Predicting Family Income for Marketing

Training and comparing Naive Bayes, Logistic regression and CART models to predict if family income is above 50K/Y

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Executive Summary

1

Random Forest classification is the best method to predict household income greater than $50K since it had the highest accuracy rate predicting family income **(83.4%)**

2

$25 Million Direct Marketing Campaign Target Group:

- Married couples - particularly the husband
- Bachelors & Masters level education

Agenda

- **Understanding raw data -** Variables, data types
- **Cleaning the data -** Sanitize Missing values, outliers
- **Preprocessing** - Encode variables
- **Model Exploration -** Build and evaluate models
- **Model Comparison -** Find the best predicting model

Understanding Raw Data

Explore, Check and Convert Data Types

```
age                  int64
workclass           object
fnlwgt               int64
education           object
education_num        int64
marital_status      object
occupation          object
relationship        object
race                object
sex                 object
capital_gain         int64
capital_loss         int64
hours_per_week       int64
native_country      object
income              object
```

```
age                  int64
workclass         category
fnlwgt               int64
education         category
education_num     category
marital_status    category
occupation        category
relationship      category
race              category
sex               category
capital_gain         int64
capital_loss         int64
hours_per_week       int64
native_country    category
income            category
dtype: object
```

- There are **32561 observations and 15 variables** in the raw data
- **Employee_num** should be treated as 'category'

Cleaning the Data

```
age                143
workclass            0
fnlwgt             992
education            0
education-num        0
marital-status       0
occupation           0
relationship         0
race                 0
sex                  0
capital-gain      2712
capital-loss      1519
hours-per-week    9008
native-country       0
class                0
dtype: int64
```

	age	fnlwgt	capital-gain	capital-loss	hours-per-week
mean	38.581647	1.897784e+05	1077.648844	87.303830	40.437456

- Before imputing corrections, we needed to **identify outliers** in the numeric variables
- Replaced all numeric columns null values to their respective **mean** values
- liminated unusual unknown values such as ' ?' and replacing the values with the **mode**

Preprocesing: Improve Model Efficiency

Dummy Variables

	workclass_ Local-gov	workclass_ Never-worked	workclass_ Private
0	0	0	0
1	0	0	0
2	0	0	1
3	0	0	1
4	0	0	1
...	...	...	...
32556	0	0	1
32557	0	0	1
32558	0	0	1
32559	0	0	1
32560	0	0	0

32561 rows × 51 columns

- Using **binary dummy** - allowing the computer to calculate them with the numeric variables

	age	fnlwgt	capital-gain	capital-loss	hours-per-week
count	32561.000000	32561.000000	32561.0	32561.0	32561.000000
mean	38.381609	179631.339130	0.0	0.0	41.565533
std	13.300577	86028.457849	0.0	0.0	3.415436
min	17.000000	12285.000000	0.0	0.0	33.000000
25%	28.000000	117827.000000	0.0	0.0	40.000000
50%	37.000000	178356.000000	0.0	0.0	40.000000
75%	47.000000	226196.000000	0.0	0.0	41.565533
max	78.000000	415847.000000	0.0	0.0	52.000000

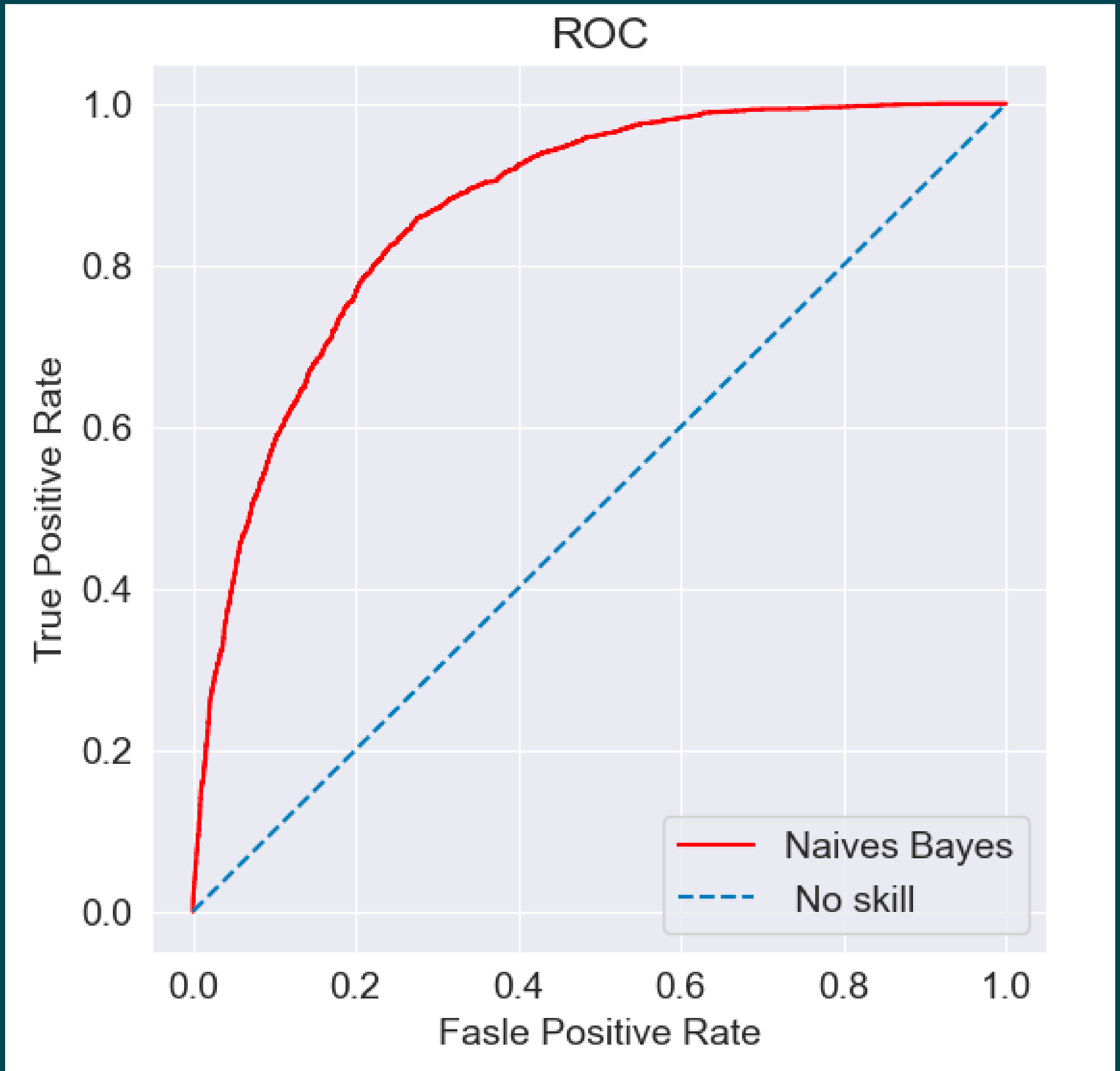
- **Normalization** the numbers (scale the variables to similar sizes) makes the graphing of the values more efficient for the ML methods

Naive Bayes

Accuracy	Misclassification	True Positive	False Positive
0.816	0.171	0.926	0.458
Specificity	**Precision**	**Prevalence**	**ROC**
0.541	0.61	0.83	0.868

Predicted

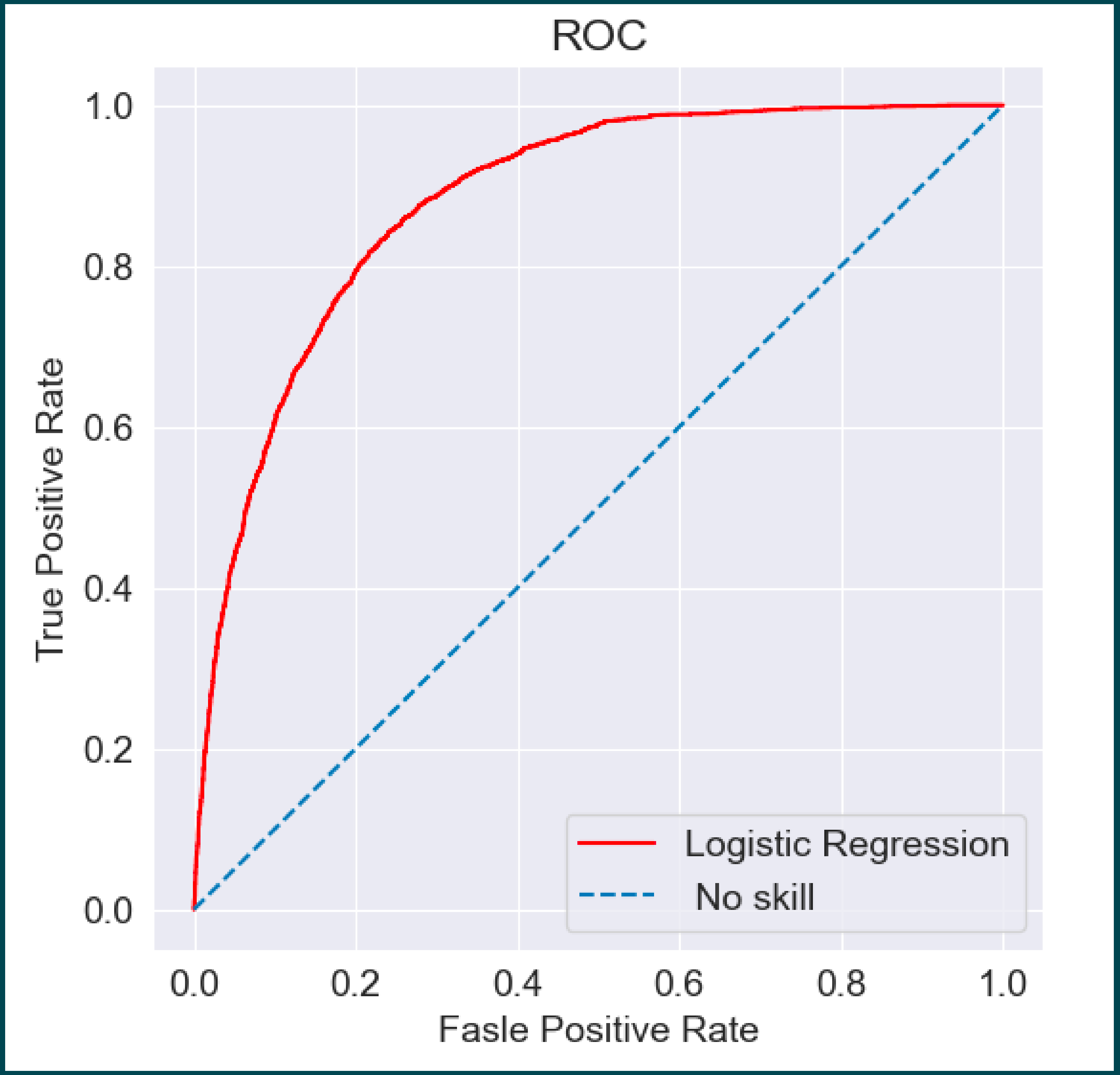
True Class		True	Negative
	True	15018	2279
	Negative	1999	3497



Logistic Regression

Accuracy	Misclassification	True Positive	False Positive
0.829	0.171	0.826	0.459
Specificity	**Precision**	**Prevalence**	**ROC**
0.541	0.69	0.834	0.88

		Predicted	
		True	Negative
True Class	True	16057	1278
	Negative	2504	2953

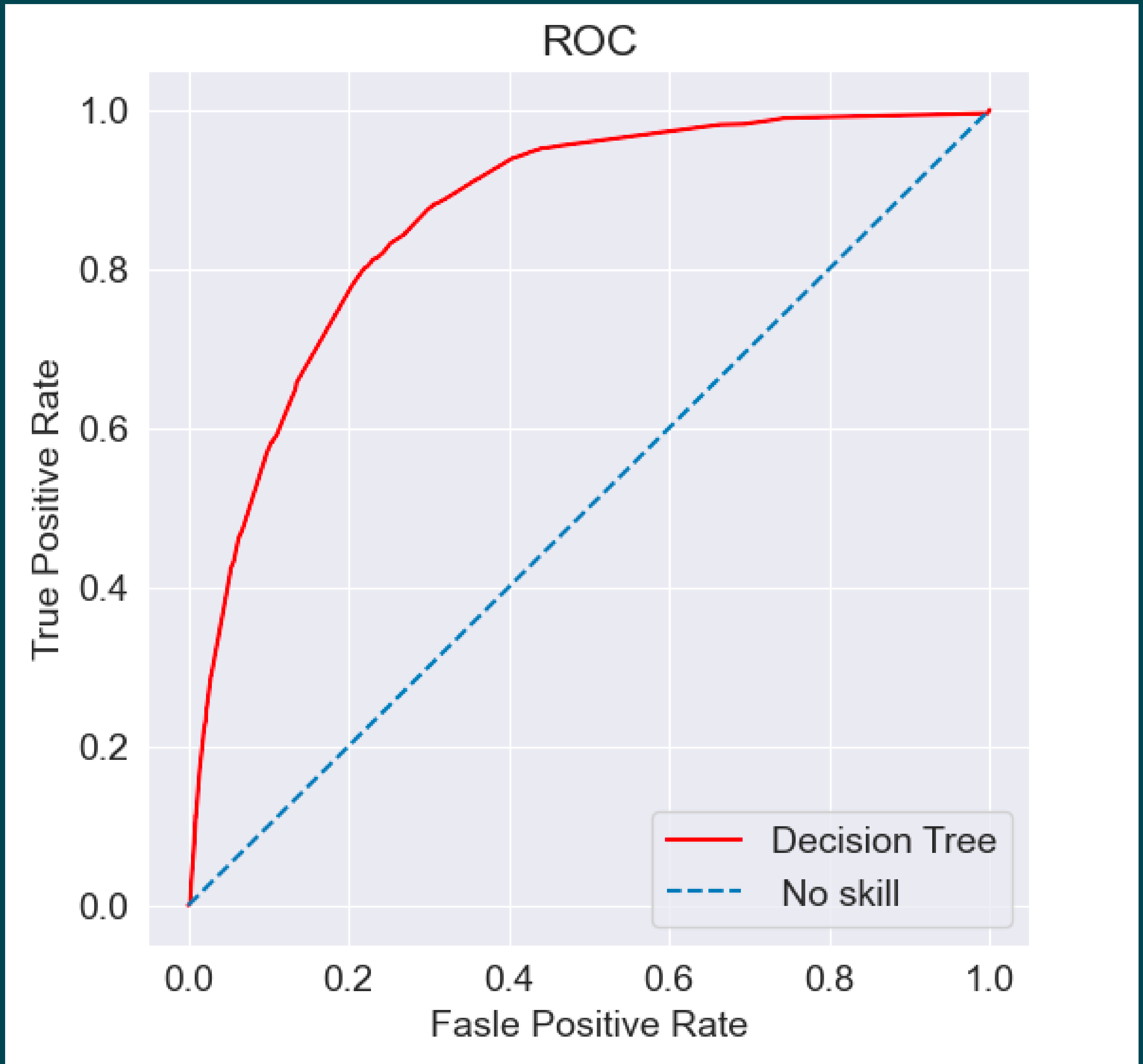


Decision Tree

Accuracy	Misclassification	True Positive	False Positive
0.82	0.171	0.915	0.402
Specificity	**Precision**	**Prevalence**	**ROC**
0.598	0.65	0.839	0.865

Predicted

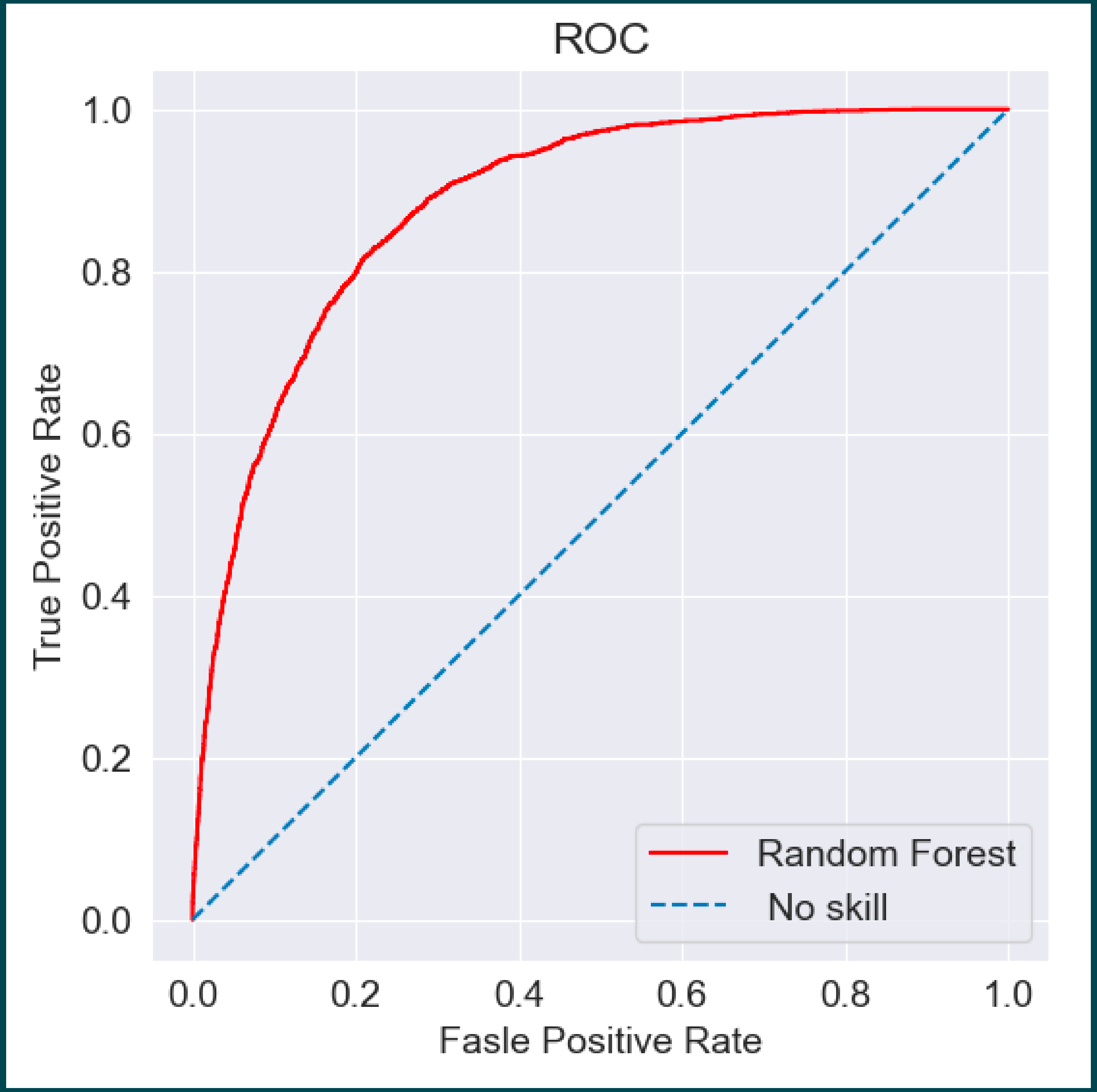
True Class		True	Negative
	True	15853	1482
	Negative	2192	3265



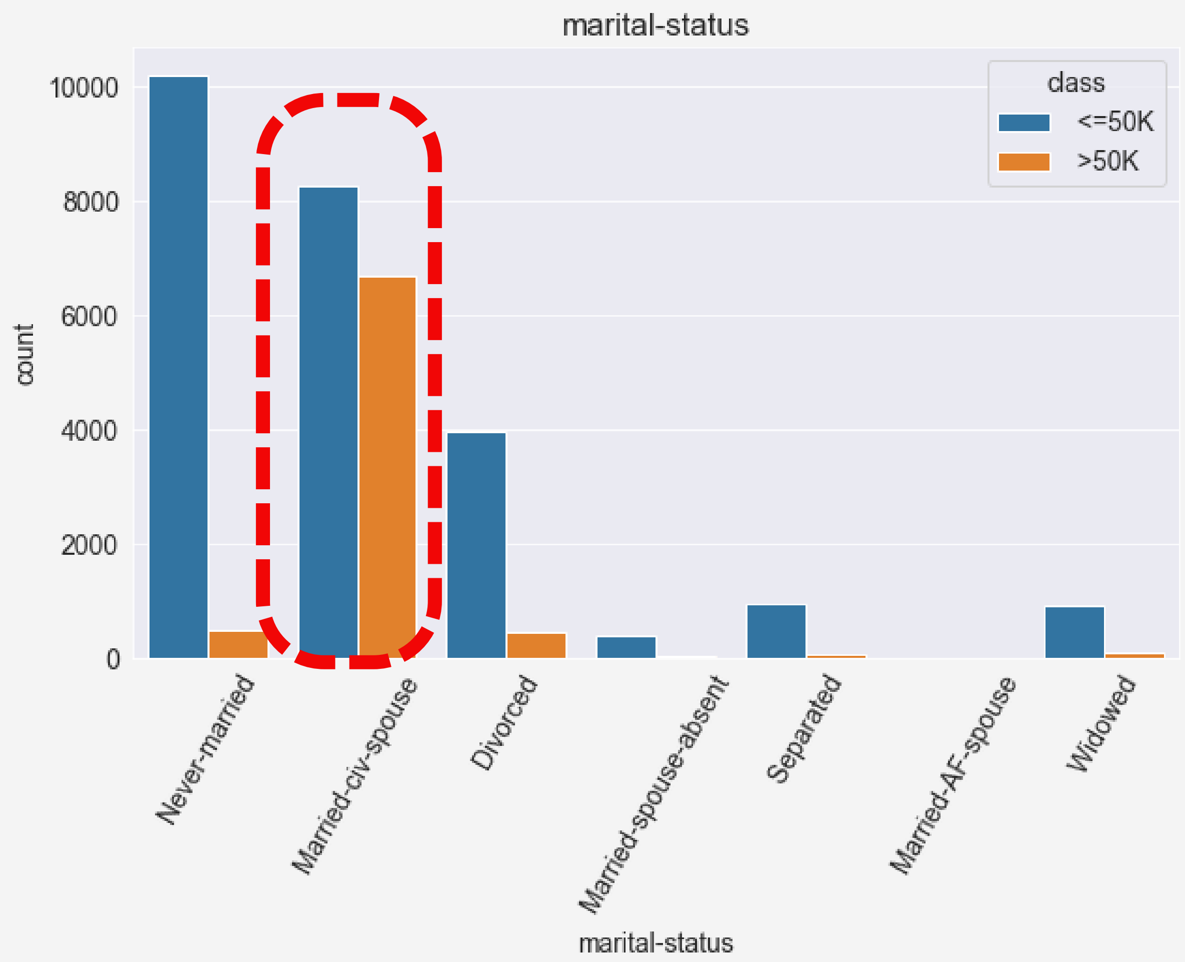
Random Forest: Most Accurate Model

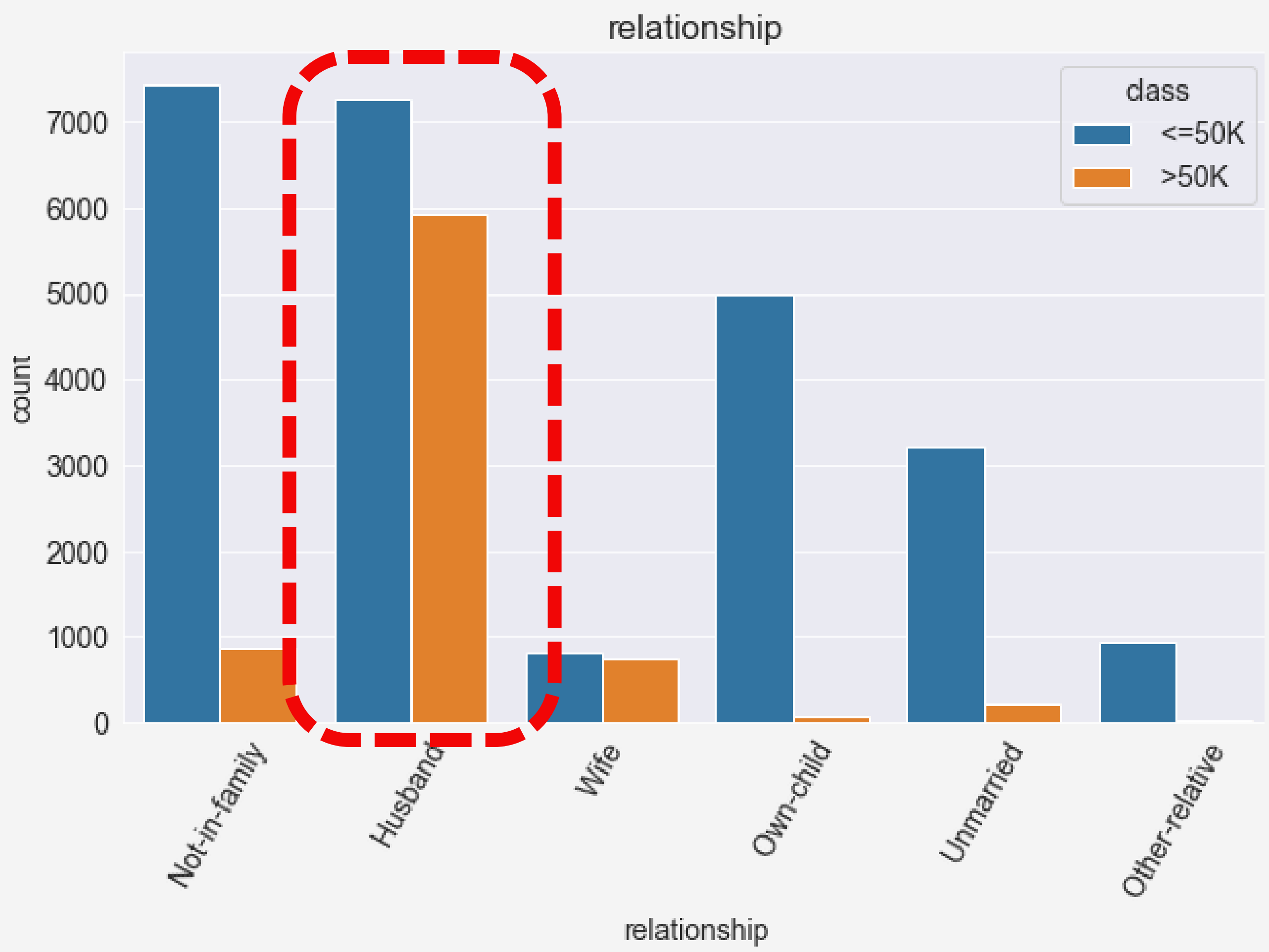
Accuracy	Misclassification	True Positive	False Positive
0.834	0.171	0.967	0.306
Specificity	**Precision**	**Prevalence**	**ROC**
0.694	0.72	0.901	0.883

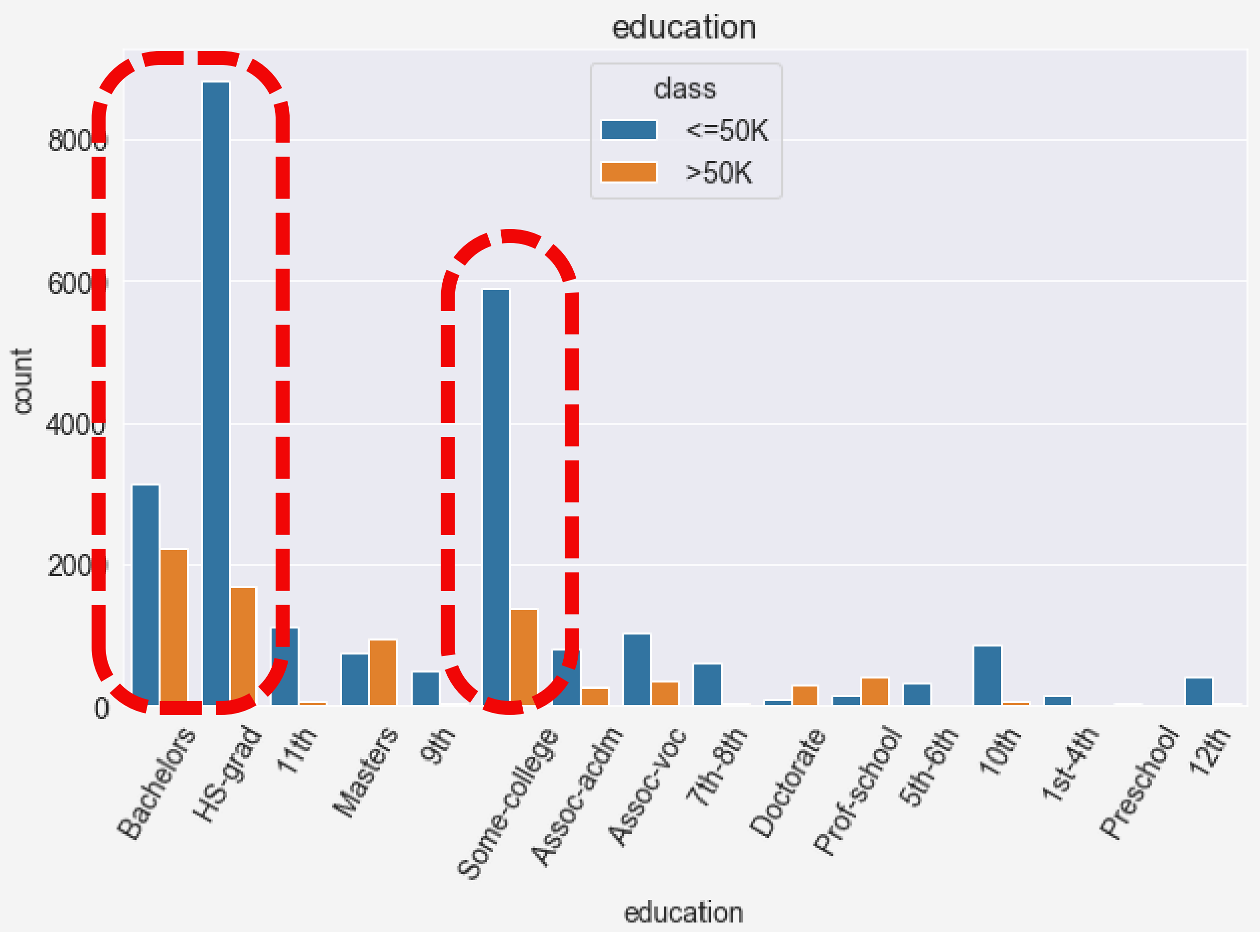
		Predicted: True	Predicted: Negative
True Class	True	16755	580
	Negative	1669	3788



Recommendations







- Most accurate model
  - Random Forest Model 83.4%

- Target
  - Married couples - particularly the husband
  - Higher educated individuals - particularly Bachelors and Master Graduates.

Appendix (1)

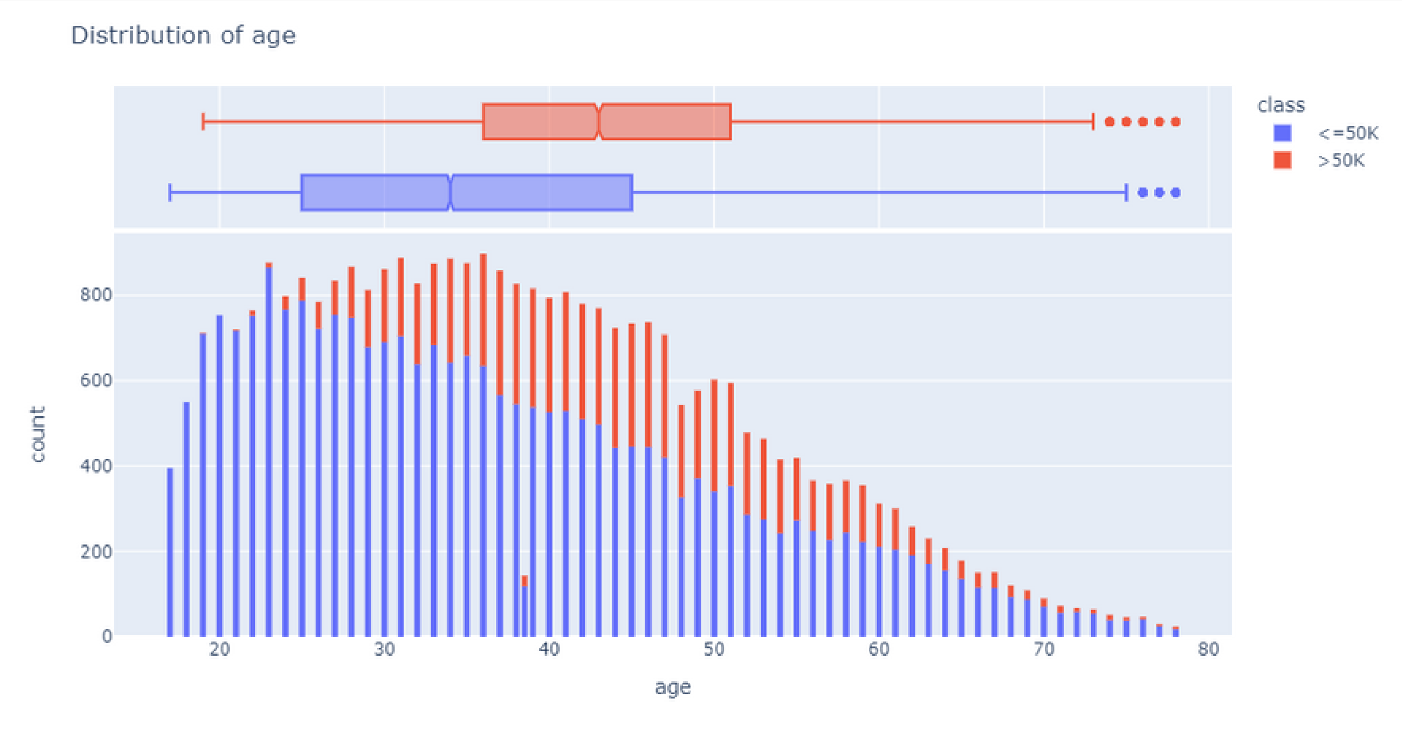
```
age                  int64
workclass           object
education           object
education_num        int64
marital_status      object
occupation          object
relationship        object
race                object
sex                 object
capital_gain         int64
capital_loss         int64
hours_per_week       int64
native_country      object
income              object
dtype: object
```

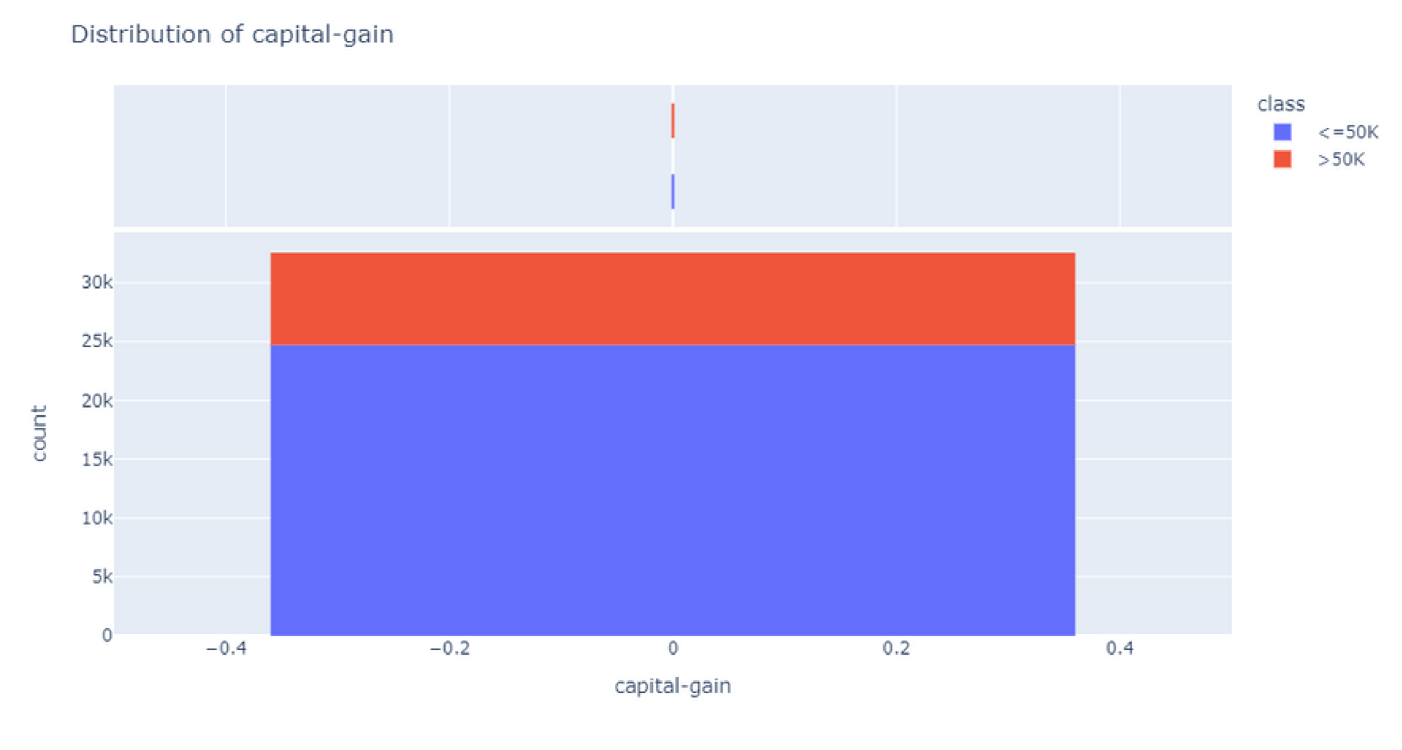
Raw Data Variable Types (Q2)

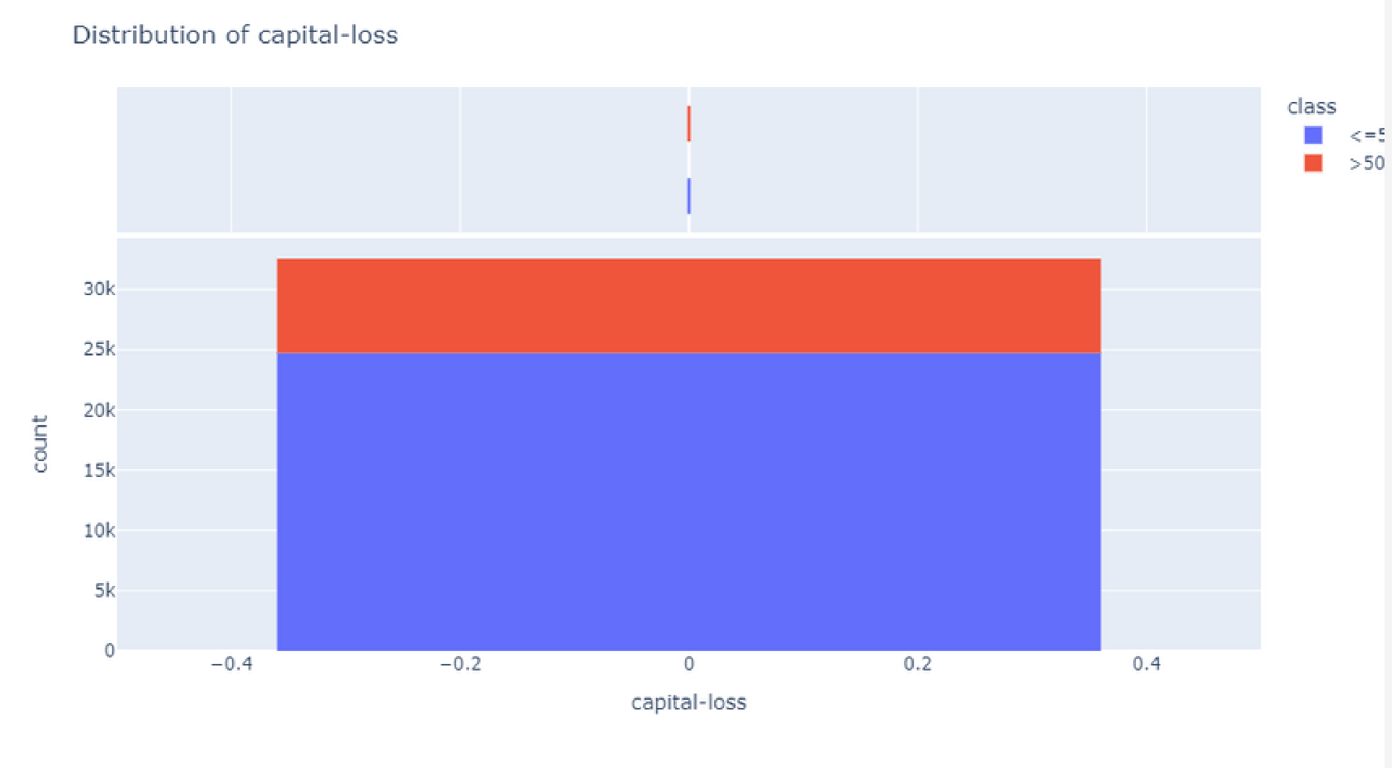
	age	capital_gain	capital_loss	hours_per_week
min	17.000000	0.000000	0.000000	1.000000
max	90.000000	99999.000000	4356.000000	99.000000
median	37.000000	0.000000	0.000000	40.000000
mean	38.581647	1077.648844	87.303830	40.437456
std	13.640433	7385.292085	402.960219	12.347429
skew	0.558743	11.953848	4.594629	0.227643
kurt	-0.166127	154.799438	20.376802	2.916687

Statistics of Numeric Values (Q4)

Appendix (2)

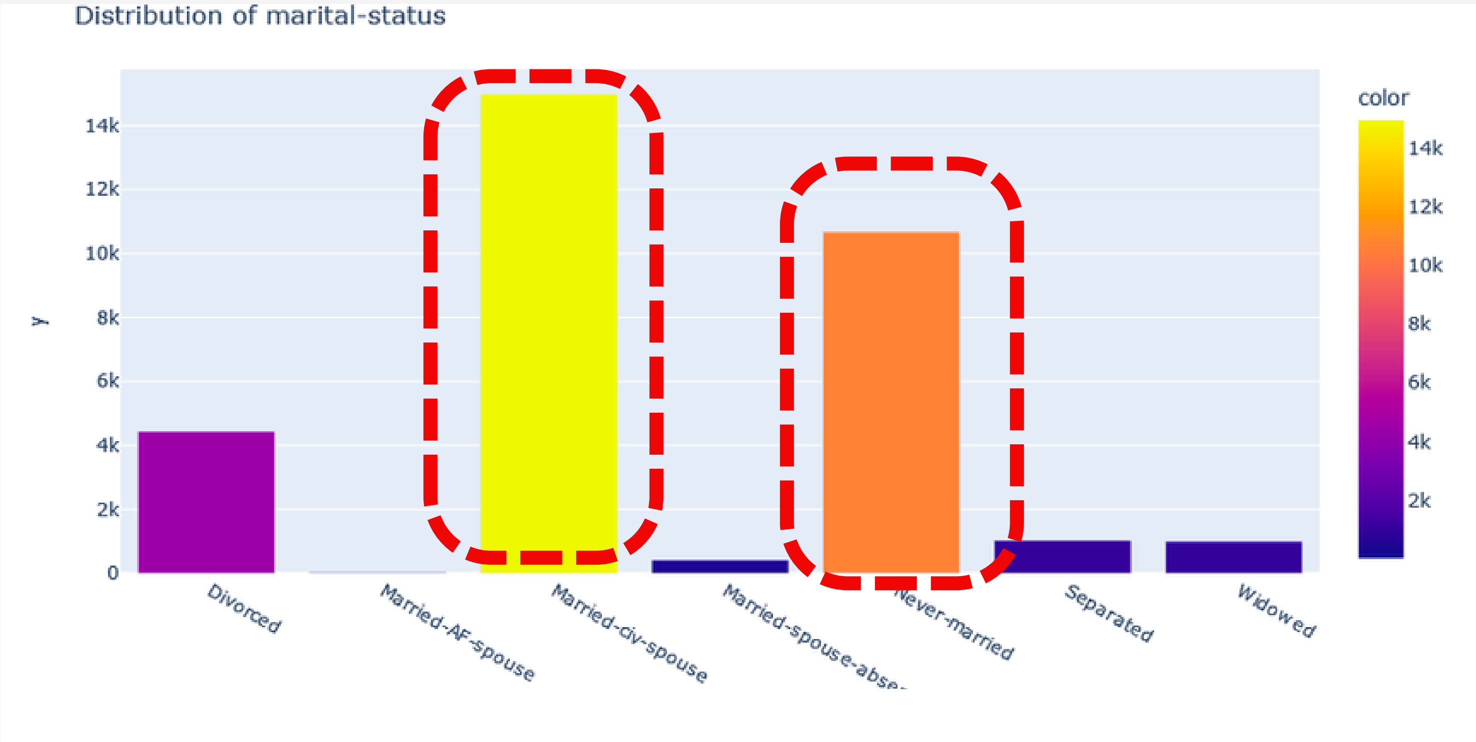


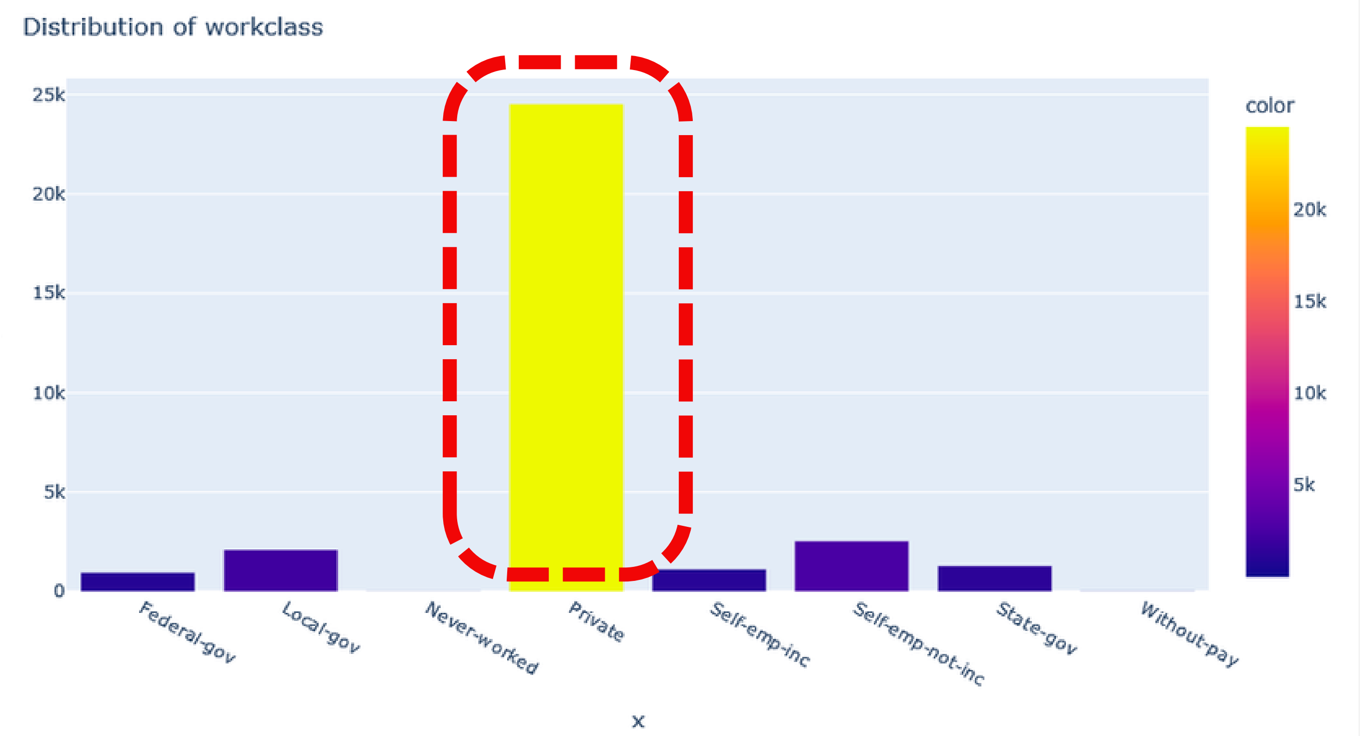


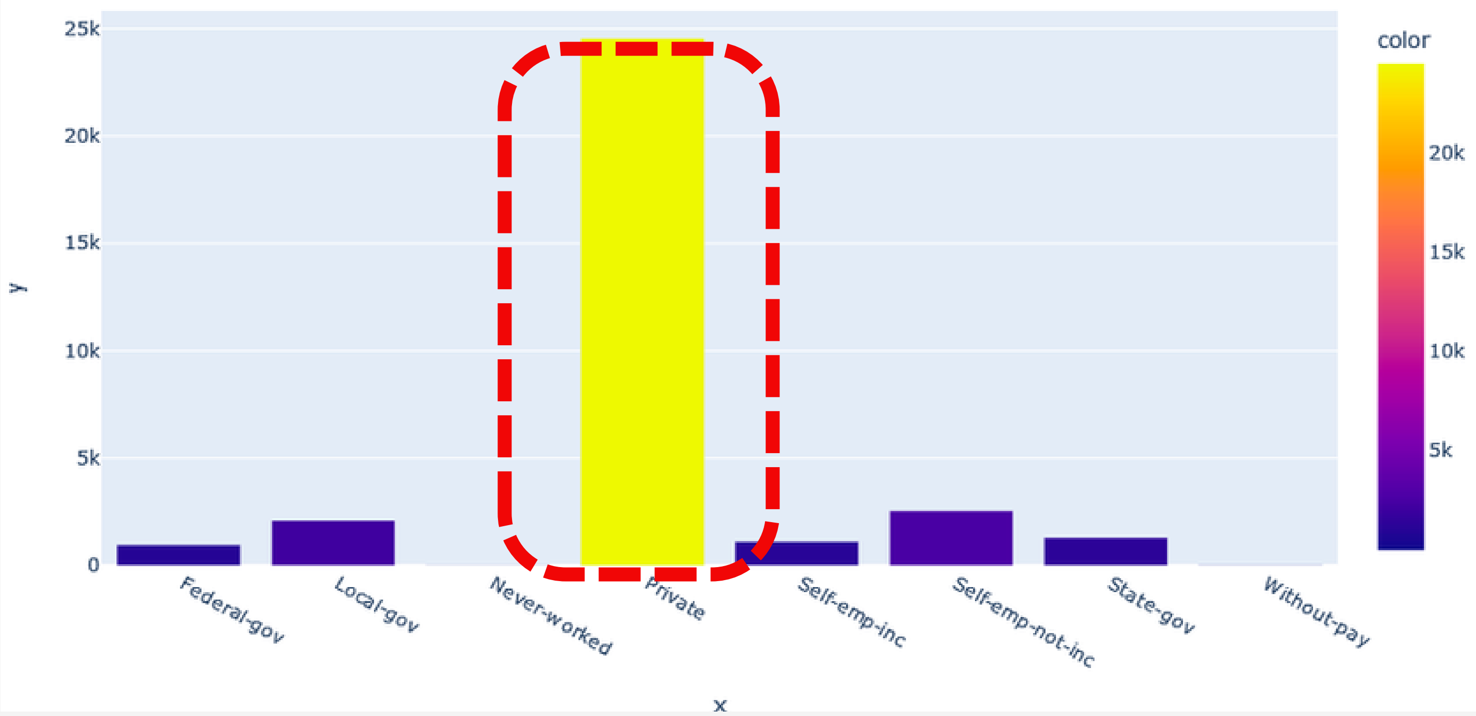


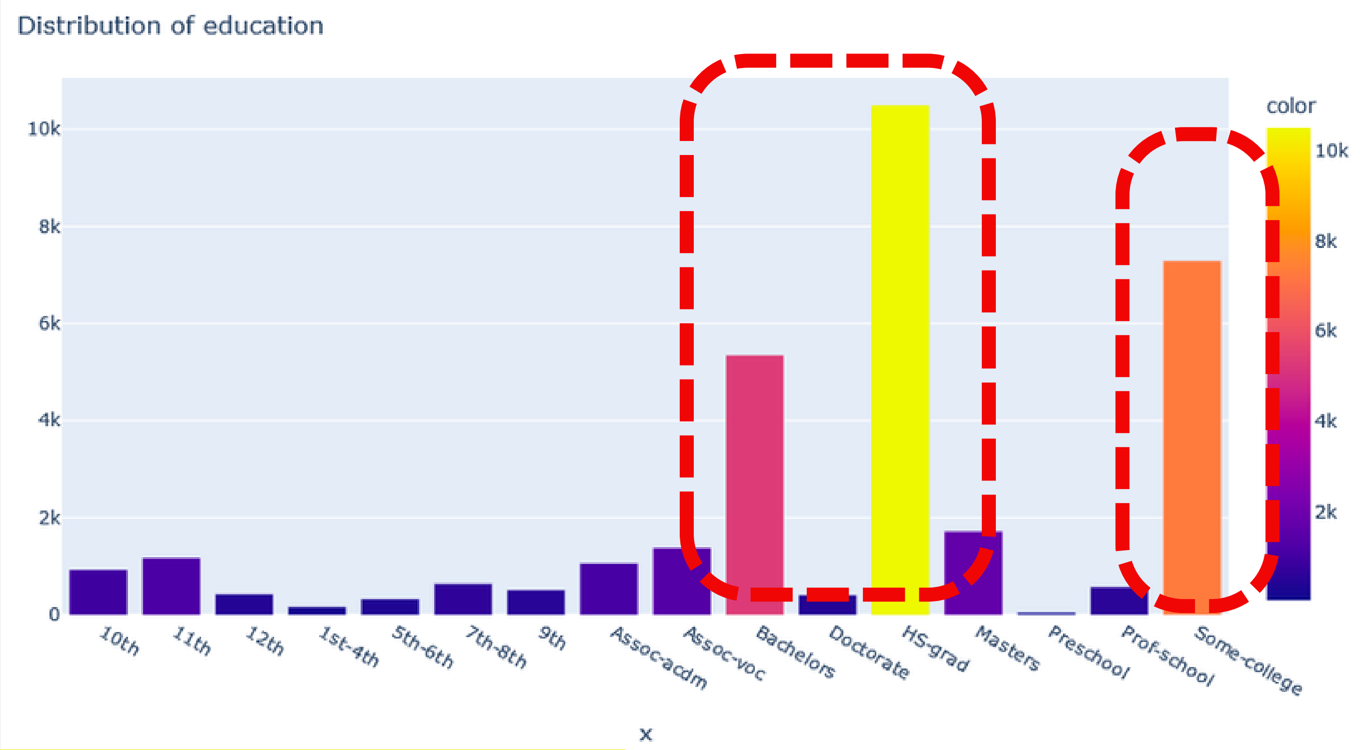
Bar Chart and Histgram of Numeric Values (Q8)

Appendix (3)



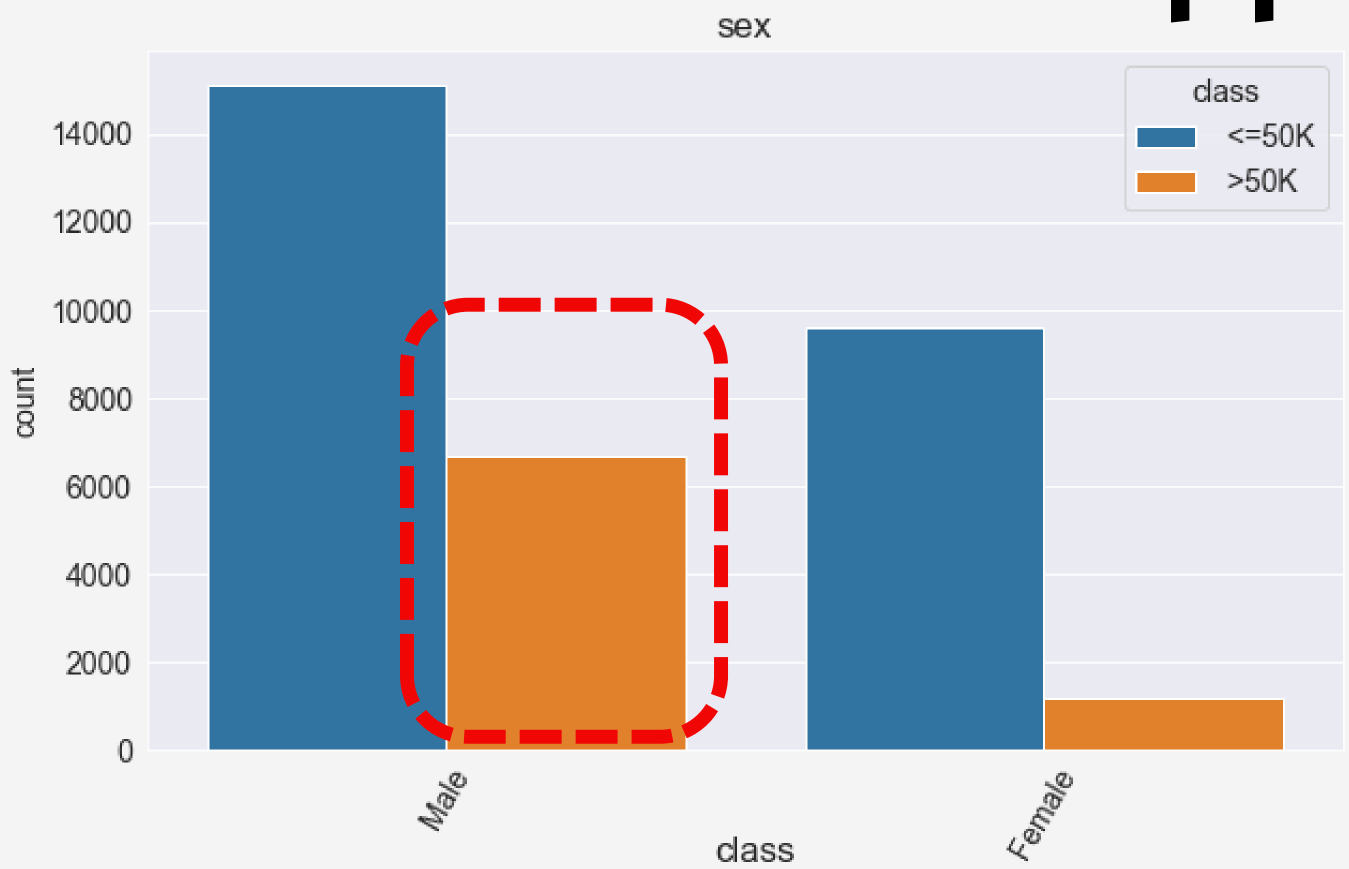


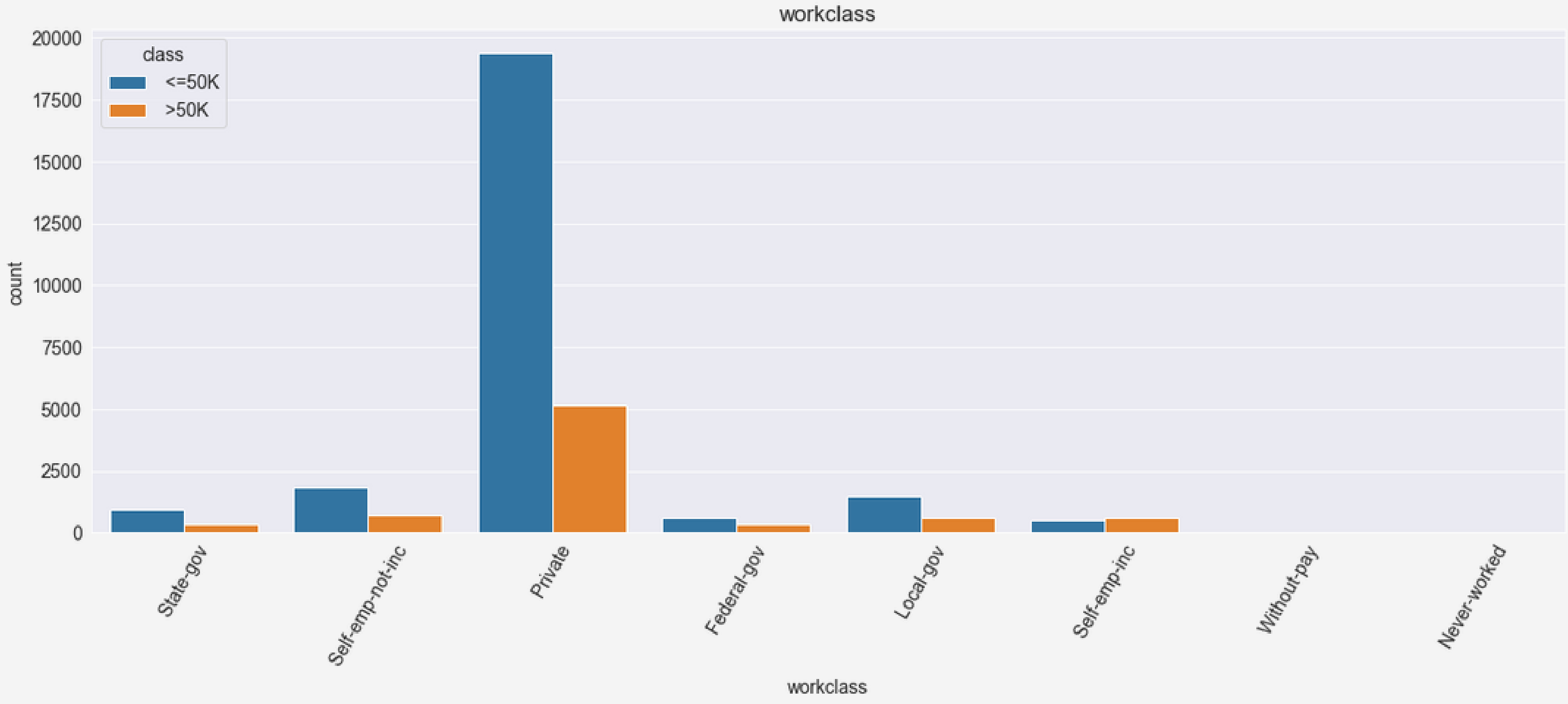


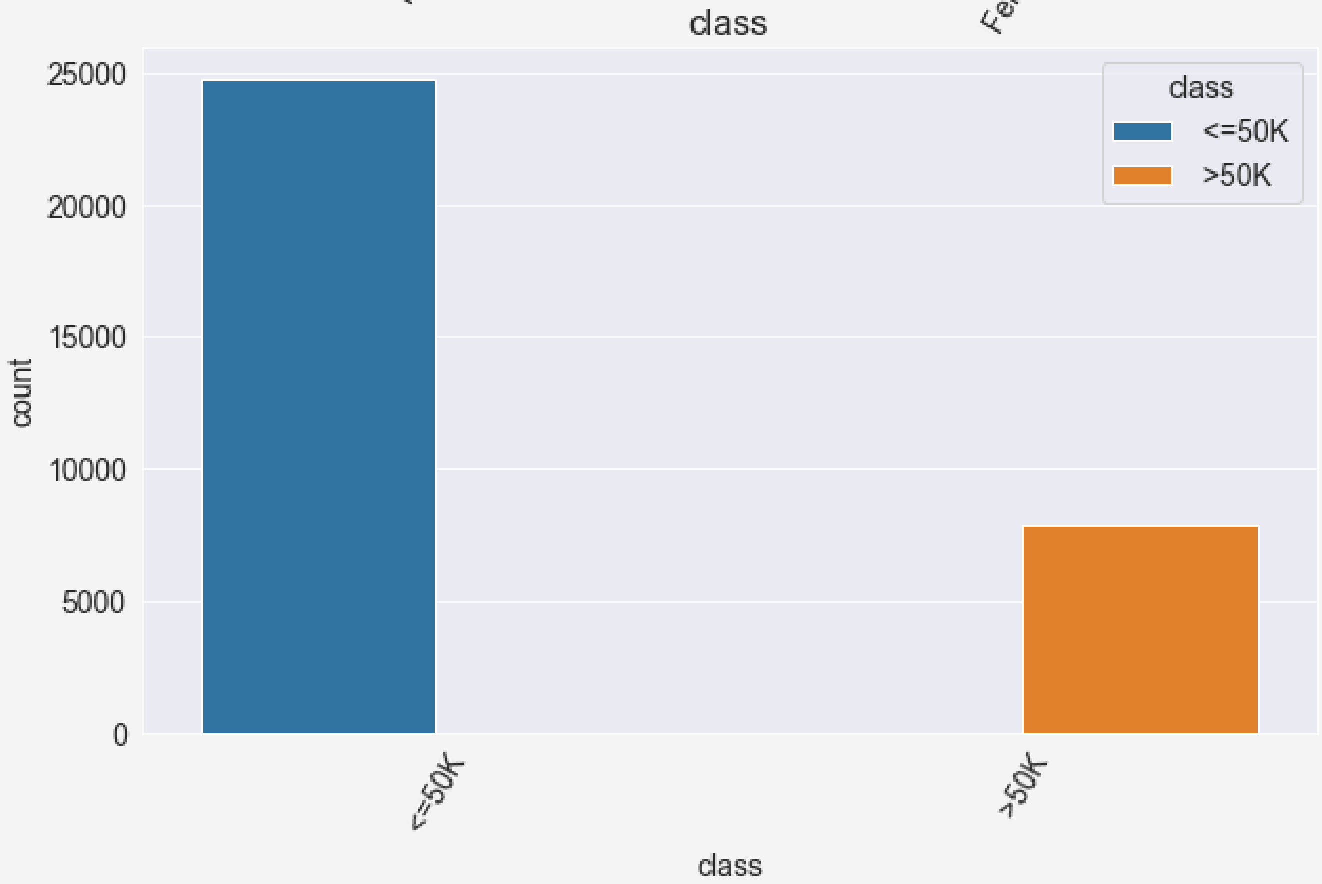


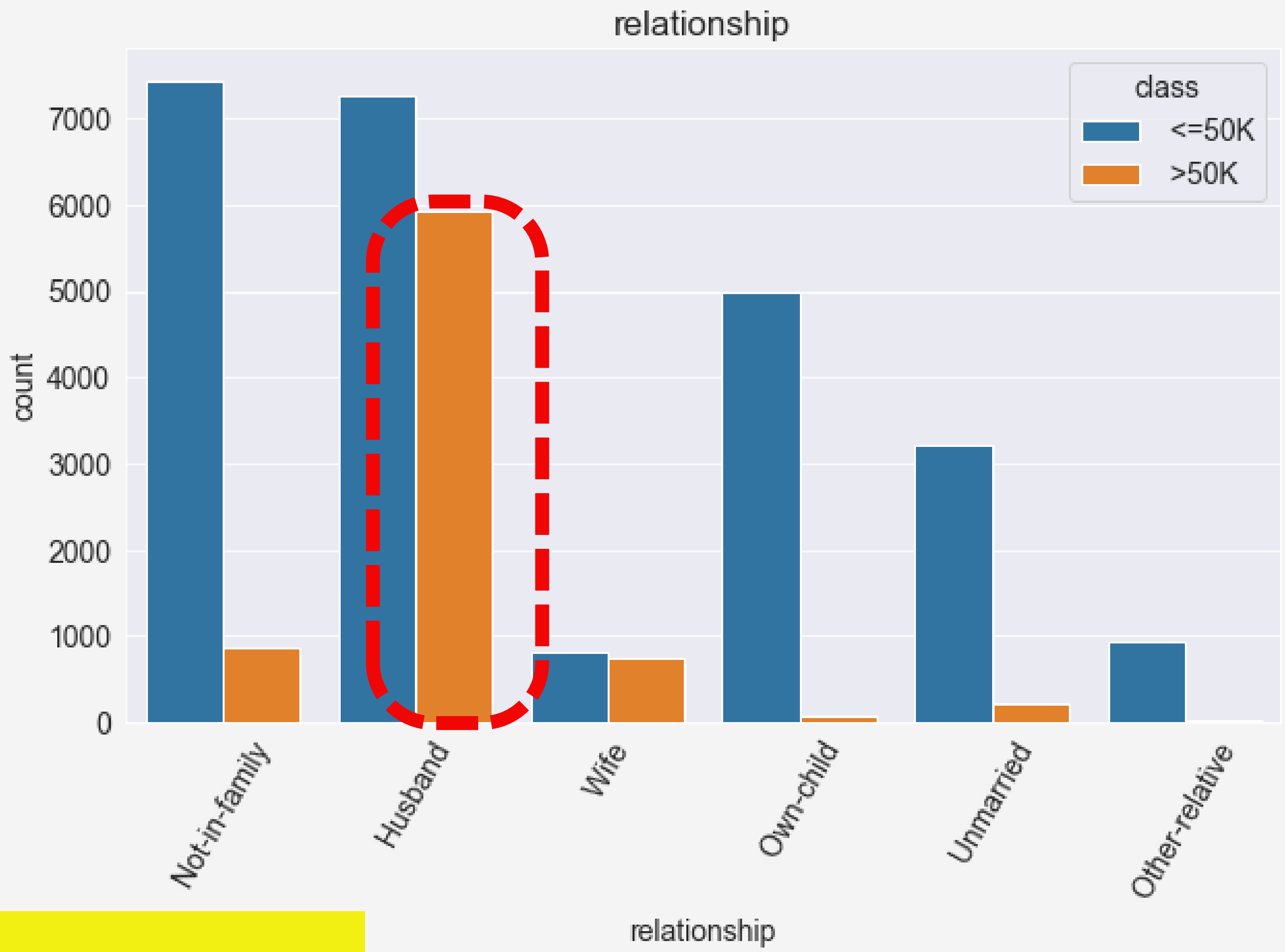
Bar Chart of Categorical Values (Q9)

Appendix (4)



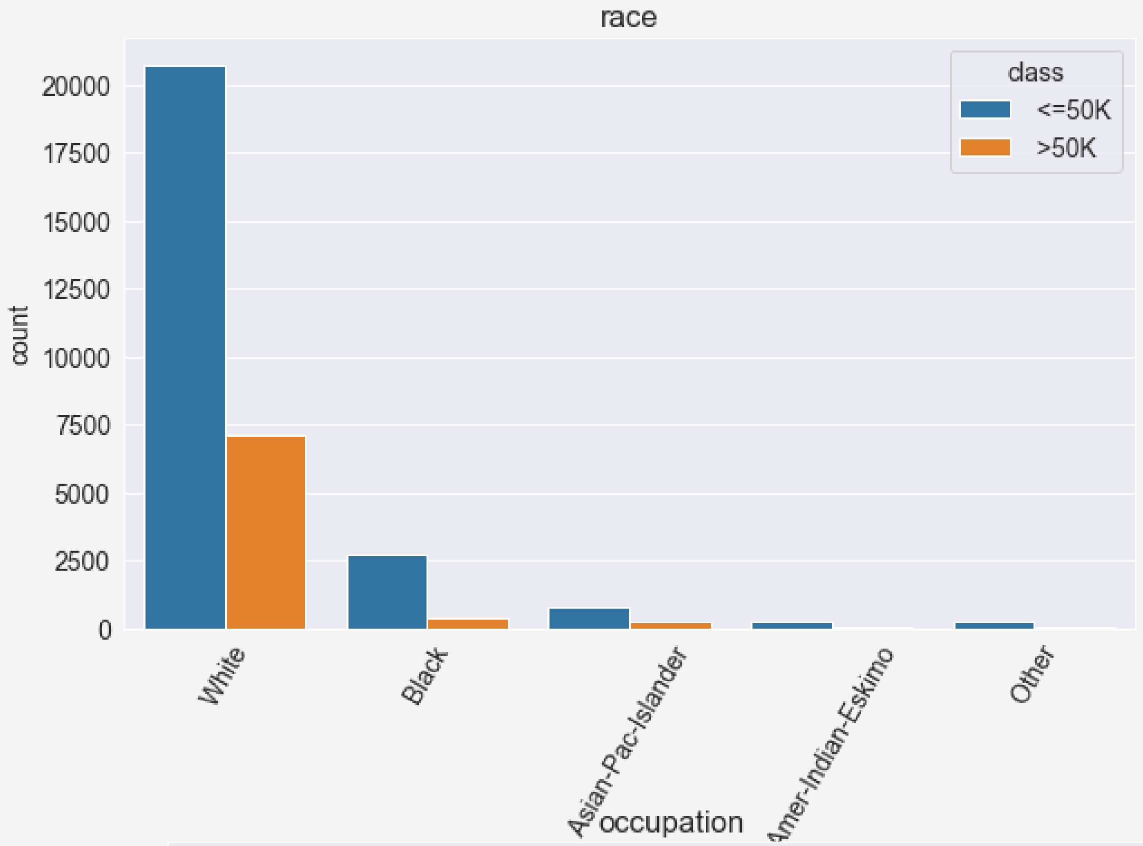


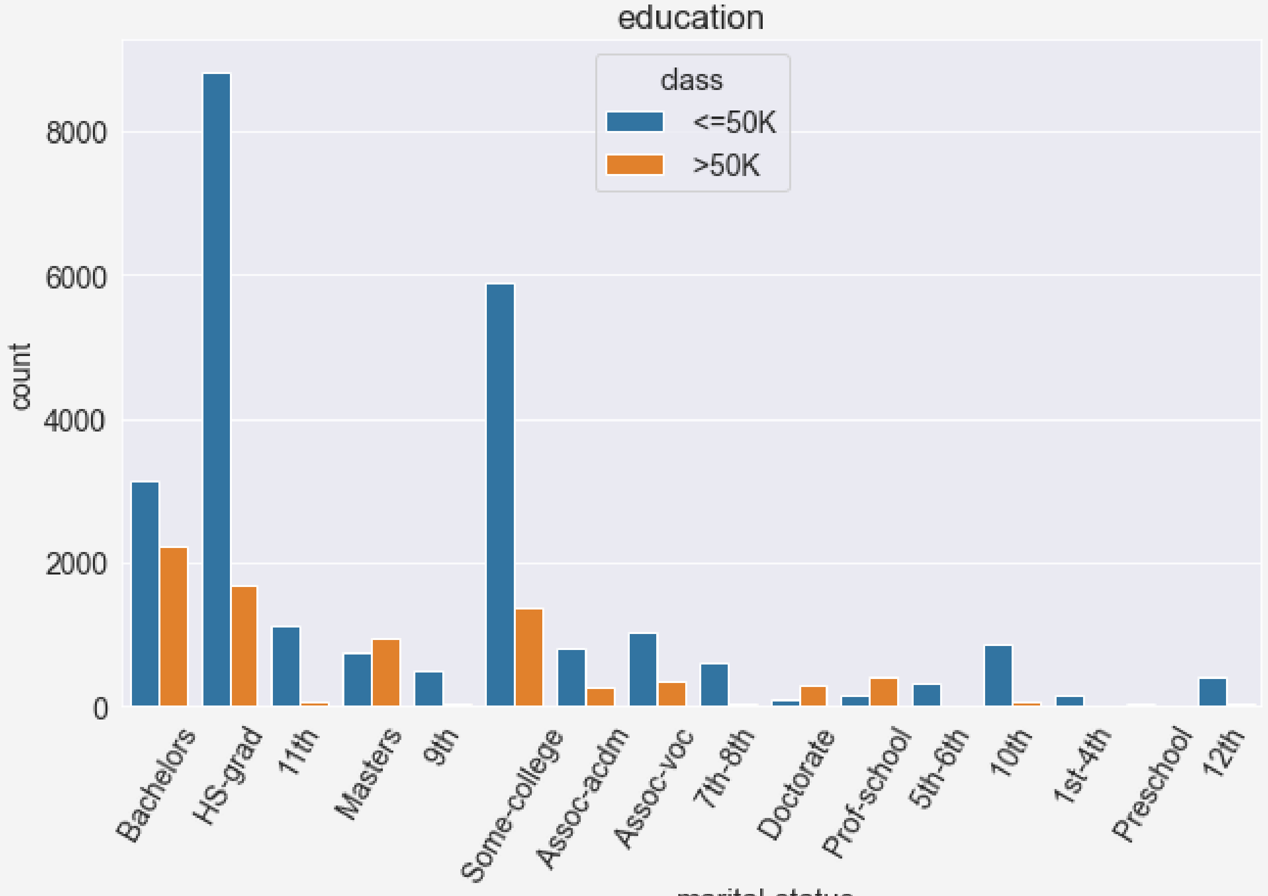


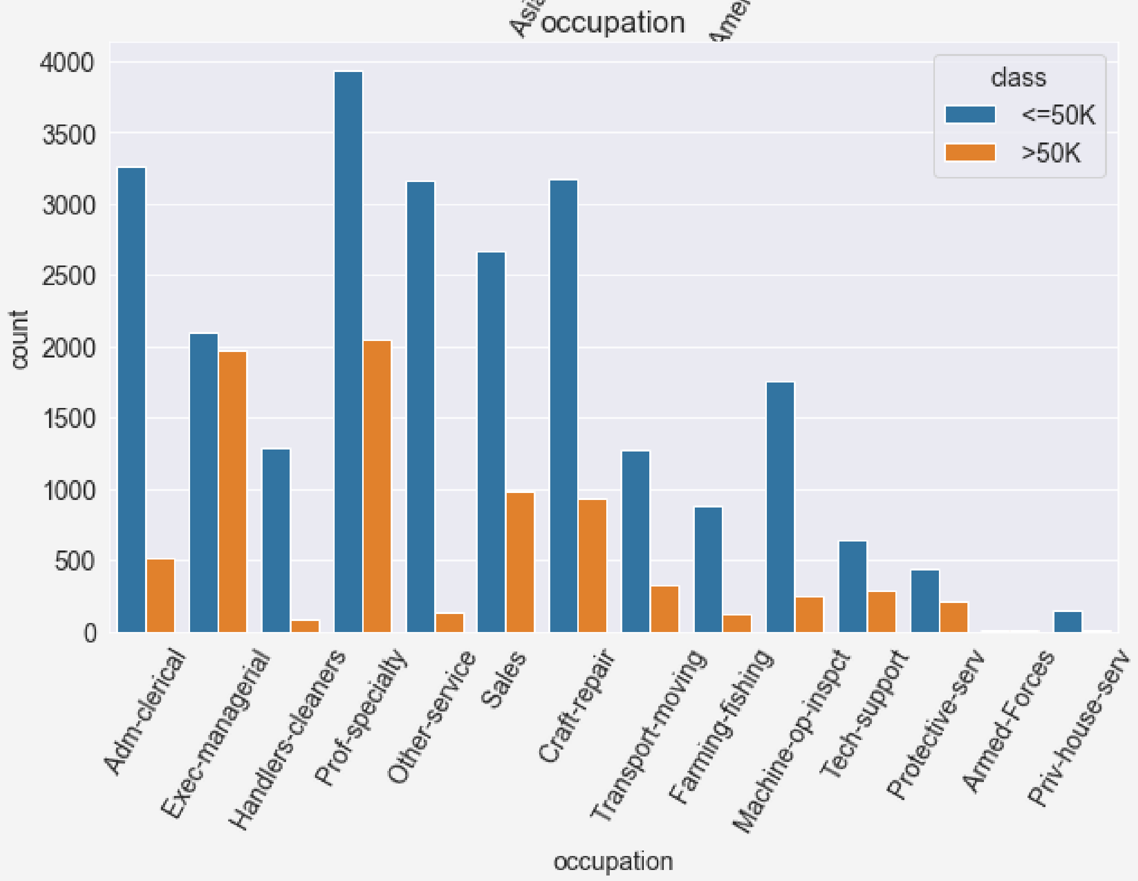


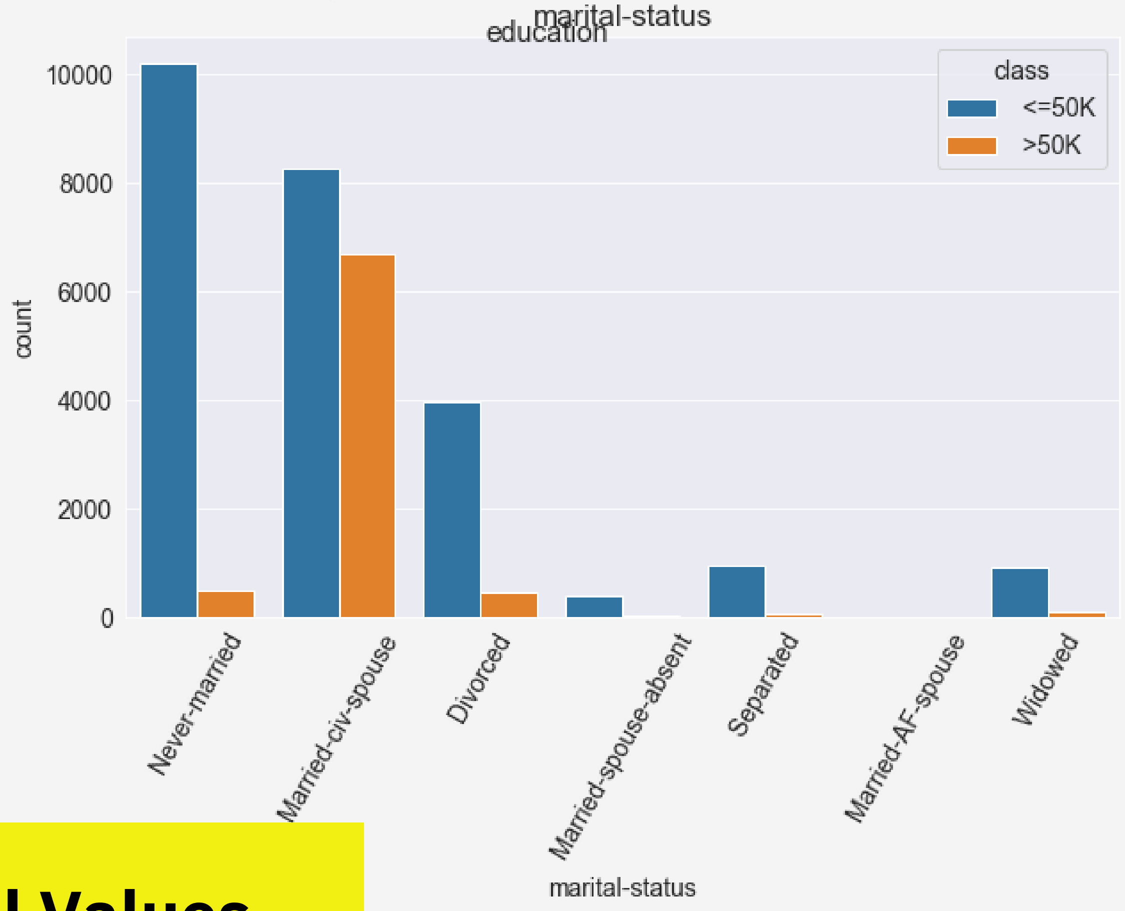
Bar Chart of Categorical Values Based on Income Class (Q9)

Appendix (5)



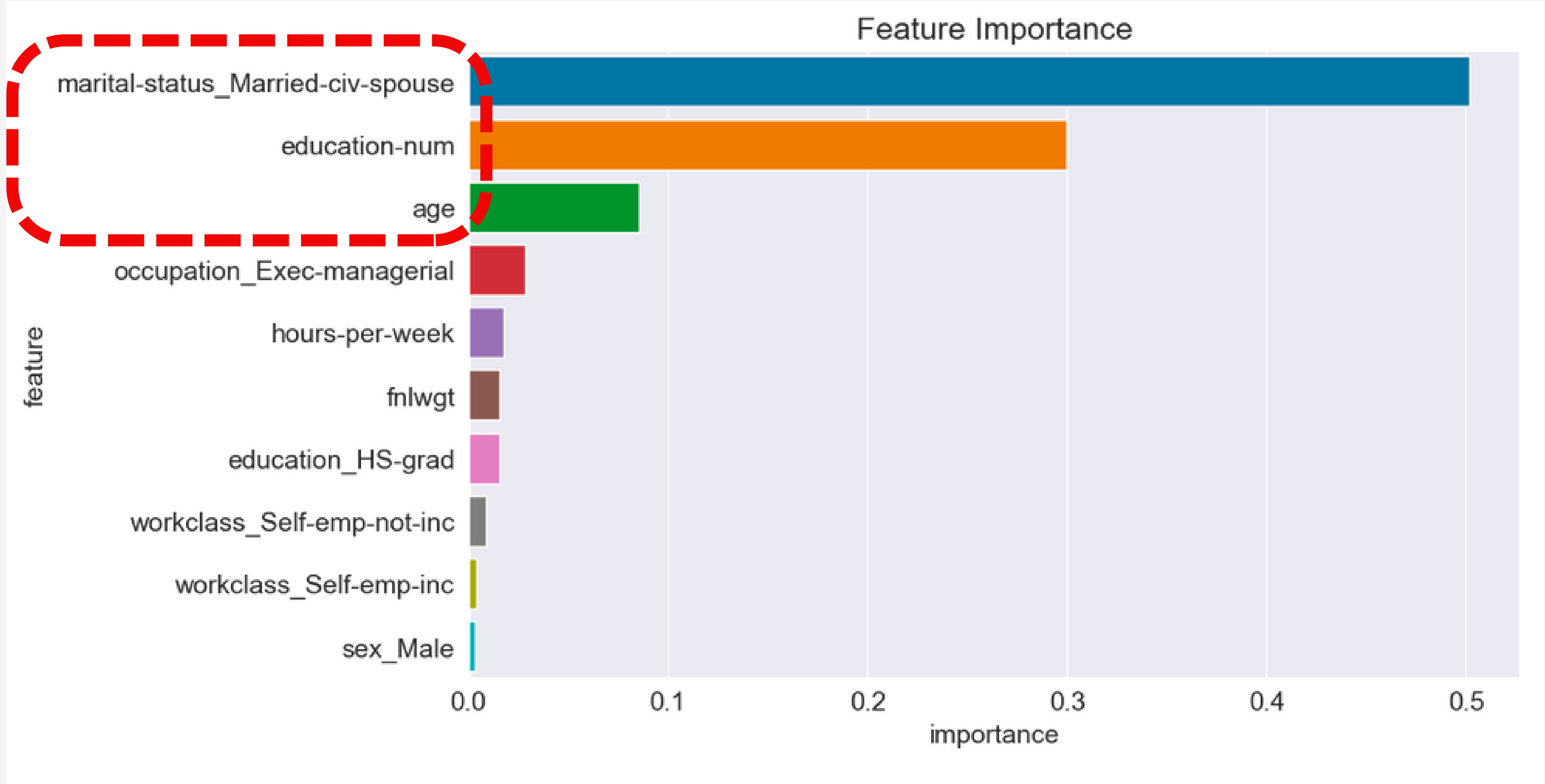


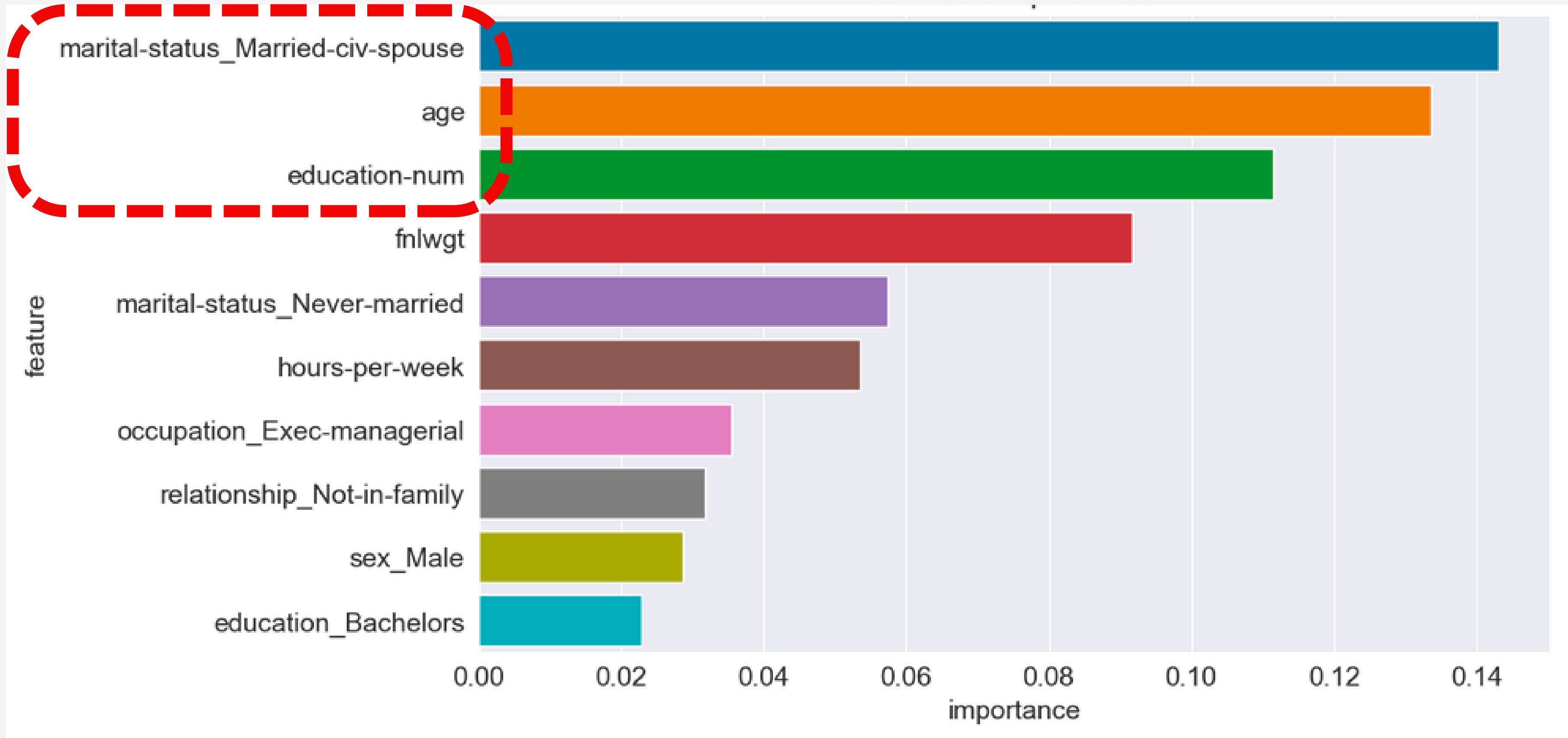




Bar Chart of Categorical Values Based on Income Class (Q9)

Appendix (6)

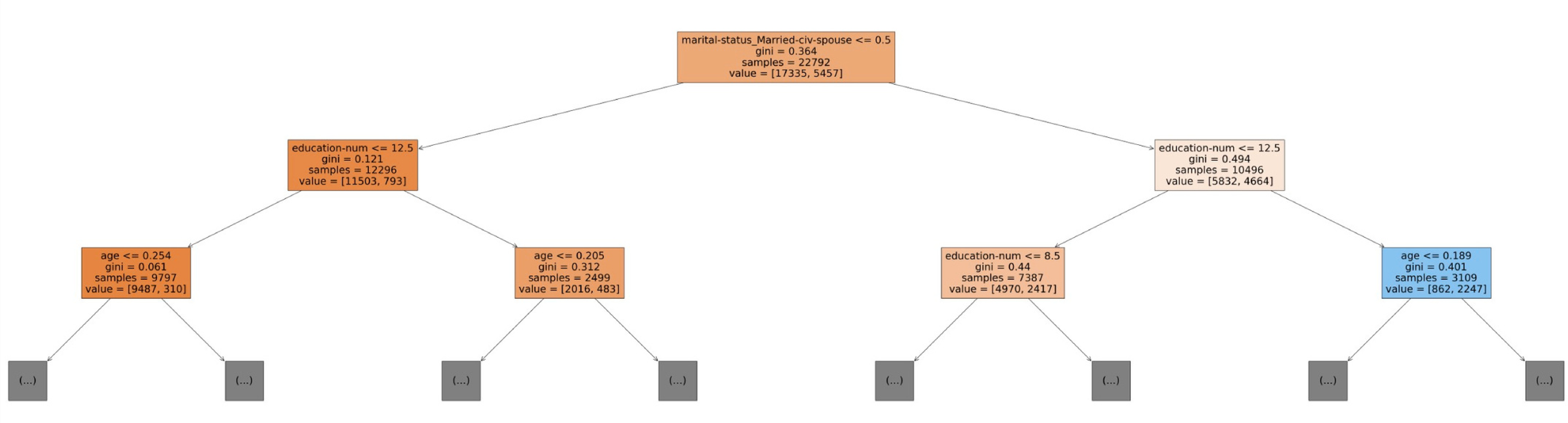




Decison Tree
Most Importand Features (Q12.2)

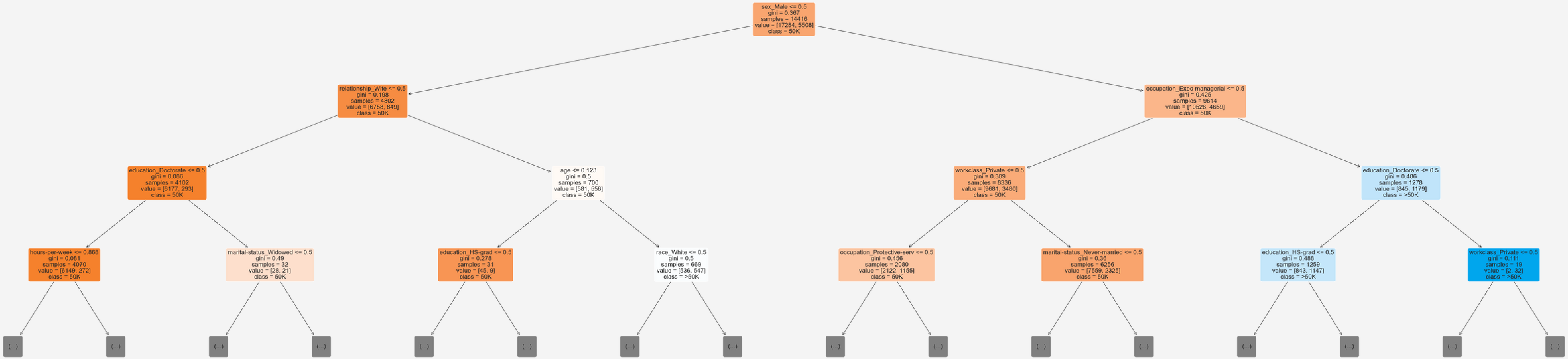
Random Forest
Most Important Features (Q12.2)

Appendix (7)



Decison Tree Structure Plot (Q12.3)

Appendix (8)



Random Forest Structure Plot (Q12.3)

Appendix (9)

	models_name	acc_train	acc_test	misclassification_rate	True Positive rate	False Positive rate	Specificity	Precision	Prevalence	ROC
0	Naive Bayes	81.580000	81.380000	17.100000	92.600000	45.800000	54.100000	61	83.000000	86.000000
1	Logistic Regression	83.400000	82.870000	17.100000	82.600000	45.900000	54.100000	69	83.400000	88.800000
2	Decision Tree	83.880000	82.050000	17.100000	91.500000	40.200000	59.800000	65	83.900000	86.500000
3	Rnadom Forest	90.130000	83.400000	17.100000	96.700000	30.600000	69.400000	72	86.500000	88.300000

Model Metrics Comparisom (Q13)

Appendix (10)

```
                           OLS Regression Results
==============================================================================
=
Dep. Variable:                  class   R-squared:
0.344
Model:                            OLS   Adj. R-squared:
0.341
Method:                 Least Squares   F-statistic:
126.5
Date:                Thu, 10 Nov 2022   Prob (F-statistic):
0.00
Time:                        15:54:38   Log-Likelihood:                  -
8129.7
No. Observations:               22792   AIC:
1.645e+04
Df Residuals:                   22697   BIC:
1.721e+04
Df Model:                          94
Covariance Type:            nonrobust
==============================================================================
================================
                                              coef    std err          t
P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
--------------------------------
const                                      -0.1296      0.101     -1.286
0.198      -0.327       0.068
age                                         0.1655      0.014     11.967
0.000       0.138       0.193
fnlwgt                                      0.0490      0.011      4.460
0.000       0.027       0.070
capital-gain                             5.437e-15   3.99e-15      1.361
0.173   -2.39e-15    1.33e-14
capital-loss                            -7.774e-16   4.15e-16     -1.874
0.061   -1.59e-15    3.59e-17
```

```
education-num                                0.0338      0.002     17.281
0.000       0.030       0.038
workclass_Local-gov                         -0.0963      0.016     -5.880
0.000      -0.128      -0.064
workclass_Never-worked                      -0.0240      0.174     -0.138
0.890      -0.365       0.317
workclass_Private                           -0.0712      0.014     -5.140
0.000      -0.098      -0.044
workclass_Self-emp-inc                       0.0287      0.019      1.543
0.123      -0.008       0.065
workclass_Self-emp-not-inc                  -0.1245      0.016     -7.694
0.000      -0.156      -0.093
workclass_State-gov                         -0.1166      0.018     -6.559
0.000      -0.151      -0.082
workclass_Without-pay                       -0.2704      0.106     -2.561
0.010      -0.477      -0.063
education_11th                              -0.0166      0.018     -0.932
0.351      -0.051       0.018
education_12th                              -0.0360      0.023     -1.546
0.122      -0.082       0.010
education_1st-4th                            0.0992      0.038      2.615
0.009       0.025       0.174
education_5th-6th                            0.0485      0.029      1.654
0.098      -0.009       0.106
education_7th-8th                           -0.0059      0.023     -0.258
0.796      -0.051       0.039
education_9th                               -0.0139      0.024     -0.591
0.555      -0.060       0.032
```

t-test and p-value for logistic regression

Appendix (11)

education_Assoc-acdm	-0.0877	0.017	-5.064	0.000	-0.122	-0.054
education_Assoc-voc	-0.0542	0.016	-3.369	0.001	-0.086	-0.023
education_Bachelors	-0.0123	0.014	-0.853	0.394	-0.040	0.016
education_Doctorate	0.1546	0.023	6.663	0.000	0.109	0.200
education_HS-grad	-0.0642	0.013	-5.134	0.000	-0.089	-0.040
education_Masters	0.0540	0.017	3.202	0.001	0.021	0.087
education_Preschool	0.1649	0.061	2.700	0.007	0.045	0.285
education_Prof-school	0.1727	0.021	8.137	0.000	0.131	0.214
education_Some-college	-0.0542	0.013	-4.236	0.000	-0.079	-0.029
marital-status_Married-AF-spouse	0.2818	0.091	3.113	0.002	0.104	0.459
marital-status_Married-civ-spouse	0.1326	0.029	4.641	0.000	0.077	0.189
marital-status_Married-spouse-absent	0.0285	0.021	1.340	0.180	-0.013	0.070
marital-status_Never-married	-0.0040	0.009	-0.457	0.648	-0.021	0.013
marital-status_Separated	0.0147	0.014	1.020	0.308	-0.014	0.043
marital-status_Widowed	0.0097	0.015	0.638	0.524	-0.020	0.039
occupation_Armed-Forces	-0.1780	0.132	-1.349	0.177	-0.437	0.081
occupation_Craft-repair	-0.0074	0.010	-0.727	0.467	-0.027	0.013
occupation_Exec-managerial	0.1445	0.010	14.478	0.000	0.125	0.164
occupation_Protective-serv	0.0738	0.018	4.050	0.000	0.038	0.109
occupation_Sales	0.0386	0.010	3.862	0.000	0.019	0.058
occupation_Tech-support	0.0684	0.015	4.512	0.000	0.039	0.098
occupation_Transport-moving	-0.0245	0.013	-1.877	0.061	-0.050	0.001
relationship_Not-in-family	-0.1512	0.028	-5.326	0.000	-0.207	-0.096
relationship_Other-relative	-0.1263	0.028	-4.488	0.000	-0.181	-0.071
relationship_Own-child	-0.1439	0.028	-5.080	0.000	-0.199	-0.088
relationship_Unmarried	-0.1364	0.029	-4.633	0.000	-0.194	-0.079
relationship_Wife	0.1166	0.013	9.017	0.000	0.091	0.142
race_Asian-Pac-Islander	0.0219	0.030	0.724	0.469	-0.037	0.081
race_Black	0.0443	0.025	1.772	0.076	-0.005	0.093
race_Other	0.0087	0.035	0.251	0.802	-0.059	0.076
race_White	0.0557	0.024	2.333	0.020	0.009	0.103
sex_Male	0.0613	0.007	8.891	0.000	0.048	0.075
native-country_Canada	-0.1027	0.105	-0.980	0.327	-0.308	0.103
native-country_China	-0.1418	0.108	-1.313	0.189	-0.353	0.070
native-country_Columbia	-0.2565	0.115	-2.231	0.026	-0.482	-0.031
native-country_Cuba	-0.1814	0.107	-1.698	0.090	-0.391	0.028

t-test and p-value for logistic regression

Appendix (12)

sex_Male	0.0613	0.007	8.891	0.000	0.048	0.075
native-country_Canada	-0.1027	0.105	-0.980	0.327	-0.308	0.103
native-country_China	-0.1418	0.108	-1.313	0.189	-0.353	0.070
native-country_Columbia	-0.2565	0.115	-2.231	0.026	-0.482	-0.031
native-country_Cuba	-0.1814	0.107	-1.698	0.090	-0.391	0.028
native-country_Dominican-Republic	-0.1611	0.110	-1.460	0.144	-0.377	0.055
native-country_Ecuador	-0.1088	0.123	-0.885	0.376	-0.350	0.132
native-country_El-Salvador	-0.1188	0.106	-1.116	0.264	-0.327	0.090
native-country_England	-0.0827	0.107	-0.775	0.439	-0.292	0.127
native-country_France	-0.0679	0.123	-0.554	0.580	-0.308	0.172
native-country_Germany	-0.0972	0.103	-0.939	0.348	-0.300	0.106
native-country_Greece	-0.1648	0.122	-1.356	0.175	-0.403	0.073
native-country_Guatemala	-0.0656	0.111	-0.591	0.554	-0.283	0.152
native-country_Haiti	-0.1668	0.116	-1.443	0.149	-0.393	0.060
native-country_Holand-Netherlands	-0.0704	0.360	-0.195	0.845	-0.777	0.636
native-country_Honduras	-0.1529	0.143	-1.067	0.286	-0.434	0.128
native-country_Hong	-0.1906	0.131	-1.449	0.147	-0.448	0.067
native-country_Hungary	-0.0349	0.157	-0.223	0.824	-0.342	0.272
native-country_India	-0.1851	0.105	-1.768	0.077	-0.390	0.020
native-country_Iran	-0.0489	0.115	-0.425	0.671	-0.274	0.177
native-country_Ireland	-0.0149	0.127	-0.117	0.907	-0.264	0.235
native-country_Italy	-0.0450	0.108	-0.415	0.678	-0.258	0.168
native-country_Jamaica	-0.1514	0.109	-1.391	0.164	-0.365	0.062
native-country_Japan	-0.0193	0.109	-0.177	0.860	-0.234	0.195
native-country_Laos	-0.1963	0.130	-1.515	0.130	-0.450	0.058
native-country_Mexico	-0.1620	0.099	-1.630	0.103	-0.357	0.033
native-country_Nicaragua	-0.1929	0.120	-1.609	0.108	-0.428	0.042
native-country_Outlying-US(Guam-USVI-etc)	-0.2829	0.151	-1.869	0.062	-0.580	0.014
native-country_Peru	-0.1756	0.126	-1.393	0.164	-0.423	0.071
native-country_Philippines	-0.0691	0.101	-0.687	0.492	-0.266	0.128

t-test and p-value for logistic regression

Appendix (13)

```
native-country_Peru                                     -0.1756      0.126      -1.393
0.164      -0.423       0.071
native-country_Philippines                              -0.0691      0.101      -0.687
0.492      -0.266       0.128
native-country_Poland                                   -0.1724      0.111      -1.552
0.121      -0.390       0.045
native-country_Portugal                                 -0.1442      0.124      -1.167
0.243      -0.387       0.098
native-country_Puerto-Rico                              -0.1472      0.105      -1.404
0.160      -0.353       0.058
native-country_Scotland                                 -0.1217      0.157      -0.776
0.438      -0.429       0.186
native-country_South                                    -0.1094      0.107      -1.023
0.306      -0.319       0.100
native-country_Taiwan                                   -0.1542      0.113      -1.367
0.172      -0.375       0.067
native-country_Thailand                                 -0.1692      0.142      -1.191
0.234      -0.448       0.109
native-country_Trinadad&Tobago                          -0.1172      0.133      -0.883
0.377      -0.377       0.143
native-country_United-States                            -0.1107      0.098      -1.132
0.258      -0.302       0.081
native-country_Vietnam                                  -0.1276      0.108      -1.183
0.237      -0.339       0.084
native-country_Yugoslavia                               -0.0940      0.147      -0.640
0.522      -0.382       0.194
==============================================================================
=
Omnibus:                        991.186   Durbin-Watson:
2.005
```

```
Prob(Omnibus):                    0.000   Jarque-Bera (JB):
1124.379
Skew:                             0.543   Prob(JB):                    6.98e-
245
Kurtosis:                         2.922   Cond. No.
1.03e+16
==============================================================================
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Notes:
[1] Standard Errors assume that the covariance matrix of the errors is
correctly specified.
[2] The smallest eigenvalue is 2.4e-26. This might indicate that there are
strong multicollinearity problems or that the design matrix is singular.
```

t-test and p-value for logistic regression