Assignment #1: German Credit

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Regression Model

```
df <- GermanCredit
df <- df %>% select(-Class) # Remove Class variable

full_model <- lm(Amount ~ ., data=df)
# summary(full_model)

# Save and Print Coefficients
full_model_coeff <- full_model$coefficients
full_model_coeff
```

```
##                             (Intercept)                                Duration
##                              6473.24572                              127.22804
##                InstallmentRatePercentage                     ResidenceDuration
##                                -783.07567                              -52.07222
##                                     Age                   NumberExistingCredits
##                                 5.75204                               75.35581
##                  NumberPeopleMaintenance                               Telephone
##                                -198.28236                             -483.36894
##                            ForeignWorker             CheckingAccountStatus.lt.0
##                                -249.97139                             -104.08052
##           CheckingAccountStatus.0.to.200           CheckingAccountStatus.gt.200
##                                 213.45397                             -614.78718
##               CheckingAccountStatus.none          CreditHistory.NoCredit.AllPaid
##                                       NA                              858.17909
##           CreditHistory.ThisBank.AllPaid                 CreditHistory.PaidDuly
##                                -50.32424                              -15.85221
##                      CreditHistory.Delay                 CreditHistory.Critical
##                                102.78461                                      NA
##                            Purpose.NewCar                      Purpose.UsedCar
##                                -1757.06185                            -1119.30058
##               Purpose.Furniture.Equipment                Purpose.Radio.Television
##                                -1836.09216                            -2071.60201
##                Purpose.DomesticAppliance                      Purpose.Repairs
##                                -2464.06380                            -1707.78133
##                         Purpose.Education                      Purpose.Vacation
##                                -1892.28951                                    NA
##                        Purpose.Retraining                      Purpose.Business
##                                -2209.35799                            -1989.46611
```

```
##                           Purpose.Other             SavingsAccountBonds.lt.100
##                                      NA                               -327.00664
##          SavingsAccountBonds.100.to.500        SavingsAccountBonds.500.to.1000
##                                -569.23487                               -643.52855
##             SavingsAccountBonds.gt.1000            SavingsAccountBonds.Unknown
##                                -385.98649                                      NA
##                 EmploymentDuration.lt.1              EmploymentDuration.1.to.4
##                                 115.35227                                51.82530
##               EmploymentDuration.4.to.7                EmploymentDuration.gt.7
##                                 113.35764                               -163.18910
##           EmploymentDuration.Unemployed       Personal.Male.Divorced.Seperated
##                                      NA                                480.33678
##               Personal.Female.NotSingle                  Personal.Male.Single
##                                 282.09482                                730.16723
##           Personal.Male.Married.Widowed                Personal.Female.Single
##                                      NA                                      NA
##             OtherDebtorsGuarantors.None     OtherDebtorsGuarantors.CoApplicant
##                                 138.71303                                752.18304
##        OtherDebtorsGuarantors.Guarantor                  Property.RealEstate
##                                      NA                               -840.99813
##                      Property.Insurance                   Property.CarOther
##                                -588.80108                               -570.75237
##                        Property.Unknown          OtherInstallmentPlans.Bank
##                                      NA                               -143.90714
##            OtherInstallmentPlans.Stores          OtherInstallmentPlans.None
##                                -62.89011                                      NA
##                             Housing.Rent                             Housing.Own
##                                 243.68008                                131.43220
##                           Housing.ForFree              Job.UnemployedUnskilled
##                                      NA                               -1715.11138
##                  Job.UnskilledResident                  Job.SkilledEmployee
##                               -1198.70995                               -1253.90023
## Job.Management.SelfEmp.HighlyQualified
##                                      NA
```

Split into Train/Test Sets and Run Model 1,000 times

```
set.seed(777)

# Create ID to help with splitting into Train/Test
df$id <- 1:nrow(df)

my_df <- data.frame()

# Run 1,000 Linear models
for(n in 1:1000){

  # Split 63.20% of the data into the train set and the rest into test
  train <- df %>% dplyr::sample_frac(0.632)
  test  <- dplyr::anti_join(df, train, by = 'id')
```

```
  # Drop id column before running model since it does not have value
  train$id <- NULL
  test$id  <- NULL

  # Run the linear model on all the independent variables
  model <- lm(Amount ~., data=train)

  # Capture the predictions on the Test / Holdout set
  predictions <- predict(model, test)

  # Save the coefficients, and R-squared for the training and holdout
  save_coeff <- model$coefficients
  save_r2_training <- summary(model)$r.squared
  save_r2_holdout <- cor(test$Amount, predict(model, newdata = test))^2

  con <- c(save_coeff, save_r2_training, save_r2_holdout)
  my_df <- rbind(my_df, con)
}

# Remove ID variable and Amount variable
df$id <- NULL
df$Amount <- NULL

# Drop dependent variable Amount and remove na

# my_df <- my_df %>% select(-Amount) %>% na.omit()

# Update Column Names
colnames(my_df)[1] <- "(Intercept)"
colnames(my_df)[2:61] <- names(df)
colnames(my_df)[62] <- "training_r2"
colnames(my_df)[63] <- "holdout_r2"

head(my_df, 3)
```

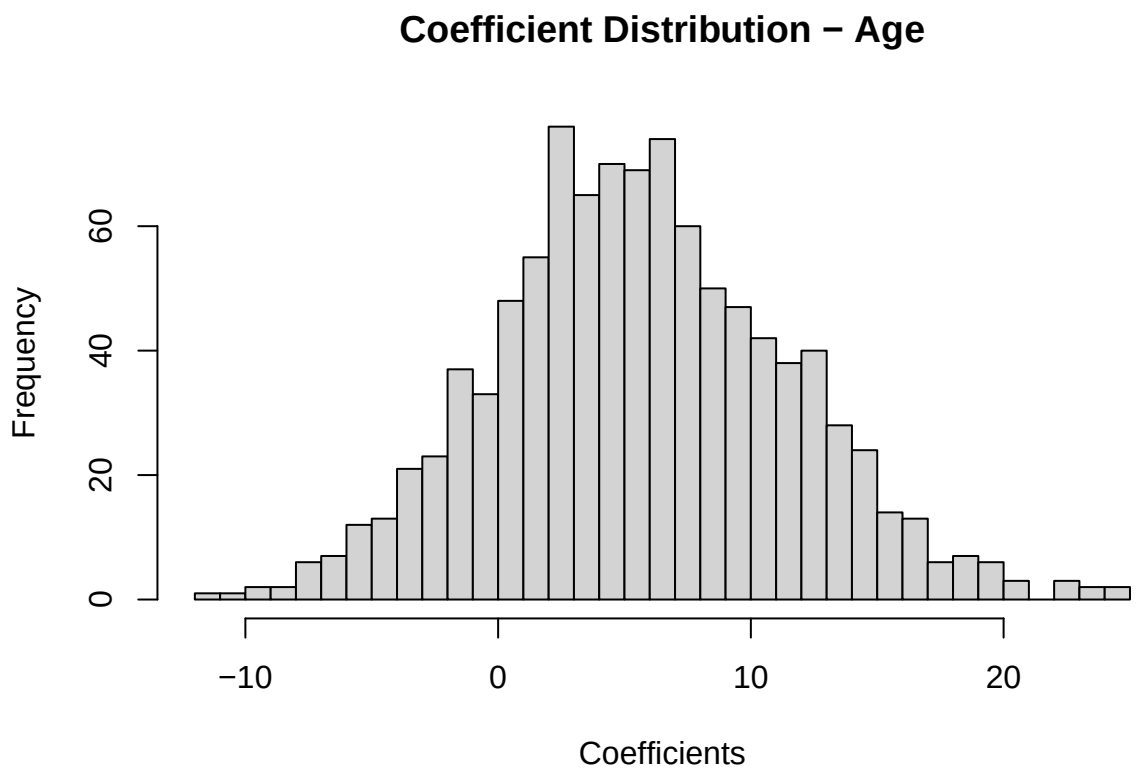
```
##   (Intercept) Duration InstallmentRatePercentage ResidenceDuration        Age
## 1    7053.006 132.5061                -811.3683          4.879213 -3.3883285
## 2    8742.704 128.5282                -808.0595       -125.022627  0.4969038
## 3    6213.055 128.2768                -855.5463         -7.752832 -3.5933384
##   NumberExistingCredits NumberPeopleMaintenance Telephone ForeignWorker
## 1             -64.89621              -276.0670 -361.8853     -332.9213
## 2             117.92245              -111.0212 -513.6035     -139.2039
## 3             159.22881              -217.7662 -372.9430     -196.7809
##   CheckingAccountStatus.lt.0 CheckingAccountStatus.0.to.200
## 1                -145.86101                       220.0945
## 2                 102.85244                       195.0846
## 3                  39.38775                       379.5955
##   CheckingAccountStatus.gt.200 CheckingAccountStatus.none
## 1                    -584.4721                         NA
## 2                    -677.3200                         NA
## 3                    -410.8699                         NA
##   CreditHistory.NoCredit.AllPaid CreditHistory.ThisBank.AllPaid
## 1                       962.4469                      -402.1201
```

```
## 2                      715.3007                       127.1241
## 3                      847.2132                      -264.0714
##   CreditHistory.PaidDuly CreditHistory.Delay CreditHistory.Critical
## 1             -325.39323          -248.09909                     NA
## 2              107.28357           248.44989                     NA
## 3               83.04295           -81.16513                     NA
##   Purpose.NewCar Purpose.UsedCar Purpose.Furniture.Equipment
## 1      -1190.621       -163.0444                   -1110.880
## 2      -3616.351      -2960.3367                   -3900.596
## 3      -2202.571      -1245.5712                   -2258.378
##   Purpose.Radio.Television Purpose.DomesticAppliance Purpose.Repairs
## 1                -1343.701                -2101.464       -1402.828
## 2                -3987.831                -4747.327       -3527.883
## 3                -2402.341                -2819.007       -1916.458
##   Purpose.Education Purpose.Vacation Purpose.Retraining Purpose.Business
## 1         -809.9535               NA          -1437.532        -1149.776
## 2        -3660.1191               NA          -4200.430        -3827.898
## 3        -1971.9619               NA          -3509.607        -2588.997
##   Purpose.Other SavingsAccountBonds.lt.100 SavingsAccountBonds.100.to.500
## 1            NA                  -442.9623                       -636.0945
## 2            NA                  -432.0049                       -633.2180
## 3            NA                  -444.3698                       -320.4523
##   SavingsAccountBonds.500.to.1000 SavingsAccountBonds.gt.1000
## 1                       -813.7547                   -349.6858
## 2                       -499.8858                   -474.0402
## 3                       -798.5119                   -366.0600
##   SavingsAccountBonds.Unknown EmploymentDuration.lt.1 EmploymentDuration.1.to.4
## 1                          NA              -250.82327                -413.26081
## 2                          NA               -79.14711                 -39.77819
## 3                          NA               162.34220                 212.60865
##   EmploymentDuration.4.to.7 EmploymentDuration.gt.7
## 1                -318.16077              -618.95656
## 2                  51.27917               -77.74344
## 3                 281.68776               -37.57796
##   EmploymentDuration.Unemployed Personal.Male.Divorced.Seperated
## 1                            NA                         624.6313
## 2                            NA                         719.7154
## 3                            NA                         678.8079
##   Personal.Female.NotSingle Personal.Male.Single Personal.Male.Married.Widowed
## 1                  333.4951            812.9995                            NA
## 2                  308.9360            714.9203                            NA
## 3                  -31.7201            638.3747                            NA
##   Personal.Female.Single OtherDebtorsGuarantors.None
## 1                     NA                    -88.6265
## 2                     NA                    164.2454
## 3                     NA                    573.1364
##   OtherDebtorsGuarantors.CoApplicant OtherDebtorsGuarantors.Guarantor
## 1                           572.7070                               NA
## 2                           516.7521                               NA
## 3                          1048.1418                               NA
##   Property.RealEstate Property.Insurance Property.CarOther Property.Unknown
## 1           -765.9383          -717.8129         -736.9864               NA
## 2           -725.9376          -507.3184         -430.6413               NA
## 3          -1062.9615          -749.6071         -850.4425               NA
```

```
##   OtherInstallmentPlans.Bank OtherInstallmentPlans.Stores
## 1                  -220.58870                    -24.26371
## 2                  -253.11178                   -110.13515
## 3                   -64.04921                     23.08561
##   OtherInstallmentPlans.None Housing.Rent Housing.Own Housing.ForFree
## 1                         NA   232.368137    258.7847              NA
## 2                         NA     8.499965   -170.6788              NA
## 3                         NA   673.179510    764.3539              NA
##   Job.UnemployedUnskilled Job.UnskilledResident Job.SkilledEmployee
## 1                -1402.272             -1144.332           -1258.025
## 2                -1830.999             -1187.417           -1263.488
## 3                -1582.527             -1269.402           -1220.914
##   Job.Management.SelfEmp.HighlyQualified training_r2 holdout_r2
## 1                                     NA   0.6178389  0.5648368
## 2                                     NA   0.6122784  0.5816260
## 3                                     NA   0.6231289  0.5467266
```

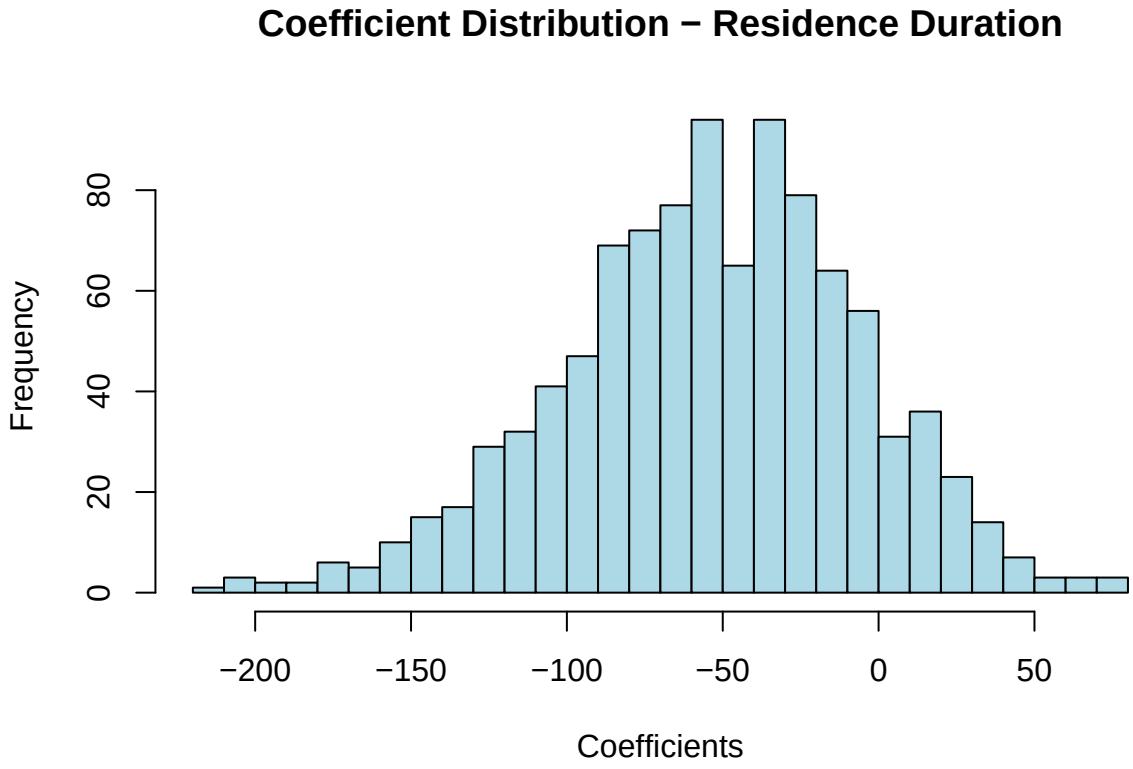
Coefficient & R-Squared Distributions

```
hist(my_df$Age,
     breaks=30,
     xlab = "Coefficients", main = "Coefficient Distribution - Age")
```



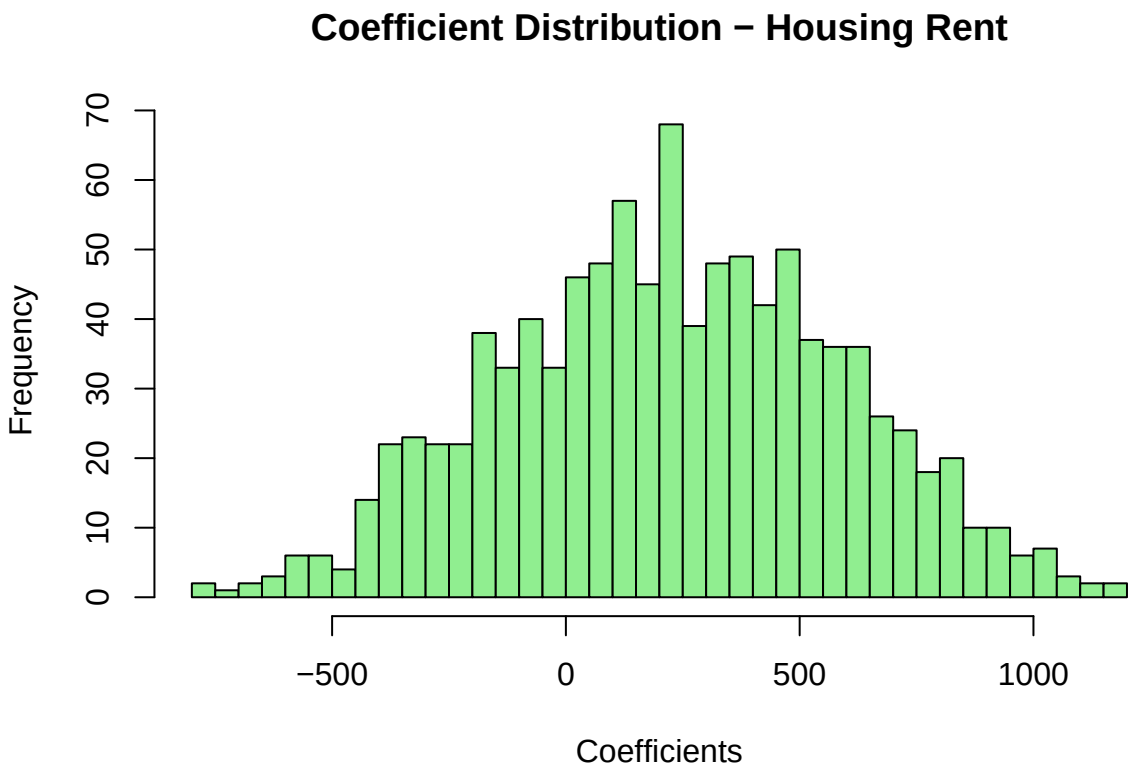
Plot Interpretation: the age coefficients are sometimes negatives which is the opposite of what I would normall think. Generally older people have higher credit, so seeing that the model sometimes says a higher age means less credit is surprising. Overall the plot indicates age tends to have a positive impact on credit amount.

```
hist(my_df$ResidenceDuration,
     breaks=30,
     xlab = "Coefficients", main = "Coefficient Distribution - Residence Duration", col="lightblue")
```

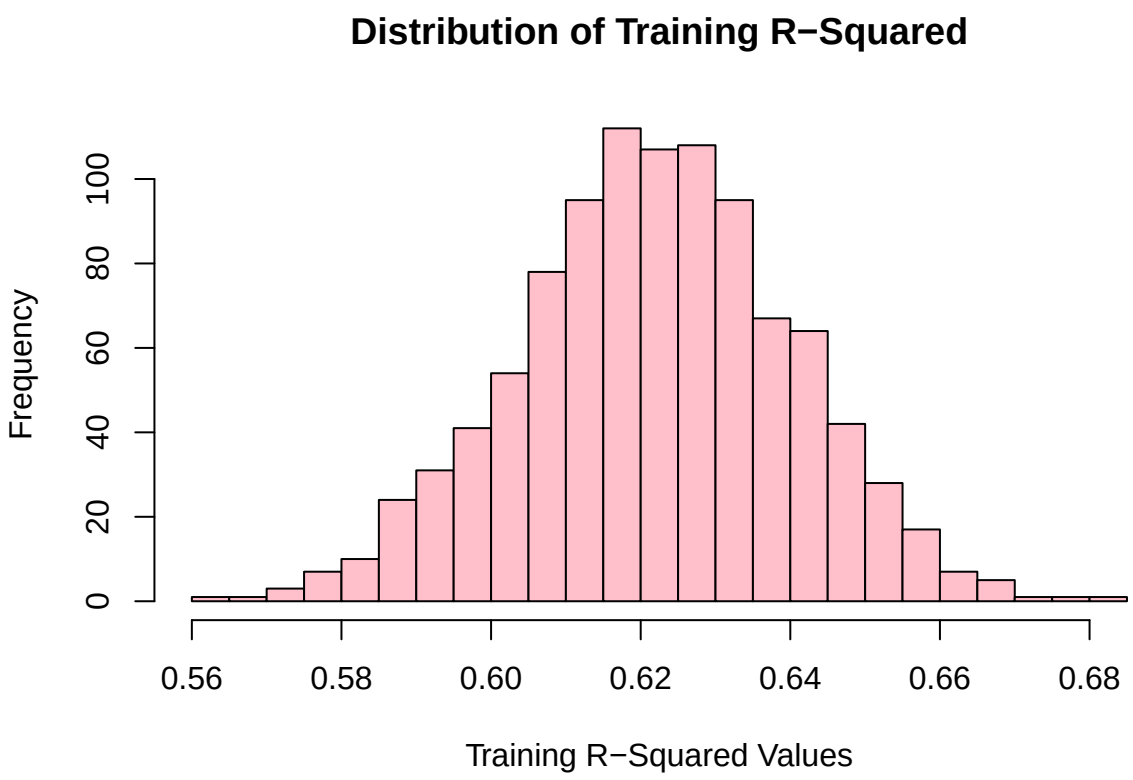


Plot Interpretation:

```
hist(my_df$Housing.Rent,
     breaks=30,
     xlab = "Coefficients", main = "Coefficient Distribution - Housing Rent", col="lightgreen")
```



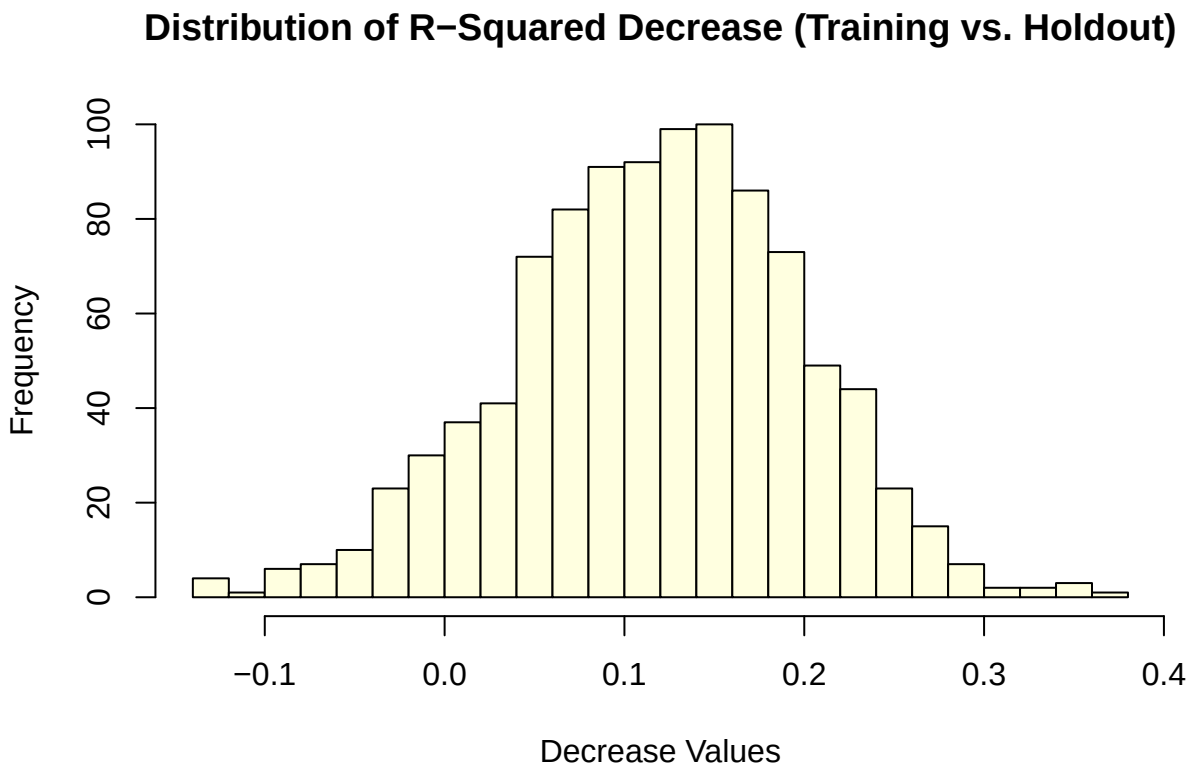

```
hist(my_df$training_r2,
     breaks=30,
     xlab = "Training R-Squared Values", main = "Distribution of Training R-Squared", col="pink")
```




```
my_df <- my_df %>% mutate(r2_decrease = (training_r2 - holdout_r2)/training_r2)
head(my_df$r2_decrease, 5)
```

```
## [1] 0.08578634 0.05006284 0.12261069 0.26808393 0.02836774
```

```
hist(my_df$r2_decrease,
     breaks=30,
     xlab = "Decrease Values", main = "Distribution of R-Squared Decrease (Training vs. Holdout)",
     col="lightyellow")
```



Summary - Interpretation of Above Plots:

```
coefficient_means <- colMeans(my_df)
head(coefficient_means, 5)
```

```
##               (Intercept)                  Duration InstallmentRatePercentage
##              6514.445005                126.992393                -782.770921
##         ResidenceDuration                       Age
##                -53.757369                  5.662497
```

```
coefficient_sds <- sapply(my_df, sd)
head(coefficient_sds, 5)
```

```
##               (Intercept)                  Duration InstallmentRatePercentage
##              1288.098431                  5.387694                 47.668309
##         ResidenceDuration                       Age
##                 47.748450                  5.836145
```

```
# Difference between coefficient_means and actual model coefficients
bind <- data.frame(cbind(coefficient_means, save_coeff))
bind$abs_diff <- abs(coefficient_means - save_coeff)
bind$percent_diff <- 100*abs(((coefficient_means - save_coeff) / save_coeff))

print(bind %>% na.omit())
```

```
##                                    coefficient_means    save_coeff    abs_diff
## (Intercept)                             6514.4450052  6787.3109335  272.865928
## Duration                                 126.9923926   121.7024620    5.289931
## InstallmentRatePercentage               -782.7709212  -803.3828621   20.611941
## ResidenceDuration                        -53.7573686    20.1154552   73.872824
## Age                                        5.6624968     1.4118155    4.250681
## NumberExistingCredits                     75.5933144     9.3048900   66.288424
## NumberPeopleMaintenance                 -207.9595145  -294.5123347   86.552820
## Telephone                               -478.1912394  -430.0143516   48.176888
## ForeignWorker                           -236.7257922  -174.4323728   62.293419
## CheckingAccountStatus.lt.0              -103.2913906    -0.3607945  102.930596
## CheckingAccountStatus.0.to.200           205.8951983   279.2494699   73.354272
## CheckingAccountStatus.gt.200            -616.6448860  -573.6950070   42.949879
## CreditHistory.NoCredit.AllPaid           849.4984033   508.5678641  340.930539
## CreditHistory.ThisBank.AllPaid           -47.9907468  -459.7257283  411.734981
## CreditHistory.PaidDuly                   -15.6668989   -61.1902427   45.523344
## CreditHistory.Delay                      113.9620829   138.9943540   25.032271
## Purpose.NewCar                         -1768.1136034 -2180.1076255  411.994022
## Purpose.UsedCar                        -1131.1941473 -1440.8553893  309.661242
## Purpose.Furniture.Equipment            -1851.4854148 -2295.6493157  444.163901
## Purpose.Radio.Television               -2085.7345008 -2454.9706733  369.236173
## Purpose.DomesticAppliance              -2481.7388581 -2559.0089901   77.270132
## Purpose.Repairs                        -1710.5724217 -1977.8988925  267.326471
## Purpose.Education                      -1907.1014641 -2429.6229301  522.521466
## Purpose.Business                       -1992.6396355 -2597.8420276  605.202392
## SavingsAccountBonds.lt.100              -329.4394441  -334.6707759    5.231332
## SavingsAccountBonds.100.to.500          -564.8601422  -201.3723119  363.487830
## SavingsAccountBonds.500.to.1000         -659.1950634  -769.0039648  109.808901
## SavingsAccountBonds.gt.1000             -386.4586074  -108.6142881  277.844319
## EmploymentDuration.lt.1                  114.2590421  -293.0847250  407.343767
## EmploymentDuration.1.to.4                 48.4814756   -89.4589353  137.940411
## EmploymentDuration.4.to.7                109.5993845  -200.9872948  310.586679
## EmploymentDuration.gt.7                 -159.3121487  -510.3288707  351.016722
## Personal.Male.Divorced.Seperated         480.5116417   503.3091425   22.797501
## Personal.Female.NotSingle                278.5919279   124.8996358  153.692292
## Personal.Male.Single                     735.2182940   892.2249404  157.006646
## OtherDebtorsGuarantors.None              129.5228933   133.9857097    4.462816
## OtherDebtorsGuarantors.CoApplicant       736.4230085   677.5142604   58.908748
## Property.RealEstate                     -837.7940304  -900.2620942   62.468064
## Property.Insurance                      -590.7038970  -511.6185864   79.085311
## Property.CarOther                       -566.1199297  -605.4682045   39.348275
## OtherInstallmentPlans.Bank              -150.7777877    31.0931649  181.870953
## OtherInstallmentPlans.Stores             -44.9924066   582.1274420  627.119849
## Housing.Rent                             227.0673423   822.5800230  595.512681
## Housing.Own                              108.5780856   583.4525437  474.874458
## Job.UnemployedUnskilled                 -1688.5415978 -1857.0267610  168.485163
## Job.UnskilledResident                   -1192.5282121 -1174.7391001   17.789112
## Job.SkilledEmployee                     -1246.9380397 -1141.4595832  105.478456
## training_r2                                 0.6219217  6787.3109335 6786.689012
## holdout_r2                                  0.5477035   121.7024620  121.154758
## r2_decrease                                 0.1170542  -803.3828621  803.499916
##                                    percent_diff
## (Intercept)                            4.020236
## Duration                               4.346609
```

```
## InstallmentRatePercentage             2.565644
## ResidenceDuration                   367.244107
## Age                                 301.079107
## NumberExistingCredits               712.404169
## NumberPeopleMaintenance              29.388521
## Telephone                            11.203553
## ForeignWorker                        35.712075
## CheckingAccountStatus.lt.0        28528.869177
## CheckingAccountStatus.0.to.200       26.268366
## CheckingAccountStatus.gt.200          7.486535
## CreditHistory.NoCredit.AllPaid       67.037374
## CreditHistory.ThisBank.AllPaid       89.561005
## CreditHistory.PaidDuly               74.396410
## CreditHistory.Delay                  18.009560
## Purpose.NewCar                       18.897875
## Purpose.UsedCar                      21.491487
## Purpose.Furniture.Equipment          19.348073
## Purpose.Radio.Television             15.040350
## Purpose.DomesticAppliance             3.019533
## Purpose.Repairs                      13.515679
## Purpose.Education                    21.506278
## Purpose.Business                     23.296351
## SavingsAccountBonds.lt.100            1.563128
## SavingsAccountBonds.100.to.500      180.505367
## SavingsAccountBonds.500.to.1000      14.279367
## SavingsAccountBonds.gt.1000         255.808259
## EmploymentDuration.lt.1             138.984987
## EmploymentDuration.1.to.4           154.194112
## EmploymentDuration.4.to.7           154.530504
## EmploymentDuration.gt.7              68.782454
## Personal.Male.Divorced.Seperated      4.529522
## Personal.Female.NotSingle           123.052634
## Personal.Male.Single                 17.597204
## OtherDebtorsGuarantors.None           3.330815
## OtherDebtorsGuarantors.CoApplicant    8.694835
## Property.RealEstate                   6.938875
## Property.Insurance                   15.457865
## Property.CarOther                     6.498818
## OtherInstallmentPlans.Bank          584.922613
## OtherInstallmentPlans.Stores        107.728962
## Housing.Rent                         72.395714
## Housing.Own                          81.390417
## Job.UnemployedUnskilled               9.072845
## Job.UnskilledResident                 1.514303
## Job.SkilledEmployee                   9.240665
## training_r2                          99.990837
## holdout_r2                           99.549965
## r2_decrease                         100.014570
```

Calculate Confidence Intervals & Width

```r
# Confidence Interval for Rep 1,000 Coefficients -------------------------------
# Transposed dataframe of confidence intervals for each variable
rep_conf <- data.frame(t(sapply(my_df[1:63], function(x) Rmisc::CI(x, ci=0.975)))) #%>% na.omit()
# Calculate Width
# rep_conf$width <- (rep_conf$upper-rep_conf$lower)*sqrt(0.632)
rep_conf$width <- rep_conf$upper-(rep_conf$lower*sqrt(0.632))

# Reorder columns
rep_conf <- rep_conf %>% select(lower, upper, width)

# Keep only valid columns, remove R2 values
rep_conf <- rep_conf[1:61,]

# Check row count after ommitting NA
nrow(rep_conf)
```

```
## [1] 61
```

```r
# Confidence Interval for Full Model -------------------------------------------
# Calculate confidence interval and rename the columns
full_model_conf <- data.frame(confint(full_model)) %>%
                   #na.omit() %>%
                   dplyr::rename(lower_full = 1, upper_full = 2)

# A
full_model_conf <- full_model_conf %>%
                   #mutate(index=1:nrow(full_model_conf)) %>%
                   #filter(index %in% (2:48)) %>%
                   mutate(width_full=upper_full-lower_full)

# Check row count
nrow(full_model_conf)
```

```
## [1] 61
```

```r
#t <- cbind(rep_conf, full_model_conf)

row.names(rep_conf) == row.names(full_model_conf)
```

```
##  [1] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [16] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [31] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [46] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [61] TRUE
```

```r
#View(cbind(row.names(rep_conf), row.names(full_model_conf)))
```

Determine how many of the repeated sample CI's are tighter

```r
# Combine the 2 dataframes and remove NA values
calc <- cbind(rep_conf, full_model_conf) %>% na.omit()

#Calculate how many of the repeated sample CI's are tighter or broader than the full model CI's. If the

# 1 means the CI is tighter (width of repeated is smaller)
calc$tighter_CI_flag <- ifelse(calc$width < calc$width_full, 1, 0)

percent <- sum(calc$tighter_CI_flag)/nrow(calc)
print(percent*100)
```

```
## [1] 97.87234
```

Conclusion: 97.87% of the simulated/repeated model's CI's are tighter/smaller. In other words, of the 47 columns left after removing NA's and the class column, 46 of the columns' confidence intervals from the repeated samples are smaller/tighter than those comapred to the CI's from the full model.