```
import pandas as pd
import pylab
import numpy as np
import sklearn
from sklearn import linear_model
import sklearn.preprocessing as preprocessing
import sklearn.metrics as metrics
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from statsmodels.stats import proportion
```

## Load the Dataset

Data set can be found from this link: https://archive.ics.uci.edu/ml/datasets/student+performance.

```
!wget https://archive.ics.uci.edu/ml/machine-learning-databases/00320/student.zip
```

```
!rm ./*.csv
!rm ./*.R
!rm student.txt
!unzip student.zip
```

```
features = ["school", "sex", "age", "address", "famsize", "Pstatus",
        "Medu", "Fedu", "Mjob", "Fjob", "reason", "guardian",
        "traveltime", "studytime", "failures", "schoolsup", "famsup", "paid",
        "activities", "nursery", "higher", "internet", "romantic", "famrel",
        "freetime", "goout", "Dalc", "Walc", "health", "absences", "G1", "G2", "G3"]
```

```
df = pd.read_csv('student-por.csv', sep=';', skiprows=1, engine='python',names=features, na_v
```

```
df
```

| | school | sex | age | address | famsize | Pstatus | Medu | Fedu | Mjob | Fjob | re |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | GP | F | 18 | U | GT3 | A | 4 | 4 | at_home | teacher | co |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | GP | F | 17 | U | GT3 | T | 1 | 1 | at_home | other | co |
| **2** | GP | F | 15 | U | LE3 | T | 1 | 1 | at_home | other | c |
| **3** | GP | F | 15 | U | GT3 | T | 4 | 2 | health | services | h |
| **4** | GP | F | 16 | U | GT3 | T | 3 | 3 | other | other | h |
| **...** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| **644** | MS | F | 19 | R | GT3 | T | 2 | 3 | services | other | co |
| **645** | MS | F | 18 | U | LE3 | T | 3 | 1 | teacher | services | co |

```
print('Total number of participants')
print(len(df))
print( )

female = df[df['sex'] == "F"]
print('Number of female participants:')
print(len(female))
print( )

male = df[df['sex'] == "M"]
print('Number of male participants:')
print(len(male))
print( )

print('Percentage of female participants:')
print(len(female)/len(df))
print( )

print('Percentage of female participants:')
print(len(male)/len(df))
print( )
```

```
Total number of participants
649

Number of female participants:
383

Number of male participants:
266

Percentage of female participants:
0.5901386748844376

Percentage of female participants:


0.4098613251155624
```

```
print('Total number of participants')
print(len(df))
print( )

urban = df[df['address'] == "U"]
print('Number of urban participants:')
print(len(urban))
print( )

rural = df[df['address'] == "R"]
print('Number of rural participants:')
print(len(rural))
print( )

print('Percentage of urban participants:')
print(len(urban)/len(df))
print( )

print('Percentage of rural participants:')
print(len(rural)/len(df))
print( )

urban_succeed = urban[urban['G3'] > 9]
urban_succeed

urban = df[df['address'] == "U"]
print('Number of urban students succeeding:')
print(len(urban_succeed))
print( )

print('Number of urban students failed:')
print(len(urban) - len(urban_succeed))
print( )

print('Percent of urban students succeeding:')
print(len(urban_succeed)/len(urban))
print( )

rural_succeed = rural[rural['G3'] > 9]
rural_succeed

rural = df[df['address'] == "R"]
print('Number of rural students succeeding:')
print(len(rural_succeed))
print( )

print('Number of rural students failed:')
print(len(rural) - len(rural_succeed))
print( )

print('Percent of rural students succeeding:')
print(len(rural_succeed)/len(rural))
print( )
print( )
```

```
Total number of participants
649

Number of urban participants:
452

Number of rural participants:
197

Percentage of urban participants:
0.6964560862865947

Percentage of rural participants:
0.3035439137134052

Number of urban students succeeding:
396

Number of urban students failed:
56

Percent of urban students succeeding:
0.8761061946902655

Number of rural students succeeding:
153

Number of rural students failed:
44

Percent of rural students succeeding:
0.7766497461928934
```

```
female_succeed = female[female['G3'] > 9]
female_succeed

female = df[df['sex'] == "F"]
print('Number of female students succeeding:')
print(len(female_succeed))
print( )

print('Number of female students failed:')
print(len(female) - len(female_succeed))
print( )

print('Percent of female students succeeding:')


print(len(female_succeed)/len(female))
print( )
```

```
Number of female students succeeding:
Number of female students succeeding:
333

Number of female students failed:
50

Percent of female students succeeding:
0.8694516971279374
```

```
male_succeed = male[male['G3'] > 9]
male_succeed

male = df[df['sex'] == "M"]
print('Number of male students succeeding:')
print(len(male_succeed))
print( )

print('Number of male students failed:')
print(len(male) - len(male_succeed))
print( )

print('Percent of male students succeeding:')
print(len(male_succeed)/len(male))
print( )
```

```
    Number of male students succeeding:
    216

    Number of male students failed:
    50

    Percent of male students succeeding:
    0.8120300751879699
```

# Cleaning the Data

```
df.head()
labels = df['G3']
labels = labels.replace(1, 0).replace(2, 0).replace(3, 0).replace(4, 0)
labels = labels.replace(5, 0).replace(6, 0).replace(7, 0).replace(8, 0)
labels = labels.replace(9, 0).replace(10, 1)
labels = labels.replace(11, 1).replace(12, 1).replace(13, 1).replace(14, 1)
labels = labels.replace(15, 1).replace(16, 1).replace(17, 1).replace(18, 1)
labels = labels.replace(19, 1).replace(20, 1)
```

```
print(labels)
```

```
    0      1
```

```
0      1
1      1
2      1
3      1
4      1
      ..
644    1
645    1
646    0
647    1
648    1
Name: G3, Length: 649, dtype: int64
```

```
data = df.drop(columns=["G3"])

#0 for Gabriel Pereira, 1 for Mousinho da Silveira
school = {'GP': 0, 'MS': 1}
data.school = [school[item] for item in data.school]

#0 for female, 1 for male
sex = {'F': 0, 'M': 1}
data.sex = [sex[item] for item in data.sex]

#0 for urban, 1 for rural
address = {'U': 0, 'R': 1}
data.address = [address[item] for item in data.address]

#0 for less than or equal to 3, 1 for greater than three
famsize = {'LE3': 0, 'GT3': 1}
data.famsize = [famsize[item] for item in data.famsize]

#0 for living together, 1 for living apart
Pstatus = {'T': 0, 'A': 1}
data.Pstatus = [Pstatus[item] for item in data.Pstatus]

#0 for teacher, 1 for health care, 2 for services, 3 for at home, 4 for other
Mjob = {'teacher': 0, 'health': 1, 'services': 2, 'at_home': 3, 'other': 4}
data.Mjob = [Mjob[item] for item in data.Mjob]
data.Fjob = [Mjob[item] for item in data.Fjob]

#0 for close to home, 1 for school reputation, 2 for course preference, 3 for other
reason = {'home': 0, 'reputation': 1, 'course': 2, 'other': 3}
data.reason = [reason[item] for item in data.reason]

#0 for mother, 1 for father, 2 for other
guardian = {'mother': 0, 'father': 1, 'other': 2}
data.guardian = [guardian[item] for item in data.guardian]

#0 for yes, 1 for no

yesOrNo = {'yes': 0, 'no': 1}
data.schoolsup = [yesOrNo[item] for item in data.schoolsup]
data.famsup = [yesOrNo[item] for item in data.famsup]
data.paid = [yesOrNo[item] for item in data.paid]
data.paid = [yesOrNo[item] for item in data.paid]
data.activities = [yesOrNo[item] for item in data.activities]
data.nursery = [yesOrNo[item] for item in data.nursery]
data.higher = [yesOrNo[item] for item in data.higher]
data.internet = [yesOrNo[item] for item in data.internet]
data.romantic = [yesOrNo[item] for item in data.romantic]

train_proportion = 0.7
train_x, test_x, train_y, test_y = train_test_split(data, labels,
                                                    train_size=train_proportion,
                                                    test_size=1-train_proportion,
                                                    random_state=419)

data
```

| | school | sex | age | address | famsize | Pstatus | Medu | Fedu | Mjob | Fjob | reason |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 0 | 0 | 18 | 0 | 1 | 1 | 4 | 4 | 3 | 0 | 2 |
| **1** | 0 | 0 | 17 | 0 | 1 | 0 | 1 | 1 | 3 | 4 | 2 |
| **2** | 0 | 0 | 15 | 0 | 0 | 0 | 1 | 1 | 3 | 4 | 3 |
| **3** | 0 | 0 | 15 | 0 | 1 | 0 | 4 | 2 | 1 | 2 | 0 |
| **4** | 0 | 0 | 16 | 0 | 1 | 0 | 3 | 3 | 4 | 4 | 0 |
| **...** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **644** | 1 | 0 | 19 | 1 | 1 | 0 | 2 | 3 | 2 | 4 | 2 |
| **645** | 1 | 0 | 18 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 2 |
| **646** | 1 | 0 | 18 | 0 | 1 | 0 | 1 | 1 | 4 | 4 | 2 |
| **647** | 1 | 1 | 17 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 2 |
| **648** | 1 | 1 | 18 | 1 | 0 | 0 | 3 | 2 | 2 | 4 | 2 |

649 rows × 32 columns

## Data Exploration

Let's look at the data distribution between female and male students to better inform our analysis.

```
all_female = data[(data['sex'] == 0)]
```

```
all_male = data[(data['sex'] == 1)]
print(len(all_female) / len(data))
print(len(all_male) / len(data))
```

```
     0.5901386748844376
     0.4098613251155624
```

So, there's about a 60/40 split with more female students than male students.

Let's look at the distribution between urban and rural students.

```
all_urban = data[(data['address'] == 0)]
all_rural = data[(data['address'] == 1)]
print(len(all_urban) / len(data))
print(len(all_rural) / len(data))
```

```
     0.6964560862865947
     0.3035439137134052
```

We can see the majority of our original data favors urban students over rural students with about a 70/30 split.

Let's look at our train and test data sets as well

```
test_female = test_x[(test_x['sex'] == 0)]
test_male = test_x[(test_x['sex'] == 1)]
test_urban = test_x[(test_x['address'] == 0)]
test_rural = test_x[(test_x['address'] == 1)]

print("Test data")
print("---------")
print("Female students:", len(test_female) / len(test_x))
print("Male students:  ", len(test_male) / len(test_x))
print()
print("Urban students:", len(test_urban) / len(test_x))
print("Rural students:", len(test_rural) / len(test_x))
```

```
     Test data
     ---------
     Female students: 0.5435897435897435
     Male students:   0.4564102564102564

     Urban students: 0.6461538461538462
     Rural students: 0.35384615384615387
```

```
train_female = train_x[(train_x['sex'] == 0)]
train_male = train_x[(train_x['sex'] == 1)]
train_urban = train_x[(train_x['address'] == 0)]
train_rural = train_x[(train_x['address'] == 1)]

print("Train data")
print("---------")
print("---------")
print("Female students:", len(train_female) / len(train_x))
print("Male students:  ", len(train_male) / len(train_x))
print()
print("Urban students:", len(train_urban) / len(train_x))
print("Rural students:", len(train_rural) / len(train_x))
```

```
Train data
---------
Female students: 0.6101321585903083
Male students:   0.3898678414096916

Urban students: 0.7180616740088106
Rural students: 0.28193832599118945
```

# Independence

```
from sklearn import linear_model

num_train = len(train_x)
cls = linear_model.LogisticRegression(max_iter=100000)
cls.fit(train_x, train_y)
```

```
LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                   intercept_scaling=1, l1_ratio=None, max_iter=100000,
                   multi_class='auto', n_jobs=None, penalty='l2',
                   random_state=None, solver='lbfgs', tol=0.0001, verbose=0,
                   warm_start=False)
```

```
predictions = cls.predict(test_x)

overall_scores = cls.score(test_x, test_y)

overall_scores
```

```
0.9230769230769231
```

```
from sklearn.metrics import classification_report
print(classification_report(predictions, test_y))
```

```
              precision    recall  f1-score   support

           0       0.68      0.76      0.72        25
           1       0.96      0.95      0.96       170

    accuracy                           0.92       195
   macro avg       0.82      0.85      0.84       195
weighted avg       0.93      0.92      0.92       195
```

## Demographic Parity

```
scores = cls.predict_proba(test_x)[:, 1]
d = {'target' : test_y.values,
     'score' : scores,
     'prediction' : predictions,
     'address' : test_x['address'],
     'gender' : test_x['sex']}

marginals = pd.DataFrame(data=d, columns=['target', 'score', 'prediction', 'address', 'gender
marginals.head()
```

|  | target | score | prediction | address | gender |
|---|---|---|---|---|---|
| **46** | 1 | 0.999177 | 1 | 0 | 0 |
| **197** | 1 | 0.999706 | 1 | 0 | 0 |
| **208** | 1 | 0.999889 | 1 | 0 | 1 |
| **326** | 1 | 0.999714 | 1 | 0 | 1 |
| **359** | 1 | 0.999999 | 1 | 1 | 0 |

## For Female vs. Male

```
postive_class = marginals[(marginals['prediction'] == 1) ]

positive_female = postive_class[(postive_class['gender'] == 0)]
positive_male = postive_class[(postive_class['gender'] == 1)]

print("# of positively classified males to females ->", len(positive_male)/len(positive_femal

female = marginals[marginals['gender'] == 0]
male = marginals[marginals['gender'] == 1]

print("% of positively classified males to females ->", (len(positive_male)/len(male))/(len(p
```

```
# of positively classified males to females -> 0.8085106382978723
% of positively classified males to females -> 0.9629452546019602
```

## For Urban vs. Rural

```
positive_urban = postive_class[(postive_class['address'] == 0)]
```

```
positive_rural = postive_class[(postive_class['address'] == 1)]

print("# of positively classified rural to urban students ->", len(positive_rural)/len(positi

urban = marginals[marginals['address'] == 0]
rural = marginals[marginals['address'] == 1]

print("% of positively classified rural to urban students ->", (len(positive_rural)/len(rural
```

```
# of positively classified rural to urban students -> 0.5315315315315315
% of positively classified rural to urban students -> 0.9706227967097533
```

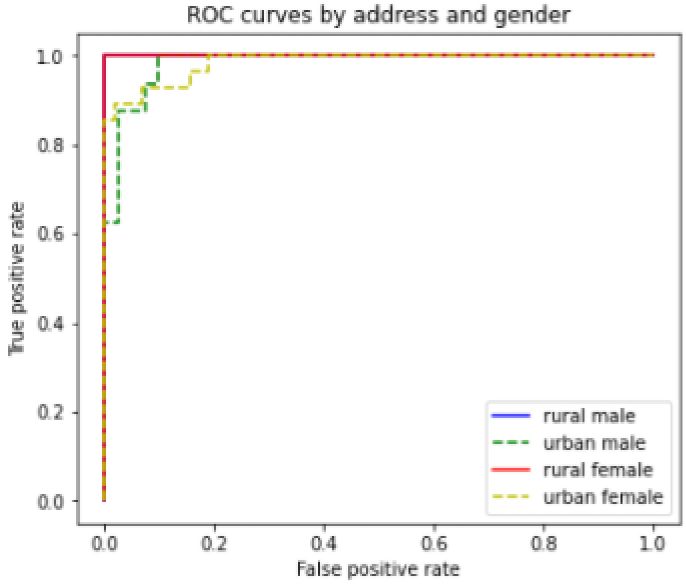
We care more about the percentage comparison because

# Seperation

```
fpr_all, tpr_all, _ = metrics.roc_curve(marginals['target'], marginals['score'])


plt.figure(1, figsize = (6,5))
plt.title('ROC curve')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')

plt.plot(fpr_all, tpr_all, color='b')
plt.legend()
plt.show()
```

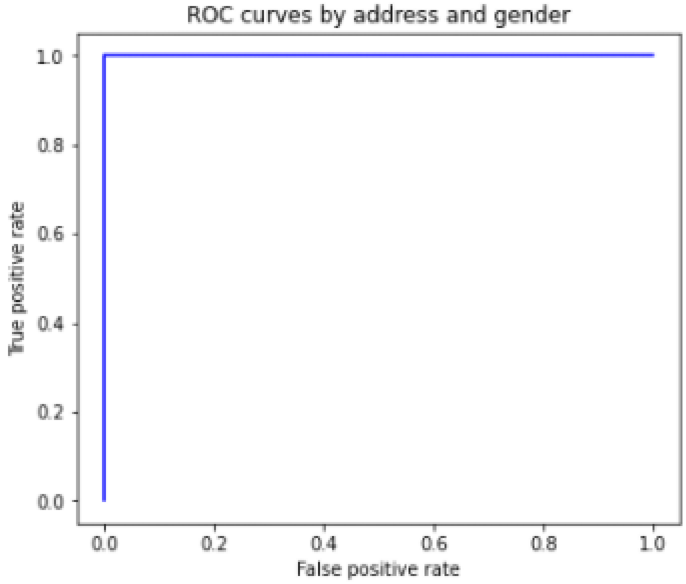
```
No handles with labels found to put in legend.
```

Please note that if a line does not show up on the ROC curve, it is most likely because none of the data points have a positive criteria or it overlaps with another ROC curve. This usually occurs with rural male because the red line takes precedence. Example Below:

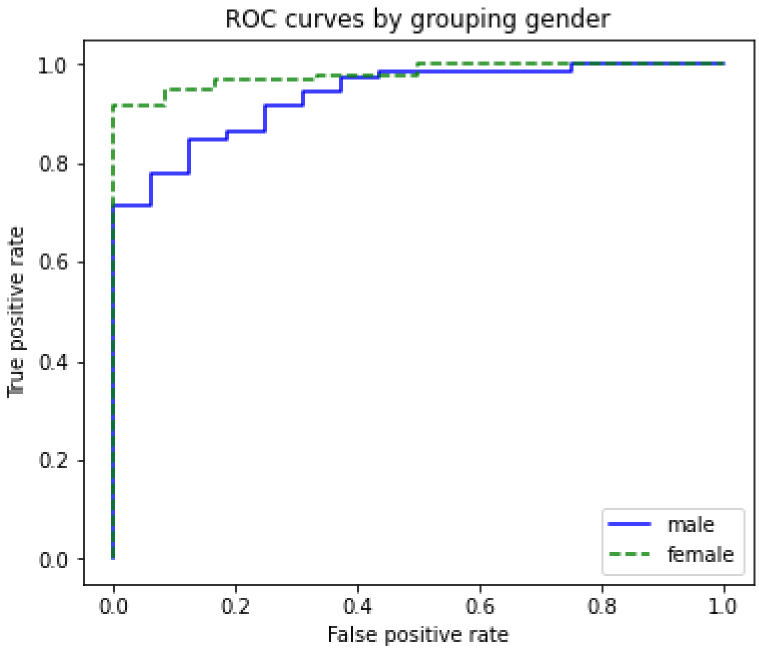


```
plt.figure(1, figsize=(6, 5))
plt.title('ROC curves by address and gender')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')
plt.plot(fpr_ruralmale, tpr_ruralmale, label='rural male', lin
```

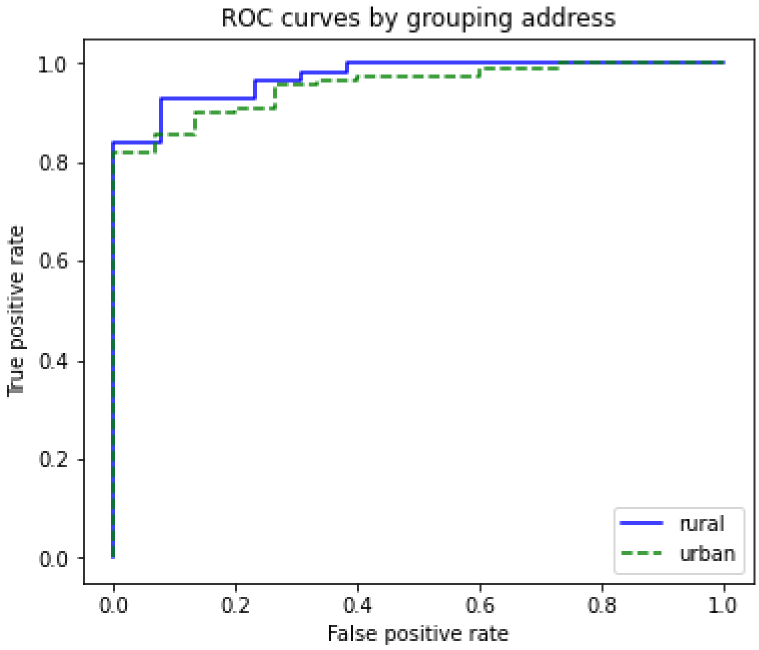
```
[<matplotlib.lines.Line2D at 0x7fa8f77c8b10>]
```



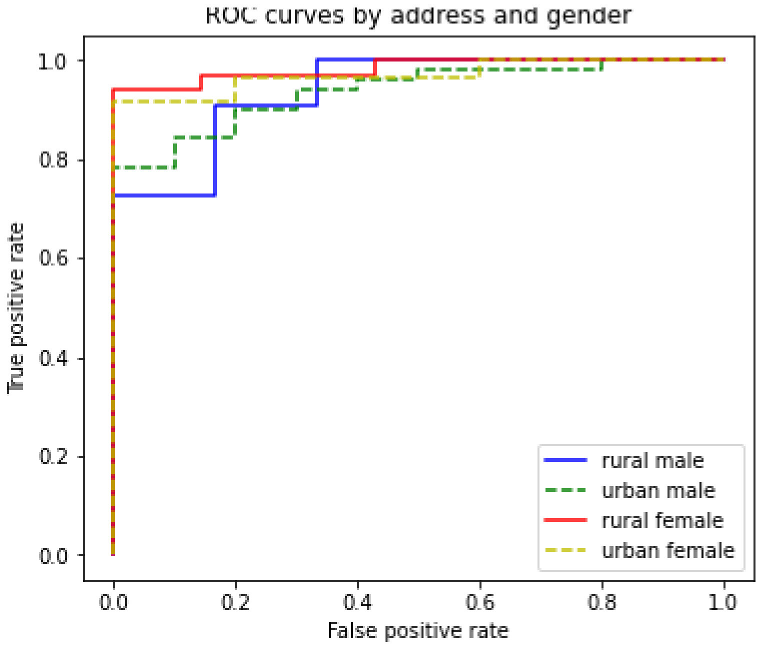
```
male = marginals[marginals['gender'] == 1]
fpr_male, tpr_male, _ = metrics.roc_curve(male['target'], male['score'])

female = marginals[marginals['gender'] == 0]
female = marginals[marginals['gender'] == 0]
fpr_female, tpr_female, _ = metrics.roc_curve(female['target'], female['score'])

plt.figure(1, figsize=(6, 5))
plt.title('ROC curves by grouping gender')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')

plt.plot(fpr_male, tpr_male, label='male', linestyle='-', color='b')
plt.plot(fpr_female, tpr_female, label='female', linestyle='--', color='g')

plt.legend()
plt.show()
```



```
rural = marginals[marginals['address'] == 1]
fpr_rural, tpr_rural, _ = metrics.roc_curve(rural['target'], rural['score'])


urban = marginals[marginals['address'] == 0]
fpr_urban, tpr_urban, _ = metrics.roc_curve(urban['target'], urban['score'])


plt.figure(1, figsize=(6, 5))
plt.title('ROC curves by grouping address')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')

plt.plot(fpr_rural, tpr_rural, label='rural', linestyle='-', color='b')
plt.plot(fpr_urban, tpr_urban, label='urban', linestyle='--', color='g')


plt.legend()
plt.show()
```



```
rural = marginals[marginals['address'] == 1]
fpr_rural, tpr_rural, _ = metrics.roc_curve(rural['target'], rural['score'])

ruralmale = rural[rural['gender'] == 1]
fpr_ruralmale, tpr_ruralmale, _ = metrics.roc_curve(ruralmale['target'], ruralmale['score'])

ruralfemale = rural[rural['gender'] == 0]
fpr_ruralfemale, tpr_ruralfemale, _ = metrics.roc_curve(ruralfemale['target'], ruralfemale['s

urban = marginals[marginals['address'] == 0]
fpr_urban, tpr_urban, _ = metrics.roc_curve(urban['target'], urban['score'])

urbanmale = urban[urban['gender'] == 1]
fpr_urbanmale, tpr_urbanmale, _ = metrics.roc_curve(urbanmale['target'], urbanmale['score'])

urbanfemale = urban[urban['gender'] == 0]
fpr_urbanfemale, tpr_urbanfemale, _ = metrics.roc_curve(urbanfemale['target'], urbanfemale['s

plt.figure(1, figsize=(6, 5))
plt.title('ROC curves by address and gender')
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')

plt.plot(fpr_ruralmale, tpr_ruralmale, label='rural male', linestyle='-', color='b')
plt.plot(fpr_urbanmale, tpr_urbanmale, label='urban male', linestyle='--', color='g')
plt.plot(fpr_ruralfemale, tpr_ruralfemale, label='rural female', linestyle='-', color='r')
plt.plot(fpr_urbanfemale, tpr_urbanfemale, label='urban female', linestyle='--', color='y')


plt.legend()
plt.show()
```


ROC curves by address and gender
True positive rate
0.0
0.2
0.4
0.6
0.8
1.0
False positive rate
0.0
0.2
0.4
0.6
0.8
1.0
rural male
urban male
rural female
urban female