Name : Paul Francis

Student ID : 21034542

In [1]:
```python
#importing packages
import pandas as pd
import numpy as np
import wbgapi as wb
import matplotlib.pyplot as plt
import sklearn.cluster as cluster
import scipy.optimize as opt
from sklearn.cluster import KMeans
from scipy.stats import norm
import seaborn as sns
from scipy.optimize import curve_fit
import itertools as iter
```

In [2]:
```python
# the list 'indicator' contains the indicator id's
# the list 'country_code' contains the code of a few countries
indicator1 = ["EN.ATM.CO2E.PC","EG.USE.ELEC.KH.PC"]
indicator2 = ["EN.ATM.METH.KT.CE","EG.ELC.ACCS.ZS"]
country_code = ['AUS','CHN','CAN','FRA','RUS','NZL','DEU','USA','ARG']
```

In [3]:
```python
# function to read dataframe in world format and return 2 dataframe
def read(indicator,country_code):
    df = wb.data.DataFrame(indicator, country_code, mrv=30)
    return df
```

In [4]:
```python
# variable storing the csv file
path = "World Indicator Repository.csv"
```

In [5]:
```python
# creating a dataframe using the function 'read'
dat  = read(indicator1, country_code)
```

In [6]:
```python
# removing 'YR' and assigning new index names to dat
dat.columns = [i.replace('YR','') for i in dat.columns]
dat=dat.stack().unstack(level=1)
dat.index.names = ['Country', 'Year']
dat.columns
```

Out[6]:
```
Index(['EG.USE.ELEC.KH.PC', 'EN.ATM.CO2E.PC'], dtype='object', name='series')
```

In [7]:
```python
# creating a dataframe using the function 'read'
dat1  = read(indicator2, country_code)
```

In [8]:
```python
# removing 'YR' and assigning new index names to dat2
dat1.columns = [i.replace('YR','') for i in dat1.columns]
dat1=dat1.stack().unstack(level=1)
dat1.index.names = ['Country', 'Year']
dat1.columns
```

Out[8]:
```
Index(['EG.ELC.ACCS.ZS', 'EN.ATM.METH.KT.CE'], dtype='object', name='series')
```

In [9]:
```python
# resetting the index for dt1 and dt2
dt1 = dat.reset_index()
dt2 = dat1.reset_index()
```

In [10]:
```python
# merging dt1 and dt2
dt = pd.merge(dt1, dt2)
dt
```

Out[10]:

series	Country	Year	EG.USE.ELEC.KH.PC	EN.ATM.CO2E.PC	EG.ELC.ACCS.ZS	EN.ATM.METH.KT.CE
0	ARG	1991	1347.592046	3.183893	92.492188	105660.0
1	ARG	1992	1410.377544	3.201675	92.829453	107470.0
2	ARG	1993	1496.904499	3.268462	93.166046	106960.0
3	ARG	1994	1576.767198	3.308174	93.501274	108430.0
4	ARG	1995	1648.895228	3.267757	93.834465	108840.0
...	...	...	...	...	...	...
247	USA	2014	12993.965579	16.026379	100.000000	620810.0
248	USA	2015	NaN	15.535342	100.000000	617170.0
249	USA	2016	NaN	15.131747	100.000000	609200.0
250	USA	2017	NaN	14.805882	100.000000	614500.0
251	USA	2018	NaN	15.240875	100.000000	622590.0

252 rows × 6 columns

In [11]:
```python
# dropping the column 'EG.USE.ELEC.KH.PC' and 'EG.ELC.ACCS.ZS'
dt.drop(['EG.USE.ELEC.KH.PC'], axis = 1, inplace = True)
dt.drop(['EG.ELC.ACCS.ZS'], axis = 1, inplace = True)
```

In [12]:
```python
dt
```

Out[12]:

series	Country	Year	EN.ATM.CO2E.PC	EN.ATM.METH.KT.CE
0	ARG	1991	3.183893	105660.0
1	ARG	1992	3.201675	107470.0
2	ARG	1993	3.268462	106960.0
3	ARG	1994	3.308174	108430.0
4	ARG	1995	3.267757	108840.0
...	...	...	...	...
247	USA	2014	16.026379	620810.0
248	USA	2015	15.535342	617170.0
249	USA	2016	15.131747	609200.0
250	USA	2017	14.805882	614500.0
251	USA	2018	15.240875	622590.0

252 rows × 4 columns

In [13]:
```python
# converting the data type of "Year" from object to int64
dt["Year"] = pd.to_numeric(dt["Year"])
```

In [14]:
```python
# function to normalise the datas in the dataframe
def norm_df(df):
    y = df.iloc[:,2:]
    df.iloc[:,2:] = (y-y.min())/ (y.max() - y.min())
    return df
```

In [15]:
```python
# normalised dataframe
dt_norm = norm_df(dt)
dt_norm
```

Out[15]:

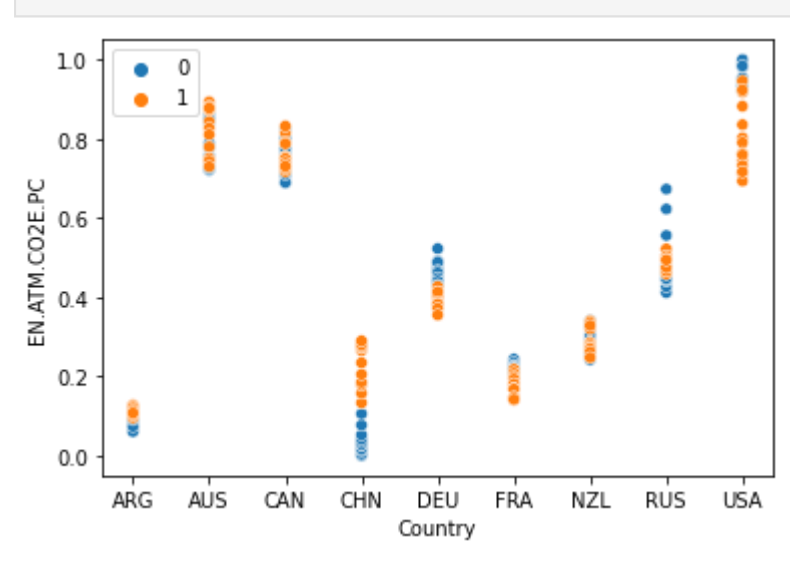
series	Country	Year	EN.ATM.CO2E.PC	EN.ATM.METH.KT.CE
0	ARG	1991	0.064064	0.060993
1	ARG	1992	0.065026	0.062488
2	ARG	1993	0.068642	0.062067
3	ARG	1994	0.070792	0.063281
4	ARG	1995	0.068604	0.063620
...	...	...	...	...
247	USA	2014	0.759328	0.486627
248	USA	2015	0.732744	0.483620
249	USA	2016	0.710894	0.477035
250	USA	2017	0.693253	0.481414
251	USA	2018	0.716802	0.488098

252 rows × 4 columns

In [16]:
```python
# dataframe that is needed to do clustering
df_fit = dt_norm.drop('Country', axis = 1)
```

In [17]:
```python
# k means clustering
k = KMeans(n_clusters=2, init='k-means++', random_state=0).fit(df_fit)
```

In [18]:
```python
# clustering the different countries based on CO2 emission rate
sns.scatterplot(data=dt_norm, x="Country", y="EN.ATM.CO2E.PC", hue=k.labels_)
plt.legend()
plt.show()
```



In [19]:
```python
# function to calculate the error range
def err_ranges(x, func, param, sigma):

    # initiate arrays for lower and upper limits
    lower = func(x, *param)
    upper = lower

    uplow = []   # list to hold upper and lower limits for parameters
    for p,s in zip(param, sigma):
        pmin = p - s
        pmax = p + s
        uplow.append((pmin, pmax))

    pmix = list(iter.product(*uplow))

    for p in pmix:
        y = func(x, *p)
        lower = np.minimum(lower, y)
        upper = np.maximum(upper, y)

    return lower, upper
```

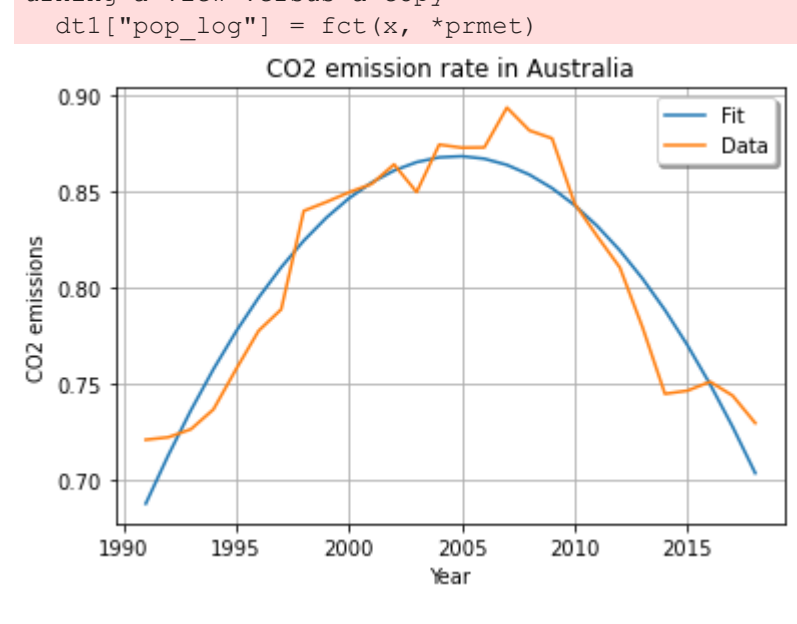
In [20]:
```python
# dataframe containing the datas of the country Australia
dt1 = dt[(dt['Country'] == 'AUS')]
dt1
```

Out[20]:

series	Country	Year	EN.ATM.CO2E.PC	EN.ATM.METH.KT.CE
28	AUS	1991	0.720832	0.102379
29	AUS	1992	0.722127	0.101900
30	AUS	1993	0.726300	0.099140
31	AUS	1994	0.736645	0.098173
32	AUS	1995	0.757474	0.096959
33	AUS	1996	0.777454	0.091109
34	AUS	1997	0.788592	0.092844
35	AUS	1998	0.839735	0.094430
36	AUS	1999	0.844355	0.103519
37	AUS	2000	0.849374	0.112194
38	AUS	2001	0.853698	0.118854
39	AUS	2002	0.863874	0.111814
40	AUS	2003	0.849502	0.078715
41	AUS	2004	0.874182	0.095984
42	AUS	2005	0.872555	0.080112
43	AUS	2006	0.872708	0.095868
44	AUS	2007	0.893398	0.093356
45	AUS	2008	0.881498	0.079889
46	AUS	2009	0.877405	0.082309
47	AUS	2010	0.843515	0.072279
48	AUS	2011	0.826552	0.113178
49	AUS	2012	0.810373	0.111451
50	AUS	2013	0.779481	0.078748
51	AUS	2014	0.744683	0.085391
52	AUS	2015	0.746338	0.083937
53	AUS	2016	0.750974	0.071420
54	AUS	2017	0.743750	0.089209
55	AUS	2018	0.729505	0.088597

In [21]:
```python
#curve_fit function implementation for Australia which has a medium CO2 emission

val = dt1.values
x, y = val[:, 1], val[:, 2]

def fct(x, a, b, c):
    return a*x**2+b*x+c
prmet, cov = opt.curve_fit(fct, x, y)

dt1["pop_log"] = fct(x, *prmet)
print("Parameters are: ", prmet)
print("Covariance is: ", cov)

plt.plot(x, dt1["pop_log"], label="Fit")
plt.plot(x, y, label="Data")
plt.grid(True)
plt.xlabel('Year')
plt.ylabel('CO2 emissions')
plt.title("CO2 emission rate in Australia")
plt.legend(loc='best', fancybox=True, shadow=True)
plt.show()
```

```
Parameters are:  [-9.46583974e-04  3.79544241e+00 -3.80370264e+03]
Covariance is:  [[ 4.11029051e-09 -1.64781533e-05  1.65149596e-02]
 [-1.64781533e-05  6.60611253e-02 -6.62088962e+01]
 [ 1.65149596e-02 -6.62088962e+01  6.63572124e+04]]
/var/folders/1k/2dy8_tcd6tn7smj8lh3zjqkw0000gn/T/ipykernel_33963/2017871200.py:10: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  dt1["pop_log"] = fct(x, *prmet)
```



In [22]:
```python
# extract the sigmas from the diagonal of the covariance matrix
sigma = np.sqrt(np.diag(cov))
print(sigma)

low, up = err_ranges(x, fct, prmet, sigma)
```

```
[6.41115474e-05 2.57023589e-01 2.57598937e+02]
```

In [23]:
```python
# Forcasting the emission rate in the coming 10 years
print("Forcasted CO2 emission")
low, up = err_ranges(2030, fct, prmet, sigma)
print("2030 between ", low, "and", up)
```

```
Forcasted CO2 emission
2030 between  -1043.2865577714929 and 1043.821638899185
```

We can see that the CO2 emmission rate in Australia first increased gradually to a rate of 0.89 in the year 2007 and then the decreased to a rate of 0.72 in the year 2018. It is also evident that the year and the CO2 emission rate has a direct relationship.

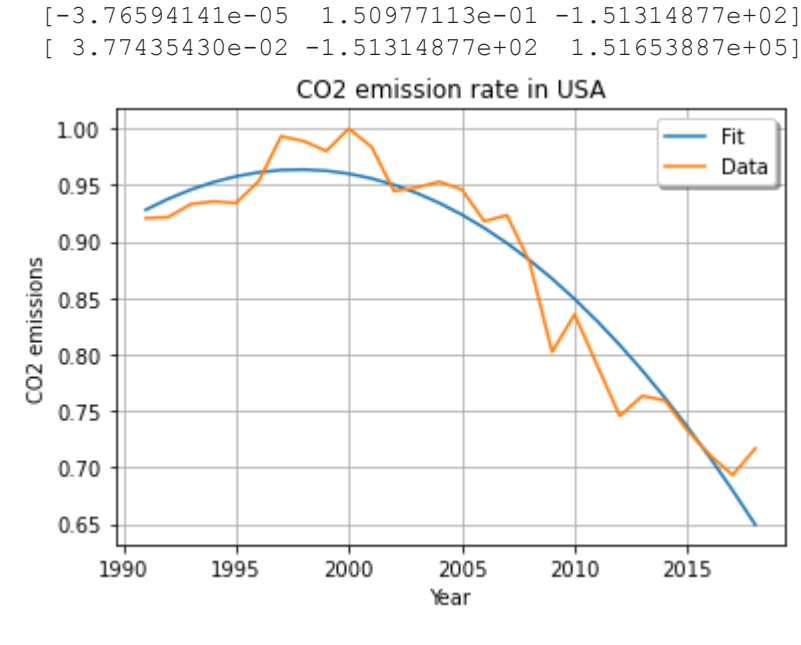
In [24]:
```python
# dataframe containing the datas of the country USA
dt2 = dt[(dt['Country'] == 'USA')]
dt2
```

Out[24]:

series	Country	Year	EN.ATM.CO2E.PC	EN.ATM.METH.KT.CE
224	USA	1991	0.920623	0.609745
225	USA	1992	0.921671	0.608794
226	USA	1993	0.933203	0.594591
227	USA	1994	0.935504	0.600408
228	USA	1995	0.934060	0.589932
229	USA	1996	0.953396	0.583950
230	USA	1997	0.993284	0.570920
231	USA	1998	0.988899	0.554519
232	USA	1999	0.980174	0.542423
233	USA	2000	1.000000	0.534417
234	USA	2001	0.983925	0.529253
235	USA	2002	0.944647	0.518817
236	USA	2003	0.947853	0.518570
237	USA	2004	0.952989	0.514604
238	USA	2005	0.946192	0.512695
239	USA	2006	0.918020	0.513340
240	USA	2007	0.923346	0.507316
241	USA	2008	0.882135	0.518264
242	USA	2009	0.802231	0.510225
243	USA	2010	0.835544	0.510696
244	USA	2011	0.790350	0.492642
245	USA	2012	0.745510	0.484430
246	USA	2013	0.763473	0.484644
247	USA	2014	0.759328	0.486627
248	USA	2015	0.732744	0.483620
249	USA	2016	0.710894	0.477035
250	USA	2017	0.693253	0.481414
251	USA	2018	0.716802	0.488098

In [25]:
```python
#curve_fit function implementation for USA which has a high CO2 emission

val2 = dt2.values
x2, y2 = val2[:, 1], val2[:, 2]

def fct(x, a, b, c):
    return a*x**2+b*x+c
prmet, cov = opt.curve_fit(fct, x2, y2)

dt2["pop_log"] = fct(x2, *prmet)
print("Parameters are: ", prmet)
print("Covariance is: ", cov)

plt.plot(x2, dt2["pop_log"], label="Fit")
plt.plot(x2, y2, label="Data")
plt.grid(True)
plt.xlabel('Year')
plt.ylabel('CO2 emissions')
plt.title("CO2 emission rate in USA")
plt.legend(loc='best', fancybox=True, shadow=True)
plt.show()
```

```
/var/folders/1k/2dy8_tcd6tn7smj8lh3zjqkw0000gn/T/ipykernel_33963/610109501.py:10: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  dt2["pop_log"] = fct(x2, *prmet)
Parameters are:  [-7.70653363e-04  3.07922715e+00 -3.07488079e+03]
Covariance is:  [[ 9.39371558e-09 -3.76594141e-05  3.77435430e-02]
 [-3.76594141e-05  1.50977113e-01 -1.51314877e+02]
 [ 3.77435430e-02 -1.51314877e+02  1.51653887e+05]]
```



In [26]:
```python
# extract the sigmas from the diagonal of the covariance matrix
sigma = np.sqrt(np.diag(cov))
print(sigma)

low, up = err_ranges(x2, fct, prmet, sigma)
```

```
[9.69211823e-05 3.88557735e-01 3.89427640e+02]
```

In [27]:
```python
# Forcasting the emission rate in the coming 10 years
print("Forcasted CO2 emission")
low, up = err_ranges(2030, fct, prmet, sigma)
print("2030 between ", low, "and", up)
```

```
Forcasted CO2 emission
2030 between  -1577.4374598421373 and 1577.7672247334017
```

We can see that the CO2 emmission rate in USA was high in the year 2000 and then the rate has been fluctuating between 0.96 and 0.71. Here also the year and CO2 emission has direct relationship.

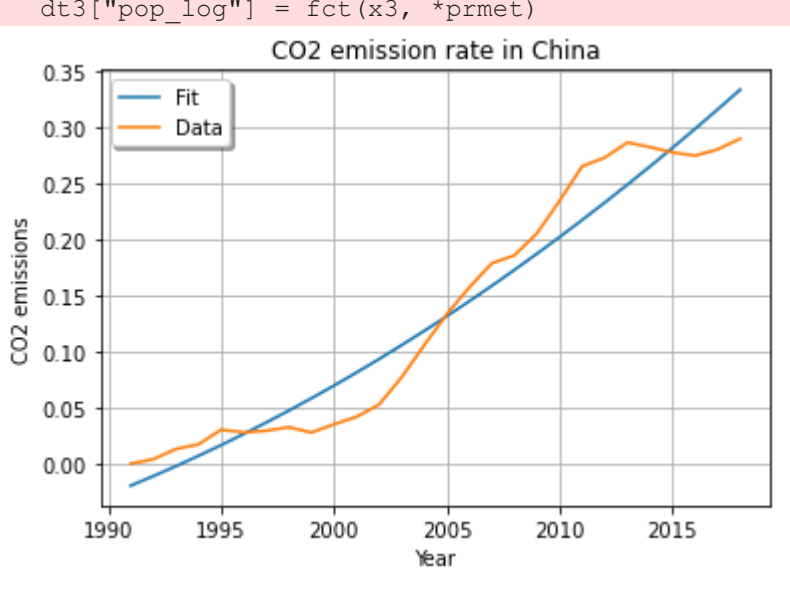
In [28]:
```python
# dataframe containing the datas of the country China
dt3 = dt[(dt['Country'] == 'CHN')]
dt3
```

Out[28]:

series	Country	Year	EN.ATM.CO2E.PC	EN.ATM.METH.KT.CE
84	CHN	1991	0.000000	0.587643
85	CHN	1992	0.004071	0.594740
86	CHN	1993	0.013139	0.599615
87	CHN	1994	0.017242	0.612909
88	CHN	1995	0.030307	0.633400
89	CHN	1996	0.027973	0.654394
90	CHN	1997	0.029392	0.627847
91	CHN	1998	0.032588	0.646107
92	CHN	1999	0.027790	0.655906
93	CHN	2000	0.035078	0.659145
94	CHN	2001	0.041815	0.654650
95	CHN	2002	0.052718	0.651114
96	CHN	2003	0.077139	0.647826
97	CHN	2004	0.105637	0.659220
98	CHN	2005	0.133337	0.665805
99	CHN	2006	0.157297	0.703555
100	CHN	2007	0.178766	0.735117
101	CHN	2008	0.185750	0.778098
102	CHN	2009	0.205442	0.815551
103	CHN	2010	0.234504	0.852666
104	CHN	2011	0.265145	0.887665
105	CHN	2012	0.272813	0.924771
106	CHN	2013	0.286306	0.947014
107	CHN	2014	0.282179	0.970305
108	CHN	2015	0.277384	0.996175
109	CHN	2016	0.274552	1.000000
110	CHN	2017	0.280131	0.997505
111	CHN	2018	0.289730	0.997092

In [29]:
```python
#curve_fit function implementation for China which has a low CO2 emission

val3 = dt3.values
x3, y3 = val3[:, 1], val3[:, 2]

def fct(x, a, b, c):
    return a*x**2+b*x+c
prmet, cov = opt.curve_fit(fct, x3, y3)

dt3["pop_log"] = fct(x3, *prmet)
print("Parameters are: ", prmet)
print("Covariance is: ", cov)

plt.plot(x3, dt3["pop_log"], label="Fit")
plt.plot(x3, y3, label="Data")
plt.grid(True)
plt.xlabel('Year')
plt.ylabel('CO2 emissions')
plt.title("CO2 emission rate in China")
plt.legend(loc='best', fancybox=True, shadow=True)
plt.show()
```

```
Parameters are:  [ 1.75922825e-04 -6.92202748e-01  6.80783820e+02]
Covariance is:  [[ 8.07844646e-09 -3.23865194e-05  3.24588894e-02]
 [-3.23865194e-05  1.29838087e-01 -1.30128640e+02]
 [ 3.24588894e-02 -1.30128640e+02  1.30420267e+05]]
/var/folders/1k/2dy8_tcd6tn7smj8lh3zjqkw0000gn/T/ipykernel_33963/2300585509.py:10: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  dt3["pop_log"] = fct(x3, *prmet)
```



In [30]:
```python
# extract the sigmas from the diagonal of the covariance matrix
sigma = np.sqrt(np.diag(cov))
print(sigma)

low, up = err_ranges(x3, fct, prmet, sigma)
```

```
[8.98801784e-05 3.60330524e-01 3.61137462e+02]
```

In [31]:
```python
# Forcasting the emission rate in the coming 10 years
print("Forcasted CO2 emission")
low, up = err_ranges(2030, fct, prmet, sigma)
print("2030 between ", low, "and", up)
```

```
Forcasted CO2 emission
2030 between  -1462.4230406425686 and 1463.5682655502064
```

The emission rate in China has been increasing from the year 1991 until now. But when compared to the other two countries, it is seen that China has the lowest emission rate. In this case also, the year and CO2 emission has a direct relationship.