Task 1: Wage Prediction Model: Data Exploration, Model Selection, and Prediction

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Data Exploration and Preparation: Analyze the features in your dataset to select relevant predictors for the wage.

```
# Load the dataset
# getwd()
# setwd("./3.Applied-Supervised-Learning-Groupwork")
load("./data_wage.RData")

# Handle missing values by removing rows with NAs
data_wage <- na.omit(data)
```

Then our idea was to get a quick overview of the dataset. Which dimensions does the dataset have? Which variable types are used?

```
# Display dataset dimensions and basic structure
dim(data_wage)
```

```
## [1] 10809    78
```

```
summary(data_wage)
```

```
##                       gender          age                              country
##  Female                 :1571   25-29  :3008   United States of America:2505
##  Male                   :9135   30-34  :2064   India                    :1576
##  Prefer not to say      :  72   22-24  :1914   China                    : 563
##  Prefer to self-describe:  31   35-39  :1195   Other                    : 468
##                                 18-21  : 838   Brazil                   : 412
##                                 40-44  : 717   Russia                   : 380
##                                 (Other):1073   (Other)                  :4905
##                                                                education
##  Bachelor's degree                                                  :2990
##  Doctoral degree                                                    :1869
##  I prefer not to answer                                             :  74
##  Master's degree                                                    :5209
##  Professional degree                                                : 281
##  Some college/university study without earning a bachelor's degree: 386
##
##                                                    undergraduate_major
##  Computer science (software engineering, etc.)                    :4239
##  Engineering (non-computer focused)                               :1704
##  Mathematics or statistics                                        :1545
##  A business discipline (accounting, economics, finance, etc.): 884
```

```
##  Physics or astronomy                                          : 626
##  Information technology, networking, or system administration: 447
##  (Other)                                                       :1364
##                job_role                                       industry
##  Data Scientist    :2505   Computers/Technology                  :3032
##  Software Engineer :1800   I am a student                        :1361
##  Student           :1588   Academics/Education                   :1317
##  Data Analyst      :1022   Accounting/Finance                    : 878
##  Research Scientist: 662   Online Service/Internet-based Services: 541
##  Other             : 606   Other                                 : 498
##  (Other)           :2626   (Other)                               :3182
##  years_experience
##  0-1    :2604
##  1-2    :1974
##  5-11   :1421
##  2-3    :1381
##  3-4    : 953
##  4-5    : 854
##  (Other):1622
##                                                                                                ML_atwork
##  I do not know                                                                                        : 815
##  No (we do not use ML methods)                                                                        :2171
##  We are exploring ML methods (and may one day put a model into production)                            :2529
##  We have well established ML methods (i.e., models in production for more than 2 years)               :1756
##  We recently started using ML methods (i.e., models in production for less than 2 years)              :2299
##  We use ML methods for generating insights (but do not put working models into production):1239
##
##  Activities_Analyze.and.understand.data.to.influence.product.or.business.decisions
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :1.000
##  Mean   :0.541
##  3rd Qu.:1.000
##  Max.   :1.000
##
##  Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.wo
##  Min.   :0.0000
##  1st Qu.:0.0000
##  Median :0.0000
##  Mean   :0.3128
##  3rd Qu.:1.0000
##  Max.   :1.0000
##
##  Activities_Build.and.or.run.the.data.infrastructure.that.my.business.uses.for.storing..analyzing..a
##  Min.   :0.0000
##  1st Qu.:0.0000
##  Median :0.0000
##  Mean   :0.3126
##  3rd Qu.:1.0000
##  Max.   :1.0000
##
##  Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
##  Min.   :0.0000
##  1st Qu.:0.0000
```

```
##  Median :0.0000
##  Mean   :0.4266
##  3rd Qu.:1.0000
##  Max.   :1.0000
##
##  Activities_Do.research.that.advances.the.state.of.the.art.of.machine.learning
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :0.000
##  Mean   :0.259
##  3rd Qu.:1.000
##  Max.   :1.000
##
##  Activities_None.of.these.activities.are.an.important.part.of.my.role.at.work
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :0.000
##  Mean   :0.154
##  3rd Qu.:0.000
##  Max.   :1.000
##
##  Notebooks_Kaggle.Kernels Notebooks_Google.Colab Notebooks_Azure.Notebook
##  Min.   :0.0000           Min.   :0.0000         Min.   :0.0000
##  1st Qu.:0.0000           1st Qu.:0.0000         1st Qu.:0.0000
##  Median :0.0000           Median :0.0000         Median :0.0000
##  Mean   :0.3335           Mean   :0.1944         Mean   :0.0741
##  3rd Qu.:1.0000           3rd Qu.:0.0000         3rd Qu.:0.0000
##  Max.   :1.0000           Max.   :1.0000         Max.   :1.0000
##
##  Notebooks_Google.Cloud.Datalab Notebooks_JupyterHub.Binder Notebooks_None
##  Min.   :0.00000                Min.   :0.0000              Min.   :0.0000
##  1st Qu.:0.00000                1st Qu.:0.0000              1st Qu.:0.0000
##  Median :0.00000                Median :0.0000              Median :0.0000
##  Mean   :0.07327                Mean   :0.2774              Mean   :0.3796
##  3rd Qu.:0.00000                3rd Qu.:1.0000              3rd Qu.:1.0000
##  Max.   :1.00000                Max.   :1.0000              Max.   :1.0000
##
##  cloud_Google.Cloud.Platform..GCP. cloud_Amazon.Web.Services..AWS.
##  Min.   :0.0000                    Min.   :0.0000
##  1st Qu.:0.0000                    1st Qu.:0.0000
##  Median :0.0000                    Median :0.0000
##  Mean   :0.2756                    Mean   :0.4596
##  3rd Qu.:1.0000                    3rd Qu.:1.0000
##  Max.   :1.0000                    Max.   :1.0000
##
##  cloud_Microsoft.Azure cloud_IBM.Cloud   cloud_Alibaba.Cloud
##  Min.   :0.0000        Min.   :0.00000   Min.   :0.00000
##  1st Qu.:0.0000        1st Qu.:0.00000   1st Qu.:0.00000
##  Median :0.0000        Median :0.00000   Median :0.00000
##  Mean   :0.2329        Mean   :0.06874   Mean   :0.02692
##  3rd Qu.:0.0000        3rd Qu.:0.00000   3rd Qu.:0.00000
##  Max.   :1.0000        Max.   :1.00000   Max.   :1.00000
##
##  cloud_I.have.not.used.any.cloud.providers Programming_Python Programming_R
```

```
##  Min.   :0.0000                            Min.   :0.0000     Min.   :0.0000
##  1st Qu.:0.0000                            1st Qu.:1.0000     1st Qu.:0.0000
##  Median :0.0000                            Median :1.0000     Median :0.0000
##  Mean   :0.3209                            Mean   :0.8832     Mean   :0.4208
##  3rd Qu.:1.0000                            3rd Qu.:1.0000     3rd Qu.:1.0000
##  Max.   :1.0000                            Max.   :1.0000     Max.   :1.0000
##
##  Programming_SQL  Programming_Bash Programming_Java
##  Min.   :0.0000   Min.   :0.0000   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.:0.0000   1st Qu.:0.0000
##  Median :1.0000   Median :0.0000   Median :0.0000
##  Mean   :0.5478   Mean   :0.1929   Mean   :0.2363
##  3rd Qu.:1.0000   3rd Qu.:0.0000   3rd Qu.:0.0000
##  Max.   :1.0000   Max.   :1.0000   Max.   :1.0000
##
##  Programming_Javascript.Typescript Programming_Visual.Basic.VBA
##  Min.   :0.000                     Min.   :0.0000
##  1st Qu.:0.000                     1st Qu.:0.0000
##  Median :0.000                     Median :0.0000
##  Mean   :0.212                     Mean   :0.0841
##  3rd Qu.:0.000                     3rd Qu.:0.0000
##  Max.   :1.000                     Max.   :1.0000
##
##  Programming_C.C.. Programming_MATLAB Programming_Scala Programming_Julia
##  Min.   :0.0000    Min.   :0.0000     Min.   :0.00000   Min.   :0.00000
##  1st Qu.:0.0000    1st Qu.:0.0000     1st Qu.:0.00000   1st Qu.:0.00000
##  Median :0.0000    Median :0.0000     Median :0.00000   Median :0.00000
##  Mean   :0.2496    Mean   :0.1548     Mean   :0.05791   Mean   :0.01508
##  3rd Qu.:0.0000    3rd Qu.:0.0000     3rd Qu.:0.00000   3rd Qu.:0.00000
##  Max.   :1.0000    Max.   :1.0000     Max.   :1.00000   Max.   :1.00000
##
##  Programming_SAS.STATA Programming_language_used_most_often
##  Min.   :0.00000       Python :5754
##  1st Qu.:0.00000       R      :1500
##  Median :0.00000       SQL    : 973
##  Mean   :0.06994       Java   : 598
##  3rd Qu.:0.00000       C/C++  : 447
##  Max.   :1.00000       C#/.NET: 309
##                        (Other):1228
##  ML_framework_Scikit.Learn ML_framework_TensorFlow ML_framework_Keras
##  Min.   :0.000             Min.   :0.0000          Min.   :0.0000
##  1st Qu.:0.000             1st Qu.:0.0000          1st Qu.:0.0000
##  Median :1.000             Median :1.0000          Median :0.0000
##  Mean   :0.702             Mean   :0.5701          Mean   :0.4681
##  3rd Qu.:1.000             3rd Qu.:1.0000          3rd Qu.:1.0000
##  Max.   :1.000             Max.   :1.0000          Max.   :1.0000
##
##  ML_framework_PyTorch ML_framework_Spark.MLlib ML_framework_H20
##  Min.   :0.0000       Min.   :0.0000           Min.   :0.00000
##  1st Qu.:0.0000       1st Qu.:0.0000           1st Qu.:0.00000
##  Median :0.0000       Median :0.0000           Median :0.00000
##  Mean   :0.2163       Mean   :0.1384           Mean   :0.08844
##  3rd Qu.:0.0000       3rd Qu.:0.0000           3rd Qu.:0.00000
##  Max.   :1.0000       Max.   :1.0000           Max.   :1.00000
```

```
##
##  ML_framework_Caret ML_framework_Xgboost ML_framework_randomForest
##  Min.   :0.0000     Min.   :0.0000       Min.   :0.0000
##  1st Qu.:0.0000     1st Qu.:0.0000       1st Qu.:0.0000
##  Median :0.0000     Median :0.0000       Median :0.0000
##  Mean   :0.1453     Mean   :0.3318       Mean   :0.3482
##  3rd Qu.:0.0000     3rd Qu.:1.0000       3rd Qu.:1.0000
##  Max.   :1.0000     Max.   :1.0000       Max.   :1.0000
##
##  ML_framework_None Visualization_ggplot2 Visualization_Matplotlib
##  Min.   :0.000     Min.   :0.0000        Min.   :0.0000
##  1st Qu.:0.000     1st Qu.:0.0000        1st Qu.:0.0000
##  Median :0.000     Median :0.0000        Median :1.0000
##  Mean   :0.118     Mean   :0.4739        Mean   :0.7495
##  3rd Qu.:0.000     3rd Qu.:1.0000        3rd Qu.:1.0000
##  Max.   :1.000     Max.   :1.0000        Max.   :1.0000
##
##  Visualization_Altair Visualization_Shiny Visualization_Plotly
##  Min.   :0.00000      Min.   :0.0000      Min.   :0.0000
##  1st Qu.:0.00000      1st Qu.:0.0000      1st Qu.:0.0000
##  Median :0.00000      Median :0.0000      Median :0.0000
##  Mean   :0.01397      Mean   :0.1777      Mean   :0.3432
##  3rd Qu.:0.00000      3rd Qu.:0.0000      3rd Qu.:1.0000
##  Max.   :1.00000      Max.   :1.0000      Max.   :1.0000
##
##  Visualization_None          percent_actively.coding
##  Min.   :0.00000    0% of my time        : 103
##  1st Qu.:0.00000    1% to 25% of my time :2155
##  Median :0.00000    100% of my time      : 276
##  Mean   :0.07429    25% to 49% of my time:2969
##  3rd Qu.:0.00000    50% to 74% of my time:3458
##  Max.   :1.00000    75% to 99% of my time:1848
##
##                     How.long.have.you.been.writing.code.to.analyze.data.
##  1-2 years                                      :3030
##  3-5 years                                      :2700
##  < 1 year                                       :2147
##  5-10 years                                     :1548
##  10-20 years                                    : 810
##  I have never written code but I want to learn: 261
##  (Other)                                        : 313
##                              For.how.many.years.have.you.used.machine.learning.methods..at.work.or.i
##  < 1 year                                                                                  :3306
##  1-2 years                                                                                 :2960
##  2-3 years                                                                                 :1411
##  3-4 years                                                                                 : 782
##  I have never studied machine learning but plan to learn in the future: 770
##  5-10 years                                                                                : 650
##  (Other)                                                                                   : 930
##  Do.you.consider.yourself.to.be.a.data.scientist. data_Categorical.Data
##  Definitely not: 813                              Min.   :0.0000
##  Definitely yes:2964                              1st Qu.:0.0000
##  Maybe         :2315                              Median :0.0000
##  Probably not  :1728                              Mean   :0.4823
```

```
##  Probably yes  :2989                                3rd Qu.:1.0000
##                                                     Max.   :1.0000
##
##  data_Genetic.Data data_Geospatial.Data data_Image.Data  data_Numerical.Data
##  Min.   :0.00000   Min.   :0.0000       Min.   :0.0000   Min.   :0.0000
##  1st Qu.:0.00000   1st Qu.:0.0000       1st Qu.:0.0000   1st Qu.:0.0000
##  Median :0.00000   Median :0.0000       Median :0.0000   Median :1.0000
##  Mean   :0.06088   Mean   :0.1416       Mean   :0.2884   Mean   :0.6337
##  3rd Qu.:0.00000   3rd Qu.:0.0000       3rd Qu.:1.0000   3rd Qu.:1.0000
##  Max.   :1.00000   Max.   :1.0000       Max.   :1.0000   Max.   :1.0000
##
##  data_Sensor.Data data_Tabular.Data data_text.Data   data_Time.Series.Data
##  Min.   :0.0000   Min.   :0.0000    Min.   :0.0000   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.:0.0000    1st Qu.:0.0000   1st Qu.:0.0000
##  Median :0.0000   Median :0.0000    Median :1.0000   Median :0.0000
##  Mean   :0.1528   Mean   :0.4421    Mean   :0.5022   Mean   :0.4699
##  3rd Qu.:0.0000   3rd Qu.:1.0000    3rd Qu.:1.0000   3rd Qu.:1.0000
##  Max.   :1.0000   Max.   :1.0000    Max.   :1.0000   Max.   :1.0000
##
##  data_Video.Data  explainability.model_Examine.individual.model.coefficients
##  Min.   :0.0000   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.:0.0000
##  Median :0.0000   Median :0.0000
##  Mean   :0.0779   Mean   :0.2268
##  3rd Qu.:0.0000   3rd Qu.:0.0000
##  Max.   :1.0000   Max.   :1.0000
##
##  explainability.model_examine.feature.correlations
##  Min.   :0.0000
##  1st Qu.:0.0000
##  Median :0.0000
##  Mean   :0.3369
##  3rd Qu.:1.0000
##  Max.   :1.0000
##
##  explainability.model_Examine.feature.importances
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :0.000
##  Mean   :0.372
##  3rd Qu.:1.000
##  Max.   :1.000
##
##  explainability.model_Create.partial.dependence.plots
##  Min.   :0.0000
##  1st Qu.:0.0000
##  Median :0.0000
##  Mean   :0.1192
##  3rd Qu.:0.0000
##  Max.   :1.0000
##
##  explainability.model_LIME.functions explainability.model_SHAP.functions
##  Min.   :0.00000                     Min.   :0.00000
##  1st Qu.:0.00000                     1st Qu.:0.00000
```

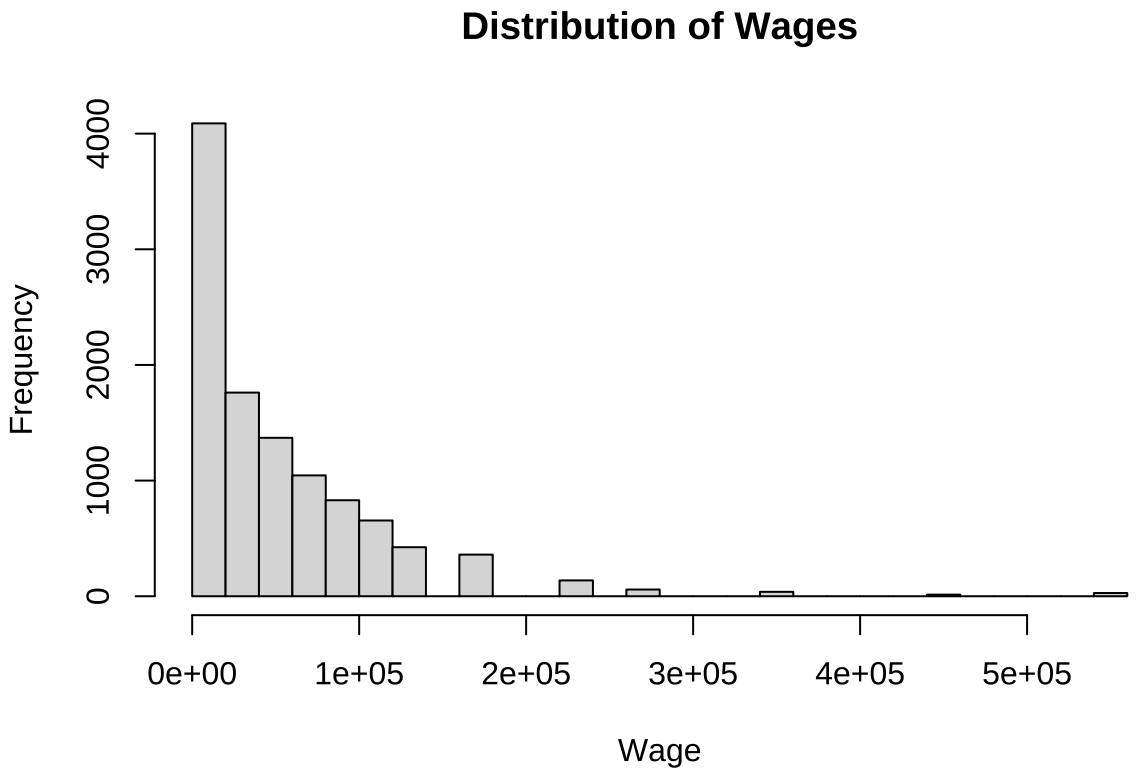
```
##  Median :0.00000                     Median :0.00000
##  Mean   :0.05995                     Mean   :0.04663
##  3rd Qu.:0.00000                     3rd Qu.:0.00000
##  Max.   :1.00000                     Max.   :1.00000
##
##  explainability.model_None.I.do.not.use.these.model.explanation.techniques
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :0.000
##  Mean   :0.101
##  3rd Qu.:0.000
##  Max.   :1.000
##
##       wage
##  Min.   :     0
##  1st Qu.:  6811
##  Median : 34780
##  Mean   : 53048
##  3rd Qu.: 75687
##  Max.   :551774
##
```

```
head(data_wage, 1)
```

```
##   gender   age                   country       education
## 3 Female 30-34 United States of America Master's degree
##                            undergraduate_major       job_role       industry
## 3 Computer science (software engineering, etc.) Data Scientist I am a student
##   years_experience     ML_atwork
## 3              0-1 I do not know
##   Activities_Analyze.and.understand.data.to.influence.product.or.business.decisions
## 3                                                                                 1
##   Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.w
## 3
##   Activities_Build.and.or.run.the.data.infrastructure.that.my.business.uses.for.storing..analyzing..a
## 3
##   Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## 3                                                                             0
##   Activities_Do.research.that.advances.the.state.of.the.art.of.machine.learning
## 3                                                                             0
##   Activities_None.of.these.activities.are.an.important.part.of.my.role.at.work
## 3                                                                            0
##   Notebooks_Kaggle.Kernels Notebooks_Google.Colab Notebooks_Azure.Notebook
## 3                        0                      0                       0
##   Notebooks_Google.Cloud.Datalab Notebooks_JupyterHub.Binder Notebooks_None
## 3                              0                           0              1
##   cloud_Google.Cloud.Platform..GCP. cloud_Amazon.Web.Services..AWS.
## 3                                 0                               0
##   cloud_Microsoft.Azure cloud_IBM.Cloud cloud_Alibaba.Cloud
## 3                     0              0                    0
##   cloud_I.have.not.used.any.cloud.providers Programming_Python Programming_R
## 3                                         1                  0             1
##   Programming_SQL Programming_Bash Programming_Java
## 3               0               0                1
##   Programming_Javascript.Typescript Programming_Visual.Basic.VBA
```

```
## 3                                0                             0
##   Programming_C.C.. Programming_MATLAB Programming_Scala Programming_Julia
## 3                 0                  1                 0                 0
##   Programming_SAS.STATA Programming_language_used_most_often
## 3                     0                                Java
##   ML_framework_Scikit.Learn ML_framework_TensorFlow ML_framework_Keras
## 3                         0                       0                  0
##   ML_framework_PyTorch ML_framework_Spark.MLlib ML_framework_H20
## 3                    0                        0               0
##   ML_framework_Caret ML_framework_Xgboost ML_framework_randomForest
## 3                  0                    0                         0
##   ML_framework_None Visualization_ggplot2 Visualization_Matplotlib
## 3                 1                     1                        1
##   Visualization_Altair Visualization_Shiny Visualization_Plotly
## 3                    0                   0                    0
##   Visualization_None percent_actively.coding
## 3                  0   75% to 99% of my time
##   How.long.have.you.been.writing.code.to.analyze.data.
## 3                                           5-10 years
##   For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## 3                                                                          < 1 year
##   Do.you.consider.yourself.to.be.a.data.scientist. data_Categorical.Data
## 3                                Definitely yes                       1
##   data_Genetic.Data data_Geospatial.Data data_Image.Data data_Numerical.Data
## 3                 0                   0               0                   1
##   data_Sensor.Data data_Tabular.Data data_text.Data data_Time.Series.Data
## 3                0                 0              1                     1
##   data_Video.Data explainability.model_Examine.individual.model.coefficients
## 3               0                                                          0
##   explainability.model_examine.feature.correlations
## 3                                                 1
##   explainability.model_Examine.feature.importances
## 3                                                1
##   explainability.model_Create.partial.dependence.plots
## 3                                                    0
##   explainability.model_LIME.functions explainability.model_SHAP.functions
## 3                                   0                                   0
##   explainability.model_None.I.do.not.use.these.model.explanation.techniques
## 3                                                                         0
##   wage
## 3    0
```

```
hist(data_wage$wage, breaks = 30, main = "Distribution of Wages", xlab = "Wage")
```



We have 10'711 observations with 78 variables like gender, age, country, education, ecetera. We were then interested in getting a visual overview of the most important data and the percentages.

Our aim was then to find the dependent variable (Y), in this case 'wage'.

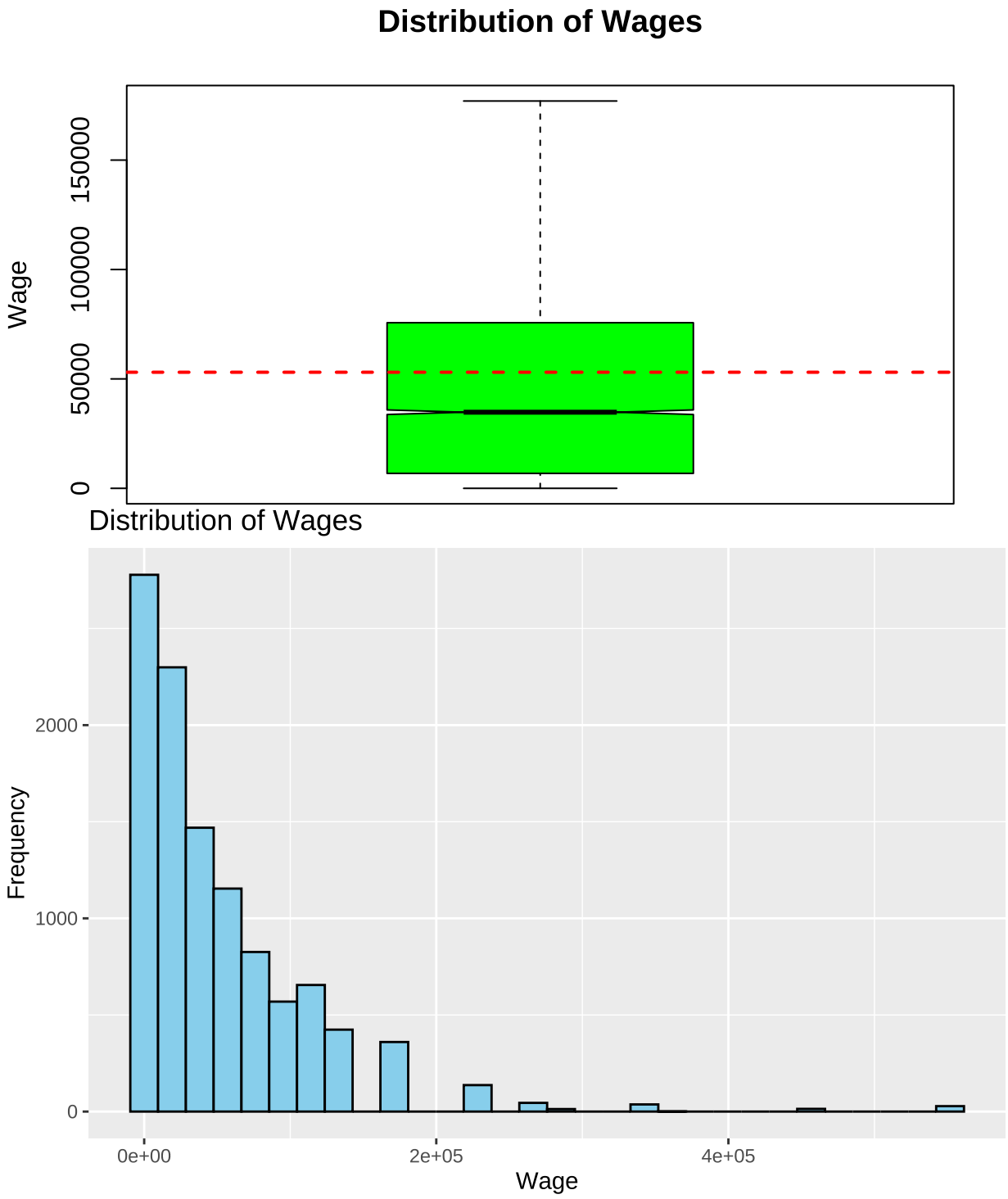
```
# Analyze the dependent variable 'wage'
summary(data_wage$wage)
```

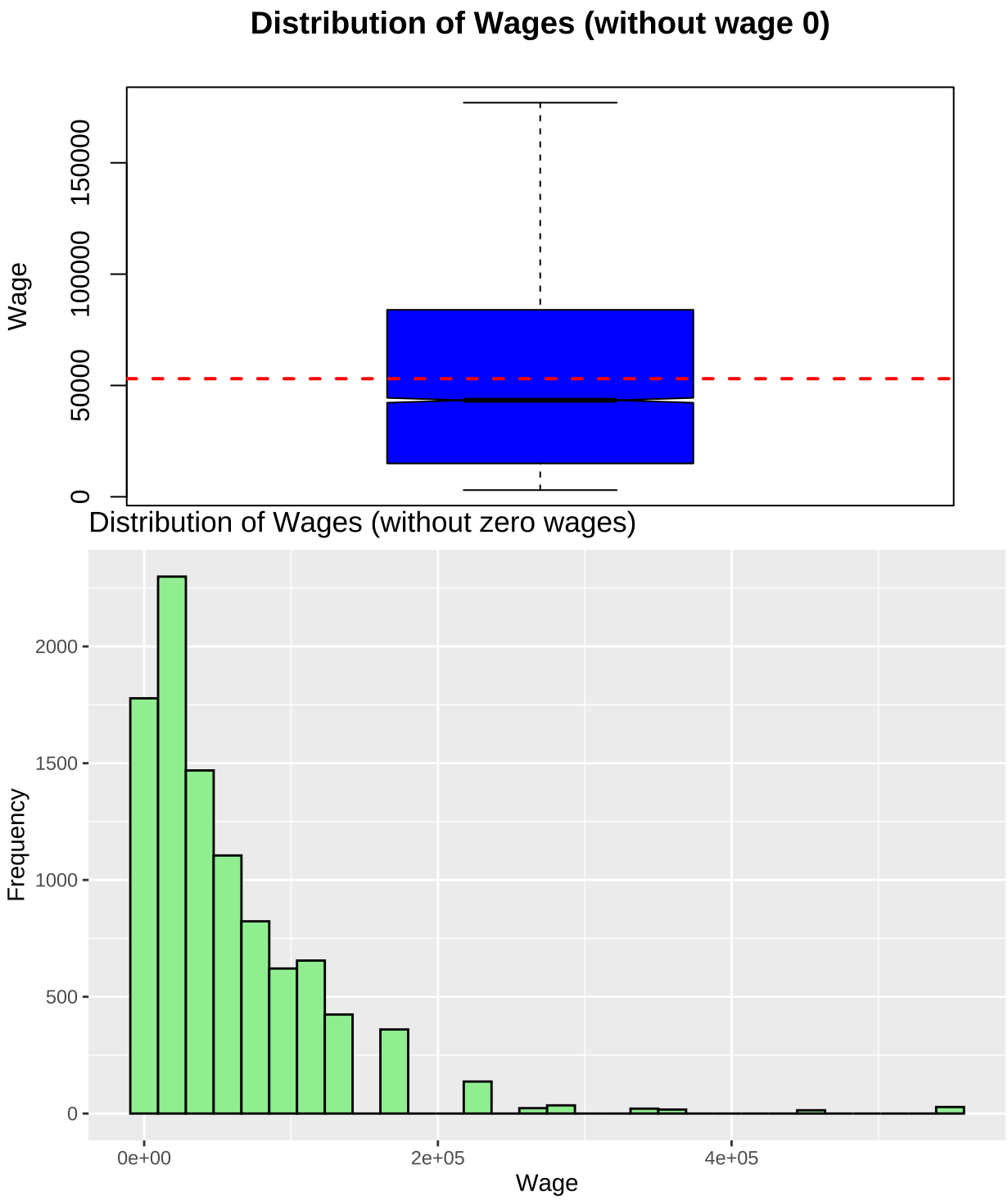
```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##       0    6811   34780   53048   75687  551774
```

We can see that the average salary is over 52,300 dollars. As the average wage is heavily distorted by high salaries - the maximum is 551,600 dollars - the median of just over 34,500 dollars is more meaningful. Because the minimum value is zero, we were interested to see how many people stated 0 as their salary (e.g. students).

```
## Number of observations with zero wage: 1000
```

This amounted to a total of 1000 people. we then created another dataset without the people who entered 0 in the wage. The average value is 57,700 dollars, the median is 43,100 dollars.Additionally, we would like to show the distribution of wages graphically.


Distribution of Wages
Wage
0
50000
100000
150000
Distribution of Wages
Frequency
0
1000
2000
0e+00
2e+05
4e+05
Wage



It was relevant for us to work with the complete data (including all upward outliers). On the other hand, we also work with the answers that have a salary of 0. We believe that not to earn any money is also relevant for our statistics. These could be people who are looking for a job or students. This is also part of a prediction model for future salaries.

We will then analyze the categorical and numerical values separately. By looking at the data we found out, that only "wage" is a numeric variable. That's why we then focused on the most important data besides the wage: gender, age, experience, country, and education.

After these analyses, we concentrated on the top earners. In other words, we looked for the top 5% of earners.

```
## [1] 541  78
```

```
##                   Female                     Male       Prefer not to say
##                       38                      497                        4
## Prefer to self-describe
##                        2
```

```
## 18-21 22-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-69 70-79   80+
##     3    18    52   106    82    70    78    55    42    33     2     0
```

```
##   0-1   1-2   2-3   3-4   4-5  5-11 11-15 15-20 20-25 25-30  30 +
##    46    38    41    33    46   101    90    53    42    24    27
```

```
##                                          Argentina
##                                                  0
##                                          Australia
##                                                 17
##                                            Austria
##                                                  0
##                                         Bangladesh
##                                                  0
##                                            Belarus
##                                                  0
##                                            Belgium
##                                                  1
##                                             Brazil
##                                                  6
##                                             Canada
##                                                 12
##                                              Chile
##                                                  1
##                                              China
##                                                  5
##                                           Colombia
##                                                  1
##                                     Czech Republic
##                                                  0
##                                            Denmark
##                                                  2
##                                              Egypt
##                                                  0
##                                            Finland
##                                                  0
##                                             France
##                                                  5
##                                            Germany
##                                                  4
##                                             Greece
##                                                  0
##                                  Hong Kong (S.A.R.)
##                                                  3
##                                            Hungary
##                                                  1
##                  I do not wish to disclose my location
```

```
##                                          2
##                                      India
##                                         24
##                                  Indonesia
##                                          1
##                       Iran, Islamic Republic of...
##                                          0
##                                    Ireland
##                                          1
##                                     Israel
##                                          5
##                                      Italy
##                                          0
##                                      Japan
##                                          6
##                                      Kenya
##                                          2
##                                   Malaysia
##                                          0
##                                     Mexico
##                                          0
##                                    Morocco
##                                          0
##                                Netherlands
##                                          3
##                                New Zealand
##                                          0
##                                    Nigeria
##                                          0
##                                     Norway
##                                          0
##                                      Other
##                                          6
##                                   Pakistan
##                                          0
##                                       Peru
##                                          0
##                                Philippines
##                                          0
##                                     Poland
##                                          0
##                                   Portugal
##                                          0
##                             Republic of Korea
##                                          1
##                                    Romania
##                                          0
##                                     Russia
##                                          3
##                                  Singapore
##                                          4
##                               South Africa
##                                          1
##                                South Korea
```

```
##                                                 3
##                                             Spain
##                                                 1
##                                            Sweden
##                                                 1
##                                       Switzerland
##                                                14
##                                          Thailand
##                                                 0
##                                           Tunisia
##                                                 1
##                                            Turkey
##                                                 0
##                                           Ukraine
##                                                 0
## United Kingdom of Great Britain and Northern Ireland
##                                                18
##                               United States of America
##                                               386
##                                          Viet Nam
##                                                 0
```

```
##                                             Bachelor's degree
##                                                            97
##                                               Doctoral degree
##                                                           163
##                                       I prefer not to answer
##                                                             2
##                                             Master's degree
##                                                           255
##                                            Professional degree
##                                                            13
## Some college/university study without earning a bachelor's degree
##                                                            11
```

We see that the top 5% of the highest earners include a total of 536 people 491 men and 38 women. The analysis of the top 5% shows that people between the ages of 30 and 34 earn the most. In terms of experience, it is people with between 5 and 11 years of work experience who earn the most. 380 of the people come from the USA, which is no surprise in this case, as most of the respondents come from the USA. However, it is interesting to note that 255 of the 536 people have a master's degree, while only 160 have a doctorate.

Then our goal was to scale numeric data to ensure that features have a similar range of values. After that our goal was to convert categorical variables into a format suitable for modeling.

```
# Remove above all wages over 200'000
data_wage <- data_wage %>% filter(wage <= 200000)
# One-hot encode categorical variables and scale numeric variables
data_encoded <- data_wage %>%
  mutate(across(where(is.character), factor)) %>%
  mutate(across(where(is.numeric), scale)) %>%
  mutate(across(where(is.factor), ~ as.numeric(as.factor(.x)) - 1))
# Add the target variable back to the transformed data
dummies <- dummyVars(" ~ .", data = data_encoded)
data_transformed <- as.data.frame(predict(dummies, newdata = data_encoded))
# Add the target variable back
data_transformed$wage <- data_wage$wage
```

Now it is time to decide which variables (characteristics) to include in the model, based on their potential relationship to the target variable "wage".

Model Selection and Training:

In this chapter we have trained different models (linear regression, random forest, Generalized Boosted Regression Model (GBM) and xgboost) in order to find the best performing one. The models were trained with the data set data_transformed.

```
# Split data into training and testing sets
set.seed(123)
split <- initial_split(data_transformed, prop = 0.8)
train_data <- training(split)
test_data <- testing(split)
# Helper function for model training and evaluation
train_and_evaluate_model <- function(model_type, data) {
  set.seed(123)
  # Define cross-validation method: Cross Validation with 5 folds means that the data is split into 5 p
  train_control <- trainControl(method = "cv", number = 5)

  if (model_type == "xgbTree") {
    data_no_wage <- data[, !names(data) %in% "wage"]
    model <- train(
      x = data_no_wage,
      y = data$wage,
      method = model_type,
      trControl = train_control,
      tuneLength = 3
    )
  } else {
    model <- train(
      wage ~ .,
      data = data,
      method = model_type,
      trControl = train_control
    )
  }
  return(model)
}
# Train models
lm_model <- train_and_evaluate_model("lm", train_data)
# We have to use the randomForest package for the random forest model and not the train_and_evaluate_mo
rf_model <- randomForest(
  wage ~ .,
  data = train_data, ntree = 50, mtry = 3, importance = TRUE, cp = 0
)
gbm_model <- train_and_evaluate_model("gbm", train_data)
```

```
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1976689875.6334             nan     0.1000 91399438.8225
##      2 1901206912.9915             nan     0.1000 75586690.1023
##      3 1833375533.2110             nan     0.1000 68249657.3525
##      4 1769329636.5547             nan     0.1000 60302547.0438
##      5 1714852903.9282             nan     0.1000 54251217.2705
##      6 1666773528.4568             nan     0.1000 47082714.1406
```

```
##      7 1624660664.4980             nan     0.1000 43388155.4000
##      8 1583566262.0740             nan     0.1000 38956160.9005
##      9 1547693204.4281             nan     0.1000 34423458.1417
##     10 1515861791.2758             nan     0.1000 31542646.5695
##     20 1290066096.9378             nan     0.1000 15216401.1429
##     40 1095737272.8344             nan     0.1000 5448841.1908
##     60 1017596706.1537             nan     0.1000 2044394.0413
##     80 974513432.6662             nan     0.1000 1675678.3538
##    100 946777711.6091             nan     0.1000 390895.1476
##    120 928008413.2429             nan     0.1000 308397.5164
##    140 914244013.2058             nan     0.1000 218681.8003
##    150 908864959.5827             nan     0.1000 -226737.5689
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1937360771.2621             nan     0.1000 128603116.0921
##      2 1831370837.6841             nan     0.1000 107706707.4066
##      3 1740514804.7992             nan     0.1000 93796663.6530
##      4 1661229251.3373             nan     0.1000 76702027.0828
##      5 1586191493.7106             nan     0.1000 75451870.0038
##      6 1525857890.3020             nan     0.1000 59681100.6940
##      7 1472415552.4707             nan     0.1000 54542808.5805
##      8 1418544836.2718             nan     0.1000 51344629.6647
##      9 1378066771.2800             nan     0.1000 41083290.0854
##     10 1332331505.2030             nan     0.1000 43546007.7324
##     20 1105085071.4079             nan     0.1000 13228339.7027
##     40 941124335.6551             nan     0.1000 4523414.7591
##     60 876881210.8053             nan     0.1000 3248363.8156
##     80 840705272.8316             nan     0.1000 2538900.6011
##    100 817279154.0451             nan     0.1000 857795.6036
##    120 802865394.4557             nan     0.1000 266136.7550
##    140 786267028.3002             nan     0.1000 437711.6611
##    150 780193263.9584             nan     0.1000 -330637.0863
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1914077878.7866             nan     0.1000 158174875.6355
##      2 1777414852.5675             nan     0.1000 134652797.7585
##      3 1666865382.1763             nan     0.1000 109130959.3316
##      4 1576320406.0135             nan     0.1000 86287472.3704
##      5 1501315360.7826             nan     0.1000 74868097.9396
##      6 1439540296.2249             nan     0.1000 62924329.8036
##      7 1388151121.2484             nan     0.1000 53150883.1672
##      8 1337311182.2403             nan     0.1000 49075131.3331
##      9 1294826717.5713             nan     0.1000 38893895.8307
##     10 1261022701.8212             nan     0.1000 33374507.7458
##     20 1034024102.2024             nan     0.1000 12442048.0852
##     40 883256742.1885             nan     0.1000 4148240.8697
##     60 820836765.6536             nan     0.1000 302991.9718
##     80 787082488.1971             nan     0.1000 847391.7834
##    100 762939788.3305             nan     0.1000 1543287.5961
##    120 744775705.3829             nan     0.1000 -442555.0532
##    140 728478013.0523             nan     0.1000 42679.8294
##    150 722656729.7371             nan     0.1000 120499.6015
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
```

```
##      1 1974374485.7976             nan     0.1000 92073314.1659
##      2 1895612447.1709             nan     0.1000 78331412.3718
##      3 1828072807.8536             nan     0.1000 67288679.7678
##      4 1766561014.2867             nan     0.1000 60100405.0016
##      5 1712300347.2714             nan     0.1000 53755475.7937
##      6 1661603779.0198             nan     0.1000 46885289.9524
##      7 1621712592.5153             nan     0.1000 40557305.5751
##      8 1580984164.3226             nan     0.1000 40142318.4638
##      9 1544218637.5259             nan     0.1000 37656433.0568
##     10 1510953709.9574             nan     0.1000 32345872.5203
##     20 1283879732.0422             nan     0.1000 14564316.4225
##     40 1092834358.1210             nan     0.1000 4268427.7850
##     60 1013691722.4889             nan     0.1000 1949795.5476
##     80 970169506.4551              nan     0.1000 1144981.9060
##    100 942818086.3417              nan     0.1000 228533.5365
##    120 923276528.3536              nan     0.1000 744879.9679
##    140 909433487.6698              nan     0.1000 -100780.7685
##    150 903450292.7437              nan     0.1000 326345.3597
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1934053242.0442             nan     0.1000 131034813.6593
##      2 1829430431.3639             nan     0.1000 106610762.8620
##      3 1740643045.4972             nan     0.1000 90481811.3185
##      4 1661689797.8941             nan     0.1000 74700269.2842
##      5 1599256916.7798             nan     0.1000 63376465.4367
##      6 1533088737.1046             nan     0.1000 65736080.2779
##      7 1478204656.7299             nan     0.1000 50589290.5271
##      8 1427098913.5363             nan     0.1000 50972153.8903
##      9 1384187726.5732             nan     0.1000 41408758.1728
##     10 1350348883.8102             nan     0.1000 34470644.3116
##     20 1112701636.0059             nan     0.1000 15341767.0933
##     40 946575625.8897              nan     0.1000 4159451.3325
##     60 879976410.8546              nan     0.1000 3278027.7458
##     80 842180721.4672              nan     0.1000 853978.8001
##    100 820538750.8407              nan     0.1000 419324.5882
##    120 798359125.1487              nan     0.1000 95693.0718
##    140 782274553.2948              nan     0.1000 -114662.2204
##    150 774534067.9645              nan     0.1000 538576.0373
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1905814624.3307             nan     0.1000 154775794.7375
##      2 1777710140.3362             nan     0.1000 127568644.6546
##      3 1667356669.2646             nan     0.1000 104690804.0478
##      4 1582045091.6013             nan     0.1000 83804753.9108
##      5 1506362020.6954             nan     0.1000 72904749.9689
##      6 1446568833.0802             nan     0.1000 57725826.8880
##      7 1393836719.2226             nan     0.1000 54364844.1738
##      8 1348011859.7573             nan     0.1000 47110148.4939
##      9 1307430324.8116             nan     0.1000 38769499.0291
##     10 1271970002.0283             nan     0.1000 33836447.4033
##     20 1049635435.4812             nan     0.1000 13164223.6317
##     40 882461410.2462              nan     0.1000 5113869.5777
##     60 826379481.6270              nan     0.1000 521650.2901
##     80 795484424.6173              nan     0.1000 -364943.7732
```

```
##    100 767861619.7570             nan     0.1000 287031.0537
##    120 744308766.3969             nan     0.1000 -176558.3921
##    140 724970815.4984             nan     0.1000 -572777.4913
##    150 716735414.0833             nan     0.1000 -659177.5521
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1953473148.1391             nan     0.1000 93497631.3985
##      2 1879501256.4275             nan     0.1000 75341518.3485
##      3 1812432404.4552             nan     0.1000 66958501.5488
##      4 1751848718.0144             nan     0.1000 61426037.8131
##      5 1700885377.8724             nan     0.1000 51734423.9718
##      6 1647127590.0843             nan     0.1000 52515298.0401
##      7 1605307443.7273             nan     0.1000 40103310.8351
##      8 1562889201.8897             nan     0.1000 41993343.4982
##      9 1529069165.9419             nan     0.1000 32227550.2442
##     10 1495928748.5416             nan     0.1000 33377568.8941
##     20 1274161577.9056             nan     0.1000 15175092.8072
##     40 1081067214.0155             nan     0.1000 4786319.5606
##     60 1004537929.0199             nan     0.1000 2784776.1307
##     80 960139764.5729              nan     0.1000 1143700.5394
##    100 931394077.7601              nan     0.1000 943285.0185
##    120 911035000.4080              nan     0.1000 972010.3903
##    140 896280290.2121              nan     0.1000 68432.5106
##    150 890028238.3229              nan     0.1000 -378676.6585
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1915753031.9677             nan     0.1000 131286211.8194
##      2 1809587893.0719             nan     0.1000 109276987.9177
##      3 1721705542.9620             nan     0.1000 89185247.9555
##      4 1638486916.6903             nan     0.1000 85537487.4184
##      5 1574772192.5563             nan     0.1000 66286548.8609
##      6 1517376649.6319             nan     0.1000 58489915.2303
##      7 1463083369.3619             nan     0.1000 54097026.2902
##      8 1410331977.7045             nan     0.1000 53272358.8273
##      9 1368581630.8969             nan     0.1000 40293104.4071
##     10 1323168627.4273             nan     0.1000 43941883.4424
##     20 1090604782.5786             nan     0.1000 16153598.9423
##     40 933594338.3755              nan     0.1000 3726910.4300
##     60 865652431.6962              nan     0.1000 453322.6708
##     80 829314640.4113              nan     0.1000 1592071.9520
##    100 804602856.6902              nan     0.1000 1353146.2628
##    120 784768620.0288              nan     0.1000 -383811.9255
##    140 771029137.4635              nan     0.1000 436023.7787
##    150 764544441.3831              nan     0.1000 367349.1182
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1884600617.0781             nan     0.1000 155646677.8218
##      2 1761695929.9058             nan     0.1000 124864574.7673
##      3 1651573159.6777             nan     0.1000 108713251.7366
##      4 1564368497.2720             nan     0.1000 85615160.6628
##      5 1490146417.1564             nan     0.1000 72086481.5653
##      6 1428888763.7935             nan     0.1000 61009811.0871
##      7 1377267331.2505             nan     0.1000 49867925.9966
##      8 1331471933.8373             nan     0.1000 43885563.0255
```

```
##      9 1291777264.0169             nan     0.1000 39253438.9517
##     10 1254604462.0572             nan     0.1000 37475198.1524
##     20 1035616708.8049             nan     0.1000 12092101.0425
##     40 877740020.9230              nan     0.1000 4124882.7692
##     60 816666553.2810              nan     0.1000 987605.5597
##     80 784017136.8424              nan     0.1000 212229.2477
##    100 756645005.1582              nan     0.1000 -24043.5769
##    120 732282951.5883              nan     0.1000 587655.6059
##    140 715555210.3815              nan     0.1000 770215.6798
##    150 706335769.5029              nan     0.1000 30304.9968
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1973099681.1420             nan     0.1000 94937346.9037
##      2 1891921242.7717             nan     0.1000 76993550.1472
##      3 1825384291.8280             nan     0.1000 66981776.8336
##      4 1764123657.3092             nan     0.1000 58713050.9242
##      5 1712637442.2289             nan     0.1000 53756308.3142
##      6 1667058258.5850             nan     0.1000 43447731.1020
##      7 1621638652.1430             nan     0.1000 46927562.0827
##      8 1582272319.6041             nan     0.1000 39597377.5896
##      9 1545296639.4765             nan     0.1000 34544017.7516
##     10 1511854842.1337             nan     0.1000 34215879.3583
##     20 1281933972.1238             nan     0.1000 18222222.7126
##     40 1077895928.8225             nan     0.1000 6573736.8933
##     60 999546778.0521              nan     0.1000 2387752.5886
##     80 954468343.6622              nan     0.1000 941418.6643
##    100 926076490.5503              nan     0.1000 894461.1735
##    120 906633729.9669              nan     0.1000 627672.6881
##    140 891511651.4977              nan     0.1000 474665.8316
##    150 885376890.8097              nan     0.1000 314324.5747
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1934563903.3200             nan     0.1000 129026862.8863
##      2 1829749993.2403             nan     0.1000 107677827.8175
##      3 1735028250.7766             nan     0.1000 89210721.0906
##      4 1650485033.6835             nan     0.1000 82549875.2653
##      5 1583161421.2772             nan     0.1000 67091722.5286
##      6 1521844428.1177             nan     0.1000 62719225.4589
##      7 1473047911.6609             nan     0.1000 47324611.8432
##      8 1424111173.7000             nan     0.1000 49209891.4043
##      9 1375993029.2989             nan     0.1000 48306017.1962
##     10 1329192038.6221             nan     0.1000 44197339.0832
##     20 1092872004.3425             nan     0.1000 12410154.8204
##     40 925689960.9912              nan     0.1000 3163979.3699
##     60 854298633.7239              nan     0.1000 2082374.0325
##     80 817242710.3539              nan     0.1000 570846.9216
##    100 796724395.6383              nan     0.1000 223132.9608
##    120 778529825.3136              nan     0.1000 270956.4552
##    140 763094838.0489              nan     0.1000 96205.0108
##    150 755843146.1533              nan     0.1000 -116862.0955
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1905191346.6862             nan     0.1000 157831350.8522
##      2 1773192931.1584             nan     0.1000 129729282.9183
```

```
##      3 1667077897.0467             nan     0.1000 104069273.0922
##      4 1579290334.3743             nan     0.1000 84309953.4414
##      5 1501479460.7164             nan     0.1000 78926555.8863
##      6 1435383956.4138             nan     0.1000 59737771.3770
##      7 1384289260.2317             nan     0.1000 50787367.7025
##      8 1338944147.7806             nan     0.1000 42905799.6744
##      9 1295494278.9317             nan     0.1000 42484774.2628
##     10 1257682104.0199             nan     0.1000 37318080.9043
##     20 1024880483.6924             nan     0.1000 14493252.1148
##     40 863097498.5732              nan     0.1000 2133836.7024
##     60 802803594.2961              nan     0.1000 53912.6291
##     80 771584110.3695              nan     0.1000 365191.6631
##    100 745080047.2756              nan     0.1000 -29333.6075
##    120 722940344.4776              nan     0.1000 373520.0397
##    140 709080806.7379              nan     0.1000 315648.7434
##    150 701586067.2830              nan     0.1000 44561.8185
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1954315141.8432             nan     0.1000 89493826.7402
##      2 1883782820.7884             nan     0.1000 70955738.5165
##      3 1807060626.2477             nan     0.1000 73567778.0016
##      4 1750056801.1189             nan     0.1000 59098083.1663
##      5 1694259177.6437             nan     0.1000 55310631.9137
##      6 1643614792.7141             nan     0.1000 49018435.4285
##      7 1600233209.7896             nan     0.1000 44372071.6563
##      8 1563580351.0308             nan     0.1000 35927298.8000
##      9 1529072911.5136             nan     0.1000 33723426.7476
##     10 1491857845.9547             nan     0.1000 36986344.9951
##     20 1267014390.8709             nan     0.1000 14025311.2656
##     40 1076036107.6775             nan     0.1000 5437889.6803
##     60 1001972283.7162             nan     0.1000 2269687.4434
##     80 958686883.1844              nan     0.1000 999711.5924
##    100 931208469.3765              nan     0.1000 844249.8413
##    120 910937785.5109              nan     0.1000 788226.4967
##    140 896346041.3732              nan     0.1000 452013.0343
##    150 890446750.0487              nan     0.1000 260419.0841
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1913975161.4080             nan     0.1000 127398681.8404
##      2 1812179790.4583             nan     0.1000 103301169.2784
##      3 1723758159.0778             nan     0.1000 87526418.4469
##      4 1644530115.7301             nan     0.1000 74817439.2943
##      5 1570317109.5783             nan     0.1000 75277407.7293
##      6 1507368829.7722             nan     0.1000 59995877.8493
##      7 1455254436.2331             nan     0.1000 50265665.8332
##      8 1403384106.7017             nan     0.1000 52068149.4817
##      9 1361295984.8192             nan     0.1000 41959293.8042
##     10 1323480967.3669             nan     0.1000 34622695.4497
##     20 1094692557.5249             nan     0.1000 13677314.2824
##     40 934169396.7656              nan     0.1000 4401256.8850
##     60 869205872.5980              nan     0.1000 2780786.7168
##     80 833625900.1324              nan     0.1000 -196826.4654
##    100 809546737.3126              nan     0.1000 -626258.0232
##    120 793223189.9157              nan     0.1000 101622.7659
```

```
##    140 773010949.0732             nan     0.1000 265138.9331
##    150 767129330.8767             nan     0.1000 -75768.1252
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1887075312.9642             nan     0.1000 151953840.0146
##      2 1757719191.6806             nan     0.1000 126112472.9819
##      3 1650825680.2117             nan     0.1000 102196783.7491
##      4 1564686152.9381             nan     0.1000 89164320.1642
##      5 1491791159.4577             nan     0.1000 69729520.2260
##      6 1427380576.5345             nan     0.1000 61072758.9348
##      7 1374552002.2587             nan     0.1000 51490764.6422
##      8 1325245497.5050             nan     0.1000 46093188.1087
##      9 1289031917.0510             nan     0.1000 35937019.1726
##     10 1255621824.1816             nan     0.1000 34671911.7118
##     20 1035098820.0987             nan     0.1000 12046949.1573
##     40 876814768.1178             nan     0.1000 4838039.2033
##     60 818301192.2111             nan     0.1000 2386139.7864
##     80 780234724.3043             nan     0.1000 -211332.1727
##    100 754319056.8045             nan     0.1000 -279320.5431
##    120 738392979.3806             nan     0.1000 -189824.4351
##    140 719830336.0742             nan     0.1000 -92351.3615
##    150 709857307.6148             nan     0.1000 -19776.4809
##
## Iter   TrainDeviance   ValidDeviance   StepSize   Improve
##      1 1904944340.6765             nan     0.1000 154538826.4794
##      2 1771515387.3861             nan     0.1000 132116606.4476
##      3 1666424350.2388             nan     0.1000 103426985.4133
##      4 1578760386.0896             nan     0.1000 87649748.8332
##      5 1504362998.1970             nan     0.1000 72763903.6077
##      6 1441721990.0903             nan     0.1000 60212678.3151
##      7 1386731210.3084             nan     0.1000 54443821.3772
##      8 1342069029.6335             nan     0.1000 43461354.4857
##      9 1297522380.1361             nan     0.1000 44529992.3530
##     10 1262737991.5176             nan     0.1000 35038843.2280
##     20 1037186094.0635             nan     0.1000 14748124.1121
##     40 878648361.5825             nan     0.1000 2645764.4513
##     60 817378316.3809             nan     0.1000 2419975.0039
##     80 785831497.4742             nan     0.1000 358979.7383
##    100 763747298.6222             nan     0.1000 -162653.3433
##    120 741396193.5411             nan     0.1000 1802618.0801
##    140 727393099.8811             nan     0.1000 411862.8284
##    150 718162672.1414             nan     0.1000 -97748.9810
```

```
xgboost_model <- train_and_evaluate_model("xgbTree", train_data)
```

```
## [16:11:50] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:50] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:51] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:51] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:11:51] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:51] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:52] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:52] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
```

```
## [16:11:52] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:52] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:53] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:53] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:53] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:53] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:54] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:54] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:55] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:55] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:55] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:55] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:56] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:56] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:57] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:57] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:58] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:58] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:59] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:11:59] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:00] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:00] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:01] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:01] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:02] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:02] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:02] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:02] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:02] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:02] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:03] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:03] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:03] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:03] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:04] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:04] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:04] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:04] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:05] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:05] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:05] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:05] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:06] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:06] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:06] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:06] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:07] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:07] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:08] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:08] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:09] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:09] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:10] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:10] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
```

```
## [16:12:10] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:10] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:11] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:11] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:12] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:12] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:13] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:13] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:14] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:14] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:14] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:14] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:14] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:14] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:15] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:12:15] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:16] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:16] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:16] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:16] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:17] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:17] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:17] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:17] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:18] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:18] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:19] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:19] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:19] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:19] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:20] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:20] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:21] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:21] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:22] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:22] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:23] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:23] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:24] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:24] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:25] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:25] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:12:25] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:26] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:26] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:26] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:26] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:26] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:26] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:27] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:27] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
```

```
## [16:12:27] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:27] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:28] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:28] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:28] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:28] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:12:29] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:30] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:30] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:30] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:12:31] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:31] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:32] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:32] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:33] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:33] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:34] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:34] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:35] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:35] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:36] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:36] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:12:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:12:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:13:36] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:13:36] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [16:13:36] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:37] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
```

```
## [16:13:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:38] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:39] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:39] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:39] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:39] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:40] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:40] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:41] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:41] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:41] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:41] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:42] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:42] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:43] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:43] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:44] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:44] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:45] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:45] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:46] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:46] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:47] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [16:13:47] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
```

```r
# Hyperparameter tuning using Grid Search and Random Search
# This is an example for Random Forest and GBM models, we could fine tune the other models as well but
set.seed(123)
# Grid search for Random Forest
rf_grid <- expand.grid(mtry = c(2, 3, 4))
rf_control <- trainControl(method = "cv", number = 5, search = "grid")
rf_tuned <- train(
  wage ~ .,
  data = train_data, method = "rf",
  trControl = rf_control, tuneGrid = rf_grid
)

# Random search for GBM
set.seed(123)
gbm_grid <- expand.grid(
  n.trees = c(100, 150, 200),
  interaction.depth = c(1, 3, 5),
  shrinkage = c(0.01, 0.1),
  n.minobsinnode = 10
)
gbm_control <- trainControl(method = "cv", number = 5, search = "random")
gbm_tuned <- train(
  wage ~ .,
  data = train_data, method = "gbm",
  trControl = gbm_control, tuneGrid = gbm_grid, verbose = FALSE
)
```

Model Evaluation

Following the training of the models we evaluate here which modes is the best performing. We will asses this using the metric RMSE, MAE and R Squared.

```
# Define your model list (including tuned models if applicable)
model_list <- list(
  "Linear Regression" = lm_model,
  "Random Forest" = rf_model,
  "Gradient Boosting" = gbm_model,
  "XGBoost" = xgboost_model,
  "Random Forest Tuned" = rf_tuned,
  "Gradient Boosting Tuned" = gbm_tuned
)

# Create empty lists to store results
predictions_list <- list()
rmse_values <- c()
mae_values <- c()
r2_values <- c()

# Iterate through the models
for (model_name in names(model_list)) {
  model <- model_list[[model_name]]
  # Make predictions
  predictions <- predict(model, newdata = test_data)
  predictions_list[[model_name]] <- predictions # Store predictions
  # Calculate and store metrics
  rmse_values[model_name] <- RMSE(predictions, test_data$wage)
  mae_values[model_name] <- MAE(predictions, test_data$wage)
  r2_values[model_name] <- R2(predictions, test_data$wage)
  # Print metrics for each model
  cat("Metrics for", model_name, "model:\n")
  cat("RMSE (", model_name, "):", rmse_values[model_name], "\n")
  cat("MAE (", model_name, "):", mae_values[model_name], "\n")
  cat("R-squared (", model_name, "):", r2_values[model_name], "\n")
  cat("\n")
}
```

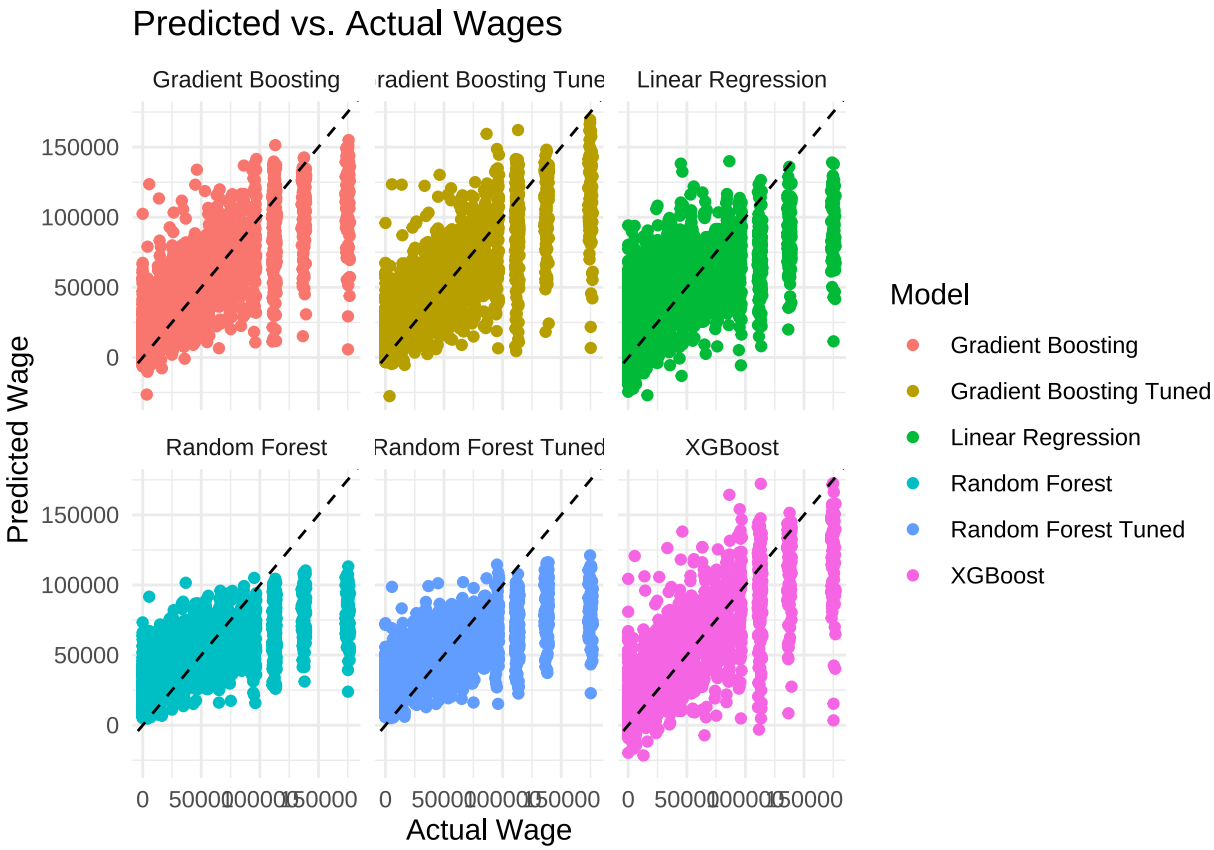
```
## Metrics for Linear Regression model:
## RMSE ( Linear Regression ): 34261.7
## MAE ( Linear Regression ): 26309.9
## R-squared ( Linear Regression ): 0.4313985
##
## Metrics for Random Forest model:
## RMSE ( Random Forest ): 33662.73
## MAE ( Random Forest ): 25642.89
## R-squared ( Random Forest ): 0.4998191
##
## Metrics for Gradient Boosting model:
## RMSE ( Gradient Boosting ): 27970.93
## MAE ( Gradient Boosting ): 19731.92
## R-squared ( Gradient Boosting ): 0.6217723
##
## Metrics for XGBoost model:
```

```
## RMSE ( XGBoost ): 26425.57
## MAE ( XGBoost ): 18136.72
## R-squared ( XGBoost ): 0.6620737
##
## Metrics for Random Forest Tuned model:
## RMSE ( Random Forest Tuned ): 32135.28
## MAE ( Random Forest Tuned ): 24455.6
## R-squared ( Random Forest Tuned ): 0.5512629
##
## Metrics for Gradient Boosting Tuned model:
## RMSE ( Gradient Boosting Tuned ): 27166.25
## MAE ( Gradient Boosting Tuned ): 18856.49
## R-squared ( Gradient Boosting Tuned ): 0.6425795
```

```r
# Create data for visualization
comparison <- data.frame(Actual = test_data$wage)
for (model_name in names(predictions_list)) {
  comparison[[model_name]] <- predictions_list[[model_name]]
}

# Reshape data for ggplot
comparison_long <- tidyr::pivot_longer(comparison,
  -Actual,
  names_to = "Model", values_to = "Predicted"
)

# Visual comparison
ggplot(comparison_long, aes(x = Actual, y = Predicted, color = Model)) +
  geom_point() +
  geom_abline(intercept = 0, slope = 1, linetype = "dashed", color = "black") +
  labs(
    title = "Predicted vs. Actual Wages",
    x = "Actual Wage", y = "Predicted Wage"
  ) +
  theme_minimal() +
  facet_wrap(~Model)
```



Winner Model The XGBoost model shows the best performance. Gradient Boosting has slightly less accurate predictions based on RMSE, MAE and R-suqred.

- RMSE (Root Mean Squared Error): The XGBoost Model shows an RMSE of 26425.57.This indicates that the wage predictions are off by approximately CHF 26,425 from the actual salaries.
- MAE (Mean Absolute Error): The MAE of 18136.72 can be interpreted as predictions are off by CHF 18,136 or less from the actual values.
- R-squared: The R-squared of 0.662 indicates that XGBoost explains about 66.2% of the variance. This means that the model captures a substantial portion of the factors influencing wage differences.

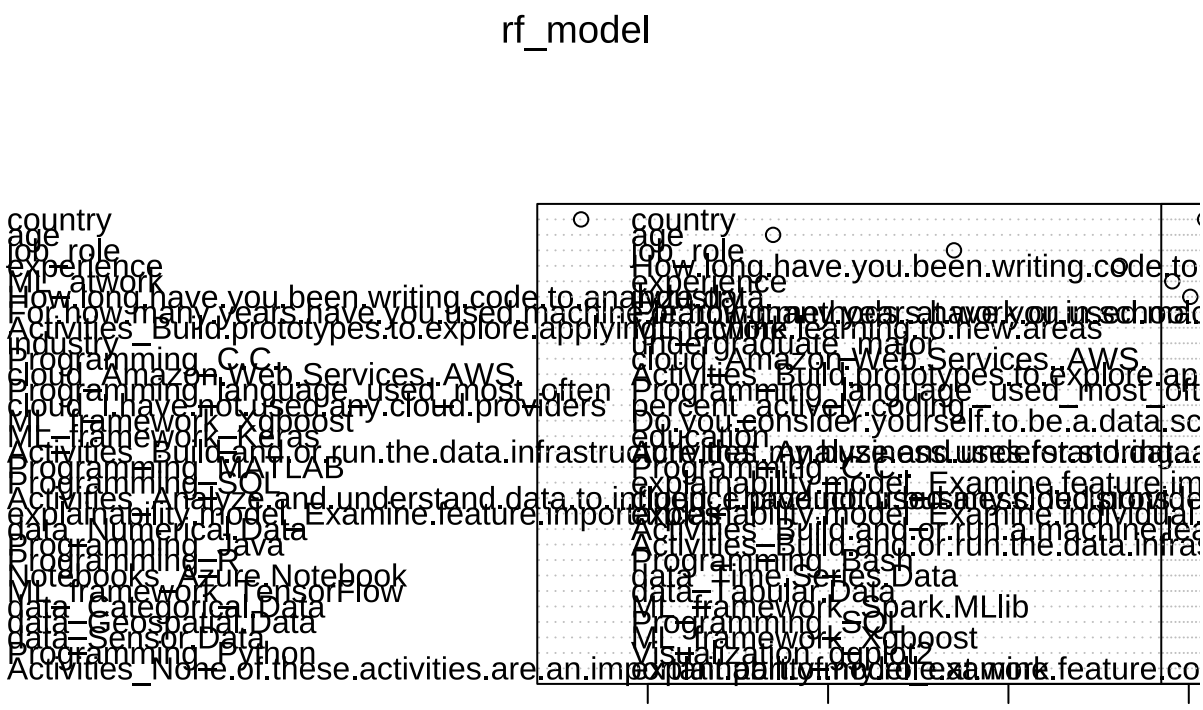
Key Findings

- XGBoost and Gradient Boosting (Untuned and Tuned): These models clearly outperform the others, with XGBoost slightly ahead in terms of RMSE, MAE and R-squared.
- Random Forest: The tuned Random Forest model shows a noticeable improvement over the basic Random Forest.
- Linear Regression: Is the simplest model and performs not that well, but is outperformed by the tree-based models (Random Forest, Gradient Boosting, XGBoost). ### Plot Interpretation The plot visually confirms the numerical results:
- The XGBoost (purple) and Gradient Boosting (red/orange) points are the tightest around the diagonal line, signifying the best predictions.
- The improvement from tuning Random Forest is evident in its slightly tighter clustering compared to the untuned version.
- Linear Regression's points are the most scattered, reflecting its lower accuracy.

Model Explanation

Here we aim to see which variables have the highest correlation with the variable wage. We will use the variable importance plot to see which variables are the most important for the model.

```
# Variable importance for Random Forest model
varImpPlot(rf_model)
```



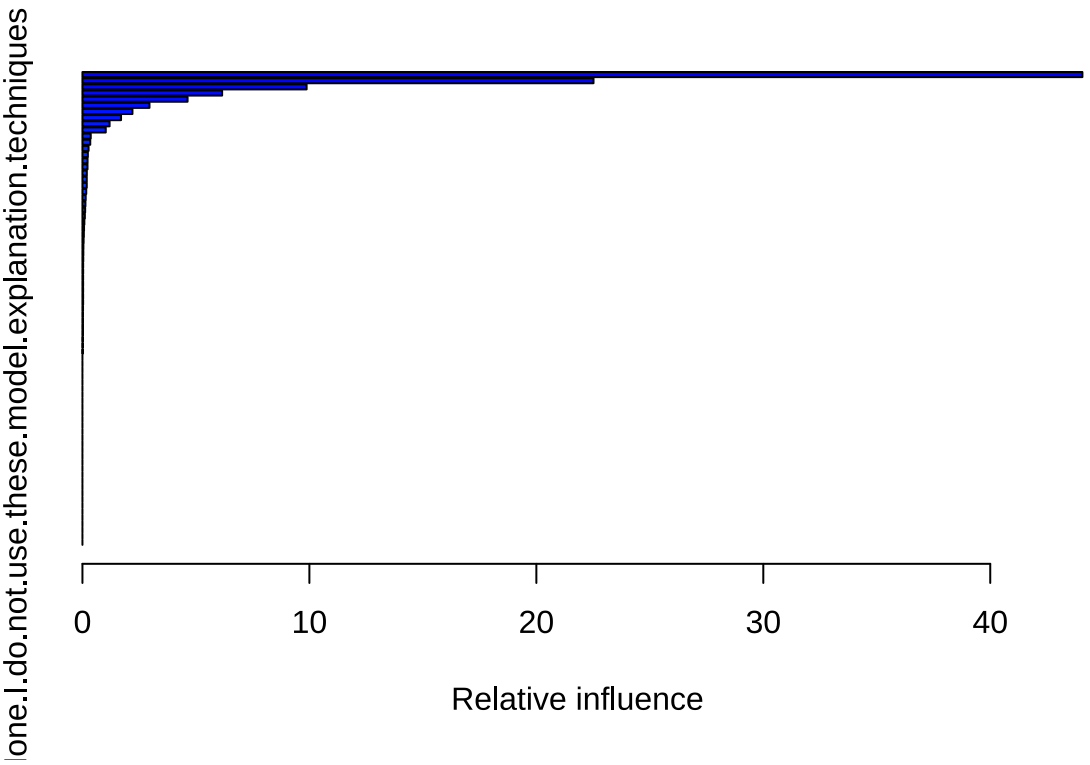

```
# Summary for all models
for (model_name in names(model_list)) {
  model <- model_list[[model_name]]
  var_imp <- varImp(model)
  cat("Variable Importance for", model_name, "Model:\n")
  print(var_imp)
  cat("\n")
  summary(model)
  cat("\n")
}
```

```
## Variable Importance for Linear Regression Model:
## lm variable importance
##
##   only 20 most important variables shown (out of 77)
##
##
## country
## age
## Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## cloud_Amazon.Web.Services..AWS.
## ML_atwork
## For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## Activities_Do.research.that.advances.the.state.of.the.art.of.machine.learning
## experience
```

```
## How.long.have.you.been.writing.code.to.analyze.data.
## industry
## Programming_Bash
## job_role
## Notebooks_Google.Colab
## Activities_Build.and.or.run.the.data.infrastructure.that.my.business.uses.for.storing..analyzing..an
## Activities_Analyze.and.understand.data.to.influence.product.or.business.decisions
## Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.wor
## ML_framework_Spark.MLlib
## Programming_R
## explainability.model_Examine.individual.model.coefficients
## Programming_MATLAB
##
##
## Variable Importance for Random Forest Model:
##
## gender
## age
## country
## education
## undergraduate_major
## job_role
## industry
## ML_atwork
## Activities_Analyze.and.understand.data.to.influence.product.or.business.decisions
## Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.wor
## Activities_Build.and.or.run.the.data.infrastructure.that.my.business.uses.for.storing..analyzing..an
## Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## Activities_Do.research.that.advances.the.state.of.the.art.of.machine.learning
## Activities_None.of.these.activities.are.an.important.part.of.my.role.at.work
## Notebooks_Kaggle.Kernels
## Notebooks_Google.Colab
## Notebooks_Azure.Notebook
## Notebooks_Google.Cloud.Datalab
## Notebooks_JupyterHub.Binder
## Notebooks_None
## cloud_Google.Cloud.Platform..GCP.
## cloud_Amazon.Web.Services..AWS.
## cloud_Microsoft.Azure
## cloud_IBM.Cloud
## cloud_Alibaba.Cloud
## cloud_I.have.not.used.any.cloud.providers
## Programming_Python
## Programming_R
## Programming_SQL
## Programming_Bash
## Programming_Java
## Programming_Javascript.Typescript
## Programming_Visual.Basic.VBA
## Programming_C.C..
## Programming_MATLAB
## Programming_Scala
## Programming_Julia
## Programming_SAS.STATA
```

```
## Programming_language_used_most_often
## ML_framework_Scikit.Learn
## ML_framework_TensorFlow
## ML_framework_Keras
## ML_framework_PyTorch
## ML_framework_Spark.MLlib
## ML_framework_H20
## ML_framework_Caret
## ML_framework_Xgboost
## ML_framework_randomForest
## ML_framework_None
## Visualization_ggplot2
## Visualization_Matplotlib
## Visualization_Altair
## Visualization_Shiny
## Visualization_Plotly
## Visualization_None
## percent_actively.coding
## How.long.have.you.been.writing.code.to.analyze.data.
## For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## Do.you.consider.yourself.to.be.a.data.scientist.
## data_Categorical.Data
## data_Genetic.Data
## data_Geospatial.Data
## data_Image.Data
## data_Numerical.Data
## data_Sensor.Data
## data_Tabular.Data
## data_text.Data
## data_Time.Series.Data
## data_Video.Data
## explainability.model_Examine.individual.model.coefficients
## explainability.model_examine.feature.correlations
## explainability.model_Examine.feature.importances
## explainability.model_Create.partial.dependence.plots
## explainability.model_LIME.functions
## explainability.model_SHAP.functions
## explainability.model_None.I.do.not.use.these.model.explanation.techniques
## experience
##
##
## Variable Importance for Gradient Boosting Model:
## gbm variable importance
##
##   only 20 most important variables shown (out of 77)
##
##
## country
## age
## job_role
## How.long.have.you.been.writing.code.to.analyze.data.
## ML_atwork
## industry
## cloud_Amazon.Web.Services..AWS.
```

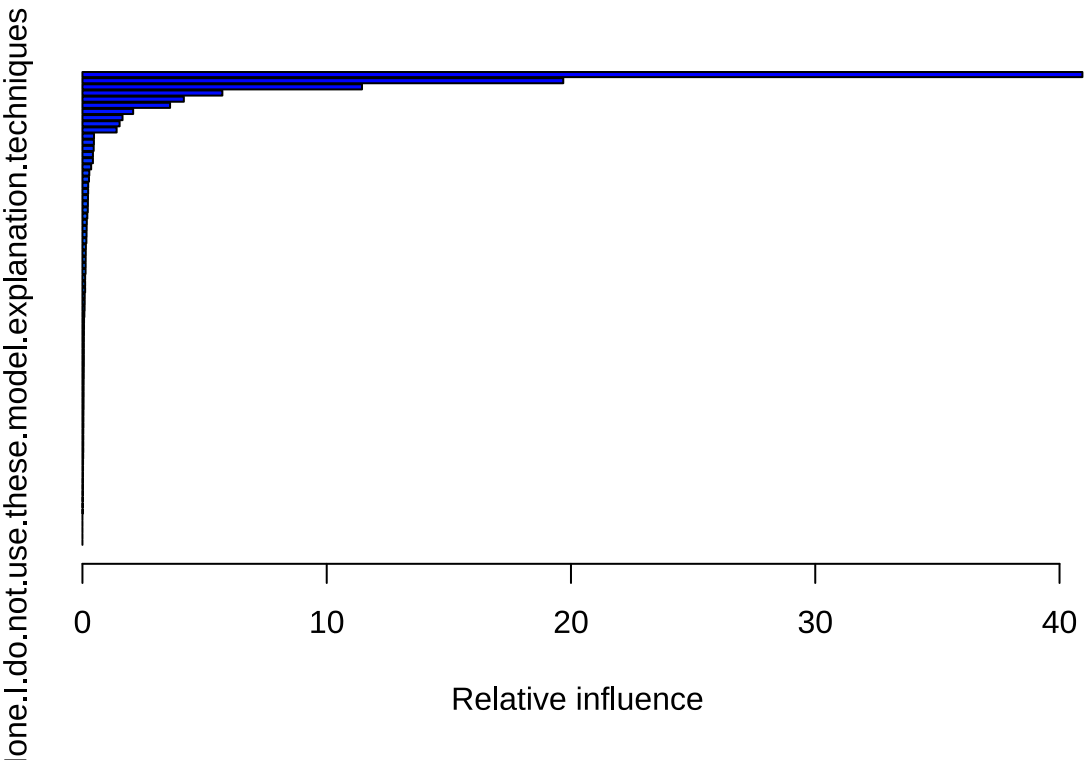
```
## Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## experience
## For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## ML_framework_Spark.MLlib
## education
## explainability.model_Examine.feature.importances
## Programming_Bash
## explainability.model_LIME.functions
## gender
## Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.work
## ML_framework_Xgboost
## Programming_language_used_most_often
## Programming_MATLAB
```




```
##
## Variable Importance for XGBoost Model:
## xgbTree variable importance
##
##   only 20 most important variables shown (out of 77)
##
##
## country
## age
## job_role
## How.long.have.you.been.writing.code.to.analyze.data.
## ML_atwork
## industry
## cloud_Amazon.Web.Services..AWS.
## Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## experience
```

```
## For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## ML_framework_Spark.MLlib
## percent_actively.coding
## Programming_language_used_most_often
## education
## Programming_MATLAB
## explainability.model_Examine.feature.importances
## Programming_Bash
## undergraduate_major
## Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.work
## gender
##
##
## Variable Importance for Random Forest Tuned Model:
## rf variable importance
##
##   only 20 most important variables shown (out of 77)
##
##
## country
## age
## job_role
## How.long.have.you.been.writing.code.to.analyze.data.
## experience
## For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## industry
## ML_atwork
## undergraduate_major
## cloud_Amazon.Web.Services..AWS.
## Programming_language_used_most_often
## Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## Do.you.consider.yourself.to.be.a.data.scientist.
## percent_actively.coding
## education
## Activities_Analyze.and.understand.data.to.influence.product.or.business.decisions
## cloud_I.have.not.used.any.cloud.providers
## Programming_C.C..
## Activities_Build.and.or.run.the.data.infrastructure.that.my.business.uses.for.storing..analyzing..and
## explainability.model_Examine.feature.importances
##
##
## Variable Importance for Gradient Boosting Tuned Model:
## gbm variable importance
##
##   only 20 most important variables shown (out of 77)
##
##
## country
## age
## job_role
## How.long.have.you.been.writing.code.to.analyze.data.
## ML_atwork
## industry
## cloud_Amazon.Web.Services..AWS.
```

```
## experience
## Activities_Build.prototypes.to.explore.applying.machine.learning.to.new.areas
## For.how.many.years.have.you.used.machine.learning.methods..at.work.or.in.school..
## education
## Activities_Build.and.or.run.a.machine.learning.service.that.operationally.improves.my.product.or.worl
## ML_framework_Spark.MLlib
## Programming_language_used_most_often
## percent_actively.coding
## undergraduate_major
## ML_framework_Xgboost
## gender
## Activities_Do.research.that.advances.the.state.of.the.art.of.machine.learning
## Programming_Bash
```



Insights from Model Comparison (General):

Several factors continue to show a strong explainability of wages across all models:

- Country: The country is a major factor when wages are predicted. This is likely because the variations in cost of living, industry concentration, and demand for machine learning talent. Then when a country has more machine learning jobs, this rises the explainability for the wage related to machine learning usage at work. (See below)
- Age and Experience: Age and years of experience are consistently strong predictors. This suggests that wages generally increase with maturity and expertise.
- Job Role: The job role has impacts on the wage. This is likely because different roles require different skill sets and responsibilities.
- Coding Experience for Data Analysis: The length of time spent coding continues to emerge as a impactful factor. This may also be connected with age and experience.
- Machine Learning Usage at Work (ML_atwork): Whether or not someone utilizes machine learning in their work is a consistent predictor. This may also be connected with the job role and country.

- Cloud Experience (AWS): Experience with Amazon Web Services (AWS) stands out as a factor in several models. This can reflect the widespread adoption of AWS in the industry.
- Domain-Specific Factors: Various domain-specific variables, such as machine learning activities or framework usage. ### Model-Specific Insights #### Linear Regression: The linear regression model emphasizes country, age, and experience, aligning with the expectation of linear relationships between these factors and salary. AWS experience is notably prominent, suggesting a potential salary premium for professionals with this skill. #### Random Forest: Compared to linear regression, the random forest model distributes importance more evenly across various predictors. Country, age, job role, and experience remain significant factors. Notably, specific programming languages and tools gain importance, indicating that tool preferences might influence salary in complex, non-linear ways. #### Gradient Boosting: The gradient boosting model shows a stronger focus on country, age, and job role. Time spent coding for data analysis emerges as a top predictor, reinforcing the value of practical coding skills in this domain. #### XGBoost: The XGBoost model closely aligns with the gradient boosting model in terms of variable importance, with country, age, coding experience, and job role. This alignment between the two top-performing models provides strong evidence for the relevance of these factors in determining salary. #### Tuned Models (Random Forest and Gradient Boosting): The tuned models show similar variable importance as their untuned models, with minor shifts in rankings. This suggests that the overall relationships between predictors and salary remain stable.

Wage Prediction:

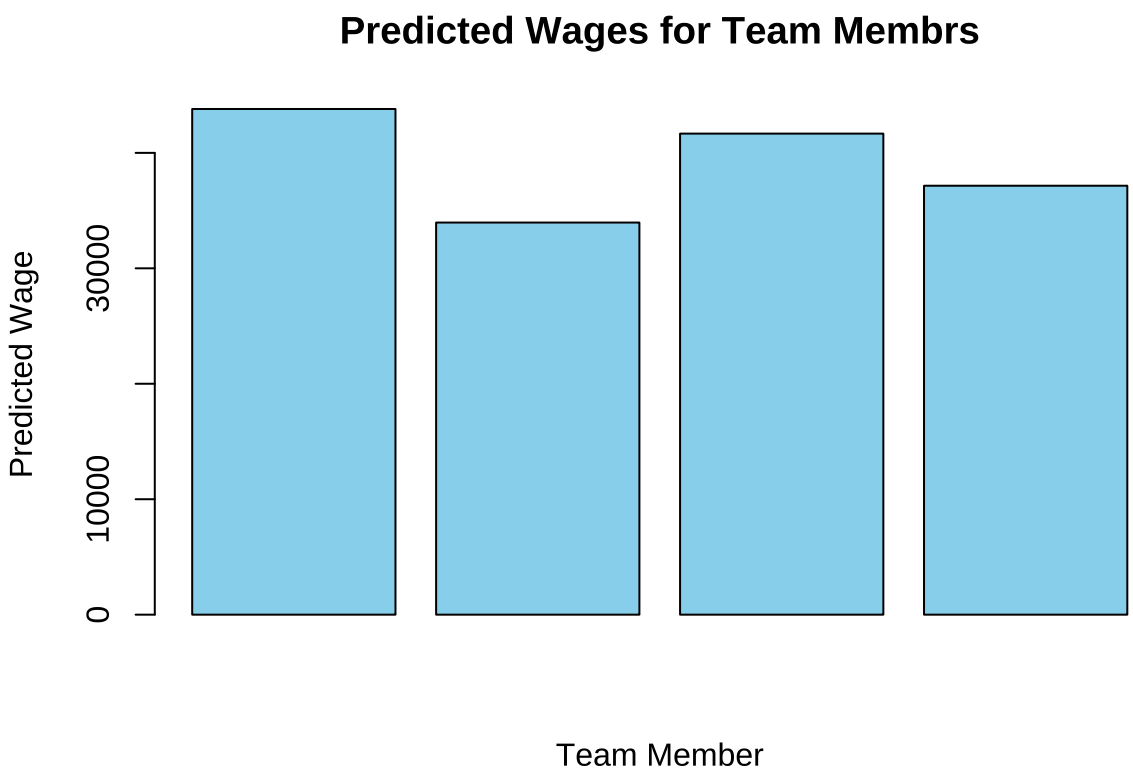
```
# Load and prepare the team data
set.seed(123)
team_data <- read_csv("./team_data.csv")

# Add experience column with consistent levels
team_data$experience <- factor(
  team_data$years_experience,
  levels = c(
    "0-1", "1-2", "2-3", "3-4", "4-5", "5-11",
    "11-15", "15-20", "20-25", "25-30", "30 +"
  ),
  ordered = TRUE
)
# Remove years_experience column and first column
team_data <- team_data[, -1] %>% select(-years_experience)
# Ensure factor levels in team_data match those in data_wage
for (col in names(team_data)) {
  if (is.character(team_data[[col]])) {
    levels_in_wage_data <- levels(data_wage[[col]])
    team_data[[col]] <- factor(team_data[[col]], levels = levels_in_wage_data)
  }
}
# One-hot encode categorical variables and scale numeric variables
team_data_encoded <- team_data %>%
  mutate(across(
    where(is.character),
    ~ factor(.x, levels = levels(data_wage[[cur_column()]]))
  )) %>%
  mutate(across(where(is.numeric), ~ scale(.x))) %>%
  mutate(across(where(is.factor), ~ as.numeric(as.factor(.x)) - 1))
# Apply dummy variable encoding
team_data_transformed <- as.data.frame(
  predict(dummies, newdata = team_data_encoded)
```

```
)
# Use XGBoost model for prediction
pred_xgboost <- predict(xgboost_model, newdata = team_data_transformed)
print(pred_xgboost)
```

```
## [1] 43798.56 33963.88 41666.16 37151.39
```

```
# Print as barplot
barplot(pred_xgboost, main = "Predicted Wages for Team Membrs", xlab = "Team Member", ylab = "Predicted
```




```
# Replace NAs with 0 in team_data
team_data_transformed[is.na(team_data_transformed)] <- 0
# use gbm_model for prediction
pred_gbm <- predict(gbm_tuned, newdata = team_data_transformed)
print(pred_gbm)
```

```
## [1] 40183.47 26912.31 24531.97 36606.36
```

Until the end we could not factor the data_wage properties to our custom team data set which is why we could not predict the wages for the team members exactly. For example the prediction with the gbm_model does not work because of the NA values in the team_data. We would have to replace the NA values with 0 in order to make the prediction work. This would distort the prediction. We will stick to the XGBoost model for our predictions and ignore the wages of gbm tuned model.

Interpreting the Predictions:

XGBoost predicts wages of 43798.56 33963.88 41666.16 and 37151.39 for the four team members. All of the team do have a higher yearly wage. This shows that eather the team members are not well displayed in the team data set or the MAE of 18136.72 has a big impact on the wage. The predictions are based on the model's learned relationships between the variables like country and experience and wages. The predictions provide an estimate of the expected salary for each team member based on these factors. When a team

member has more years of experience this than noted in the dataset this could lead to a higher wage than now printed.

Impact of Replacing NAs with 0:

Replacing missing values (NAs) with zeros will propably distort the predictions:

- Meaning Change: Zeros has a specific meaning in data (e.g., absence of a characteristic). Replacing NAs with zeros has changed the interpretation of the data.
- Skewed Relationships: Zeros skew the relationships between variables. If a model learned a relationship based on actual zeros, it make incorrect assumptions.
- Loss of Information: Replacing NAs with zeros discards information.

H2O AutoML analysis

```
# H2O AutoML Setup
h2o.init()
```

```
##  Connection successful!
##
## R is connected to the H2O cluster:
##     H2O cluster uptime:         2 days 1 hours
##     H2O cluster timezone:       Europe/Zurich
##     H2O data parsing timezone:  UTC
##     H2O cluster version:        3.44.0.3
##     H2O cluster version age:    5 months and 6 days
##     H2O cluster name:           H2O_started_from_R_mischahaenen_xvp655
##     H2O cluster total nodes:    1
##     H2O cluster total memory:   6.56 GB
##     H2O cluster total cores:    10
##     H2O cluster allowed cores:  10
##     H2O cluster healthy:        TRUE
##     H2O Connection ip:          localhost
##     H2O Connection port:        54321
##     H2O Connection proxy:       NA
##     H2O Internal Security:      FALSE
##     R Version:                  R version 4.4.0 (2024-04-24)
```

```
# Convert the dataset to H2O object
h2o_data <- as.h2o(data_transformed)
```

```
##   |                                                                              |
```

```
# Split dataset into training and validation sets
splits <- h2o.splitFrame(h2o_data, ratios = c(0.8), seed = 12)
train <- splits[[1]]
valid <- splits[[2]]

# Set the dependent variable
dep_var <- "wage"

# Run H2O AutoML
automl <- h2o.automl(
  x = setdiff(colnames(h2o_data), dep_var),
  y = dep_var,
  training_frame = train,
```

```
  max_runtime_secs = 600,
  seed = 12
)
```

```
##   |                                                                              |
## 16:17:14.294: AutoML: XGBoost is not available; skipping it.  |
```

```
# View leaderboard of models generated by AutoML
lb <- automl@leaderboard
print(lb, n = nrow(lb))
```

```
##                                                  model_id     rmse        mse
## 1      StackedEnsemble_AllModels_6_AutoML_5_20240527_161714 25964.90  674176103
## 2      StackedEnsemble_AllModels_5_AutoML_5_20240527_161714 25967.91  674332145
## 3       StackedEnsemble_Best1000_1_AutoML_5_20240527_161714 25973.29  674611716
## 4      StackedEnsemble_AllModels_3_AutoML_5_20240527_161714 25975.73  674738378
## 5      StackedEnsemble_AllModels_4_AutoML_5_20240527_161714 25977.46  674828287
## 6      StackedEnsemble_AllModels_2_AutoML_5_20240527_161714 26139.05  683250139
## 7      StackedEnsemble_AllModels_1_AutoML_5_20240527_161714 26195.51  686204784
## 8   StackedEnsemble_BestOfFamily_4_AutoML_5_20240527_161714 26445.12  699344533
## 9   StackedEnsemble_BestOfFamily_2_AutoML_5_20240527_161714 26446.63  699424260
## 10  StackedEnsemble_BestOfFamily_3_AutoML_5_20240527_161714 26447.76  699483967
## 11                          GBM_2_AutoML_5_20240527_161714 26448.68  699532927
## 12  StackedEnsemble_BestOfFamily_6_AutoML_5_20240527_161714 26449.46  699573767
## 13             GBM_grid_1_AutoML_5_20240527_161714_model_50 26497.95  702141257
## 14             GBM_grid_1_AutoML_5_20240527_161714_model_40 26528.26  703748767
## 15                          GBM_3_AutoML_5_20240527_161714 26566.21  705763394
## 16                          GBM_5_AutoML_5_20240527_161714 26635.24  709435912
## 17              GBM_grid_1_AutoML_5_20240527_161714_model_2 26635.95  709473949
## 18             GBM_grid_1_AutoML_5_20240527_161714_model_11 26646.82  710052994
## 19  StackedEnsemble_BestOfFamily_5_AutoML_5_20240527_161714 26654.68  710472068
## 20             GBM_grid_1_AutoML_5_20240527_161714_model_16 26681.86  711921630
## 21             GBM_grid_1_AutoML_5_20240527_161714_model_54 26718.94  713901497
## 22             GBM_grid_1_AutoML_5_20240527_161714_model_66 26733.13  714659999
## 23              GBM_grid_1_AutoML_5_20240527_161714_model_1 26751.83  715660668
## 24             GBM_grid_1_AutoML_5_20240527_161714_model_13 26759.06  716047534
## 25             GBM_grid_1_AutoML_5_20240527_161714_model_71 26761.13  716157897
## 26             GBM_grid_1_AutoML_5_20240527_161714_model_67 26784.99  717435948
## 27             GBM_grid_1_AutoML_5_20240527_161714_model_17 26792.13  717818438
## 28             GBM_grid_1_AutoML_5_20240527_161714_model_14 26902.42  723740463
## 29              GBM_grid_1_AutoML_5_20240527_161714_model_4 26919.73  724671816
## 30             GBM_grid_1_AutoML_5_20240527_161714_model_24 26932.79  725375355
## 31              GBM_grid_1_AutoML_5_20240527_161714_model_5 26949.65  726283374
## 32              GBM_grid_1_AutoML_5_20240527_161714_model_7 26968.33  727290906
## 33             GBM_grid_1_AutoML_5_20240527_161714_model_47 26988.98  728404784
## 34                          GBM_4_AutoML_5_20240527_161714 27009.60  729518345
## 35             GBM_grid_1_AutoML_5_20240527_161714_model_20 27014.63  729790321
## 36              GBM_grid_1_AutoML_5_20240527_161714_model_8 27030.65  730656091
## 37              GBM_grid_1_AutoML_5_20240527_161714_model_6 27034.54  730866390
## 38             GBM_grid_1_AutoML_5_20240527_161714_model_27 27053.88  731912276
## 39             GBM_grid_1_AutoML_5_20240527_161714_model_70 27071.05  732841532
## 40             GBM_grid_1_AutoML_5_20240527_161714_model_32 27124.78  735753561
## 41             GBM_grid_1_AutoML_5_20240527_161714_model_22 27158.92  737606821
## 42             GBM_grid_1_AutoML_5_20240527_161714_model_44 27169.71  738193196
## 43             GBM_grid_1_AutoML_5_20240527_161714_model_15 27174.21  738437958
```

```
## 44             GBM_grid_1_AutoML_5_20240527_161714_model_46 27174.81  738470490
## 45             GBM_grid_1_AutoML_5_20240527_161714_model_48 27214.09  740606756
## 46             GBM_grid_1_AutoML_5_20240527_161714_model_59 27292.72  744892559
## 47             GBM_grid_1_AutoML_5_20240527_161714_model_35 27293.08  744912337
## 48             GBM_grid_1_AutoML_5_20240527_161714_model_58 27370.61  749150187
## 49             GBM_grid_1_AutoML_5_20240527_161714_model_41 27427.25  752254146
## 50             GBM_grid_1_AutoML_5_20240527_161714_model_30 27439.71  752937714
## 51             GBM_grid_1_AutoML_5_20240527_161714_model_60 27445.99  753282238
## 52  StackedEnsemble_BestOfFamily_1_AutoML_5_20240527_161714 27457.01  753887163
## 53                           GBM_1_AutoML_5_20240527_161714 27462.28  754176930
## 54             GBM_grid_1_AutoML_5_20240527_161714_model_45 27562.45  759688440
## 55             GBM_grid_1_AutoML_5_20240527_161714_model_49 27637.57  763835546
## 56             GBM_grid_1_AutoML_5_20240527_161714_model_10 27689.98  766735112
## 57             GBM_grid_1_AutoML_5_20240527_161714_model_34 27691.52  766820173
## 58             GBM_grid_1_AutoML_5_20240527_161714_model_19 27741.70  769601888
## 59             GBM_grid_1_AutoML_5_20240527_161714_model_25 27747.85  769943440
## 60             GBM_grid_1_AutoML_5_20240527_161714_model_65 27760.54  770647710
## 61             GBM_grid_1_AutoML_5_20240527_161714_model_26 27784.49  771977922
## 62             GBM_grid_1_AutoML_5_20240527_161714_model_55 27796.10  772623419
## 63             GBM_grid_1_AutoML_5_20240527_161714_model_39 27817.75  773827255
## 64             GBM_grid_1_AutoML_5_20240527_161714_model_53 27849.59  775599523
## 65             GBM_grid_1_AutoML_5_20240527_161714_model_62 27884.65  777553663
## 66             GBM_grid_1_AutoML_5_20240527_161714_model_21 27890.82  777897636
## 67              GBM_grid_1_AutoML_5_20240527_161714_model_3 27965.43  782065355
## 68             GBM_grid_1_AutoML_5_20240527_161714_model_57 27991.85  783543534
## 69             GBM_grid_1_AutoML_5_20240527_161714_model_56 27993.50  783636165
## 70             GBM_grid_1_AutoML_5_20240527_161714_model_51 27998.46  783913585
## 71             GBM_grid_1_AutoML_5_20240527_161714_model_52 28006.42  784359360
## 72             GBM_grid_1_AutoML_5_20240527_161714_model_33 28011.82  784661916
## 73             GBM_grid_1_AutoML_5_20240527_161714_model_37 28023.60  785322313
## 74             GBM_grid_1_AutoML_5_20240527_161714_model_36 28046.19  786588773
## 75             GBM_grid_1_AutoML_5_20240527_161714_model_43 28087.27  788894991
## 76             GBM_grid_1_AutoML_5_20240527_161714_model_38 28092.83  789207081
## 77             GBM_grid_1_AutoML_5_20240527_161714_model_61 28165.43  793291442
## 78             GBM_grid_1_AutoML_5_20240527_161714_model_42 28200.00  795239923
## 79             GBM_grid_1_AutoML_5_20240527_161714_model_63 28228.09  796825154
## 80             GBM_grid_1_AutoML_5_20240527_161714_model_68 28258.16  798523842
## 81             GBM_grid_1_AutoML_5_20240527_161714_model_64 28272.00  799305825
## 82             GBM_grid_1_AutoML_5_20240527_161714_model_69 28275.60  799509390
## 83             GBM_grid_1_AutoML_5_20240527_161714_model_28 28445.69  809157537
## 84             GBM_grid_1_AutoML_5_20240527_161714_model_23 28512.45  812959636
## 85            GBM_grid_1_AutoML_5_20240527_161714_model_143 28513.83  813038329
## 86             GBM_grid_1_AutoML_5_20240527_161714_model_31 28700.12  823696854
## 87              GBM_grid_1_AutoML_5_20240527_161714_model_9 28994.69  840691787
## 88             GBM_grid_1_AutoML_5_20240527_161714_model_29 29053.92  844130394
## 89                           DRF_1_AutoML_5_20240527_161714 29056.03  844252867
## 90             GBM_grid_1_AutoML_5_20240527_161714_model_18 29106.19  847170440
## 91                           XRT_1_AutoML_5_20240527_161714 29280.58  857352545
## 92             GBM_grid_1_AutoML_5_20240527_161714_model_12 29385.90  863531133
## 93     DeepLearning_grid_1_AutoML_5_20240527_161714_model_3 33427.69 1117410129
## 94     DeepLearning_grid_1_AutoML_5_20240527_161714_model_1 33657.07 1132798128
## 95     DeepLearning_grid_2_AutoML_5_20240527_161714_model_3 34492.96 1189764568
## 96     DeepLearning_grid_3_AutoML_5_20240527_161714_model_3 34648.28 1200502997
## 97                   DeepLearning_1_AutoML_5_20240527_161714 35252.52 1242740151
```

```
## 98     DeepLearning_grid_1_AutoML_5_20240527_161714_model_4 35290.76 1245437671
## 99     DeepLearning_grid_1_AutoML_5_20240527_161714_model_2 35482.68 1259020539
## 100    DeepLearning_grid_3_AutoML_5_20240527_161714_model_1 37665.88 1418718551
## 101    DeepLearning_grid_1_AutoML_5_20240527_161714_model_9 37830.86 1431174240
## 102    DeepLearning_grid_2_AutoML_5_20240527_161714_model_2 39043.54 1524397795
## 103          GBM_grid_1_AutoML_5_20240527_161714_model_144 39294.17 1544031532
## 104    DeepLearning_grid_2_AutoML_5_20240527_161714_model_1 39302.54 1544689698
## 105    DeepLearning_grid_3_AutoML_5_20240527_161714_model_2 39730.65 1578524659
## 106                          GLM_1_AutoML_5_20240527_161714 45471.23 2067632637
##          mae    rmsle mean_residual_deviance
## 1   18009.48      NaN              674176103
## 2   17846.61 2.956382              674332145
## 3   18009.83      NaN              674611716
## 4   18018.16      NaN              674738378
## 5   18011.69      NaN              674828287
## 6   18107.75      NaN              683250139
## 7   18135.04      NaN              686204784
## 8   18373.15      NaN              699344533
## 9   18376.06      NaN              699424260
## 10  18375.23      NaN              699483967
## 11  18424.63      NaN              699532927
## 12  18385.73      NaN              699573767
## 13  18430.52      NaN              702141257
## 14  18568.50      NaN              703748767
## 15  18516.35      NaN              705763394
## 16  18638.08      NaN              709435912
## 17  18566.23      NaN              709473949
## 18  18595.78      NaN              710052994
## 19  18418.75 2.967527              710472068
## 20  18879.91      NaN              711921630
## 21  18758.09      NaN              713901497
## 22  18807.11      NaN              714659999
## 23  18893.10      NaN              715660668
## 24  18759.59      NaN              716047534
## 25  18678.27      NaN              716157897
## 26  18701.58      NaN              717435948
## 27  18816.02      NaN              717818438
## 28  19017.39      NaN              723740463
## 29  18955.03      NaN              724671816
## 30  18828.14      NaN              725375355
## 31  18879.64      NaN              726283374
## 32  18958.86      NaN              727290906
## 33  19043.54      NaN              728404784
## 34  18917.85      NaN              729518345
## 35  19184.56      NaN              729790321
## 36  18840.89      NaN              730656091
## 37  18972.96      NaN              730866390
## 38  19124.66      NaN              731912276
## 39  18934.29      NaN              732841532
## 40  18982.02      NaN              735753561
## 41  19320.22      NaN              737606821
## 42  19061.13      NaN              738193196
## 43  19362.26      NaN              738437958
## 44  19052.18      NaN              738470490
```

```
## 45  19216.95      NaN             740606756
## 46  19088.58      NaN             744892559
## 47  19347.58      NaN             744912337
## 48  19318.84      NaN             749150187
## 49  19486.72      NaN             752254146
## 50  19134.98      NaN             752937714
## 51  19335.40      NaN             753282238
## 52  19153.68      NaN             753887163
## 53  19183.27      NaN             754176930
## 54  19321.66      NaN             759688440
## 55  19681.10      NaN             763835546
## 56  19439.10      NaN             766735112
## 57  19345.92      NaN             766820173
## 58  19611.89      NaN             769601888
## 59  19722.01      NaN             769943440
## 60  19813.26      NaN             770647710
## 61  19681.69      NaN             771977922
## 62  19580.60      NaN             772623419
## 63  19692.38      NaN             773827255
## 64  19549.62      NaN             775599523
## 65  19725.13      NaN             777553663
## 66  19993.74      NaN             777897636
## 67  19762.75      NaN             782065355
## 68  19840.18      NaN             783543534
## 69  19697.51      NaN             783636165
## 70  19745.15      NaN             783913585
## 71  19823.26      NaN             784359360
## 72  20111.61      NaN             784661916
## 73  19730.67      NaN             785322313
## 74  19991.29      NaN             786588773
## 75  19894.31      NaN             788894991
## 76  19835.08      NaN             789207081
## 77  19892.07      NaN             793291442
## 78  20278.18      NaN             795239923
## 79  19929.81      NaN             796825154
## 80  20221.33      NaN             798523842
## 81  20055.30      NaN             799305825
## 82  20102.89      NaN             799509390
## 83  20625.04      NaN             809157537
## 84  20497.91      NaN             812959636
## 85  20552.02      NaN             813038329
## 86  20481.36      NaN             823696854
## 87  20651.17 2.998277             840691787
## 88  20767.06      NaN             844130394
## 89  20922.92 3.029713             844252867
## 90  21239.19      NaN             847170440
## 91  21311.85 3.054159             857352545
## 92  21413.42 3.042164             863531133
## 93  25013.82      NaN            1117410129
## 94  25047.86      NaN            1132798128
## 95  26819.93 3.233892            1189764568
## 96  26824.12 3.222534            1200502997
## 97  25555.22      NaN            1242740151
## 98  27046.79      NaN            1245437671
```

```
## 99  26454.98      NaN             1259020539
## 100 32022.41 3.466682             1418718551
## 101 29277.75      NaN             1431174240
## 102 31430.53 3.398667             1524397795
## 103 31595.26 3.399275             1544031532
## 104 33462.02 3.495290             1544689698
## 105 31832.95 3.399779             1578524659
## 106 36843.21 3.486076             2067632637
##
## [106 rows x 6 columns]
```

```
# Export leaderboard to Excel
lb_table <- as.data.table(lb)
write_xlsx(lb_table, "./trained_ML_models.xlsx")

# Find the best performing model per a certain criterion and explore it
best_model <- h2o.get_best_model(automl, criterion = "rmse")
best_model
```

```
## Model Details:
## ==============
##
## H2ORegressionModel: stackedensemble
## Model ID:  StackedEnsemble_AllModels_6_AutoML_5_20240527_161714
## Model Summary for Stacked Ensemble:
##                                         key            value
## 1                          Stacking strategy cross_validation
## 2       Number of base models (used / total)            15/90
## 3           # GBM base models (used / total)            15/76
## 4           # DRF base models (used / total)              0/2
## 5  # DeepLearning base models (used / total)             0/11
## 6           # GLM base models (used / total)              0/1
## 7                      Metalearner algorithm              GLM
## 8         Metalearner fold assignment scheme           Random
## 9                        Metalearner nfolds                5
## 10                  Metalearner fold_column               NA
## 11        Custom metalearner hyperparameters             None
##
##
## H2ORegressionMetrics: stackedensemble
## ** Reported on training data. **
##
## MSE:  248137828
## RMSE:  15752.39
## MAE:  10936.96
## RMSLE:  NaN
## Mean Residual Deviance :  248137828
##
##
##
## H2ORegressionMetrics: stackedensemble
## ** Reported on cross-validation data. **
## ** 5-fold cross-validation on training data (Metrics computed for combined holdout predictions) **
##
## MSE:  674176103
```

```
## RMSE:  25964.9
## MAE:  18009.48
## RMSLE:  NaN
## Mean Residual Deviance :  674176103
##
##
## Cross-Validation Metrics Summary:
##                                        mean                  sd
## mae                             18007.178000          524.487500
## mean_residual_deviance     674254900.000000     47922920.000000
## mse                        674254900.000000     47922920.000000
## null_deviance          3497230300000.000000 245591020000.000000
## r2                                0.673613            0.017318
## residual_deviance      1140216600000.000000  93928670000.000000
## rmse                            25953.297000          922.793640
## rmsle                                     NA            0.000000
##                                  cv_1_valid           cv_2_valid
## mae                             17673.145000         18429.521000
## mean_residual_deviance     653348800.000000     692309060.000000
## mse                        653348800.000000     692309060.000000
## null_deviance          3704485300000.000000 3413444400000.000000
## r2                                0.690212            0.655543
## residual_deviance      1147280400000.000000 1175540700000.000000
## rmse                            25560.688000         26311.768000
## rmsle                                     NA                   NA
##                                  cv_3_valid           cv_4_valid
## mae                             17508.540000         18700.998000
## mean_residual_deviance     610680100.000000     740448600.000000
## mse                        610680100.000000     740448600.000000
## null_deviance          3416517200000.000000 3779048800000.000000
## r2                                0.693913            0.662173
## residual_deviance      1044263000000.000000 1275052400000.000000
## rmse                            24711.943000         27211.184000
## rmsle                                     NA                   NA
##                                  cv_5_valid
## mae                             17723.688000
## mean_residual_deviance     674487940.000000
## mse                        674487940.000000
## null_deviance          3172655400000.000000
## r2                                0.666222
## residual_deviance      1058946100000.000000
## rmse                            25970.906000
## rmsle                                     NA
```

```
# Predictions and performance on the validation set
pred_best_model <- h2o.predict(best_model, valid)
```

```
##   |                                                                              |
```

```
perf_best_model <- h2o.performance(best_model, valid)

# Summarize the performance
rmse <- h2o.rmse(perf_best_model)
mae <- h2o.mae(perf_best_model)
r2 <- h2o.r2(perf_best_model)
```

```r
cat("RMSE (Stacked Ensemble):", rmse, "\n")
```

```
## RMSE (Stacked Ensemble): 25375.57
```

```r
cat("MAE (Stacked Ensemble):", mae, "\n")
```

```
## MAE (Stacked Ensemble): 17715.41
```

```r
cat("R-squared (Stacked Ensemble):", r2, "\n")
```

```
## R-squared (Stacked Ensemble): 0.6820313
```

```r
# Variable Importance for Stacked Ensemble Model
summary(best_model)
```

```
## Model Details:
## ==============
##
## H2ORegressionModel: stackedensemble
## Model Key:  StackedEnsemble_AllModels_6_AutoML_5_20240527_161714
## Model Summary for Stacked Ensemble:
##                                         key            value
## 1                          Stacking strategy cross_validation
## 2       Number of base models (used / total)            15/90
## 3           # GBM base models (used / total)            15/76
## 4           # DRF base models (used / total)              0/2
## 5  # DeepLearning base models (used / total)             0/11
## 6           # GLM base models (used / total)              0/1
## 7                      Metalearner algorithm              GLM
## 8         Metalearner fold assignment scheme           Random
## 9                        Metalearner nfolds                5
## 10                  Metalearner fold_column               NA
## 11        Custom metalearner hyperparameters             None
##
## H2ORegressionMetrics: stackedensemble
## ** Reported on training data. **
##
## MSE:  248137828
## RMSE:  15752.39
## MAE:  10936.96
## RMSLE:  NaN
## Mean Residual Deviance :  248137828
##
##
##
## H2ORegressionMetrics: stackedensemble
## ** Reported on cross-validation data. **
## ** 5-fold cross-validation on training data (Metrics computed for combined holdout predictions) **
##
## MSE:  674176103
## RMSE:  25964.9
## MAE:  18009.48
## RMSLE:  NaN
## Mean Residual Deviance :  674176103
##
##
```

```
## Cross-Validation Metrics Summary:
##                                        mean                  sd
## mae                             18007.178000          524.487500
## mean_residual_deviance     674254900.000000     47922920.000000
## mse                        674254900.000000     47922920.000000
## null_deviance          3497230300000.000000 245591020000.000000
## r2                                0.673613            0.017318
## residual_deviance      1140216600000.000000  93928670000.000000
## rmse                            25953.297000          922.793640
## rmsle                                     NA            0.000000
##                                  cv_1_valid           cv_2_valid
## mae                             17673.145000         18429.521000
## mean_residual_deviance     653348800.000000     692309060.000000
## mse                        653348800.000000     692309060.000000
## null_deviance          3704485300000.000000 3413444400000.000000
## r2                                0.690212            0.655543
## residual_deviance      1147280400000.000000 1175540700000.000000
## rmse                            25560.688000         26311.768000
## rmsle                                     NA                   NA
##                                  cv_3_valid           cv_4_valid
## mae                             17508.540000         18700.998000
## mean_residual_deviance     610680100.000000     740448600.000000
## mse                        610680100.000000     740448600.000000
## null_deviance          3416517200000.000000 3779048800000.000000
## r2                                0.693913            0.662173
## residual_deviance      1044263000000.000000 1275052400000.000000
## rmse                            24711.943000         27211.184000
## rmsle                                     NA                   NA
##                                  cv_5_valid
## mae                             17723.688000
## mean_residual_deviance     674487940.000000
## mse                        674487940.000000
## null_deviance          3172655400000.000000
## r2                                0.666222
## residual_deviance      1058946100000.000000
## rmse                            25970.906000
## rmsle                                     NA
##
## NULL
```

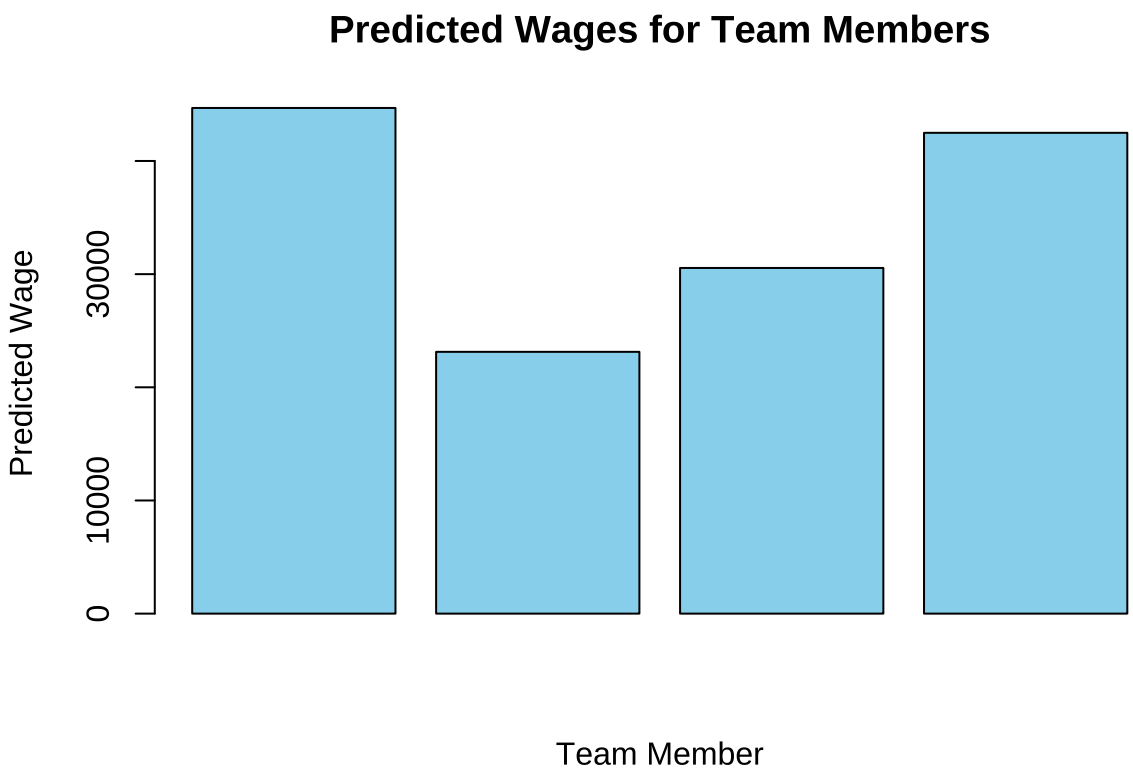
```
# Use the best-performing model from H2O AutoML for predictions
pred_best_model <- as.data.frame(
  h2o.predict(best_model, as.h2o(team_data_transformed))
)
```

```
##   |                                                                              |
##   |                                                                              |
```

```
predicted_wages <- pred_best_model$predict
print(predicted_wages)
```

```
## [1] 44685.43 23135.08 30545.87 42489.11
```

```r
barplot(predicted_wages, main = "Predicted Wages for Team Members", xlab = "Team Member", ylab = "Predi
```




```r
# Conclusion
cat(
  "The best-performing model was", best_model@model_id,
  "with an RMSE of", rmse, ", MAE of", mae, ", and R-squared of", r2, ".\n"
)
```

```
## The best-performing model was StackedEnsemble_AllModels_6_AutoML_5_20240527_161714 with an RMSE of 25
```

Interpretation for H2O Wages Prediction

The H2O model used for wage prediction is a stacked ensemble. It combines 88 basemodels (76 GBMs (Gradient Boosting Machines), 2 DRFs (Distributed Random Forests), 9 Deep Learning models, and 1 GLM (Generalized Linear Model).) multiple base models to improve prediction accuracy. Like in our previous trainings a cross validation with 5 folds was used to evaluate the performance.

Variables for Stacked Ensemble Model:

The stacked ensemble model incorporates a diverse set of predictors to estimate wages accurately. Sadly the variable importance details are not provided in the output summary. Also with var_imp we could not get the variable importance. ### Summary The H2O stacked ensemble model demonstrates a slightly better performance with a cross-validated R-squared of approximately 0.68, indicating that around 68% of the variance in wages can be explained by the model's predictors.

Conclusion and Recommendations

The wage prediction grou work identified key factors influencing the wage of the provided dataset. The XGBoost model and the H2O AutoML stacked ensemble showed the best overall metrics. Key factors

influencing wages include country, age, experience, job role, coding experience, ML usage at work, and AWS experience.

Recommendations:

- Boruta Algorithm: Usage of the Boruta algorithm to identify and retain only the most important variables. This would improve the models performance.
- Imputation Techniques: Use advanced imputation techniques for handling missing values instead of replacing NAs with zeros.
- Ensemble Methods: Combine predictions from multiple models. Like h2o AutoML does.
- Hyperparameter Tuning: Continuously optimize hyperparameters using techniques like grid search or random search to enhance model performance.
- New Features: Incorporate relevant features such as certifications, specific project experience and soft skills.

Whit more time we could implement these recommodations, the model's R-squared value can potentially be increased, leading to more accurate wage predictions.