In [1]:

```
#Import Libraries
import csv
import numpy as np
import pandas as pd

### Import Descision Tree Classifier
from sklearn.ensemble import RandomForestRegressor
from sklearn.neighbors import KNeighborsRegressor
from sklearn.svm import SVR
from sklearn.linear_model import LinearRegression
from sklearn.ensemble import GradientBoostingRegressor

from sklearn.preprocessing import scale
from sklearn.decomposition import PCA
from sklearn.ensemble import VotingRegressor

from sklearn.model_selection import train_test_split
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import GridSearchCV

# Perform the necessary imports
import matplotlib.pyplot as plt
## for pearsonr correlation just feed x and y to this
from scipy.stats import pearsonr
pd.options.display.max_columns=60
#Change the Number Fromat of DATA frame
pd.options.display.float_format = '{:,.4f}'.format
```

In [2]:

```
### Load the Data
seed=40
SEED=40
path="C:\\Users\\fbaharkoush\\IE 598 Machine Learning\\Homework\\Group Project\\"
df_Eco=pd.read_csv(path+"MLF_GP2_EconCycle.csv").drop("Date",axis=1)
if df_Eco.isnull().sum().sum()==0:
    print("No Missing Values in the dataset")
```

```
No Missing Values in the dataset
```

In [3]:

```
df_Eco.describe()
```

Out[3]:

| | T1Y Index | T2Y Index | T3Y Index | T5Y Index | T7Y Index | T10Y Index | CP1M | CP3M | CP6M | CP1M_T1 |
|---|---|---|---|---|---|---|---|---|---|---|
| **count** | 223.0000 | 223.0000 | 223.0000 | 223.0000 | 223.0000 | 223.0000 | 223.0000 | 223.0000 | 223.0000 | 223.000 |
| **mean** | 8.0307 | 8.4107 | 8.5636 | 8.8087 | 8.9798 | 9.0735 | 7.9422 | 7.9369 | 7.8928 | 0.981 |
| **std** | 3.1586 | 2.9544 | 2.8204 | 2.6477 | 2.5427 | 2.4475 | 3.4051 | 3.3294 | 3.1814 | 0.086 |
| **min** | 3.1800 | 3.8400 | 4.1700 | 4.7100 | 5.0500 | 5.3300 | 3.1100 | 3.1400 | 3.1900 | 0.717 |
| **25%** | 5.7350 | 6.1800 | 6.4100 | 6.6950 | 6.9650 | 7.1750 | 5.6050 | 5.6450 | 5.6350 | 0.933 |
| **50%** | 7.6700 | 8.0000 | 8.1300 | 8.3300 | 8.5200 | 8.6100 | 7.7300 | 7.7200 | 7.6200 | 0.972 |
| **75%** | 9.8400 | 10.0750 | 10.3750 | 10.5250 | 10.6400 | 10.6850 | 9.3450 | 9.3450 | 9.3000 | 1.033 |
| **max** | 16.7200 | 16.4600 | 16.2200 | 15.9300 | 15.6500 | 15.3200 | 18.9500 | 18.0700 | 16.6600 | 1.339 |

In [4]:
```
df_Eco.head(1)
```

Out[4]:

| | T1Y Index | T2Y Index | T3Y Index | T5Y Index | T7Y Index | T10Y Index | CP1M | CP3M | CP6M | CP1M_T1Y | CP3M_T1Y | CP6M_T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 10.4100 | 9.8600 | 9.5000 | 9.2000 | 9.1400 | 9.1000 | 9.7500 | 9.9500 | 10.0100 | 0.9366 | 0.9558 | 0.96 |

In [5]:
```
traget_variables=['USPHCI', 'PCT 3MO FWD', 'PCT 6MO FWD', 'PCT 9MO FWD']
X_features=list(df_Eco.drop(traget_variables,axis=1).columns)
```

In [6]:
```
X=scale(df_Eco[X_features].values)
```

## PCA

In [7]:
```
# Create PCA instance: model
pca_model = PCA()
### Fit the Features value to PCA
pca_model.fit_transform(X)
```

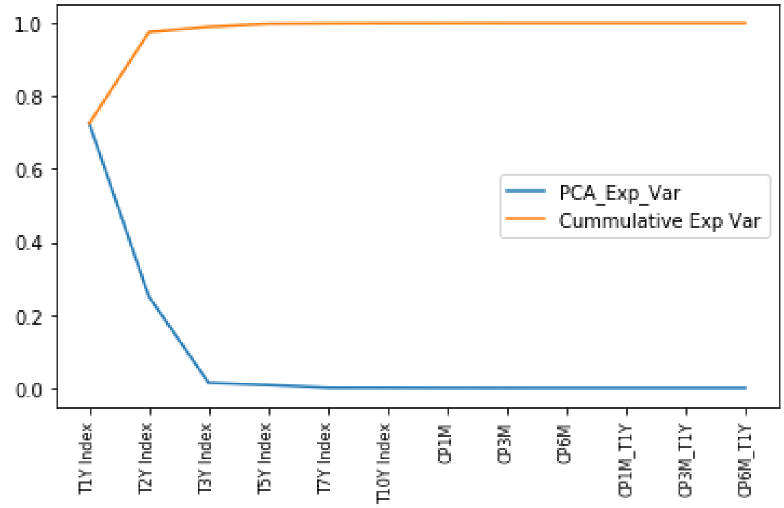
Out[7]:
```
array([[ 1.11214451e+00,  6.17581349e-01, -4.41063547e-01, ...,
         1.34097620e-02, -9.99721397e-03,  2.28652184e-03],
       [ 1.06203268e+00,  3.41115562e-01, -3.92792807e-01, ...,
        -6.70512415e-03, -1.91876227e-03,  6.22659904e-03],
       [ 1.06821108e+00,  4.97441887e-01, -4.55770468e-01, ...,
        -7.21509588e-03,  8.06870412e-04,  5.13546008e-03],
       ...,
       [-2.35968182e+00,  9.69941838e-02, -2.47184098e-01, ...,
        -3.81553651e-03,  3.87635866e-03,  6.92349229e-04],
       [-2.47206142e+00, -3.28048208e-01, -2.50716222e-01, ...,
        -5.40530754e-03,  2.34832833e-03, -5.93912041e-04],
       [-2.57943927e+00, -9.21334922e-01, -1.90554111e-01, ...,
        -1.08503357e-02,  1.86035254e-03, -1.59232533e-03]])
```

In [8]:
```
df_pca_exp_var=pd.DataFrame({"Features":X_features,
              "PCA_Exp_Var":pca_model.explained_variance_ratio_}).sort_values("PCA_Exp_V
df_pca_exp_var["Cummulative Exp Var"]=df_pca_exp_var["PCA_Exp_Var"].cumsum()
df_pca_exp_var.head()
```

Out[8]:

| | Features | PCA_Exp_Var | Cummulative Exp Var |
|---|---|---|---|
| **0** | T1Y Index | 0.7250 | 0.7250 |
| **1** | T2Y Index | 0.2505 | 0.9755 |
| **2** | T3Y Index | 0.0145 | 0.9899 |
| **3** | T5Y Index | 0.0085 | 0.9984 |
| **4** | T7Y Index | 0.0007 | 0.9991 |

In [9]:
```
plotX = df_pca_exp_var.iloc[:, 0]
plotY1 = df_pca_exp_var.iloc[:, 1]
plotY2 = df_pca_exp_var.iloc[:, 2]
plt.xticks(rotation=90)
plt.plot(plotX, plotY1)
plt.plot(plotX, plotY2)
plt.legend(['PCA_Exp_Var', 'Cummulative Exp Var'])
plt.tick_params(axis='x', which='major', labelsize=8)
plt.tight_layout()
```



The PCA shows 99% of the data is captured through the first 4 features.

In [10]:
```
### Selecting Features thats explaince 99% of the data accroding to PCA
X_features_pca=list(df_pca_exp_var[df_pca_exp_var["Cummulative Exp Var"]<=.999]["Feature
X_pca=scale(df_Eco[X_features_pca].values)
```

In [13]:
```
print("List of Principle Components",X_features_pca)
```

```
List of Principle Components ['T1Y Index', 'T2Y Index', 'T3Y Index', 'T5Y Index']
```

## 1. Linear Regression

In [11]:
```
lr_model=LinearRegression()
```

In [12]:
```
list_of_r_square_train=[]
list_of_r_square_test=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.25,random_state=SEED)
    lr_model.fit(X_train,y_train)
    list_of_r_square_train.append(lr_model.score(X_train, y_train))
    list_of_r_square_test.append(lr_model.score(X_test, y_test))
```

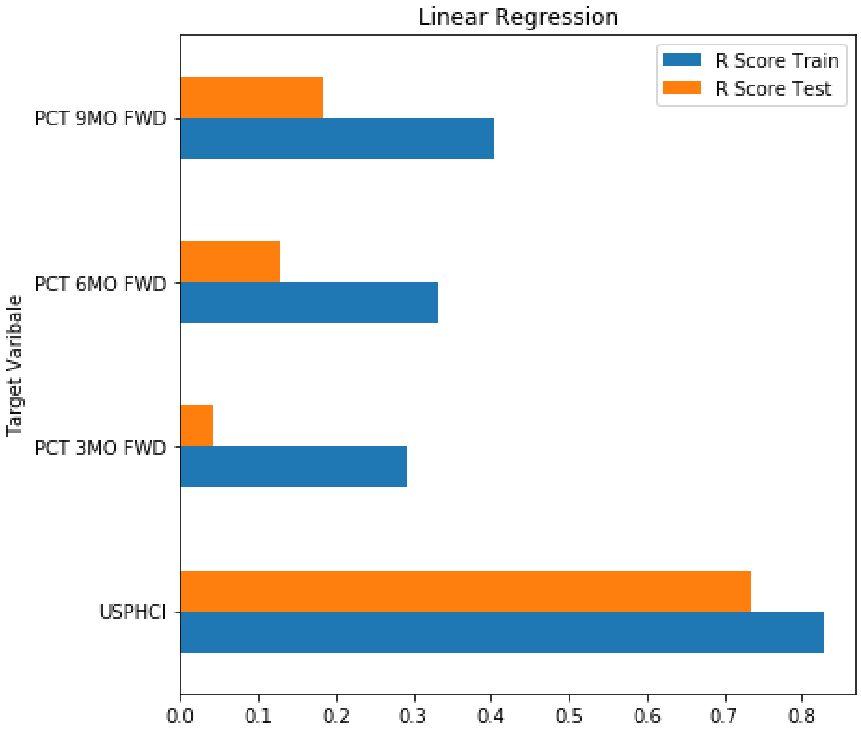
In [14]:
```
df_linear_reg_summarry=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test})
df_linear_reg_summarry["PCA"]=False
df_linear_reg_summarry['Model']='Linear Regression'
df_linear_reg_summarry
```

Out[14]:

| | Target Varibale | R Score Train | R Score Test | PCA | Model |
|---|---|---|---|---|---|
| **0** | USPHCI | 0.8274 | 0.7349 | False | Linear Regression |
| **1** | PCT 3MO FWD | 0.2913 | 0.0413 | False | Linear Regression |
| **2** | PCT 6MO FWD | 0.3330 | 0.1293 | False | Linear Regression |
| **3** | PCT 9MO FWD | 0.4048 | 0.1827 | False | Linear Regression |

In [15]:
```
df_linear_reg_summarry.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="Linea
```

Out[15]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1dd6a2df048>
```



## 1.1 Linear Regression

In [16]:
```
del X_train,X_test,y_train,y_test , lr_model
```

In [17]:
```
lr_model=LinearRegression()
```

In [18]:
```
list_of_r_square_train=[]
list_of_r_square_test=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X_pca,y,test_size=0.25,random_state=2
    lr_model.fit(X_train,y_train)
    list_of_r_square_train.append(lr_model.score(X_train, y_train))
    list_of_r_square_test.append(lr_model.score(X_test, y_test))
```

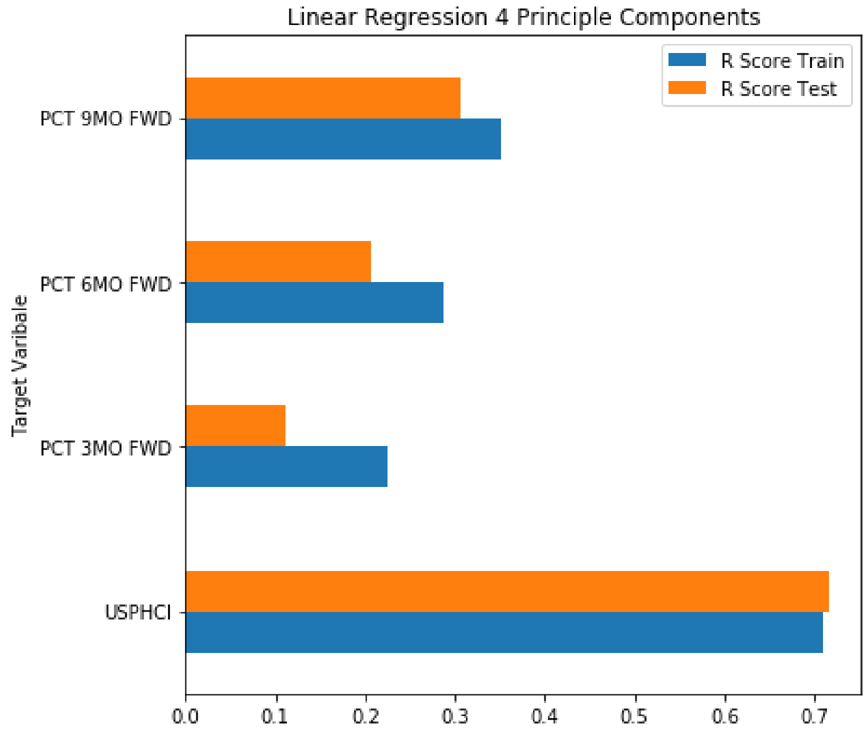
In [21]:
```
df_linear_reg_summary_pca=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test})
df_linear_reg_summary_pca["PCA"]=True
df_linear_reg_summary_pca["Model"]="Linear Regression"
df_linear_reg_summary_pca
```

Out[21]:

| | Target Varibale | R Score Train | R Score Test | PCA | Model |
|---|---|---|---|---|---|
| **0** | USPHCI | 0.7093 | 0.7157 | True | Linear Regression |
| **1** | PCT 3MO FWD | 0.2246 | 0.1112 | True | Linear Regression |
| **2** | PCT 6MO FWD | 0.2875 | 0.2069 | True | Linear Regression |
| **3** | PCT 9MO FWD | 0.3521 | 0.3059 | True | Linear Regression |

In [22]:
```
df_linear_reg_summary_pca.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),
                               title="Linear Regression 4 Principle Components")
```

Out[22]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1dd6f593c88>
```



## 2. Fitting SVR

In [23]:
```
del X_train,X_test,y_train,y_test
```

In [24]:
```
### Instantiate a random forests regressor 'rf'
svr_model = SVR(gamma='auto')
### Parameter
params_svr = {
'kernel': ['linear', 'poly', 'rbf', 'sigmoid'],
'degree': [1,2,3,4, 6, 8],
'C': [1,2,3,4,5]}
```

In [25]:
```
list_of_r_square_train=[]
list_of_r_square_test=[]
list_of_r_best_param=[]
list_of_grid_sarch_best_score=[]
list_of_svr_best_estimator=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.25,random_state=seed)
    svr_grid_search=GridSearchCV(estimator=svr_model,
                 param_grid=params_svr,iid=False,
                 cv=10,
                 scoring='r2',
                 verbose=1,
                 n_jobs=-1)
    svr_grid_search.fit(X_train, y_train)
    list_of_r_square_train.append(svr_grid_search.score(X_train, y_train))
    list_of_r_square_test.append(svr_grid_search.score(X_test, y_test))
    list_of_grid_sarch_best_score.append(svr_grid_search.best_score_)
    list_of_svr_best_estimator.append(svr_grid_search.best_estimator_)
    list_of_r_best_param.append(svr_grid_search.best_params_)
```

```
Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:    4.1s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:    3.2s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:    3.4s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:    3.9s finished
```

In [27]:

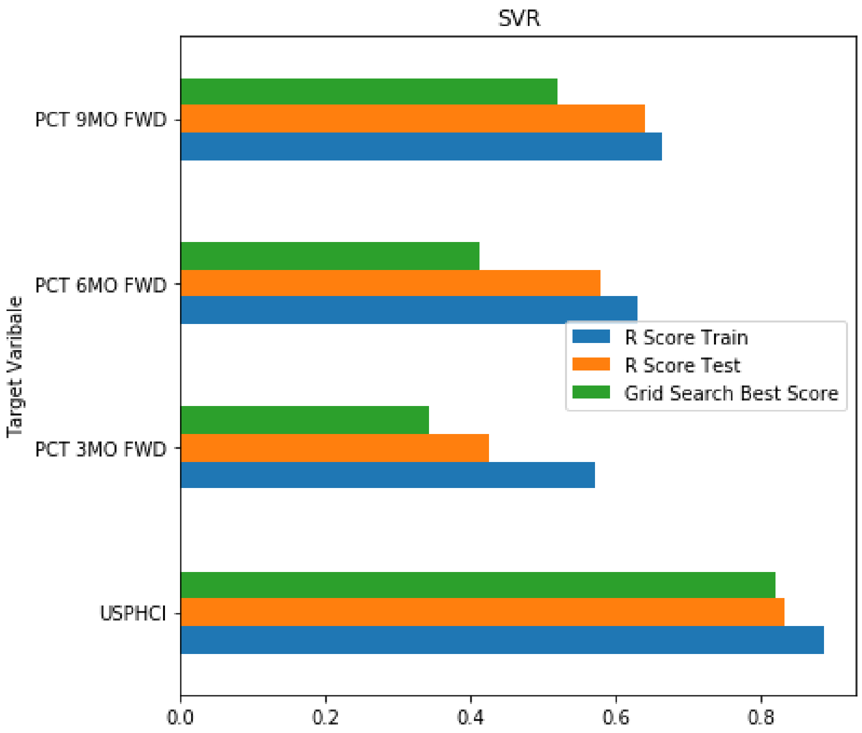
```
df_svr_summary=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test,
             "Grid Search Best Score":list_of_grid_sarch_best_score,
             "Best Estimator":list_of_svr_best_estimator,
             "Best Parameters":list_of_r_best_param})
df_svr_summary["PCA"]=False
df_svr_summary["Model"]="SVR"
df_svr_summary
```

Out[27]:

| | Target Varibale | R Score Train | R Score Test | Grid Search Best Score | Best Estimator | Best Parameters | PCA | Model |
|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.8861 | 0.8333 | 0.8193 | SVR(C=5, cache_size=200, coef0=0.0, degree=1, ... | {'C': 5, 'degree': 1, 'kernel': 'rbf'} | False | SVR |
| **1** | PCT 3MO FWD | 0.5703 | 0.4249 | 0.3425 | SVR(C=2, cache_size=200, coef0=0.0, degree=1, ... | {'C': 2, 'degree': 1, 'kernel': 'rbf'} | False | SVR |
| **2** | PCT 6MO FWD | 0.6293 | 0.5779 | 0.4128 | SVR(C=3, cache_size=200, coef0=0.0, degree=1, ... | {'C': 3, 'degree': 1, 'kernel': 'rbf'} | False | SVR |
| **3** | PCT 9MO FWD | 0.6634 | 0.6391 | 0.5191 | SVR(C=3, cache_size=200, coef0=0.0, degree=1, ... | {'C': 3, 'degree': 1, 'kernel': 'rbf'} | False | SVR |

In [28]:
```
df_svr_summary.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="SVR")
```

Out[28]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1dd6f889160>
```



## 2.1 SVR with 4 Principle Components Explananing 99% of Variance

In [29]:
```
del X_train,X_test,y_train,y_test, svr_model , svr_grid_search
```

In [30]:
```
### Instantiate a random forests regressor 'rf'
svr_model = SVR(gamma='auto')
### Parameter
params_svr = {
'kernel': ['linear', 'poly', 'rbf', 'sigmoid'],
'degree': [1,2,3,4, 6, 8],
'C': [1,2,3,4,5]}
```

In [31]:

```python
list_of_r_square_train=[]
list_of_r_square_test=[]
list_of_r_best_param=[]
list_of_grid_sarch_best_score=[]
list_of_svr_best_estimator=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X_pca,y,test_size=0.25,random_state=s
    svr_grid_search=GridSearchCV(estimator=svr_model,
                 param_grid=params_svr,iid=False,
                 cv=10,
                 scoring='r2',
                 verbose=1,
                 n_jobs=-1)
    svr_grid_search.fit(X_train, y_train)
    list_of_r_square_train.append(svr_grid_search.score(X_train, y_train))
    list_of_r_square_test.append(svr_grid_search.score(X_test, y_test))
    list_of_grid_sarch_best_score.append(svr_grid_search.best_score_)
    list_of_svr_best_estimator.append(svr_grid_search.best_estimator_)
    list_of_r_best_param.append(svr_grid_search.best_params_)
```

```
Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:  1.8min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:  1.8min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:  1.5min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 120 candidates, totalling 1200 fits

[Parallel(n_jobs=-1)]: Done 1200 out of 1200 | elapsed:  2.1min finished
```

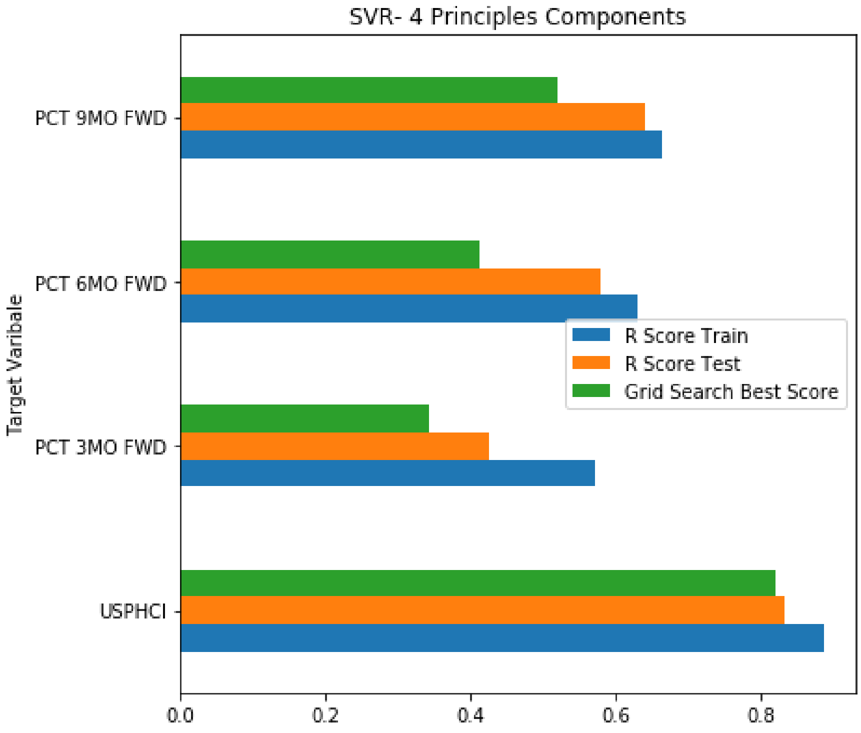
In [34]:
```
df_svr_summary_pca=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test,
             "Grid Search Best Score":list_of_grid_sarch_best_score,
             "Best Estimator":list_of_svr_best_estimator,
             "Best Parameters":list_of_r_best_param})
df_svr_summary_pca["PCA"]=True
df_svr_summary_pca["Model"]="SVR"
df_svr_summary_pca
```

Out[34]:

| | Target Varibale | R Score Train | R Score Test | Grid Search Best Score | Best Estimator | Best Parameters | PCA | Model |
|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.7779 | 0.7525 | 0.7244 | SVR(C=4, cache_size=200, coef0=0.0, degree=1, ... | {'C': 4, 'degree': 1, 'kernel': 'rbf'} | True | SVR |
| **1** | PCT 3MO FWD | 0.4316 | 0.2722 | 0.2216 | SVR(C=2, cache_size=200, coef0=0.0, degree=1, ... | {'C': 2, 'degree': 1, 'kernel': 'rbf'} | True | SVR |
| **2** | PCT 6MO FWD | 0.5150 | 0.4544 | 0.3109 | SVR(C=5, cache_size=200, coef0=0.0, degree=1, ... | {'C': 5, 'degree': 1, 'kernel': 'rbf'} | True | SVR |
| **3** | PCT 9MO FWD | 0.5351 | 0.5345 | 0.4164 | SVR(C=5, cache_size=200, coef0=0.0, degree=1, ... | {'C': 5, 'degree': 1, 'kernel': 'rbf'} | True | SVR |

In [35]:
```
df_svr_summary.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="SVR- 4 Princi
```

Out[35]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1dd6faa4160>
```



### 3. KNeighborsRegressor

In [36]:

```
### Instantiate a random forests regressor 'rf'
knn_model = KNeighborsRegressor()
### Parameter
params_kkn = {
'n_neighbors': list(range(1, 100)),
'p': [1,2]}
```

In [37]:

```
list_of_r_square_train=[]
list_of_r_square_test=[]
list_of_r_best_param=[]
list_of_grid_sarch_best_score=[]
list_of_svr_best_estimator=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.25,random_state=seed)
    knn_grid_search=GridSearchCV(estimator=knn_model,
                 param_grid=params_kkn,
                                 iid=False,
                                 cv=10,
                                 scoring='r2',
                                 n_jobs=-1,
                                 verbose=1)
    knn_grid_search.fit(X_train, y_train)
    list_of_r_square_train.append(knn_grid_search.score(X_train, y_train))
    list_of_r_square_test.append(knn_grid_search.score(X_test, y_test))
    list_of_grid_sarch_best_score.append(knn_grid_search.best_score_)
    list_of_svr_best_estimator.append(knn_grid_search.best_estimator_)
    list_of_r_best_param.append(knn_grid_search.best_params_)
```

```
Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    1.0s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    1.0s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    0.8s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    0.7s finished
```

In [38]:

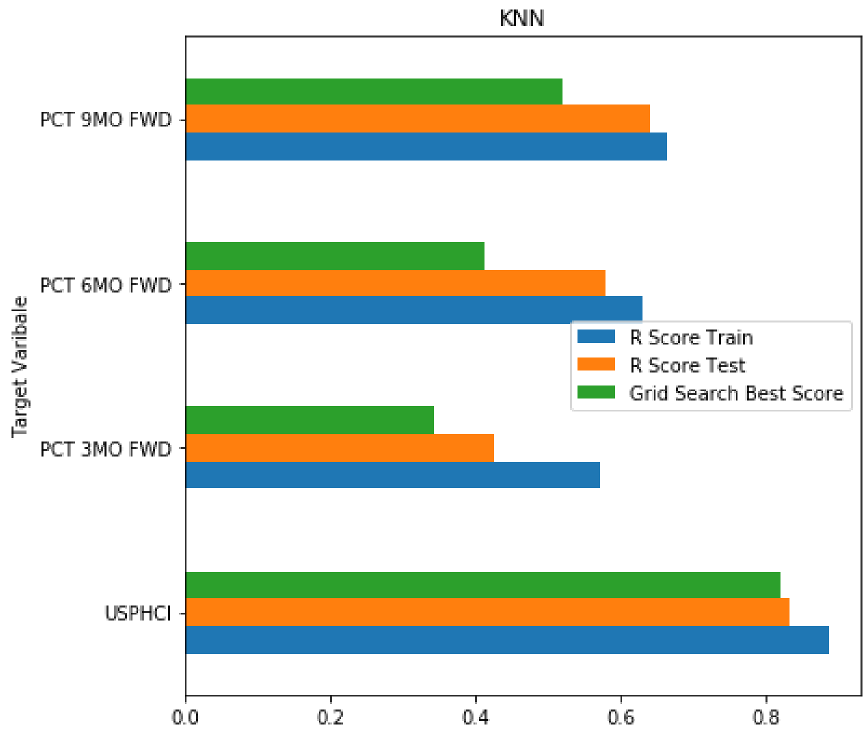
```
df_knn_summary=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test,
             "Grid Search Best Score":list_of_grid_sarch_best_score,
             "Best Estimator":list_of_svr_best_estimator,
             "Best Parameters":list_of_r_best_param})
df_knn_summary["PCA"]=False
df_knn_summary["Model"]="KNN Regressor"
df_knn_summary
```

Out[38]:

| | Target Varibale | R Score Train | R Score Test | Grid Search Best Score | Best Estimator | Best Parameters | PCA | Model |
|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.9366 | 0.8777 | 0.8468 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 3, 'p': 2} | False | KNN Regressor |
| **1** | PCT 3MO FWD | 0.4772 | 0.3656 | 0.2371 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 10, 'p': 2} | False | KNN Regressor |
| **2** | PCT 6MO FWD | 0.6178 | 0.6021 | 0.2792 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 6, 'p': 1} | False | KNN Regressor |
| **3** | PCT 9MO FWD | 0.6900 | 0.6978 | 0.4228 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 6, 'p': 1} | False | KNN Regressor |

In [39]:
```
df_svr_summary.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="KNN")
```

Out[39]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1dd6fba2908>
```



## 3.1 KNeighborsRegressor with 4 Principle Components Explananing 99% of Variance

In [40]:
```
del X_train,X_test,y_train,y_test, svr_model , svr_grid_search
```

In [41]:
```
### Instantiate a random forests regressor 'rf'
knn_model = KNeighborsRegressor()
### Parameter
params_kkn = {
'n_neighbors': list(range(1, 100)),
'p': [1,2]}
```

In [42]:

```
list_of_r_square_train=[]
list_of_r_square_test=[]
list_of_r_best_param=[]
list_of_grid_sarch_best_score=[]
list_of_svr_best_estimator=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X_pca,y,test_size=0.25,random_state=s
    knn_grid_search=GridSearchCV(estimator=knn_model,
                 param_grid=params_kkn,
                                 iid=False,
                                 cv=10,
                                 scoring='r2',
                                 n_jobs=-1,
                                 verbose=1)
    knn_grid_search.fit(X_train, y_train)
    list_of_r_square_train.append(knn_grid_search.score(X_train, y_train))
    list_of_r_square_test.append(knn_grid_search.score(X_test, y_test))
    list_of_grid_sarch_best_score.append(knn_grid_search.best_score_)
    list_of_svr_best_estimator.append(knn_grid_search.best_estimator_)
    list_of_r_best_param.append(knn_grid_search.best_params_)
```

```
Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    0.8s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    0.8s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    0.6s finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 198 candidates, totalling 1980 fits

[Parallel(n_jobs=-1)]: Done 1980 out of 1980 | elapsed:    0.7s finished
```

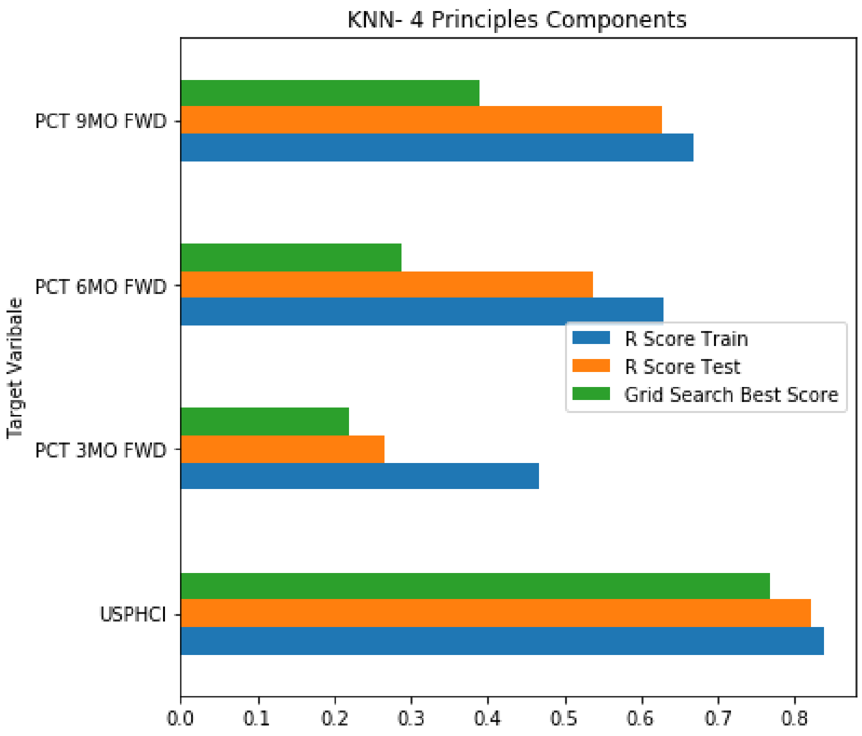
```
In [43]: df_knn_summary_pca=pd.DataFrame({"Target Varibale":traget_variables,
                       "R Score Train":list_of_r_square_train,
                      "R Score Test":list_of_r_square_test,
                      "Grid Search Best Score":list_of_grid_sarch_best_score,
                      "Best Estimator":list_of_svr_best_estimator,
                      "Best Parameters":list_of_r_best_param})
         df_knn_summary_pca["PCA"]=True
         df_knn_summary_pca["Model"]="KNN Regressor"
         df_knn_summary_pca
```

Out[43]:

| | Target Varibale | R Score Train | R Score Test | Grid Search Best Score | Best Estimator | Best Parameters | PCA | Model |
|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.8381 | 0.8210 | 0.7690 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 7, 'p': 2} | True | KNN Regressor |
| **1** | PCT 3MO FWD | 0.4665 | 0.2668 | 0.2189 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 11, 'p': 2} | True | KNN Regressor |
| **2** | PCT 6MO FWD | 0.6309 | 0.5364 | 0.2869 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 6, 'p': 1} | True | KNN Regressor |
| **3** | PCT 9MO FWD | 0.6696 | 0.6265 | 0.3893 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 6, 'p': 1} | True | KNN Regressor |

```
In [44]: df_knn_summary_pca.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="KNN- 4 Pr
```

```
Out[44]: <matplotlib.axes._subplots.AxesSubplot at 0x1dd6fd6a278>
```



## Random Forest Regressor

In [45]:

```
del X_train,X_test,y_train,y_test
```

In [46]:

```
rf_model = RandomForestRegressor(random_state= SEED)
params_rf = {
'n_estimators': [100,200,300,400],
'max_depth': [1,2,3,4,5,6],
'min_samples_leaf': [0.1,.12,.15, 0.2],
'max_features': ['log2','sqrt']}
```

In [47]:

```
list_of_r_square_train=[]
list_of_r_square_test=[]
list_of_r_best_param=[]
list_of_grid_sarch_best_score=[]
list_of_svr_best_estimator=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.25,random_state=seed)
    rf_grid_search=GridSearchCV(estimator=rf_model,
                 param_grid=params_rf,
                                iid=False,
                                cv=10,
                                scoring='r2',
                                n_jobs=-1,
                                verbose=1)
    rf_grid_search.fit(X_train, y_train)
    list_of_r_square_train.append(rf_grid_search.score(X_train, y_train))
    list_of_r_square_test.append(rf_grid_search.score(X_test, y_test))
    list_of_grid_sarch_best_score.append(rf_grid_search.best_score_)
    list_of_svr_best_estimator.append(rf_grid_search.best_estimator_)
    list_of_r_best_param.append(rf_grid_search.best_params_)
```

```
Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 144 tasks      | elapsed:    5.9s
[Parallel(n_jobs=-1)]: Done 744 tasks      | elapsed:   28.5s
[Parallel(n_jobs=-1)]: Done 1744 tasks      | elapsed:  1.1min
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.2min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Done 212 tasks      | elapsed:    8.2s
[Parallel(n_jobs=-1)]: Done 764 tasks      | elapsed:   29.0s
[Parallel(n_jobs=-1)]: Done 1514 tasks      | elapsed:   57.7s
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.2min finished

Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 212 tasks      | elapsed:    6.7s
[Parallel(n_jobs=-1)]: Done 1112 tasks      | elapsed:   36.2s
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.1min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Done 236 tasks      | elapsed:    7.5s
[Parallel(n_jobs=-1)]: Done 836 tasks      | elapsed:   27.8s
[Parallel(n_jobs=-1)]: Done 1836 tasks      | elapsed:  1.1min
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.1min finished
```

In [48]:

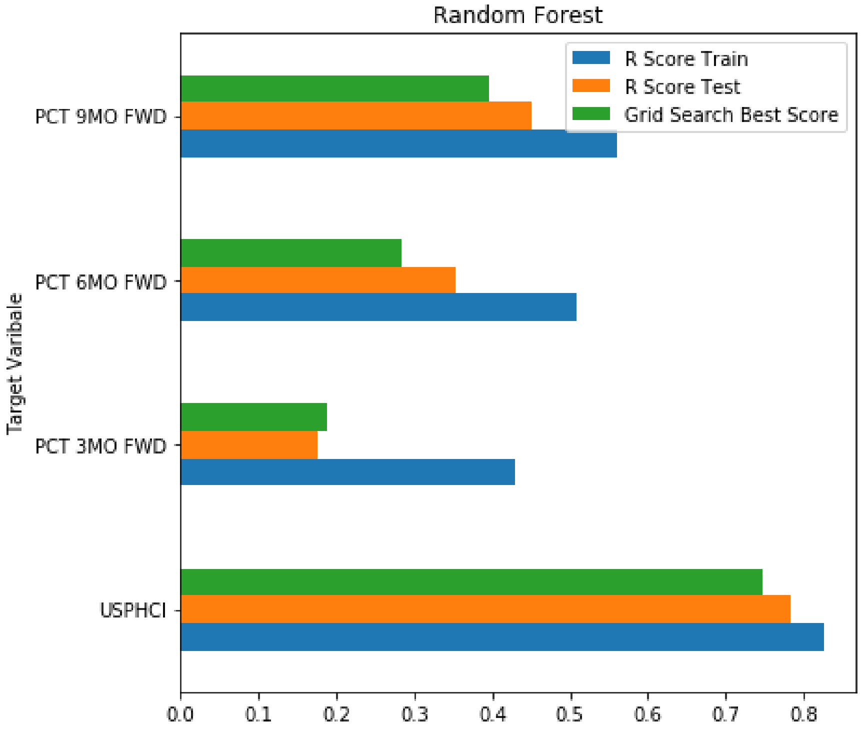
```
df_rf_summary=pd.DataFrame({"Target Varibale":traget_variables,
               "R Score Train":list_of_r_square_train,
              "R Score Test":list_of_r_square_test,
              "Grid Search Best Score":list_of_grid_sarch_best_score,
              "Best Estimator":list_of_svr_best_estimator,
              "Best Parameters":list_of_r_best_param})
df_rf_summary["PCA"]=False
df_rf_summary["Model"]="Random Forest"
df_rf_summary
```

Out[48]:

| | Target Varibale | R Score Train | R Score Test | Grid Search Best Score | Best Estimator | Best Parameters | PCA | Model |
|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.8258 | 0.7831 | 0.7472 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 4, 'max_features': 'log2', 'min_... | False | Random Forest |
| **1** | PCT 3MO FWD | 0.4284 | 0.1751 | 0.1866 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 5, 'max_features': 'log2', 'min_... | False | Random Forest |
| **2** | PCT 6MO FWD | 0.5088 | 0.3539 | 0.2822 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 5, 'max_features': 'log2', 'min_... | False | Random Forest |
| **3** | PCT 9MO FWD | 0.5600 | 0.4514 | 0.3967 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 5, 'max_features': 'log2', 'min_... | False | Random Forest |

```
In [49]: df_rf_summary.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="Random Forest'
```

```
Out[49]: <matplotlib.axes._subplots.AxesSubplot at 0x1dd6ff75ba8>
```



## Random Forest Regressor with 4 Principle Components

```
In [50]: del X_train,X_test,y_train,y_test , rf_model , rf_grid_search
```

```
In [51]: rf_model = RandomForestRegressor(random_state= SEED)
         params_rf = {
         'n_estimators': [100,200,300,400],
         'max_depth': [1,2,3,4,5,6],
         'min_samples_leaf': [0.1,.12,.15, 0.2],
         'max_features': ['log2','sqrt']}
```

In [52]:

```
list_of_r_square_train=[]
list_of_r_square_test=[]
list_of_r_best_param=[]
list_of_grid_sarch_best_score=[]
list_of_svr_best_estimator=[]
for y_variable in traget_variables:
    y=scale(df_Eco[y_variable].values)
    X_train,X_test,y_train,y_test=train_test_split(X_pca,y,test_size=0.25,random_state=s
    rf_grid_search=GridSearchCV(estimator=rf_model,
                 param_grid=params_rf,
                                iid=False,
                                cv=10,
                                scoring='r2',
                                n_jobs=-1,
                                verbose=1)
    rf_grid_search.fit(X_train, y_train)
    list_of_r_square_train.append(rf_grid_search.score(X_train, y_train))
    list_of_r_square_test.append(rf_grid_search.score(X_test, y_test))
    list_of_grid_sarch_best_score.append(rf_grid_search.best_score_)
    list_of_svr_best_estimator.append(rf_grid_search.best_estimator_)
    list_of_r_best_param.append(rf_grid_search.best_params_)
```

```
Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 212 tasks      | elapsed:    7.0s
[Parallel(n_jobs=-1)]: Done 869 tasks      | elapsed:   30.6s
[Parallel(n_jobs=-1)]: Done 1619 tasks      | elapsed:   55.7s
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.1min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Done 224 tasks      | elapsed:    7.6s
[Parallel(n_jobs=-1)]: Done 524 tasks      | elapsed:   22.9s
[Parallel(n_jobs=-1)]: Done 1024 tasks      | elapsed:   43.1s
[Parallel(n_jobs=-1)]: Done 1724 tasks      | elapsed:  1.2min
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.3min finished

Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.
[Parallel(n_jobs=-1)]: Done 191 tasks      | elapsed:    7.2s
[Parallel(n_jobs=-1)]: Done 641 tasks      | elapsed:   22.7s
[Parallel(n_jobs=-1)]: Done 1391 tasks      | elapsed:   47.8s
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.1min finished
[Parallel(n_jobs=-1)]: Using backend LokyBackend with 4 concurrent workers.

Fitting 10 folds for each of 192 candidates, totalling 1920 fits

[Parallel(n_jobs=-1)]: Done 236 tasks      | elapsed:    7.8s
[Parallel(n_jobs=-1)]: Done 836 tasks      | elapsed:   27.6s
[Parallel(n_jobs=-1)]: Done 1836 tasks      | elapsed:  1.0min
[Parallel(n_jobs=-1)]: Done 1920 out of 1920 | elapsed:  1.1min finished
```

In [53]:

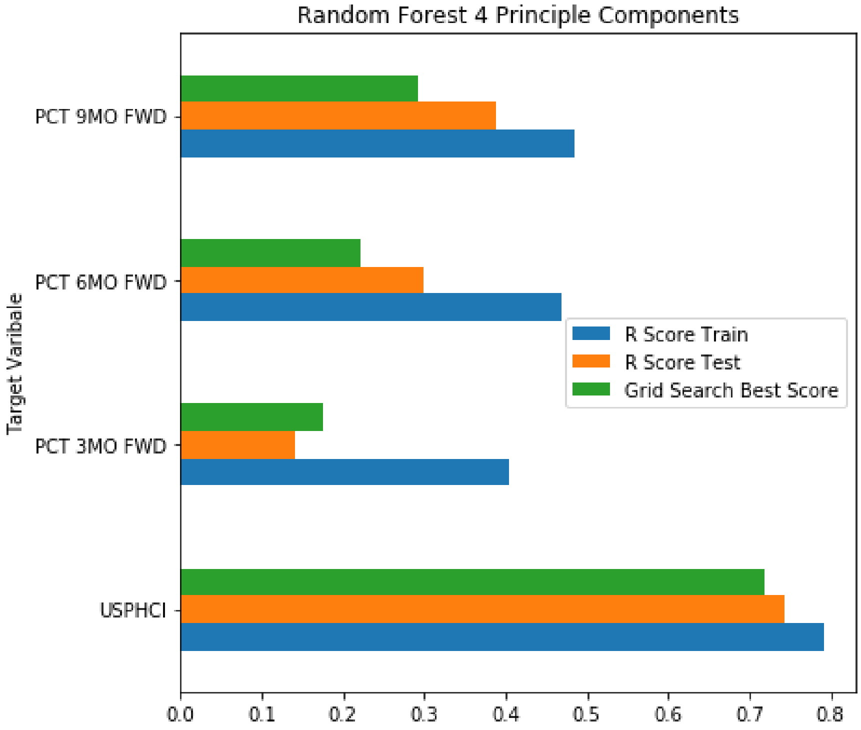
```
df_rf_summary_pca=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test,
             "Grid Search Best Score":list_of_grid_sarch_best_score,
             "Best Estimator":list_of_svr_best_estimator,
             "Best Parameters":list_of_r_best_param})
df_rf_summary_pca["PCA"]=True
df_rf_summary_pca["Model"]="Random Forest"
df_rf_summary_pca
```

Out[53]:

| | Target Varibale | R Score Train | R Score Test | Grid Search Best Score | Best Estimator | Best Parameters | PCA | Model |
|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.7916 | 0.7427 | 0.7174 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 4, 'max_features': 'log2', 'min_... | True | Random Forest |
| **1** | PCT 3MO FWD | 0.4043 | 0.1416 | 0.1757 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 3, 'max_features': 'log2', 'min_... | True | Random Forest |
| **2** | PCT 6MO FWD | 0.4687 | 0.2997 | 0.2219 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 3, 'max_features': 'log2', 'min_... | True | Random Forest |
| **3** | PCT 9MO FWD | 0.4849 | 0.3891 | 0.2929 | (DecisionTreeRegressor(criterion='mse', max_de... | {'max_depth': 3, 'max_features': 'log2', 'min_... | True | Random Forest |

```
In [54]: df_rf_summary_pca.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="Random For
```

```
Out[54]: <matplotlib.axes._subplots.AxesSubplot at 0x1dd6fdaae10>
```



### Gradient Boosting

```
In [55]: del X_train,X_test,y_train,y_test
```

```
In [ ]: gb_model=GradientBoostingRegressor(n_estimators=500, max_depth=1, random_state=SEED)
        list_of_r_square_train=[]
        list_of_r_square_test=[]
        for y_variable in traget_variables:
            y=scale(df_Eco[y_variable].values)
            X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.25,random_state=212)
            gb_model.fit(X_train,y_train)
            list_of_r_square_train.append(gb_model.score(X_train, y_train))
            list_of_r_square_test.append(gb_model.score(X_test, y_test))
```

In [59]:

```
df_gb_summary=pd.DataFrame({"Target Varibale":traget_variables,
              "R Score Train":list_of_r_square_train,
             "R Score Test":list_of_r_square_test})
df_gb_summary["PCA"]=False
df_gb_summary["Model"]="Gradient Boosting"
df_gb_summary
```

Out[59]:

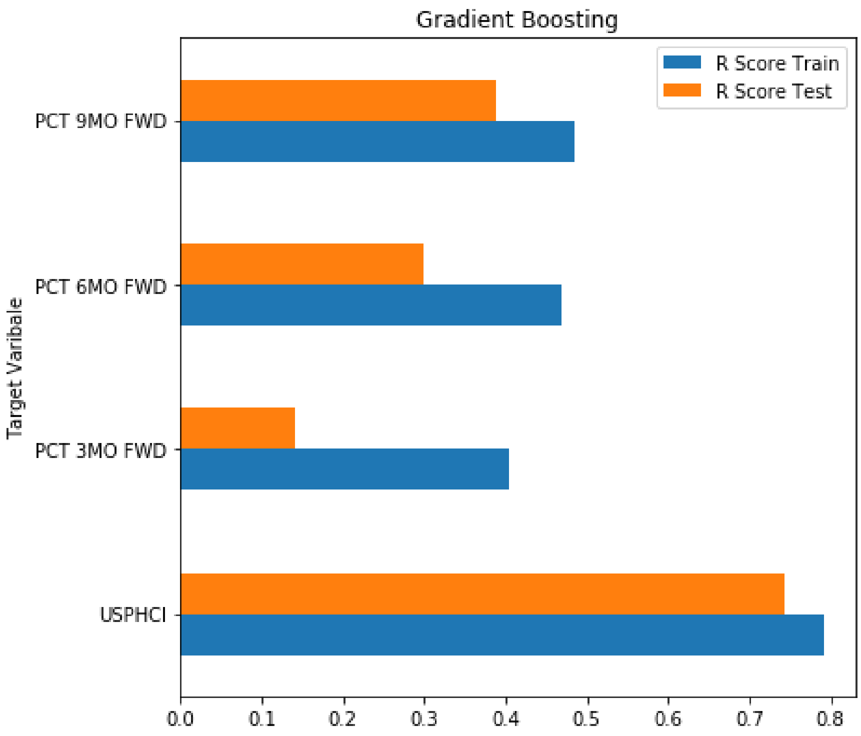
| | Target Varibale | R Score Train | R Score Test | PCA | Model |
|---|---|---|---|---|---|
| **0** | USPHCI | 0.7916 | 0.7427 | False | Gradient Boosting |
| **1** | PCT 3MO FWD | 0.4043 | 0.1416 | False | Gradient Boosting |
| **2** | PCT 6MO FWD | 0.4687 | 0.2997 | False | Gradient Boosting |
| **3** | PCT 9MO FWD | 0.4849 | 0.3891 | False | Gradient Boosting |

In [61]:

```
df_gb_summary.plot("Target Varibale",kind='barh',figsize=(6.5,6.5),title="Gradient Boost
```

Out[61]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x1dd6ffc8240>
```



In [62]:

```
list_of_res_df=['df_gb_summarry',
 'df_knn_summary',
 'df_knn_summary_pca',
 'df_linear_reg_summarry',
 'df_linear_reg_summary_pca',
 'df_rf_summary',
 'df_rf_summary_pca',
 'df_sgb_summarry',
 'df_svr_summary',
 'df_svr_summary_pca']
```

In [100]:

```
df_result=pd.concat([df_gb_summary,
 df_knn_summary,
 df_knn_summary_pca,
 df_linear_reg_summarry,
 df_linear_reg_summary_pca,
 df_rf_summary,
 df_rf_summary_pca,
 df_svr_summary,
 df_svr_summary_pca],sort=False,ignore_index=True).sort_values(["Target Varibale","R Sco
drop=True)
df_result['Model_Rank']=df_result.groupby("Target Varibale").cumcount()+1
```

In [123]:

```
df_result["Target Model"]=df_result["Target Varibale"]+" "+df_result["Model"]
```

### Best Modles in terms of R^2

In [124]:

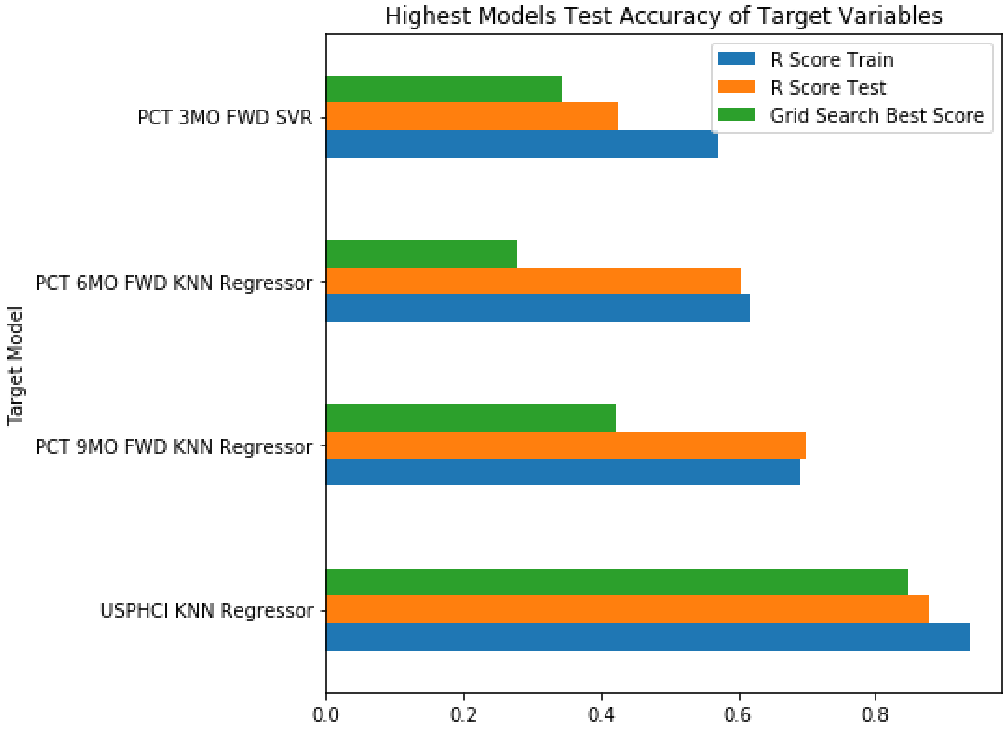
```
df_result.query("Model_Rank==1")
```

Out[124]:

| | Target Varibale | R Score Train | R Score Test | PCA | Model | Grid Search Best Score | Best Estimator | Best Parameters | M |
|---|---|---|---|---|---|---|---|---|---|
| **0** | USPHCI | 0.9366 | 0.8777 | False | KNN Regressor | 0.8468 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 3, 'p': 2} | |
| **9** | PCT 9MO FWD | 0.6900 | 0.6978 | False | KNN Regressor | 0.4228 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 6, 'p': 1} | |
| **18** | PCT 6MO FWD | 0.6178 | 0.6021 | False | KNN Regressor | 0.2792 | KNeighborsRegressor(algorithm='auto', leaf_siz... | {'n_neighbors': 6, 'p': 1} | |
| **27** | PCT 3MO FWD | 0.5703 | 0.4249 | False | SVR | 0.3425 | SVR(C=2, cache_size=200, coef0=0.0, degree=1, ... | {'C': 2, 'degree': 1, 'kernel': 'rbf'} | |

```
In [132]: df_result.query("Model_Rank==1").plot(x="Target Model",y=["R Score Train","R Score Test'
                                                kind='barh',figsize=(6.5,6.5),title="Highest Model
```

```
Out[132]: <matplotlib.axes._subplots.AxesSubplot at 0x1dd77009c50>
```



```
In [ ]:
```

```
In [ ]:
```