6.5.3 Choosing Among Models Using the Validation Set Approach and Cross-Validation

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```
In [1]: # conventional way to import pandas
        import pandas as pd
        # conventional way to import seaborn
        import seaborn as sns
        # conventional way to import numpy
        import numpy as np

        from sklearn import metrics
        import matplotlib.pyplot as plt

        data = pd.read_csv("https://vincentarelbundock.github.io/Rdatasets/csv/ISLR/Hitters.csv

        data.head()
```

```
Out[1]:                    AtBat  Hits  HmRun  Runs  RBI  Walks  Years  CAtBat  CHits  \
        -Andy Allanson       293    66      1    30   29     14      1     293     66
        -Alan Ashby          315    81      7    24   38     39     14    3449    835
        -Alvin Davis         479   130     18    66   72     76      3    1624    457
        -Andre Dawson        496   141     20    65   78     37     11    5628   1575
        -Andres Galarraga    321    87     10    39   42     30      2     396    101

                           CHmRun  CRuns  CRBI  CWalks League Division  PutOuts  \
        -Andy Allanson          1     30    29      14      A        E      446
        -Alan Ashby            69    321   414     375      N        W      632
        -Alvin Davis           63    224   266     263      A        W      880
        -Andre Dawson         225    828   838     354      N        E      200
        -Andres Galarraga      12     48    46      33      N        E      805

                           Assists  Errors  Salary NewLeague
        -Andy Allanson          33      20     NaN         A
        -Alan Ashby             43      10   475.0         N
        -Alvin Davis            82      14   480.0         A
        -Andre Dawson           11       3   500.0         N
        -Andres Galarraga       40       4    91.5         N
```

After listing the data we can see that some have missing data for their Salary. Next drop all the rows that contain NaN data.

```
In [2]: data = data.dropna()
        data.index.name = 'Player'
        data.head()
```

```
Out[2]:                     AtBat  Hits  HmRun  Runs  RBI  Walks  Years  CAtBat  CHits  \
        Player
        -Alan Ashby           315    81      7    24   38     39     14    3449    835
        -Alvin Davis          479   130     18    66   72     76      3    1624    457
        -Andre Dawson         496   141     20    65   78     37     11    5628   1575
        -Andres Galarraga     321    87     10    39   42     30      2     396    101
        -Alfredo Griffin      594   169      4    74   51     35     11    4408   1133

                            CHmRun  CRuns  CRBI  CWalks League Division  PutOuts  \
        Player
        -Alan Ashby             69    321   414     375      N        W      632
        -Alvin Davis            63    224   266     263      A        W      880
        -Andre Dawson          225    828   838     354      N        E      200
        -Andres Galarraga       12     48    46      33      N        E      805
        -Alfredo Griffin        19    501   336     194      A        W      282

                            Assists  Errors  Salary NewLeague
        Player
        -Alan Ashby              43      10   475.0         N
        -Alvin Davis             82      14   480.0         A
        -Andre Dawson            11       3   500.0         N
        -Andres Galarraga        40       4    91.5         N
        -Alfredo Griffin        421      25   750.0         A
```

Change the string values into dummy values

```
In [3]: dummieVariables = pd.get_dummies(data[['League', 'Division', 'NewLeague']])
        dummieVariables.info()
        print(dummieVariables.head())

        y = data.Salary
        X_ = data.drop(['Salary', 'League', 'Division', 'NewLeague'], axis=1).astype('float64'

        X = pd.concat([X_, dummieVariables[['League_N', 'Division_W', 'NewLeague_N']]], axis=1
        X.head()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 263 entries, -Alan Ashby to -Willie Wilson
Data columns (total 6 columns):
League_A       263 non-null uint8
League_N       263 non-null uint8
Division_E     263 non-null uint8
Division_W     263 non-null uint8
NewLeague_A    263 non-null uint8
NewLeague_N    263 non-null uint8
```

```
dtypes: uint8(6)
memory usage: 3.6+ KB
                   League_A  League_N  Division_E  Division_W  NewLeague_A  \
Player
-Alan Ashby               0         1           0           1            0
-Alvin Davis              1         0           0           1            1
-Andre Dawson             0         1           1           0            0
-Andres Galarraga         0         1           1           0            0
-Alfredo Griffin          1         0           0           1            1

                   NewLeague_N
Player
-Alan Ashby                  1
-Alvin Davis                 0
-Andre Dawson                1
-Andres Galarraga            1
-Alfredo Griffin             0
```

```
Out[3]:                    AtBat   Hits  HmRun  Runs   RBI  Walks  Years  CAtBat  \
        Player
        -Alan Ashby        315.0   81.0    7.0  24.0  38.0   39.0   14.0  3449.0
        -Alvin Davis       479.0  130.0   18.0  66.0  72.0   76.0    3.0  1624.0
        -Andre Dawson      496.0  141.0   20.0  65.0  78.0   37.0   11.0  5628.0
        -Andres Galarraga  321.0   87.0   10.0  39.0  42.0   30.0    2.0   396.0
        -Alfredo Griffin   594.0  169.0    4.0  74.0  51.0   35.0   11.0  4408.0

                            CHits  CHmRun  CRuns   CRBI  CWalks  PutOuts  Assists  \
        Player
        -Alan Ashby         835.0    69.0  321.0  414.0   375.0    632.0     43.0
        -Alvin Davis        457.0    63.0  224.0  266.0   263.0    880.0     82.0
        -Andre Dawson      1575.0   225.0  828.0  838.0   354.0    200.0     11.0
        -Andres Galarraga   101.0    12.0   48.0   46.0    33.0    805.0     40.0
        -Alfredo Griffin   1133.0    19.0  501.0  336.0   194.0    282.0    421.0

                           Errors  League_N  Division_W  NewLeague_N
        Player
        -Alan Ashby          10.0         1           1            1
        -Alvin Davis         14.0         0           1            0
        -Andre Dawson         3.0         1           0            1
        -Andres Galarraga     4.0         1           0            1
        -Alfredo Griffin     25.0         0           1            0
```

Now we will split the data into a traning and testing set

```
In [4]: from sklearn.model_selection import train_test_split
        X_train, X_test, y_train, y_test = train_test_split(X, y, random_state=1)
```

bla bla

```
In [5]: import itertools
        import statsmodels.api as sm
        max_feature=18


        # Functions found at "https://github.com/qx0731/ISL_python/blob/master/Chapter_6_sec_6
        def validateRSS(y_train, X_train, y_test, X_test, predictors_list):
            model = sm.OLS(y_train, X_train[list(predictors_list)]).fit()
            RSS = ((model.predict(X_test[list(predictors_list)]) - y_test) ** 2).sum()
            return {'Model':model, "RSS":RSS}

        def validateBestModel(y_train, X_train, y_test, X_test, K):
            results = []
            for c in itertools.combinations(X_train.columns, K):
                results.append(validateRSS(y_train, X_train, y_test, X_test, c))
            allModels =  pd.DataFrame(results)

            bestModel = allModels.loc[allModels["RSS"].argmin()]
            return bestModel


        def validateForwardStepwiseSelection(y_train, X_train, y_test, X_test, predictors_list
            remaining_predictors = [p for p in X_train.columns if p not in predictors_list]
            results = []
            for p in remaining_predictors:
                results.append(validateRSS(y_train, X_train, y_test, X_test, predictors_list+[

            allModels = pd.DataFrame(results)
            bestModel = allModels.loc[allModels['RSS'].argmin()]
            return bestModel

        def validateBackwardStepwiseSelection(y_train, X_train, y_test, X_test, predictors_lis
            results = []
            for combo in itertools.combinations(predictors_list, len(predictors_list)-1):
                results.append(validateRSS(y_train, X_train, y_test, X_test,  combo))

            allModels = pd.DataFrame(results)
            bestModel = allModels.loc[allModels['RSS'].argmin()]
            return bestModel
```

```
C:\Users\au479931\AppData\Local\Continuum\anaconda3\lib\site-packages\statsmodels\compat\panda
  from pandas.core import datetools
```

bla bla

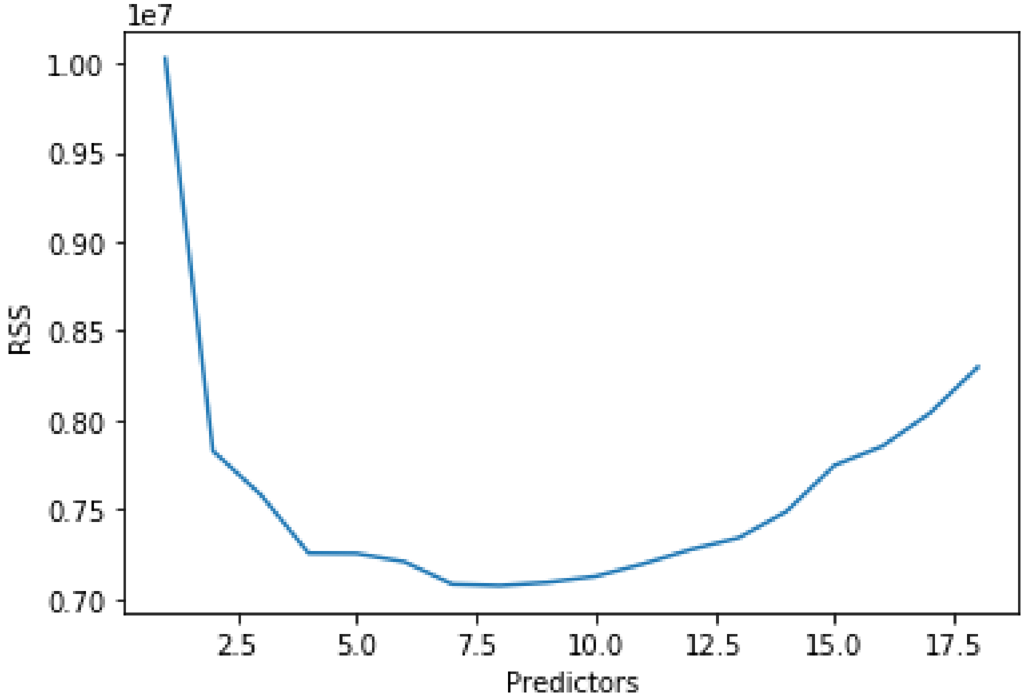
```
In [6]: validationModels = pd.DataFrame(columns=["RSS", "Model"])
        for i in range(1,(max_feature+1)):
            validationModels.loc[i] = validateBestModel(y_train, X_train, y_test, X_test, i)


        validationModelsForward = pd.DataFrame(columns=["RSS", "Model"])
        predictors_list = []
        for i in range(1,len(X.columns)+1):
            validationModelsForward.loc[i] = validateForwardStepwiseSelection(y_train, X_train
            predictors_list = validationModelsForward.loc[i]["Model"].model.exog_names
```

```
C:\Users\au479931\AppData\Local\Continuum\anaconda3\lib\site-packages\ipykernel_launcher.py:18
C:\Users\au479931\AppData\Local\Continuum\anaconda3\lib\site-packages\ipykernel_launcher.py:29
```

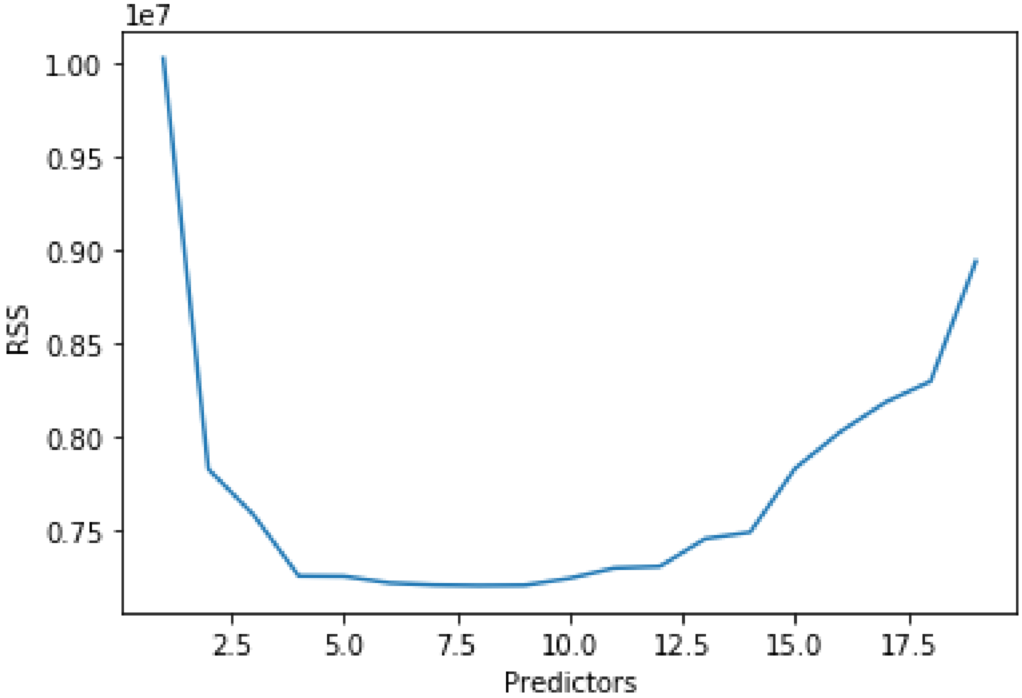
bla bla

```
In [7]: plt.figure()
        plt.plot(validationModels["RSS"])
        plt.xlabel('Predictors')
        plt.ylabel('RSS')
        plt.show()
```

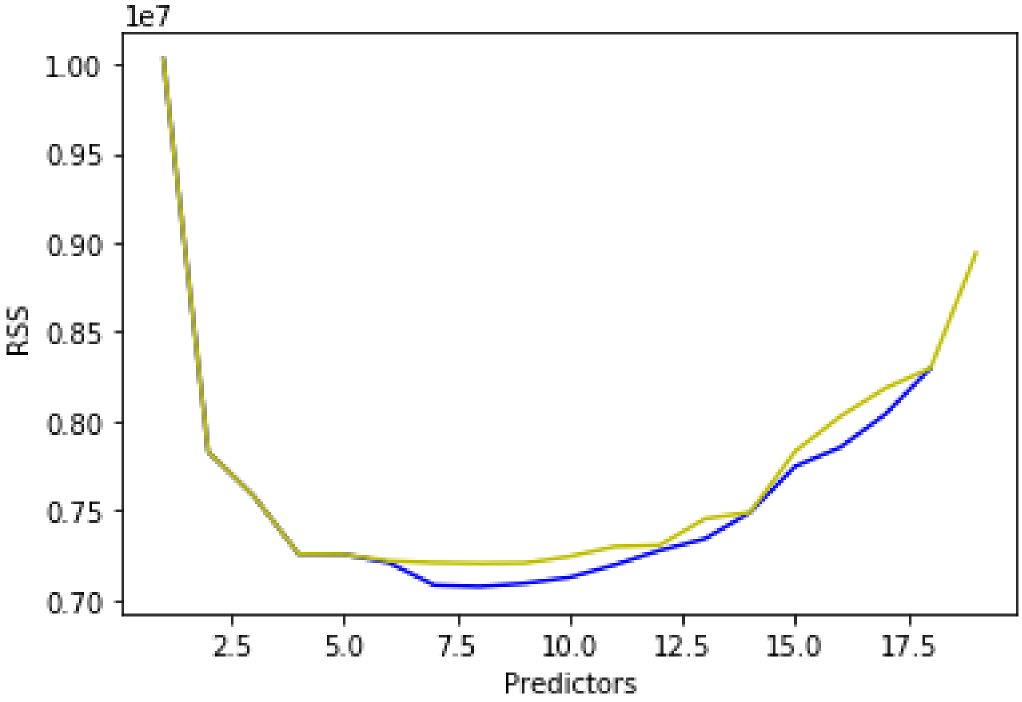


bla bla

```
In [8]: plt.figure()
        plt.plot(validationModelsForward["RSS"])
        plt.xlabel('Predictors')
        plt.ylabel('RSS')
        plt.show()
```



```
In [16]: plt.figure()
         plt.plot(validationModels["RSS"],'b')
         plt.plot(validationModelsForward["RSS"],'y')
         plt.xlabel('Predictors')
         plt.ylabel('RSS')
         plt.show()
```



Now we've tried to validate best subset and forward stepwise selection, let's continue with Cross-Validation

```
In [9]: k = 10
        np.random.seed(seed = 21)
        train_index = np.random.choice(k, size = len(y), replace = True)
        crossValidationErrors = pd.DataFrame(columns=range(1,k+1), index=range(1,len(X.columns
```

bla bla

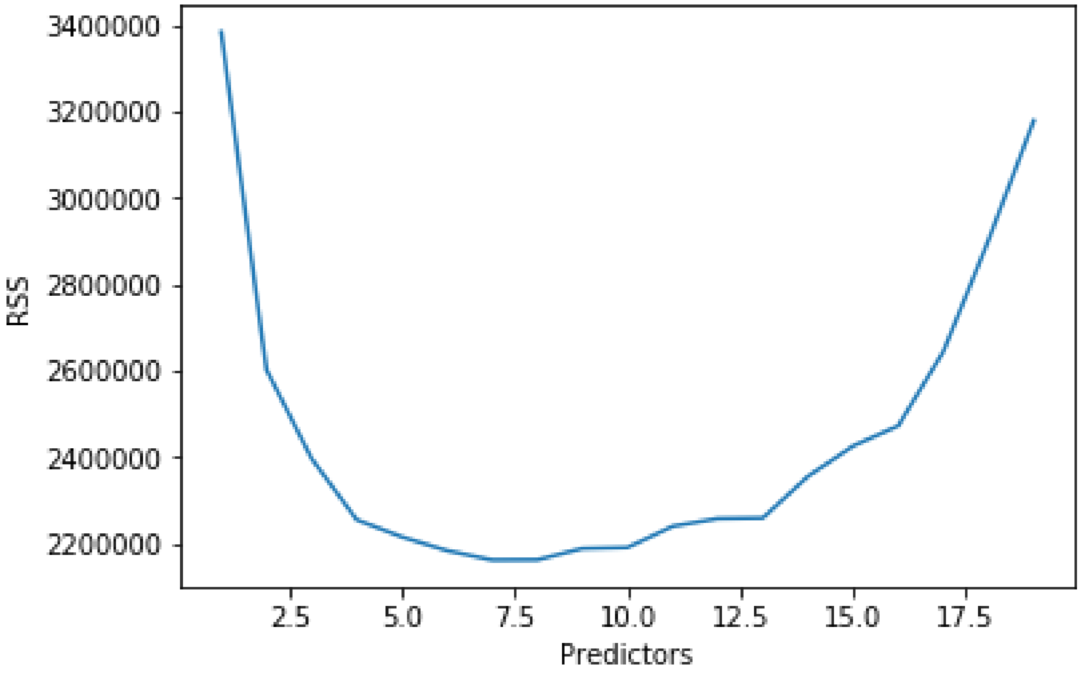
```
In [10]: crossValidationModels = pd.DataFrame(columns=["RSS", "Model"])
         for j in range(1,k+1):
             predictors_list = []
             for i in range(1,len(X.columns)+1):
                 crossValidationModels.loc[i] = validateForwardStepwiseSelection(y[train_index

                 crossValidationErrors[j][i] = crossValidationModels.loc[i]["RSS"]
                 predictors_list = crossValidationModels.loc[i]["Model"].model.exog_names
```

```
C:\Users\au479931\AppData\Local\Continuum\anaconda3\lib\site-packages\ipykernel_launcher.py:29
```

bla bla

```
In [11]: crossValidationMeanErrors = crossValidationErrors.mean(axis = 1)
         plt.figure()
         plt.plot(crossValidationMeanErrors)
         plt.xlabel('Predictors')
         plt.ylabel('RSS')
         plt.show()
```



bla bla

```
In [12]: print(crossValidationModels.loc[5, "Model"].summary())
```

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                 Salary   R-squared:                       0.771
Model:                            OLS   Adj. R-squared:                  0.766
Method:                 Least Squares   F-statistic:                     155.0
Date:                Fri, 04 May 2018   Prob (F-statistic):           1.40e-71
Time:                        17:52:26   Log-Likelihood:                -1704.1
No. Observations:                 235   AIC:                             3418.
Df Residuals:                     230   BIC:                             3435.
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
Walks          6.3470      0.934      6.795      0.000       4.507       8.187
CHits          1.3658      0.353      3.869      0.000       0.670       2.061
CAtBat        -0.2803      0.103     -2.713      0.007      -0.484      -0.077
```

```
PutOuts        0.2629      0.083      3.167      0.002       0.099       0.426
CWalks        -0.1555      0.228     -0.681      0.496      -0.605       0.294
==============================================================================
Omnibus:                       95.002   Durbin-Watson:                   2.014
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              564.877
Skew:                           1.469   Prob(JB):                    2.18e-123
Kurtosis:                      10.004   Cond. No.                         153.
==============================================================================

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
```