum <- sum(warming_data$scc_2.1)

#make vectors
ramsey_damage_per_ton <- c(scc_1_sum,scc_2_sum, scc_2.1_sum, scc_3_sum, scc_4_sum, scc_5_sum )

ramsey_r <- c(0.01, 0.02, 0.021, 0.03, 0.04, 0.05)
ramsey_scc_df<- data.frame(ramsey_r,ramsey_damage_per_ton)

# Plot this point on our graph from 4d
ggplot(data= ramsey_scc_df, aes(x= ramsey_r, y=ramsey_damage_per_ton)) +
  geom_point()+
  geom_line()+
  theme_bw()+
  labs(
    y = "SCC per ton ($)",
    x = "Discount Rate",
    title = "Social Cost of Carbon Against Discount Rates ")+
  annotate("text", x = 0.0285, y = 69, color = " purple", label = "Discount Rate of 2.1%")+
  geom_point(aes(x = 0.021, y = 68.37845), color = "purple")
```



5. Possible Climate Policies

Policy A

```r
#Find the present value of damages
warming_data$base_a <- warming_data$damage_baseline/((1+.02)^warming_data$x1)

# Sum the present values
present_val_base_a_sum <- sum(warming_data$base_a)

# add X1.5 to warming values and rerun
warming_data$warming_1.5_a <- 1.5*(warming_data$warming_baseline)

# Find the damages of a warming change (1.5* baseline) using damages function
warming_data$damage_1.5_a <- quadratic_function(warming_data$warming_1.5_a)

#Find the present value of damages of 1.5 warming values
warming_data$base_1.5_a <- warming_data$damage_1.5_a/((1+.02)^warming_data$x1)

# Sum the present values
present_val_1.5_a_sum <- sum(warming_data$base_1.5_a)

# Expected present value of damages under policy A
expected_value <- function(p1, x1, p2, x2) p1*x1+p2*x2

expected_policyA <- expected_value(0.5, present_val_base_a_sum, 0.5, present_val_1.5_a_sum)
expected_policyA
```

```
## [1] 2.931794e+15
```

Expected present value of damages up to 2100 under Policy A is equal to \$ 2.9317944×10^{15}.

Policy B

```r
# Make a warming column for policy B, where  warming will continue until 2050 as in the "baseline" data
warming_data$base_b <- ifelse(warming_data$year >= 2050, 1.29, warming_data$warming_baseline)

# Find damages associated with Policy B
warming_data$damage_policyB <- quadratic_function(warming_data$base_b)

#Find the present value of damages of Policy B
warming_data$pv_damage_policyB <- warming_data$damage_policyB/((1+.02)^warming_data$x1)

# Sum the present values
sum_pv_damage_policyB <- sum(warming_data$pv_damage_policyB)

sum_pv_damage_policyB
```

```
## [1] 7.098796e+14
```

Expected present value of damages up to 2100 under Policy B is equal to \$ 7.0987961×10^{14}.

With society being risk neutral, X could be equal to the summed present value of Policy A subtracted by the summed present value of Policy B, for it to still make economic sense to pursue Policy B over Policy A. After that point, society would be more likely to pursue Policy A as it would be economically more affordable.

Under Policy A, society would have more risk associated with potential outcome. If society is risk averse and the costs of the two policies were the same, society would be more likely to choose to pursue Policy B due to the higher utility society gains.