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Question 2

In [541]:

```python
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
sns.set()
from sklearn import linear_model
from sklearn.linear_model import Ridge
from yellowbrick.regressor import ResidualsPlot
from sklearn.linear_model import LinearRegression
from itertools import combinations
from sklearn.metrics import mean_squared_error, r2_score
from sklearn.linear_model import LassoCV
from sklearn.linear_model import RidgeCV
```

In [2]:

```python
data_HW3=pd.read_csv("Credit.csv")
```

Question 2a – Select the training set

In [3]:

```python
randomly_organized=data_HW3.sample(frac=1)
```

In [4]:

```python
train_set = randomly_organized[0:200]
devel_set = randomly_organized[200:300]
valid_set = randomly_organized[300:400]
```
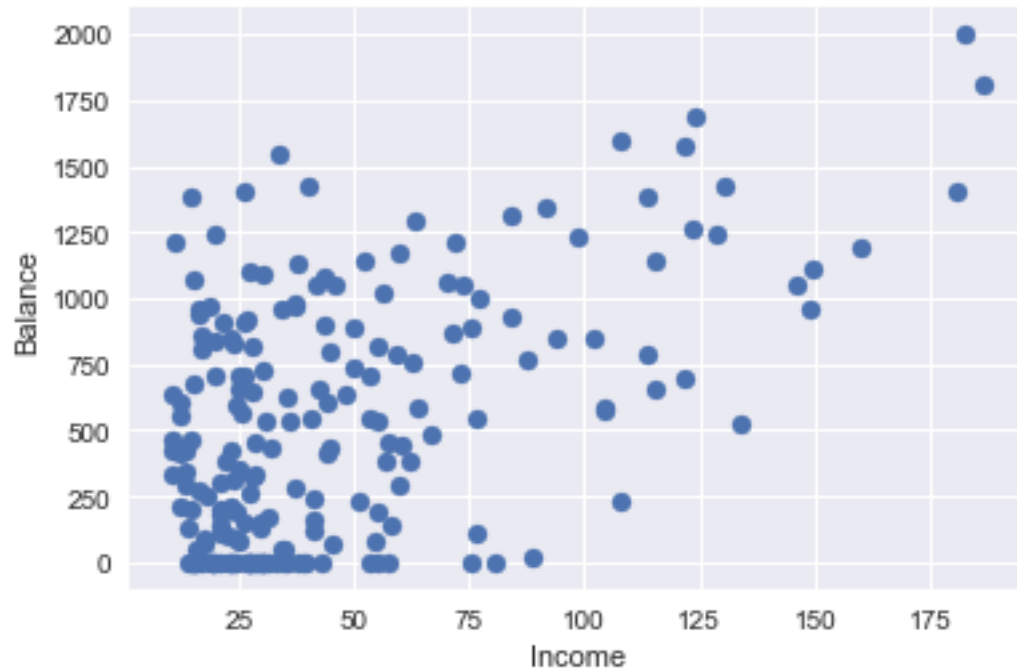
Question 2b – data exploration

```
In [563]:
```

```
plt.scatter(train_set['Income'],train_set['Balance'])
plt.ylabel('Balance')
plt.xlabel('Income')
```

```
Out[563]:
```
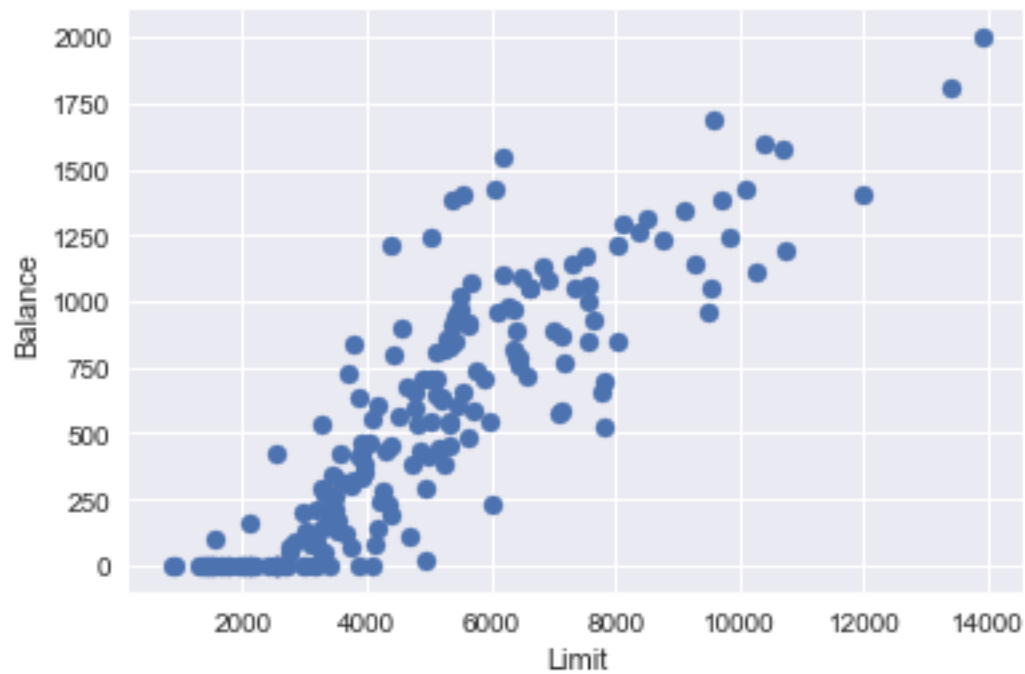
```
Text(0.5,0,'Income')
```



```
In [564]:
```

```
plt.scatter(train_set['Limit'],train_set['Balance'])
plt.ylabel('Balance')
plt.xlabel('Limit')
```

```
Out[564]:
```
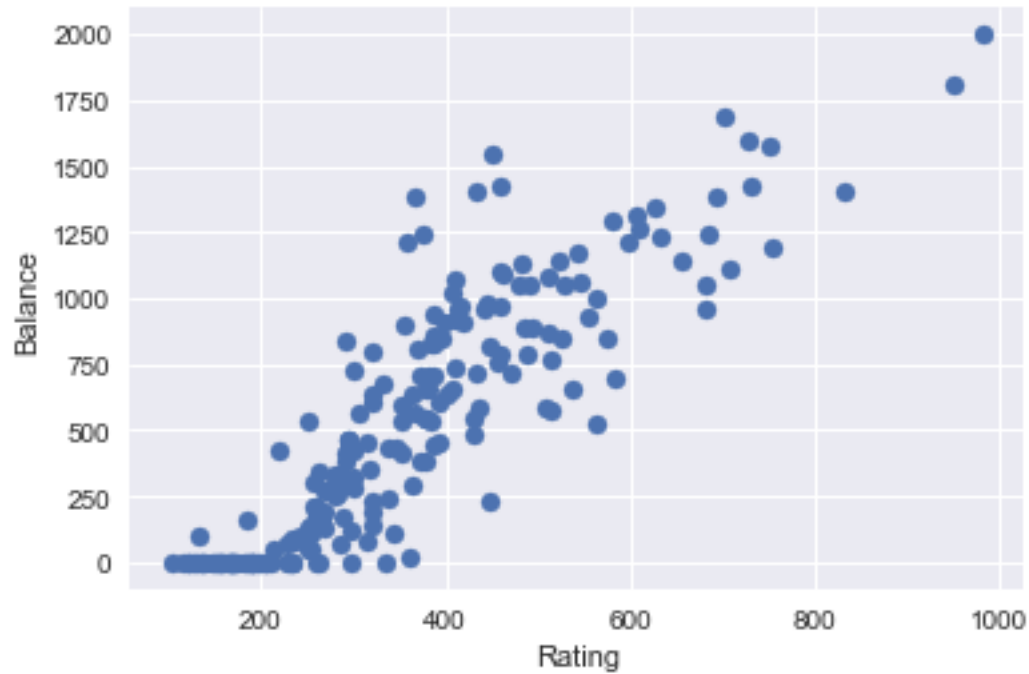
```
Text(0.5,0,'Limit')
```

In [565]:

```python
plt.scatter(train_set['Rating'],train_set['Balance'])
plt.ylabel('Balance')
plt.xlabel('Rating')
```
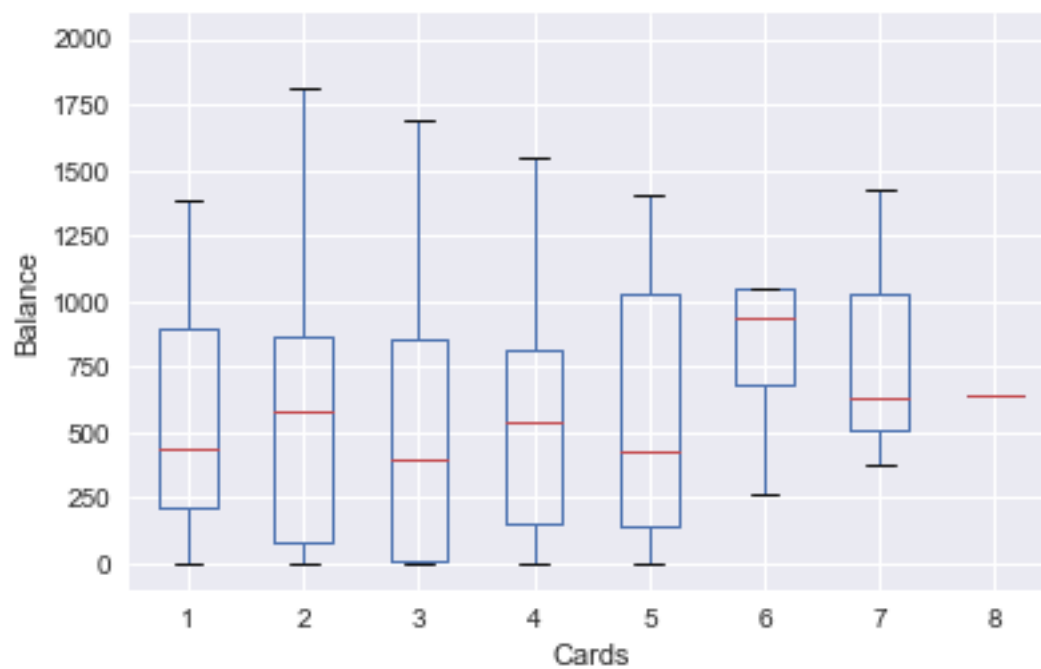
Out[565]:

Text(0.5,0,'Rating')

In [566]:

```python
train_set.boxplot(column='Balance', by='Cards')
plt.ylabel('Balance')
```

Out[566]:
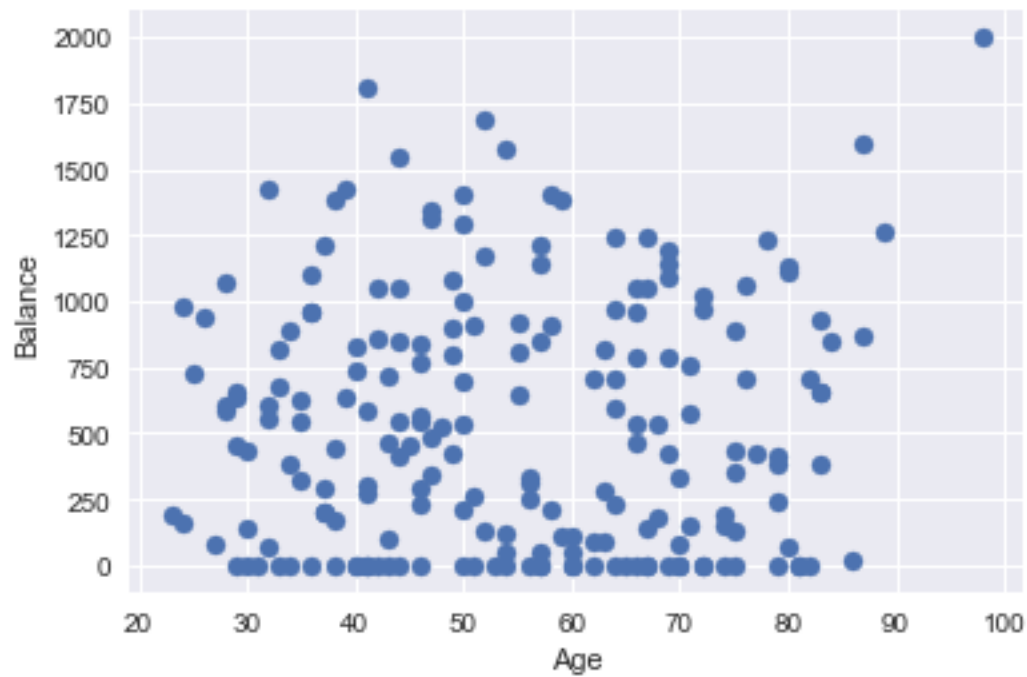
Text(0,0.5,'Balance')

In [567]:

```python
plt.scatter(train_set['Age'],train_set['Balance'])
plt.ylabel('Balance')
plt.xlabel('Age')
```
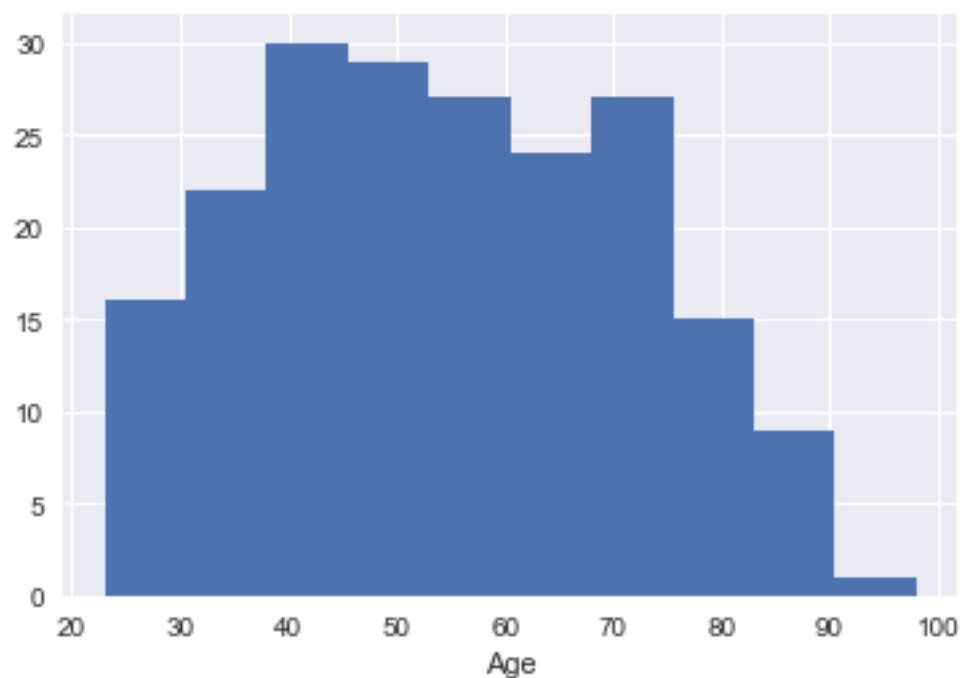
Out[567]:

Text(0.5,0,'Age')

In [568]:

```python
plt.hist(train_set['Age'])
plt.xlabel('Age')
```

Out[568]:

Text(0.5,0,'Age')

In [569]:

```
train_set.boxplot(column='Balance', by='Education')
plt.ylabel('Balance')
```

Out[569]:

Text(0,0.5,'Balance')
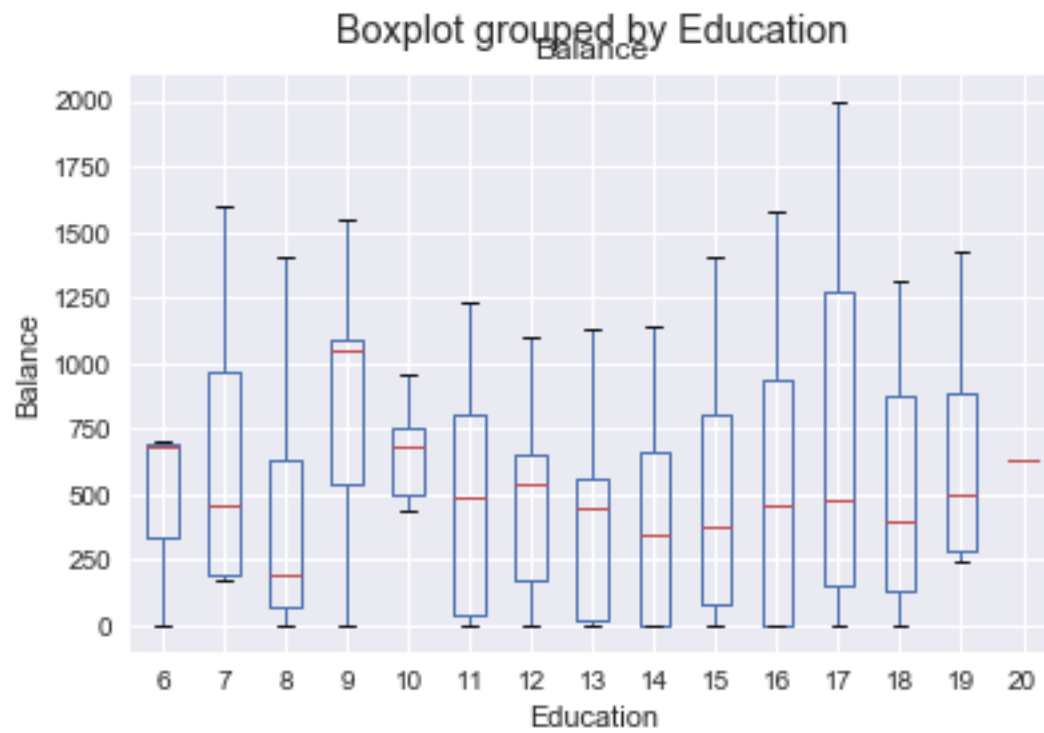
In [570]:

```
train_set.boxplot(column='Balance', by='Gender')
plt.ylabel('Balance')
```

Out[570]:

Text(0,0.5,'Balance')

In [571]:

```
train_set.boxplot(column='Balance', by='Married')
plt.ylabel('Balance')
```

Out[571]:

Text(0,0.5,'Balance')

Boxplot grouped by Married

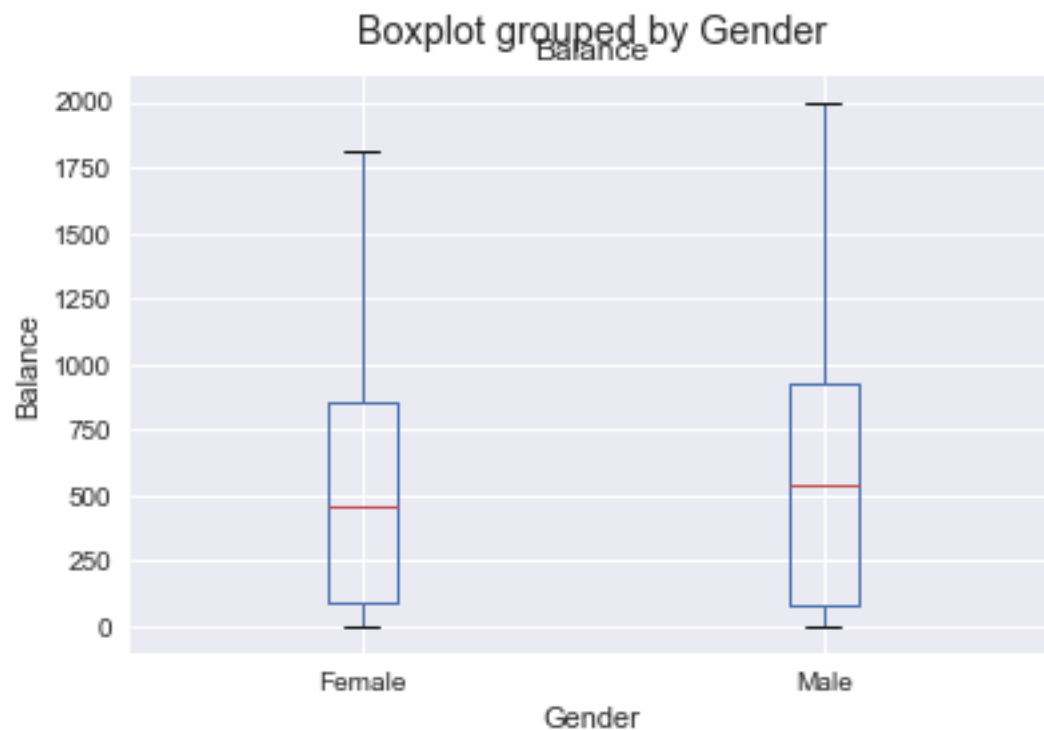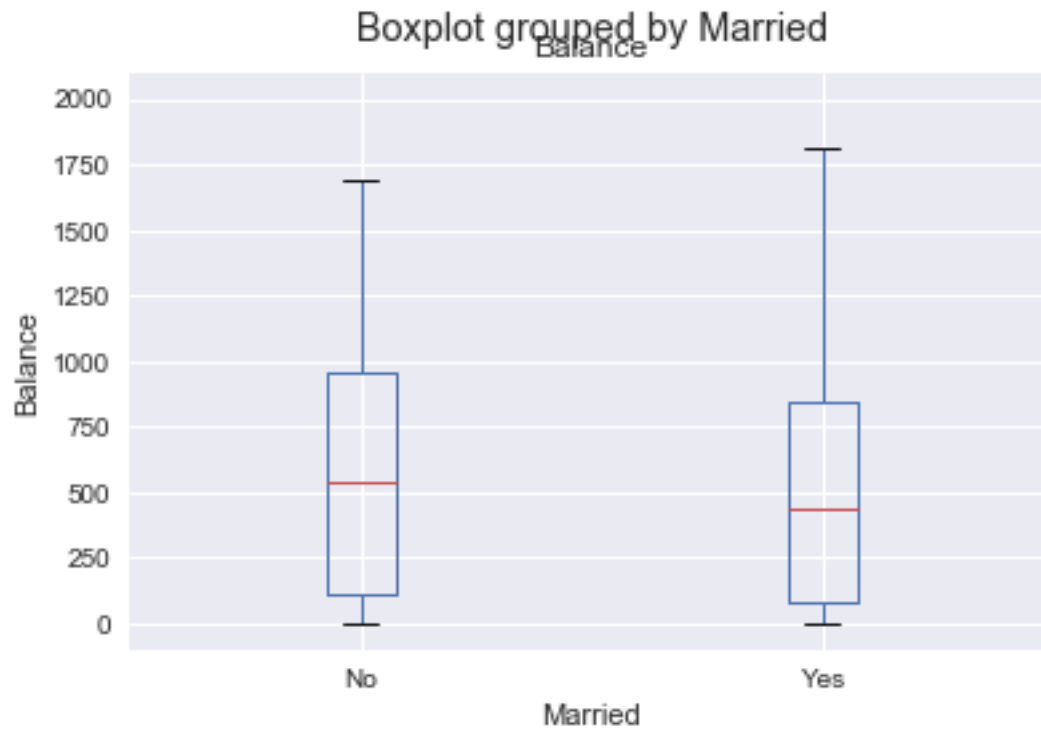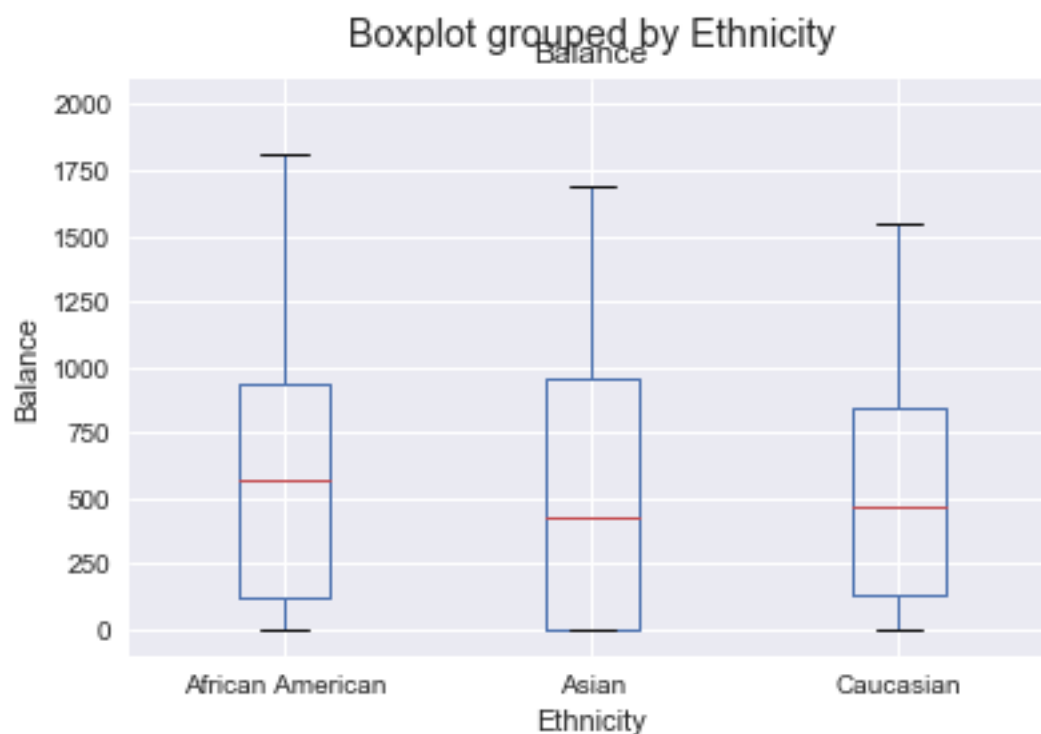In [572]:

```
train_set.boxplot(column='Balance', by='Ethnicity')
plt.ylabel('Balance')
```

Out[572]:

Text(0,0.5,'Balance')

Boxplot grouped by Ethnicity

Implications of the exploration for the regression analysis: from the plots we can see that "Limit" and "Rating" are highly correlated predictors compared to other predictors; "Gender", "Married" and "Ethnicity" are categorical predictors; and we can spot a few outliers in the scatter plots for "Limit" and "Rating".

Question 2c – Assumption of Normality

In [439]:

```python
Income=[]
a=np.array(train_set[0:200]["Income"])
Income=a.reshape((200,1))

Limit=[]
a=np.array(train_set[0:200]["Limit"])
Limit=a.reshape((200,1))

Rating=[]
a=np.array(train_set[0:200]["Rating"])
Rating=a.reshape((200,1))

Cards=[]
a=np.array(train_set[0:200]["Cards"])
Cards=a.reshape((200,1))

Age=[]
a=np.array(train_set[0:200]["Age"])
Age=a.reshape((200,1))

Education=[]
a=np.array(train_set[0:200]["Education"])
Education=a.reshape((200,1))

Male=[]
a=np.array(train_set[0:200]["Gender"])
for i in range(200):
    if a[i] == 'Male':
        a[i] = 1
    else:
        a[i] = 0
Male=a.reshape((200,1))

Yes_student=[]
a=np.array(train_set[0:200]["Student"])
for i in range(200):
    if a[i] == 'Yes':
        a[i] = 1
    else:
        a[i] = 0
```

```python
Yes_student=a.reshape((200,1))


Yes_married=[]
a=np.array(train_set[0:200]["Married"])
for i in range(200):
    if a[i] == 'Yes':
        a[i] = 1
    else:
        a[i] = 0
Yes_married=a.reshape((200,1))


Caucasian=[]
a=np.array(train_set[0:200]["Ethnicity"])
for i in range(200):
    if a[i] == 'Caucasian':
        a[i] = 1
    else:
        a[i] = 0
Caucasian=a.reshape((200,1))

African_American=[]
a=np.array(train_set[0:200]["Ethnicity"])
for i in range(200):
    if a[i] == 'African American':
        a[i] = 1
    else:
        a[i] = 0
African_American=a.reshape((200,1))


All_data=np.concatenate((Income,Limit,Rating,Cards,Age,Education,Male,Yes_studen
t,Yes_married,Caucasian,African_American), axis=1)
```

In [187]:

```python
LinearRegression_2c = LinearRegression().fit(All_data, train_set['Balance'])
```

```
linear = linear_model.LinearRegression()
visualizer = ResidualsPlot(linear,hist=False)
visualizer.fit(All_data, train_set['Balance'])
visualizer.poof()
```


Residuals for LinearRegression Model
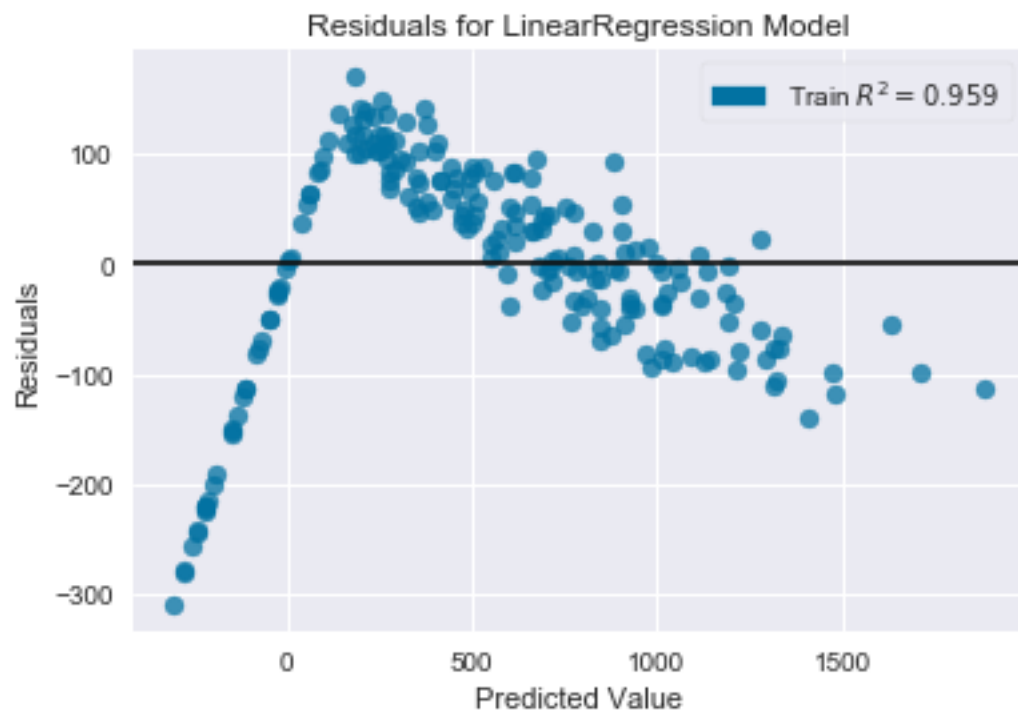
Linear regression is not so reliable in this case because the residuals don't have constant variance. If the residuals had constant variance (e.g., they are spread out equally on both sides of 0), we would know linear regression was a good fit in this case.

Question 2d – Variable selection

```
Income_dev=[]
a=np.array(devel_set[0:100]["Income"])
Income_dev=a.reshape((100,1))

Limit_dev=[]
a=np.array(devel_set[0:100]["Limit"])
Limit_dev=a.reshape((100,1))

Rating_dev=[]
a=np.array(devel_set[0:100]["Rating"])
Rating_dev=a.reshape((100,1))

Cards_dev=[]
a=np.array(devel_set[0:100]["Cards"])
Cards_dev=a.reshape((100,1))

Age_dev=[]
```

```python
a=np.array(devel_set[0:100]["Age"])

Age_dev=a.reshape((100,1))

Education_dev=[]
a=np.array(devel_set[0:100]["Education"])
Education_dev=a.reshape((100,1))

Male_dev=[]
a=np.array(devel_set[0:100]["Gender"])
for i in range(100):
    if a[i] == 'Male':
        a[i] = 1
    else:
        a[i] = 0
Male_dev=a.reshape((100,1))

Yes_student_dev=[]
a=np.array(devel_set[0:100]["Student"])
for i in range(100):
    if a[i] == 'Yes':
        a[i] = 1
    else:
        a[i] = 0
Yes_student_dev=a.reshape((100,1))

Yes_married_dev=[]
a=np.array(devel_set[0:100]["Married"])
for i in range(100):
    if a[i] == 'Yes':
        a[i] = 1
    else:
        a[i] = 0
Yes_married_dev=a.reshape((100,1))

Caucasian_dev=[]
a=np.array(devel_set[0:100]["Ethnicity"])
for i in range(100):
    if a[i] == 'Caucasian':
        a[i] = 1
    else:
        a[i] = 0
Caucasian_dev=a.reshape((100,1))

African_American_dev=[]
a=np.array(devel_set[0:100]["Ethnicity"])
for i in range(100):
    if a[i] == 'African American':
        a[i] = 1
    else:
        a[i] = 0
African_American_dev=a.reshape((100,1))

All_dev=np.concatenate((Income_dev,Limit_dev,Rating_dev,Cards_dev,Age_dev,Educat
```

```
ion_dev,Male_dev,Yes_student_dev,Yes_married_dev,Caucasian_dev,African_American_
dev), axis=1)
```

In [61]:

```python
def subset_selection(sets, n):
    return list(combinations(sets, n))
```

In [548]:

```python
mse_scores = []
var_names = []
All_names = ['Income','Limit','Rating','Cards','Age','Education','Male','Yes_stu
dent','Yes_married','Caucasian','African_American']
All_groups_train = Income,Limit,Rating,Cards,Age,Education,Male,Yes_student,Yes_
married,Caucasian,African_American
All_groups_dev = Income_dev,Limit_dev,Rating_dev,Cards_dev,Age_dev,Education_dev
,Male_dev,Yes_student_dev,Yes_married_dev,Caucasian_dev,African_American_dev
for i in range(1,12):
    subset_train = subset_selection(All_groups_train,i)
    subset_dev = subset_selection(All_groups_dev,i)
    subset_names = subset_selection(All_names,i)
    for j in range(np.shape(subset_train)[0]):
        linear_regression_2d = LinearRegression().fit(np.reshape(subset_train[j]
,(-1,200)).T, train_set['Balance'])
        pred = linear_regression_2d.predict(np.reshape(subset_dev[j],(-1,100)).T
)
        mse_scores.append(mean_squared_error(devel_set['Balance'], pred))
        var_names.append(subset_names[j])
```

In [549]:

```python
min(mse_scores)
```

Out[549]:

```
9692.8656086594929
```

In [550]:

```python
len(mse_scores)
```

Out[550]:

```
2047
```

```
numbers_of_i=[]
for i in range(2046):
    if mse_scores[i] == min(mse_scores):
        print(i)
```

1025

In [552]:

```
var_names[1025]
```

Out[552]:

```
('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Yes_student')
```

So, best subset selection in this case is the combination of "Income", "Limit", "Rating", "Cards", "Age" and "Student".

QUESTION 2e – ridge regularization

In [500]:

```
Alpha=[1e-6,1e-5,1e-4,1e-3,1e-2,1e-1,1,10] #regularization parameter
ridge_regularization_2e = RidgeCV(alphas=Alpha,cv=5).fit(All_data, train_set['Ba
lance']) #5-fold cross validation
```

In [510]:

```
ridge_regularization_2e.alpha_ #this is our best performed regularization parame
ter for ridge regression
```

Out[510]:

```
0.10000000000000001
```

Question 2f – Lasso regularization

In [503]:

```
lasso_regularization_2f = linear_model.LassoCV(alphas=Alpha,cv=5).fit(All_data,
train_set['Balance'])
```

```
/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/coordina
te_descent.py:492: ConvergenceWarning: Objective did not converge. Y
ou might want to increase the number of iterations. Fitting data wit
h very small alpha may cause precision problems.
  ConvergenceWarning)
```

```
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ou might want to increase the number of iterations. Fitting data wit
h very small alpha may cause precision problems.
  ConvergenceWarning)
```

In [511]:

```
lasso_regularization_2f.alpha_  #this is our best performed regularization parame
ter for lasso regression
```

Out[511]:

1.0

Question 2g – performance evaluation

In [521]:

```python
Income_valid=[]
a=np.array(valid_set[0:100]["Income"])
Income_valid=a.reshape((100,1))

Limit_valid=[]
a=np.array(valid_set[0:100]["Limit"])
Limit_valid=a.reshape((100,1))

Rating_valid=[]
a=np.array(valid_set[0:100]["Rating"])
Rating_valid=a.reshape((100,1))

Cards_valid=[]
a=np.array(valid_set[0:100]["Cards"])
Cards_valid=a.reshape((100,1))

Age_valid=[]
a=np.array(valid_set[0:100]["Age"])
Age_valid=a.reshape((100,1))

Education_valid=[]
a=np.array(valid_set[0:100]["Education"])
Education_valid=a.reshape((100,1))

Male_valid=[]
a=np.array(valid_set[0:100]["Gender"])
for i in range(100):
    if a[i] == 'Male':
        a[i] = 1
    else:
        a[i] = 0
Male_valid=a.reshape((100,1))

Yes_student_valid=[]
a=np.array(valid_set[0:100]["Student"])
for i in range(100):
    if a[i] == 'Yes':
        a[i] = 1
    else:
        a[i] = 0
Yes_student_valid=a.reshape((100,1))

Yes_married_valid=[]
a=np.array(valid_set[0:100]["Married"])
for i in range(100):
    if a[i] == 'Yes':
        a[i] = 1
    else:
```

```
        else:
            a[i] = 0
Yes_married_valid=a.reshape((100,1))

Caucasian_valid=[]
a=np.array(valid_set[0:100]["Ethnicity"])
for i in range(100):
    if a[i] == 'Caucasian':
        a[i] = 1
    else:
        a[i] = 0
Caucasian_valid=a.reshape((100,1))

African_American_valid=[]
a=np.array(valid_set[0:100]["Ethnicity"])
for i in range(100):
    if a[i] == 'African American':
        a[i] = 1
    else:
        a[i] = 0
African_American_valid=a.reshape((100,1))

All_data_valid=np.concatenate((Income_valid,Limit_valid,Rating_valid,Cards_valid
,Age_valid,Education_valid,Male_valid,Yes_student_valid,Yes_married_valid,Caucas
ian_valid,African_American_valid), axis=1)
```

In [562]:

```
linear_regression_2d = LinearRegression().fit(np.concatenate((Income,Limit,Ratin
g,Cards,Age,Yes_student), axis=1), train_set['Balance'])
pred = linear_regression_2d.predict(np.concatenate((Income_valid,Limit_valid,Rat
ing_valid,Cards_valid,Age_valid,Yes_student_valid),axis=1))
mse_scores_validation=mean_squared_error(valid_set['Balance'], pred)
print(mse_scores_validation) #miminum mse for subset selection
```

10478.2469232

```python
mse_scores_2e_validation = []
var_names_2e_validation = []
All_groups_valid = Income_valid,Limit_valid,Rating_valid,Cards_valid,Age_valid,E
ducation_valid,Male_valid,Yes_student_valid,Yes_married_valid,Caucasian_valid,Af
rican_American_valid
for i in range(1,12):
    subset_train = subset_selection(All_groups_train,i)
    subset_valid = subset_selection(All_groups_valid,i)
    subset_names = subset_selection(All_names,i)
    for j in range(np.shape(subset_train)[0]):
        ridge_regularization_2e = Ridge(alpha=0.1).fit(np.reshape(subset_train[j
],(-1,200)).T, train_set['Balance'])
        pred = ridge_regularization_2e.predict(np.reshape(subset_valid[j],(-1,10
0)).T)
        mse_scores_2e_validation.append(mean_squared_error(valid_set['Balance'],
pred))
        var_names_2e_validation.append(subset_names[j])
```

```python
min(mse_scores_2e_validation) #minimum mse for ridge
```

Out[556]:

```
10426.692368902248
```

```python
len(mse_scores_2e_validation)
```

Out[557]:

```
2047
```

```python
numbers_of_i=[]
for i in range(2047):
    if mse_scores_2e_validation[i] == min(mse_scores_2e_validation):
        print(i)
```

```
1827
```

```
In [559]:
```

```
var_names_2e_validation[1827]
```

```
Out[559]:
```

```
('Income',
 'Limit',
 'Rating',
 'Cards',
 'Age',
 'Male',
 'Yes_student',
 'African_American')
```

```
In [560]:
```

```
mse_scores_2f_validation = []
var_names_2f_validation = []
for i in range(1,12):
    subset_train = subset_selection(All_groups_train,i)
    subset_valid = subset_selection(All_groups_valid,i)
    subset_names = subset_selection(All_names,i)
    for j in range(np.shape(subset_train)[0]):
        lasso_regularization_2f = linear_model.Lasso(alpha=1).fit(np.reshape(sub
set_train[j],(-1,200)).T, train_set['Balance'])
        pred = lasso_regularization_2f.predict(np.reshape(subset_valid[j],(-1,10
0)).T)
        mse_scores_2f_validation.append(mean_squared_error(valid_set['Balance'],
pred))
        var_names_2f_validation.append(subset_names[j])
```

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/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/coordina
te_descent.py:492: ConvergenceWarning: Objective did not converge. Y
ou might want to increase the number of iterations. Fitting data wit
h very small alpha may cause precision problems.
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/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/coordina
te_descent.py:492: ConvergenceWarning: Objective did not converge. Y
ou might want to increase the number of iterations. Fitting data wit
h very small alpha may cause precision problems.
  ConvergenceWarning)
```

In [561]:

```python
min(mse_scores_2f_validation) #minimum mse for lasso
```

Out[561]:

10455.56490050275

In [425]:

```python
len(mse_scores_2f_validation)
```

Out[425]:

2047

In [426]:

```python
numbers_of_i=[]
for i in range(2047):
    if mse_scores_2f_validation[i] == min(mse_scores_2f_validation):
        print(i)
```

1991

In [427]:

```python
var_names_2f_validation[1991]
```

Out[427]:

```
('Income',
 'Limit',
 'Rating',
 'Cards',
 'Age',
 'Male',
 'Yes_student',
 'Yes_married',
 'African_American')
```

In [531]:

```python
print(mse_scores_validation)
print(min(mse_scores_2e_validation))
print(min(mse_scores_2f_validation))
```

10478.2469232
10426.6923689
10455.5649005

So ridge regularization works best, then lasso, then subset selection. I came to this conclusion because minumum MSE on the validation set is the smallest for ridge; it's the largest for subset selection; and it's in the middle for lasso.
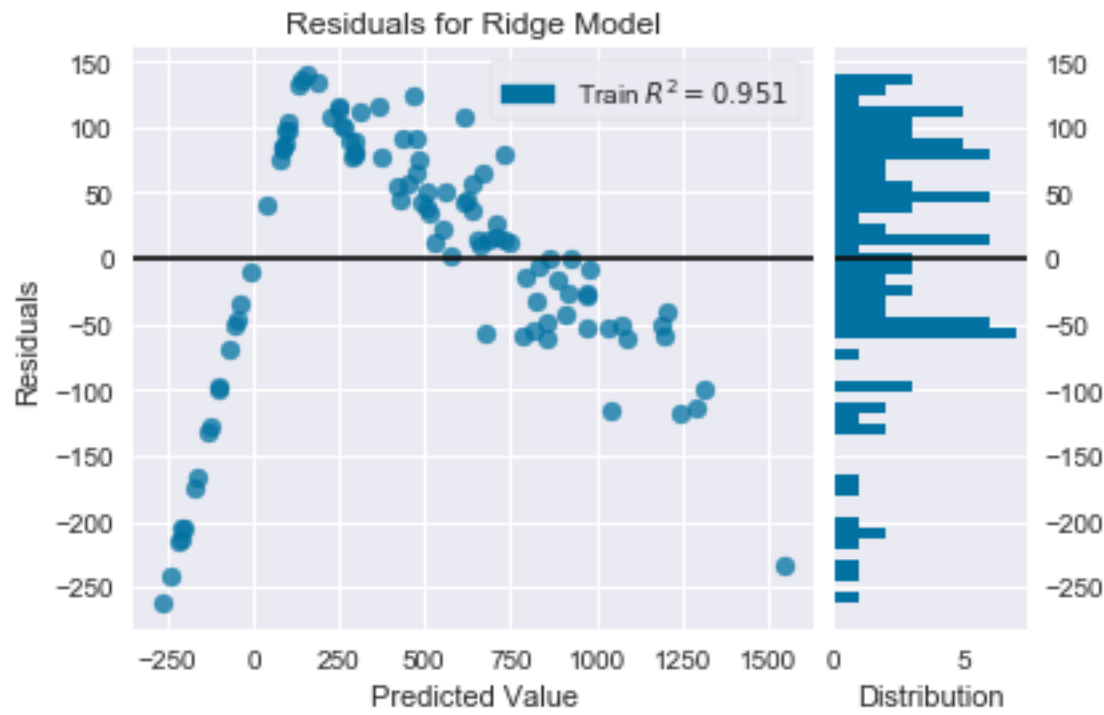
# Question 2h – Interpretation of the results

In [539]:

```
visualizer = ResidualsPlot(linear_regression_2d)
visualizer.fit(All_data_valid, valid_set['Balance'])
visualizer.poof()
```


Residuals for LinearRegression Model
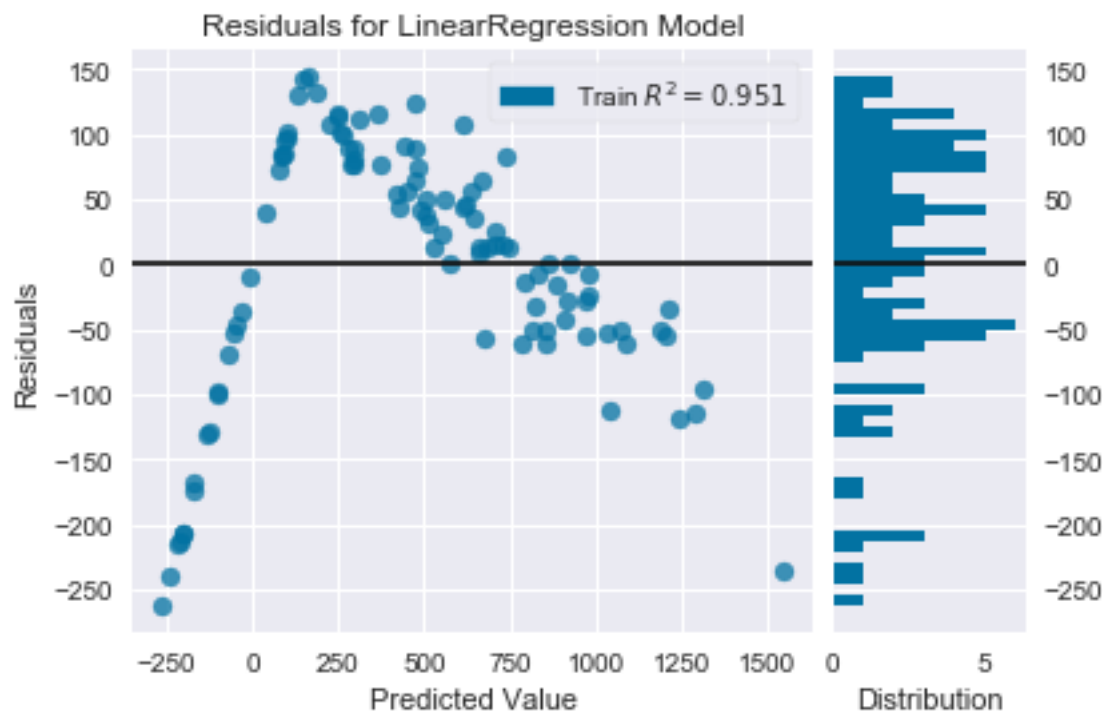
In [540]:

```
visualizer = ResidualsPlot(ridge_regularization_2e)
visualizer.fit(All_data_valid, valid_set['Balance'])
visualizer.poof()
```


Residuals for Ridge Model

In [546]:

```
visualizer = ResidualsPlot(lasso_regularization_2f)
visualizer.fit(All_data_valid, valid_set['Balance'])
visualizer.poof()
```

```
/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/coordina
te_descent.py:492: ConvergenceWarning: Objective did not converge. Y
ou might want to increase the number of iterations. Fitting data wit
h very small alpha may cause precision problems.
  ConvergenceWarning)
/anaconda3/lib/python3.6/site-packages/sklearn/linear_model/coordina
te_descent.py:492: ConvergenceWarning: Objective did not converge. Y
ou might want to increase the number of iterations. Fitting data wit
h very small alpha may cause precision problems.
  ConvergenceWarning)
```
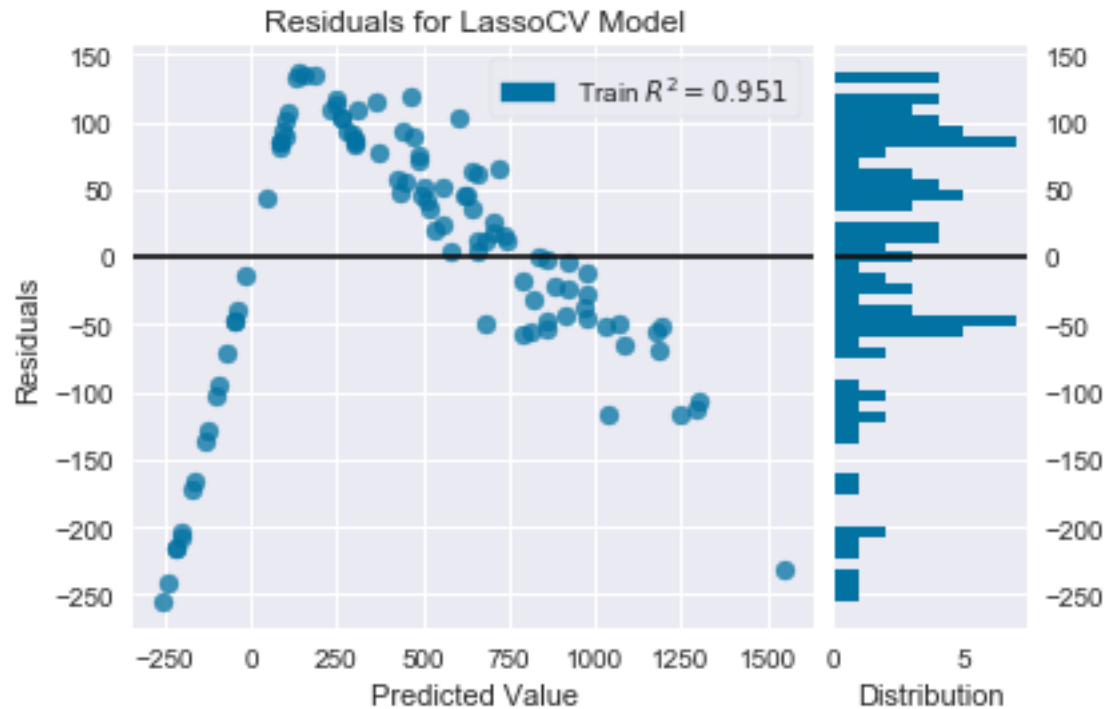

From the residual plots above, we can't really tell which model performs best. But from my answer from 2g, we know ridge performs best, then lasso, then subset selection.

In [553]:

```
print(var_names[1025])
print(var_names_2e_validation[1827])
print(var_names_2f_validation[1991])
```

```
('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Yes_student')
('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Male', 'Yes_student',
'African_American')
('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Male', 'Yes_student',
'Yes_married', 'African_American')
```

According to outputs above, the best predictors from subset selection are: ('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Student');

best predictors from ridge regression are: ('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Gender', 'Student', 'African_American');

best predictors from Lasso regression are: ('Income', 'Limit', 'Rating', 'Cards', 'Age', 'Gender', 'Student', 'Married', 'African_American').