Notebook

October 14, 2025

[42]:
```
import numpy as np
import pandas as pd
import seaborn as sns
import plotly.express as px
import matplotlib.pyplot as plt
import plotly.graph_objects as go
from plotly.subplots import make_subplots
from scipy import stats
from xgboost import XGBRegressor
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression, Ridge, RidgeCV
from sklearn.ensemble import RandomForestRegressor, GradientBoostingRegressor
from sklearn.metrics import r2_score, mean_squared_error, classification_report
from sklearn.metrics import ConfusionMatrixDisplay
```

[44]:
```
df = pd.read_csv(r'C:\Users\gopip\Downloads\Cleaned-Life-Exp.csv')
```

[46]:
```
df.head(10)
```

[46]:

	Country	Year	Status	Life expectancy	Adult Mortality	infant deaths	Alcohol	percentage expenditure	Hepatitis B	Measles
0	Afghanistan	1.621762	-0.459399	-0.443691	0.790238	0.268824	-1.133571	-0.335570	-0.635971	-0.110384
1	Afghanistan	1.404986	-0.459399	-0.979279	0.854614	0.285786	-1.133571	-0.334441	-0.755661	-0.168124
2	Afghanistan	1.188210	-0.459399	-0.979279	0.830473	0.302749	-1.133571	-0.334594	-0.675868	-0.173531
3	Afghanistan	0.971434	-0.459399	-1.021286	0.862660	0.328193	-1.133571	-0.332096	-0.556178	0.032045
4	Afghanistan	0.754658	-0.459399	-1.052791	0.886801	0.345155	-1.133571	-0.367862	-0.516281	0.051757
5	Afghanistan	0.537882	-0.459399	-1.094798	0.918989	0.370599	-1.133571	-0.331344	-0.596074	-0.037556
6	Afghanistan	0.321106	-0.459399	-1.115802	0.935083					
7	Afghanistan	0.104330	-0.459399	-1.168310	0.983365					
8	Afghanistan	-0.112446	-0.459399	-1.231321	1.047740					
9	Afghanistan	-0.329222	-0.459399	-1.252324	1.047740					

```
6       0.396043 -1.133571               -0.342874    -0.715764  0.038499
7       0.421487 -1.128635               -0.358415    -0.675868 -0.071572
8       0.438450 -1.131103               -0.365944    -0.715764 -0.111518
9       0.455412 -1.128635               -0.362793    -0.675868 -0.037469

   …     Polio  Total expenditure  Diphtheria  HIV/AIDS       GDP  \
0  … -3.268019           0.889486   -0.730578 -0.323445 -0.483546
1  … -1.048077           0.897493   -0.857092 -0.323445 -0.481553
2  … -0.877312           0.877476   -0.772749 -0.323445 -0.480218
3  … -0.663856           1.033609   -0.646235 -0.323445 -0.477539
4  … -0.621165           0.773387   -0.604064 -0.323445 -0.520044
5  … -0.706547           1.305842   -0.688407 -0.323445 -0.485714
6  … -0.834621           1.393918   -0.814920 -0.323445 -0.493244
7  … -0.791930           0.957544   -0.772749 -0.323445 -0.498328
8  … -0.834621           0.316996   -0.814920 -0.323445 -0.498575
9  … -1.048077           0.597236   -1.025777 -0.323445 -0.505393

   Population  thinness  1-19 years  thinness 5-9 years  \
0    0.343993              2.796805            2.757185
1   -0.203706              2.864687            2.801550
2    0.311126              2.909942            2.845914
3   -0.148469              2.955197            2.912461
4   -0.160246              3.023079            2.956826
5   -0.161810              3.068333            3.001190
6   -0.204415              3.113588            3.067737
7   -0.164330              3.158843            3.112102
8    0.227274              3.204097            3.156466
9   -0.166627              3.249352            3.200831

   Income composition of resources  Schooling
0                        -0.704483  -0.563614
1                        -0.718710  -0.593391
2                        -0.747164  -0.623168
3                        -0.780360  -0.652944
4                        -0.823042  -0.742275
5                        -0.851496  -0.831606
6                        -0.917889  -0.920936
7                        -0.922631  -0.980490
8                        -1.007994  -1.069820
9                        -1.055417  -1.159151

[10 rows x 22 columns]
```

[48]:
```
df.shape
```

[48]:
```
(2938, 22)
```

[50]:
```
df.columns
```

[50]:
```
Index(['Country', 'Year', 'Status', 'Life expectancy', 'Adult Mortality',
       'infant deaths', 'Alcohol', 'percentage expenditure', 'Hepatitis B',
       'Measles', 'BMI', 'under-five deaths', 'Polio', 'Total expenditure',
       'Diphtheria', 'HIV/AIDS', 'GDP', 'Population', 'thinness  1-19 years',
       'thinness 5-9 years', 'Income composition of resources', 'Schooling'],
      dtype='object')
```

[52]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2938 entries, 0 to 2937
Data columns (total 22 columns):
 #   Column                           Non-Null Count  Dtype
---  ------                           --------------  -----
 0   Country                          2938 non-null   object
 1   Year                             2938 non-null   float64
 2   Status                           2938 non-null   float64
 3   Life expectancy                  2938 non-null   float64
 4   Adult Mortality                  2938 non-null   float64
 5   infant deaths                    2938 non-null   float64
 6   Alcohol                          2938 non-null   float64
 7   percentage expenditure           2938 non-null   float64
 8   Hepatitis B                      2938 non-null   float64
 9   Measles                          2938 non-null   float64
 10  BMI                              2938 non-null   float64
 11  under-five deaths                2938 non-null   float64
 12  Polio                            2938 non-null   float64
 13  Total expenditure                2938 non-null   float64
 14  Diphtheria                       2938 non-null   float64
 15  HIV/AIDS                         2938 non-null   float64
 16  GDP                              2938 non-null   float64
 17  Population                       2938 non-null   float64
 18  thinness  1-19 years             2938 non-null   float64
 19  thinness 5-9 years               2938 non-null   float64
 20  Income composition of resources  2938 non-null   float64
 21  Schooling                        2938 non-null   float64
dtypes: float64(21), object(1)
memory usage: 505.1+ KB
```

[54]:
```
df.isnull().sum()
```

[54]:
```
Country                          0
Year                             0
Status                           0
Life expectancy                  0
Adult Mortality                  0
```

```
infant deaths                      0
Alcohol                            0
percentage expenditure             0
Hepatitis B                        0
Measles                            0
BMI                                0
under-five deaths                  0
Polio                              0
Total expenditure                  0
Diphtheria                         0
HIV/AIDS                           0
GDP                                0
Population                         0
thinness  1-19 years               0
thinness 5-9 years                 0
Income composition of resources    0
Schooling                          0
dtype: int64
```

[56]:
```
df.duplicated().sum()
```

[56]:
```
0
```

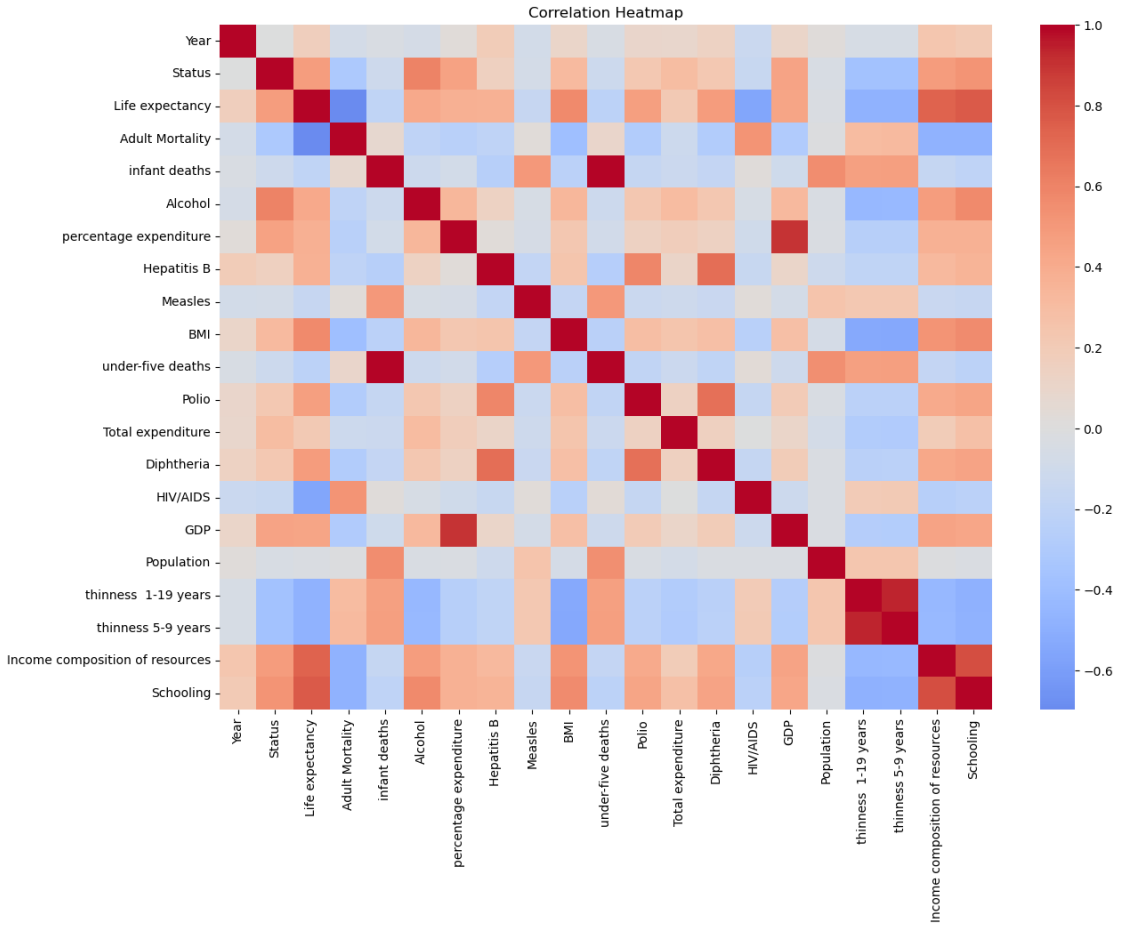
[58]:
```
df.describe().T
```

[58]:

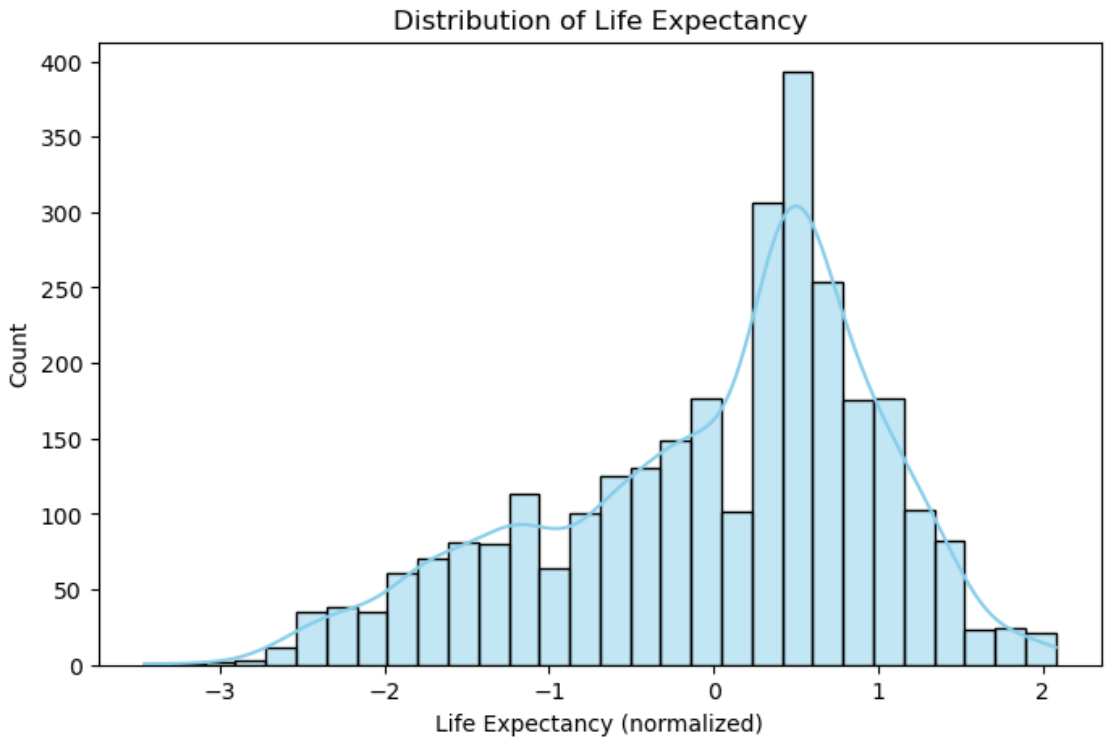
	count	mean	std	min	\
Year	2938.0	2.369453e-14	1.000170	-1.629878	
Status	2938.0	1.233413e-16	1.000170	-0.459399	
Life expectancy	2938.0	1.284142e-04	0.999561	-3.457687	
Adult Mortality	2938.0	-3.753395e-04	0.998839	-1.318060	
infant deaths	2938.0	0.000000e+00	1.000170	-0.257017	
Alcohol	2938.0	-1.962432e-02	0.985558	-1.767049	
percentage expenditure	2938.0	5.320606e-17	1.000170	-0.371433	
Hepatitis B	2938.0	-1.070416e-01	1.007555	-3.189357	
Measles	2938.0	2.902149e-17	1.000170	-0.211036	
BMI	2938.0	-1.204857e-02	1.002242	-1.862284	
under-five deaths	2938.0	1.451074e-17	1.000170	-0.262038	
Polio	2938.0	-5.422906e-03	1.000026	-3.396093	
Total expenditure	2938.0	-2.648810e-03	0.967425	-2.229185	
Diphtheria	2938.0	-5.636102e-03	1.000254	-3.387365	
HIV/AIDS	2938.0	-9.673829e-18	1.000170	-0.323445	
GDP	2938.0	-5.867877e-02	0.932894	-0.827823	
Population	2938.0	-1.022654e-02	0.885175	-0.479363	
thinness 1-19 years	2938.0	8.752749e-03	0.998222	-1.072469	
thinness 5-9 years	2938.0	8.345688e-03	0.997877	-1.058164	
Income composition of resources	2938.0	-9.392396e-03	1.002607	-2.976073	
Schooling	2938.0	-4.486178e-03	1.008433	-3.571075	

	25%	50%	75%	max
Year	-0.762774	0.104330	0.971434	1.621762
Status	-0.459399	-0.459399	-0.459399	2.176759
Life expectancy	-0.643224	0.301932	0.677369	2.076724
Adult Mortality	-0.730634	-0.167348	0.506583	4.491830
infant deaths	-0.257017	-0.231573	-0.070428	15.009326
Alcohol	-0.899100	-0.240113	0.729856	3.274483
percentage expenditure	-0.369076	-0.338774	-0.149286	9.429403
Hepatitis B	-0.396359	0.311926	0.600825	0.804604
Measles	-0.211036	-0.209553	-0.179615	18.295468
BMI	-0.957869	0.233464	0.887138	2.443979
under-five deaths	-0.262038	-0.237104	-0.087495	15.322224
Polio	-0.236944	0.446115	0.616880	0.702262
Total expenditure	-0.631817	-0.067333	0.585225	4.668722
Diphtheria	-0.182352	0.450217	0.618901	0.703244
HIV/AIDS	-0.323445	-0.323445	-0.185566	9.623530
GDP	-0.492302	-0.393025	-0.164617	7.828360
Population	-0.203358	-0.162123	-0.046133	21.002167
thinness 1-19 years	-0.733059	-0.325767	0.547126	5.172675
thinness 5-9 years	-0.725430	-0.326150	0.538959	5.263781
Income composition of resources	-0.661801	0.225020	0.722968	1.704457
Schooling	-0.593391	0.091477	0.687013	2.592731

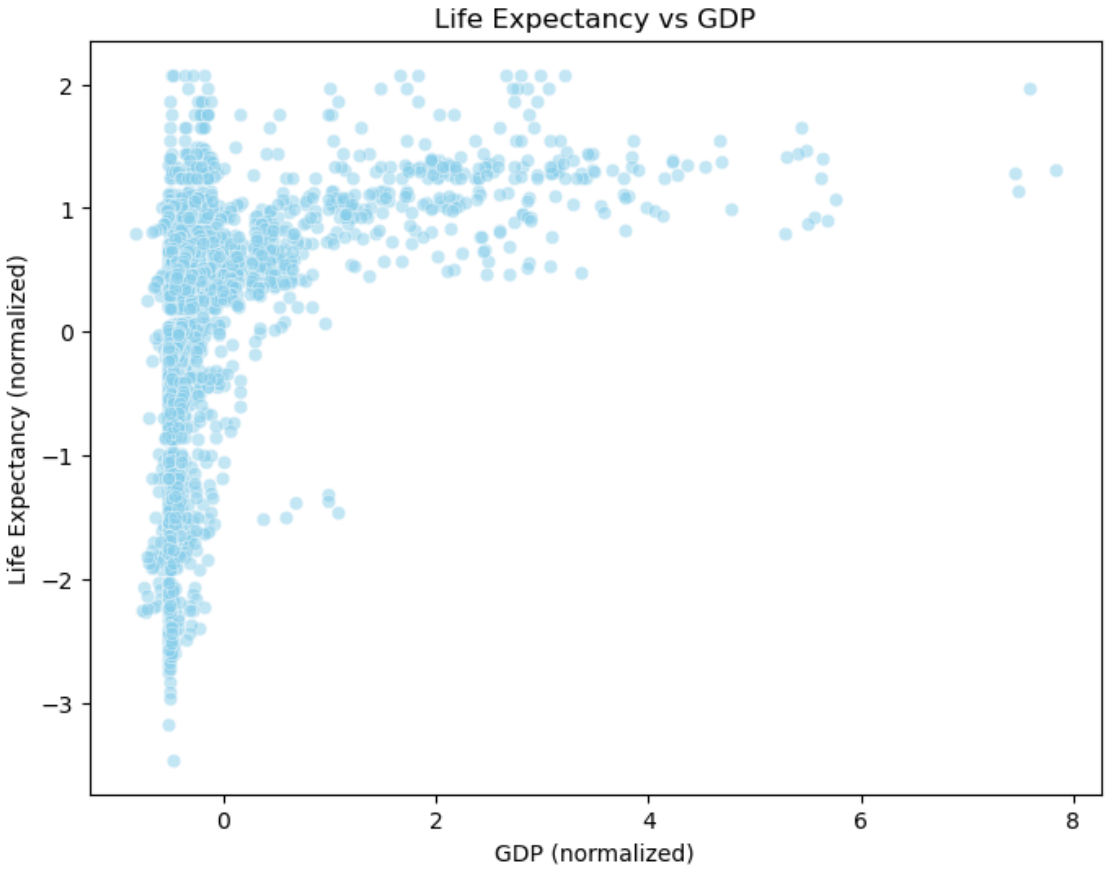
[59]:
```
plt.figure(figsize=(14,10))
corr = df.corr(numeric_only=True)
sns.heatmap(corr, cmap="coolwarm", center=0)
plt.title("Correlation Heatmap")
plt.show()
```



[61]:
```
plt.figure(figsize=(8,5))
sns.histplot(df["Life expectancy"], kde=True, bins=30, color="skyblue")
plt.title("Distribution of Life Expectancy")
plt.xlabel("Life Expectancy (normalized)")
plt.ylabel("Count")
plt.show()
```



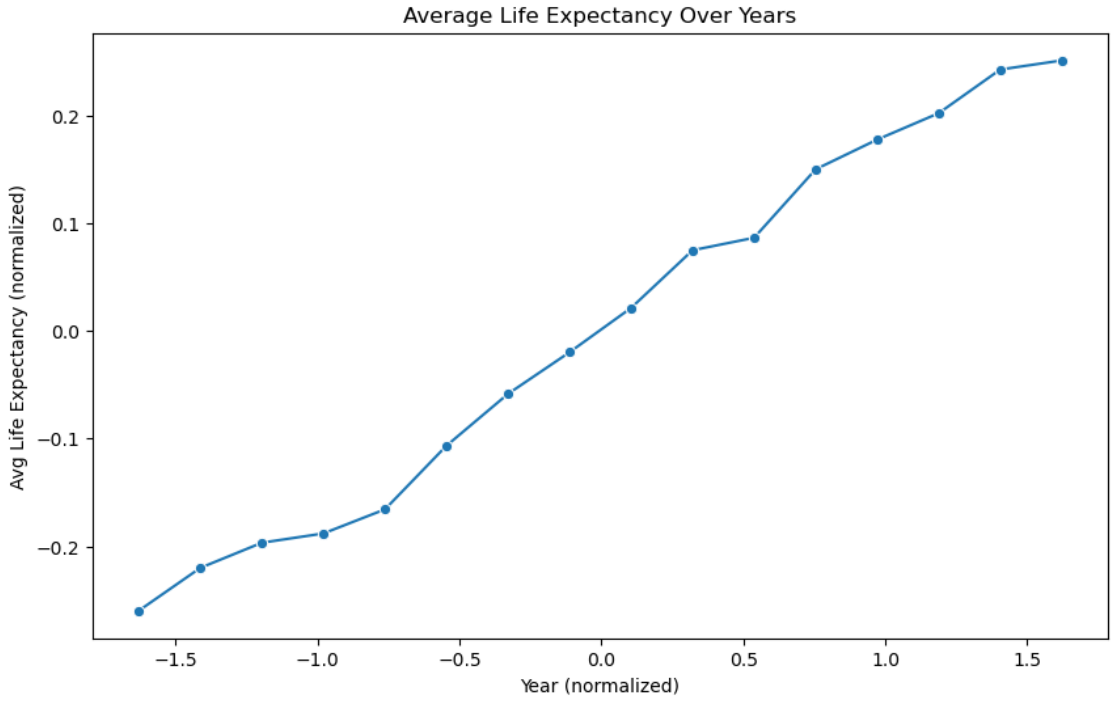
[62]:
```
plt.figure(figsize=(8,6))
sns.scatterplot(x="GDP", y="Life expectancy", data=df, alpha=0.5,␣
 ↪color="skyblue")
plt.title("Life Expectancy vs GDP")
plt.xlabel("GDP (normalized)")
plt.ylabel("Life Expectancy (normalized)")
plt.show()
```



[63]:
```
plt.figure(figsize=(8,6))
sns.scatterplot(x="Income composition of resources", y="Life expectancy",␣
↪data=df, alpha=0.5, color="darkblue")
plt.title("Life Expectancy vs Income Composition of Resources")
plt.xlabel("Income Composition (normalized)")
plt.ylabel("Life Expectancy (normalized)")
plt.show()
```

[64]:
```
plt.figure(figsize=(8,6))
sns.scatterplot(x="Total expenditure", y="Life expectancy", data=df, alpha=0.5,␣
↪color="green")
plt.title("Life Expectancy vs Health Expenditure")
plt.xlabel("Health Expenditure (normalized)")
plt.ylabel("Life Expectancy (normalized)")
plt.show()
```

[65]:
```
plt.figure(figsize=(10,6))
yearly_trend = df.groupby("Year")["Life expectancy"].mean()
sns.lineplot(x=yearly_trend.index, y=yearly_trend.values, marker="o")
plt.title("Average Life Expectancy Over Years")
plt.xlabel("Year (normalized)")
plt.ylabel("Avg Life Expectancy (normalized)")
plt.show()
```



[66]:
```
fig = px.scatter(df, x = 'percentage expenditure', y = 'Life expectancy', color␣
↪= 'Status',
                 title = 'Relation Of Life Expectancy With Expenditure On␣
↪Healthcare')
fig.update_traces(marker_line_color = 'sienna', marker_line_width = 1,␣
↪marker_size = 9)
fig.update_layout(title = {'font_color' : 'rebeccapurple', 'x' : 0.5, 'y' : 0.9,
                           'xanchor' : 'center', 'yanchor' : 'top'},
                  font_color = 'burlywood')
fig.show()
```

[67]:
```
correlation = df.corr(numeric_only = True)
correlation
```

[67]:

	Year	Status	Life expectancy	\
Year	1.000000	-0.001864	0.169590	
Status	-0.001864	1.000000	0.481376	
Life expectancy	0.169590	0.481376	1.000000	
Adult Mortality	-0.079278	-0.314881	-0.696561	
infant deaths	-0.037415	-0.112252	-0.196353	
Alcohol	-0.065912	0.603330	0.414547	
percentage expenditure	0.031400	0.454261	0.381160	
Hepatitis B	0.197841	0.153526	0.374444	
Measles	-0.082493	-0.076955	-0.157428	

BMI	0.109703	0.313953	0.570549
under-five deaths	-0.042937	-0.115195	-0.222293
Polio	0.097626	0.221909	0.470382
Total expenditure	0.090303	0.303780	0.216871
Diphtheria	0.137787	0.218632	0.484297
HIV/AIDS	-0.139741	-0.148590	-0.555889
GDP	0.105161	0.449379	0.443216
Population	0.022581	-0.045008	-0.027582
thinness 1-19 years	-0.048383	-0.370542	-0.481332
thinness 5-9 years	-0.051432	-0.368851	-0.475448
Income composition of resources	0.242170	0.487844	0.741218
Schooling	0.209493	0.525895	0.767789

	Adult Mortality	infant deaths	Alcohol	\
Year	-0.079278	-0.037415	-0.065912	
Status	-0.314881	-0.112252	0.603330	
Life expectancy	-0.696561	-0.196353	0.414547	
Adult Mortality	1.000000	0.078814	-0.207477	
infant deaths	0.078814	1.000000	-0.117828	
Alcohol	-0.207477	-0.117828	1.000000	
percentage expenditure	-0.242509	-0.085612	0.340482	
Hepatitis B	-0.212281	-0.250616	0.133357	
Measles	0.031242	0.501128	-0.051701	
BMI	-0.393301	-0.226488	0.339633	
under-five deaths	0.094198	0.996629	-0.114507	
Polio	-0.279729	-0.169860	0.230918	
Total expenditure	-0.117052	-0.130737	0.306566	
Diphtheria	-0.280109	-0.174266	0.230257	
HIV/AIDS	0.523653	0.025231	-0.050425	
GDP	-0.291561	-0.105537	0.323916	
Population	-0.007562	0.558406	-0.034811	
thinness 1-19 years	0.308948	0.464584	-0.440234	
thinness 5-9 years	0.314107	0.470329	-0.428939	
Income composition of resources	-0.480557	-0.160168	0.479511	
Schooling	-0.478550	-0.208503	0.573899	

	percentage expenditure	Hepatitis B	\
Year	0.031400	0.197841	
Status	0.454261	0.153526	
Life expectancy	0.381160	0.374444	
Adult Mortality	-0.242509	-0.212281	
infant deaths	-0.085612	-0.250616	
Alcohol	0.340482	0.133357	
percentage expenditure	1.000000	0.028609	
Hepatitis B	0.028609	1.000000	
Measles	-0.056596	-0.181475	
BMI	0.231015	0.247296	

```
under-five deaths                -0.087852    -0.265504
Polio                             0.148716     0.584728
Total expenditure                 0.173268     0.116425
Diphtheria                        0.145136     0.694897
HIV/AIDS                         -0.097857    -0.149050
GDP                               0.899958     0.100183
Population                       -0.023477    -0.106928
thinness  1-19 years             -0.253316    -0.194567
thinness 5-9 years               -0.254793    -0.196319
Income composition of resources   0.371627     0.320424
Schooling                         0.375748     0.352805
```

```
                                  Measles       BMI  …     Polio  \
Year                            -0.082493  0.109703  …  0.097626
Status                          -0.076955  0.313953  …  0.221909
Life expectancy                 -0.157428  0.570549  …  0.470382
Adult Mortality                  0.031242 -0.393301  … -0.279729
infant deaths                    0.501128 -0.226488  … -0.169860
Alcohol                         -0.051701  0.339633  …  0.230918
percentage expenditure          -0.056596  0.231015  …  0.148716
Hepatitis B                     -0.181475  0.247296  …  0.584728
Measles                          1.000000 -0.173334  … -0.134580
BMI                             -0.173334  1.000000  …  0.291933
under-five deaths                0.507809 -0.237226  … -0.187981
Polio                           -0.134580  0.291933  …  1.000000
Total expenditure               -0.107260  0.248577  …  0.141318
Diphtheria                      -0.140201  0.290607  …  0.675638
HIV/AIDS                         0.030899 -0.243649  … -0.160435
GDP                             -0.072216  0.288284  …  0.204350
Population                       0.253105 -0.064503  … -0.038667
thinness  1-19 years             0.223050 -0.536729  … -0.227447
thinness 5-9 years               0.219450 -0.543227  … -0.227958
Income composition of resources -0.145815  0.525444  …  0.406050
Schooling                       -0.153456  0.567547  …  0.438654
```

```
                                 Total expenditure  Diphtheria  HIV/AIDS  \
Year                                      0.090303    0.137787 -0.139741
Status                                    0.303780    0.218632 -0.148590
Life expectancy                           0.216871    0.484297 -0.555889
Adult Mortality                          -0.117052   -0.280109  0.523653
infant deaths                            -0.130737   -0.174266  0.025231
Alcohol                                   0.306566    0.230257 -0.050425
percentage expenditure                    0.173268    0.145136 -0.097857
Hepatitis B                               0.116425    0.694897 -0.149050
Measles                                  -0.107260   -0.140201  0.030899
BMI                                       0.248577    0.290607 -0.243649
under-five deaths                        -0.132400   -0.194844  0.038062
```

```
Polio                                0.141318    0.675638 -0.160435
Total expenditure                    1.000000    0.158101 -0.002569
Diphtheria                           0.158101    1.000000 -0.165686
HIV/AIDS                            -0.002569   -0.165686  1.000000
GDP                                  0.099460    0.194101 -0.126286
Population                          -0.071721   -0.028146 -0.022461
thinness  1-19 years                -0.283814   -0.235142  0.204358
thinness 5-9 years                  -0.290412   -0.228202  0.207582
Income composition of resources      0.185058    0.428544 -0.255080
Schooling                            0.272985    0.449027 -0.228213

                                          GDP  Population  thinness  1-19 years  \
Year                                 0.105161    0.022581             -0.048383
Status                               0.449379   -0.045008             -0.370542
Life expectancy                      0.443216   -0.027582             -0.481332
Adult Mortality                     -0.291561   -0.007562              0.308948
infant deaths                       -0.105537    0.558406              0.464584
Alcohol                              0.323916   -0.034811             -0.440234
percentage expenditure               0.899958   -0.023477             -0.253316
Hepatitis B                          0.100183   -0.106928             -0.194567
Measles                             -0.072216    0.253105              0.223050
BMI                                  0.288284   -0.064503             -0.536729
under-five deaths                   -0.109089    0.545926              0.466938
Polio                                0.204350   -0.038667             -0.227447
Total expenditure                    0.099460   -0.071721             -0.283814
Diphtheria                           0.194101   -0.028146             -0.235142
HIV/AIDS                            -0.126286   -0.022461              0.204358
GDP                                  1.000000   -0.025957             -0.272325
Population                          -0.025957    1.000000              0.243335
thinness  1-19 years                -0.272325    0.243335              1.000000
thinness 5-9 years                  -0.275792    0.241212              0.939540
Income composition of resources      0.446871   -0.008294             -0.441313
Schooling                            0.434148   -0.031170             -0.490374

                                  thinness 5-9 years  \
Year                                        -0.051432
Status                                      -0.368851
Life expectancy                             -0.475448
Adult Mortality                              0.314107
infant deaths                                0.470329
Alcohol                                     -0.428939
percentage expenditure                      -0.254793
Hepatitis B                                 -0.196319
Measles                                      0.219450
BMI                                         -0.543227
under-five deaths                            0.471508
Polio                                       -0.227958
```

```
Total expenditure                -0.290412
Diphtheria                       -0.228202
HIV/AIDS                          0.207582
GDP                              -0.275792
Population                        0.241212
thinness  1-19 years              0.939540
thinness 5-9 years                1.000000
Income composition of resources  -0.429147
Schooling                        -0.478534
```

	Income composition of resources	Schooling
Year	0.242170	0.209493
Status	0.487844	0.525895
Life expectancy	0.741218	0.767789
Adult Mortality	-0.480557	-0.478550
infant deaths	-0.160168	-0.208503
Alcohol	0.479511	0.573899
percentage expenditure	0.371627	0.375748
Hepatitis B	0.320424	0.352805
Measles	-0.145815	-0.153456
BMI	0.525444	0.567547
under-five deaths	-0.179160	-0.225149
Polio	0.406050	0.438654
Total expenditure	0.185058	0.272985
Diphtheria	0.428544	0.449027
HIV/AIDS	-0.255080	-0.228213
GDP	0.446871	0.434148
Population	-0.008294	-0.031170
thinness 1-19 years	-0.441313	-0.490374
thinness 5-9 years	-0.429147	-0.478534
Income composition of resources	1.000000	0.812760
Schooling	0.812760	1.000000

```
[21 rows x 21 columns]
```

[69]:
```
fig = px.imshow(correlation, text_auto = '.3f', title = 'Correlation Matrix',
                color_continuous_scale = 'oranges', aspect = 'auto')
fig.update_layout(title = {'font_color' : 'saddlebrown', 'x' : 0.5,  'y' : 0.9,
                           'xanchor' : 'center', 'yanchor' : 'top'},
                  font_color = 'peru')
fig.show()
```

[70]:
```
from scipy.stats import pearsonr
corr_coef, p_value = pearsonr(df["GDP"], df["Life expectancy"])
print("Pearson Correlation Coefficient between GDP and Life Expectancy:",␣
 ↪round(corr_coef, 3))
print("p-value:", p_value)
```

```
Pearson Correlation Coefficient between GDP and Life Expectancy: 0.443
p-value: 1.2228647364841722e-141
```

[72]:
```
from scipy.stats import ttest_ind

median_gdp = df["GDP"].median()
high_income = df[df["GDP"] > median_gdp]["Life expectancy"]
low_income = df[df["GDP"] <= median_gdp]["Life expectancy"]

# Perform independent t-test
t_stat, p_val = ttest_ind(high_income, low_income, equal_var=False)

print("T-test Results: Life Expectancy (High vs Low Income Countries)")
print("T-statistic:", round(t_stat, 3))
print("p-value:", p_val)

# Interpretation
if p_val < 0.05:
    print("Significant difference in life expectancy between high and low␣
 ↪income countries.")
else:
    print("No significant difference in life expectancy between high and low␣
 ↪income countries.")
```

```
T-test Results: Life Expectancy (High vs Low Income Countries)
T-statistic: 35.02
p-value: 1.340002634814662e-221
Significant difference in life expectancy between high and low income countries.
```

[74]:
```
df = df.drop(columns = ['Country', 'Year', 'Total expenditure', 'Population'],␣
 ↪axis = 1)
```

[75]:
```
X = df.drop('Life expectancy', axis = 1)
y = df['Life expectancy']
```

[77]:
```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2,␣
 ↪random_state = 2)
```

[79]:
```
forest = RandomForestRegressor(n_estimators = 200, random_state = 2)
forest.fit(X_train, y_train)
```

[79]:
```
RandomForestRegressor(n_estimators=200, random_state=2)
```

[81]:
```
from sklearn.metrics import r2_score, mean_squared_error,␣
 ↪root_mean_squared_error
pred_forest = forest.predict(X_test)

r2_forest = r2_score(y_test, pred_forest)
```

```
print("R2 Score is:", r2_forest)

rmse_forest = root_mean_squared_error(y_test, pred_forest)
print("Root Mean Squared Error is:", rmse_forest)
```

```
R2 Score is: 0.9606849608243323
Root Mean Squared Error is: 0.20671130771117557
```

[82]:
```
gradient = GradientBoostingRegressor(n_estimators = 1000, learning_rate = 0.06,
                                     min_samples_split = 10, min_samples_leaf =␣
 ↪10,
                                     random_state = 2)

gradient.fit(X_train, y_train)
```

[82]:
```
GradientBoostingRegressor(learning_rate=0.06, min_samples_leaf=10,
                          min_samples_split=10, n_estimators=1000,
                          random_state=2)
```

[83]:
```
from sklearn.metrics import r2_score, root_mean_squared_error
pred_gradient = gradient.predict(X_test)

r2_gradient = r2_score(y_test, pred_gradient)
print("R2 Score is:", r2_gradient)

rmse_gradient = root_mean_squared_error(y_test, pred_gradient)
print("Root Mean Squared Error is:", rmse_gradient)
```

```
R2 Score is: 0.961079029825194
Root Mean Squared Error is: 0.2056727271605674
```

[84]:
```
from sklearn.linear_model import LinearRegression
X_train_numeric = X_train.select_dtypes(include=["number"])
X_test_numeric = X_test.select_dtypes(include=["number"])

linear = LinearRegression()
linear.fit(X_train_numeric, y_train)
```

[84]:
```
LinearRegression()
```

[87]:
```
ridge = Ridge(alpha = 1e-2)

ridge.fit(X_train, y_train)
```

[87]:
```
Ridge(alpha=0.01)
```

[88]:
```
from sklearn.metrics import r2_score, root_mean_squared_error
```

```
pred_ridge = ridge.predict(X_test)
r2_ridge = r2_score(y_test, pred_ridge)
print("R² Score is:", r2_ridge)
rmse_ridge = root_mean_squared_error(y_test, pred_ridge)
print("Root Mean Squared Error is:", rmse_ridge)
```

```
R² Score is: 0.8250411938081144
Root Mean Squared Error is: 0.4360665575642641
```

[95]:
```
linear = LinearRegression()

linear.fit(X_train, y_train)
```

[95]:
```
LinearRegression()
```

[96]:
```
from sklearn.metrics import r2_score, root_mean_squared_error

pred_linear = linear.predict(X_test)
r2_linear = r2_score(y_test, pred_linear)
print("R² Score is:", r2_linear)
rmse_linear = root_mean_squared_error(y_test, pred_linear)
print("Root Mean Squared Error is:", rmse_linear)
```

```
R² Score is: 0.8250470805750202
Root Mean Squared Error is: 0.436059221426607
```

[97]:
```
alphas = [1e-4, 1e-3, 1e-2, 1e-1, 1e+0, 1e+1, 1e+2, 1e+3, 1e+4]

ridgecv = RidgeCV(alphas = alphas)

ridgecv.fit(X_train, y_train)
```

[97]:
```
RidgeCV(alphas=[0.0001, 0.001, 0.01, 0.1, 1.0, 10.0, 100.0, 1000.0, 10000.0])
```

[98]:
```
from sklearn.metrics import r2_score, root_mean_squared_error
pred_ridgecv = ridgecv.predict(X_test)
r2_ridgecv = r2_score(y_test, pred_ridgecv)
print("R² Score is:", r2_ridgecv)
rmse_ridgecv = root_mean_squared_error(y_test, pred_ridgecv)
print("Root Mean Squared Error is:", rmse_ridgecv)
```

```
R² Score is: 0.8249883781075009
Root Mean Squared Error is: 0.4361323714074826
```

[99]:
```
from xgboost import XGBRegressor
regressor = XGBRegressor(n_estimators = 1000, learning_rate = 0.06, max_depth =␣
↪10,
                         random_state = 2)
```

```
regressor.fit(X_train, y_train)
```

[99]:
```
XGBRegressor(base_score=None, booster=None, callbacks=None,
             colsample_bylevel=None, colsample_bynode=None,
             colsample_bytree=None, device=None, early_stopping_rounds=None,
             enable_categorical=False, eval_metric=None, feature_types=None,
             feature_weights=None, gamma=None, grow_policy=None,
             importance_type=None, interaction_constraints=None,
             learning_rate=0.06, max_bin=None, max_cat_threshold=None,
             max_cat_to_onehot=None, max_delta_step=None, max_depth=10,
             max_leaves=None, min_child_weight=None, missing=nan,
             monotone_constraints=None, multi_strategy=None, n_estimators=1000,
             n_jobs=None, num_parallel_tree=None, …)
```

[100]:
```
from sklearn.metrics import r2_score, root_mean_squared_error

pred_regressor = regressor.predict(X_test)
r2_regressor = r2_score(y_test, pred_regressor)
print("R² Score is:", r2_regressor)

rmse_regressor = root_mean_squared_error(y_test, pred_regressor)
print("Root Mean Squared Error is:", rmse_regressor)
```

```
R² Score is: 0.9630616206753468
Root Mean Squared Error is: 0.20036589306971922
```

[101]:
```
from sklearn.metrics import r2_score, root_mean_squared_error

# --- Random Forest ---
pred_forest = forest.predict(X_test)
r2_forest = r2_score(y_test, pred_forest)
rmse_forest = root_mean_squared_error(y_test, pred_forest)

# --- Gradient Boosting ---
pred_gradient = gradient.predict(X_test)
r2_gradient = r2_score(y_test, pred_gradient)
rmse_gradient = root_mean_squared_error(y_test, pred_gradient)

# --- XGBoost ---
pred_regressor = regressor.predict(X_test)
r2_regressor = r2_score(y_test, pred_regressor)
rmse_regressor = root_mean_squared_error(y_test, pred_regressor)

# --- Linear Regression ---
pred_linear = linear.predict(X_test)
r2_linear = r2_score(y_test, pred_linear)
rmse_linear = root_mean_squared_error(y_test, pred_linear)
```

```
# --- Ridge ---
pred_ridge = ridge.predict(X_test)
r2_ridge = r2_score(y_test, pred_ridge)
rmse_ridge = root_mean_squared_error(y_test, pred_ridge)

# --- RidgeCV ---
pred_ridgecv = ridgecv.predict(X_test)
r2_ridgecv = r2_score(y_test, pred_ridgecv)
rmse_ridgecv = root_mean_squared_error(y_test, pred_ridgecv)
```

[102]:
```
comparison = pd.DataFrame()

comparison['Type'] = ['Random Forest Regressor', 'Gradient Boosting Regressor',
                      'XGBRegressor', 'LinearRegression', 'Ridge', 'RidgeCV']
comparison['r2 Score'] = [r2_forest, r2_gradient, r2_regressor, r2_linear,␣
 ↪r2_ridge,
                          r2_ridgecv]
comparison['Root Mean Squared Error'] = [rmse_forest, rmse_gradient,␣
 ↪rmse_regressor,
                                         rmse_linear, rmse_ridge, rmse_ridgecv]

comparison
```

[102]:

	Type	r2 Score	Root Mean Squared Error
0	Random Forest Regressor	0.960685	0.206711
1	Gradient Boosting Regressor	0.961079	0.205673
2	XGBRegressor	0.963062	0.200366
3	LinearRegression	0.825047	0.436059
4	Ridge	0.825041	0.436067
5	RidgeCV	0.824988	0.436132

[104]:
```
from plotly.subplots import make_subplots
import plotly.express as px

fig = make_subplots(
    rows=1, cols=2,
    specs=[[{'type': 'bar'}, {'type': 'bar'}]],
    subplot_titles=['R² Score', 'Root Mean Square Error'],
    horizontal_spacing=0.2
)

# Use the exact column names from your DataFrame
fig1 = px.bar(comparison, x='Type', y='r2 Score', text_auto='.3f')
fig2 = px.bar(comparison, x='Type', y='Root Mean Squared Error', text_auto='.
 ↪3f')

fig.add_trace(fig1['data'][0], row=1, col=1)
```

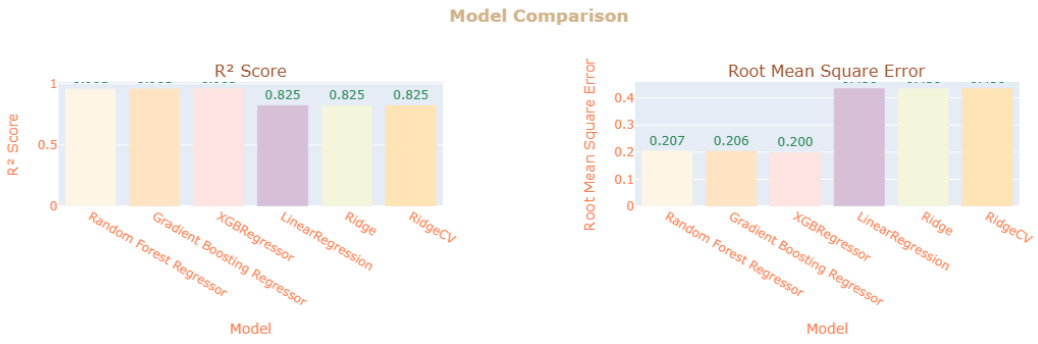
```
fig.add_trace(fig2['data'][0], row=1, col=2)

fig.update_xaxes(title_text='Model', row=1, col=1)
fig.update_xaxes(title_text='Model', row=1, col=2)

fig.update_traces(
    textposition='outside',
    textfont_color='seagreen',
    marker_color=['oldlace', 'bisque', 'mistyrose', 'thistle', 'beige',␣
 ↪'moccasin']
)
fig.update_annotations(font_color='sienna')

fig.update_layout(
    title={
        'text': '<b>Model Comparison</b>',
        'x': 0.5,
        'y': 0.92,
        'xanchor': 'center',
        'yanchor': 'top',
        'font_color': 'tan'
    },
    font_color='coral',
    yaxis={'title': 'R² Score'},
    yaxis2={'title': 'Root Mean Square Error'}
)

fig.show()
```



[ ]:

This notebook was converted with convert.ploomber.io