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Working document for Assignment 1 for International Climate Policy

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In [ ]:
```
import os
import kaleido
import pandas as pd
import plotly.io as pio
import plotly.express as px
import matplotlib.pyplot as plt
from scipy.stats import ttest_ind
from sklearn.metrics import r2_score
from sympy import symbols, Eq, solve
pio.renderers.default = "notebook+pdf"
from sklearn.linear_model import LinearRegression

path = r'C:/Users/amart/OneDrive - The University of Chicago/IntlClimatePolicy_P
```

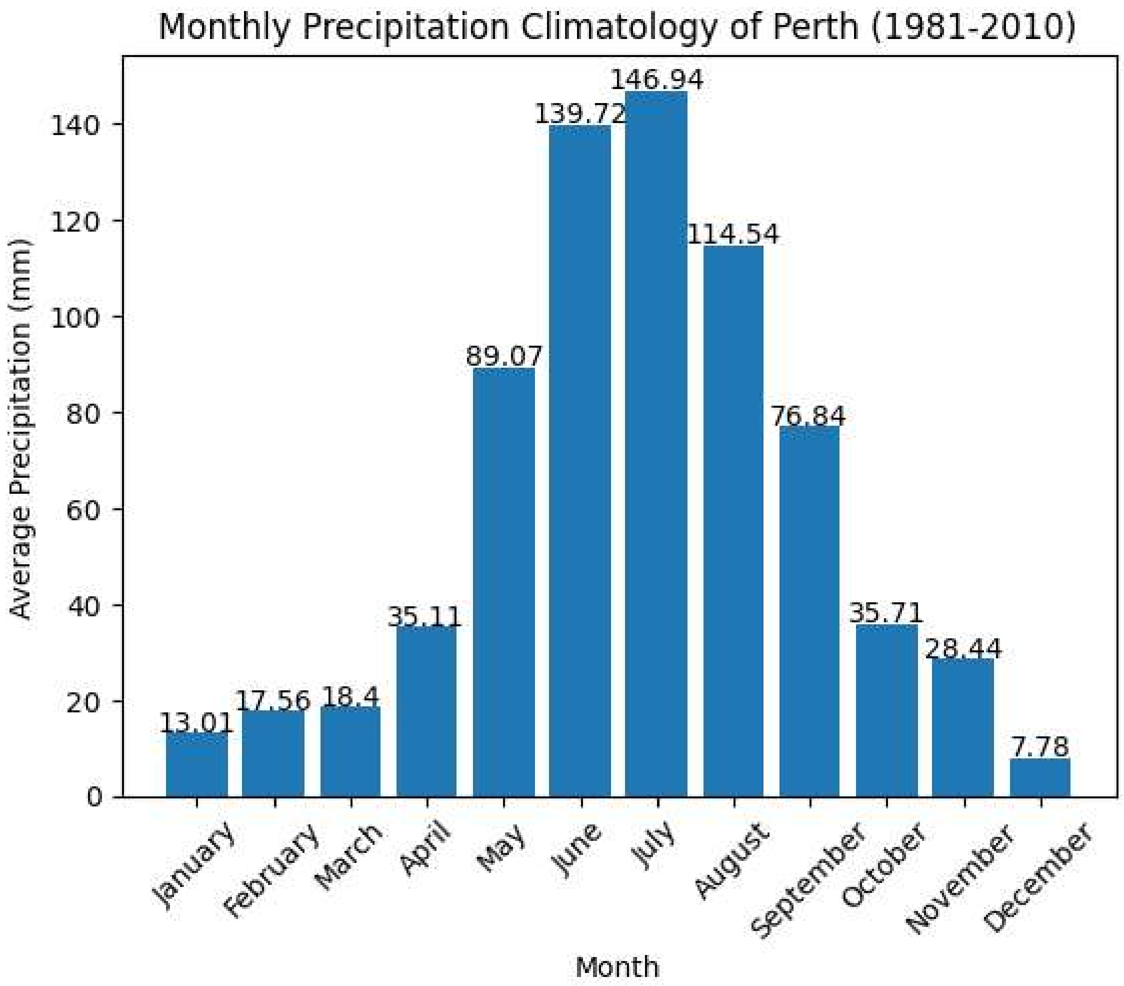
Q2. Australian climate data analysis

Q2. a)

In [ ]:
```
perth_df = pd.read_csv(os.path.join(path,
                                    'indiv1_perth_airport.csv'), engine='python'

perth_df['DATE'] = pd.to_datetime(perth_df['DATE'])
perth_df.set_index('DATE', inplace=True)

# Filter data from 1981 to 2010
filtered_df = perth_df.loc['1981':'2010']
# Calculate the average precipitation for each month
monthly_climatology = filtered_df.groupby(filtered_df.index.month)['PRCP'].mean(
# Print the average precipitation for each month
for month, avg_precipitation in monthly_climatology.items():
    print(f"Month: {month}, Average Precipitation: {avg_precipitation}")
# Find the rainiest month
rainiest_month = monthly_climatology.idxmax()
print(f"The rainiest month on average across 1981 to 2019 is month number {raini

# Create a figure and a set of subplots
fig, ax = plt.subplots()
# Plot the average precipitation for each month
ax.bar(monthly_climatology.index, monthly_climatology.values)
# Setting x and y-axis labels
ax.set_xlabel('Month')
ax.set_ylabel('Average Precipitation (mm)')

ax.set_title('Monthly Precipitation Climatology of Perth (1981-2010)')

# List of month names for x-tick labels
months = ['January', 'February', 'March', 'April', 'May', 'June', 'July', 'Augus
ax.set_xticks(range(1, 13))
```

```python
ax.set_xticklabels(months, rotation=45)

# Showing values of y-axis by annotating each data point with its
# corresponding value
for i, v in enumerate(monthly_climatology.values):
    ax.text(i+1, v + 0.5, str(round(v, 2)), ha='center')

plt.show()
```

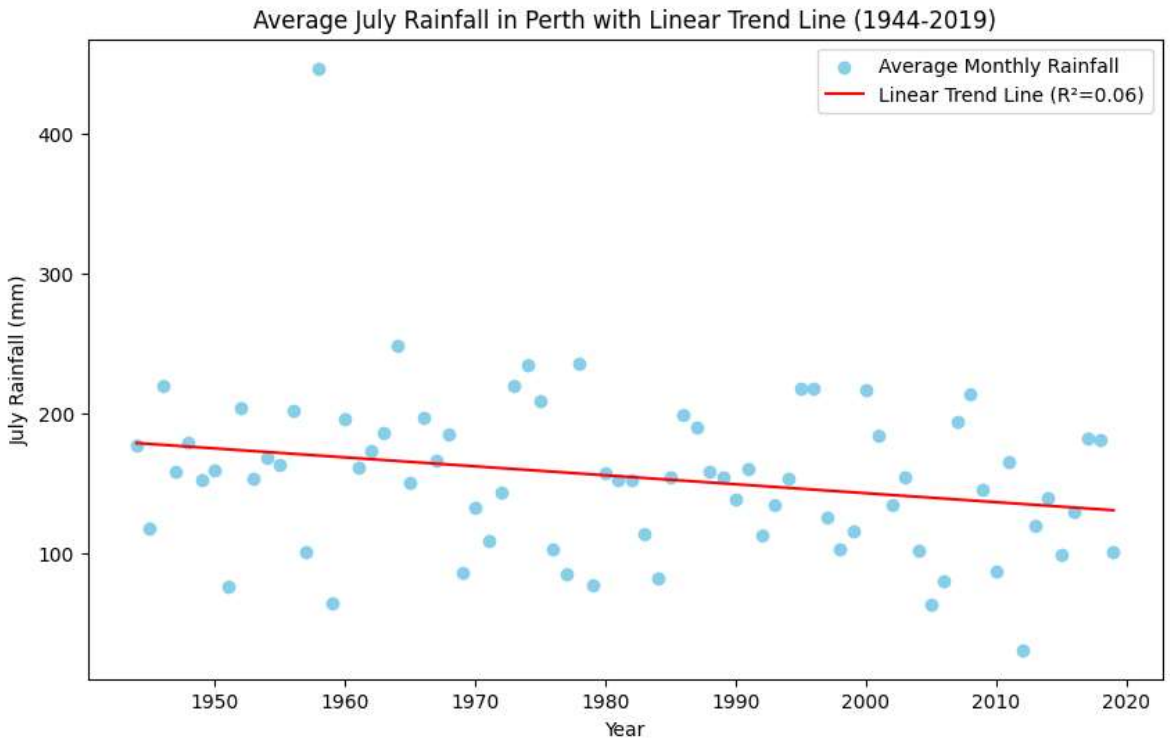
```
Month: 1, Average Precipitation: 13.006666666666666
Month: 2, Average Precipitation: 17.560000000000002
Month: 3, Average Precipitation: 18.4
Month: 4, Average Precipitation: 35.10666666666667
Month: 5, Average Precipitation: 89.06666666666666
Month: 6, Average Precipitation: 139.72
Month: 7, Average Precipitation: 146.94
Month: 8, Average Precipitation: 114.53999999999999
Month: 9, Average Precipitation: 76.83999999999999
Month: 10, Average Precipitation: 35.70666666666667
Month: 11, Average Precipitation: 28.44
Month: 12, Average Precipitation: 7.78
The rainiest month on average across 1981 to 2019 is month number 7
```



Q2. b)

In [ ]:
```python
# Filter data from 1944 onwards
filtered_df = perth_df.loc['1944':]

def plot_rainfall_trend(df, month, y_label, title):
```

```python
    # Ensure month is a list-like object
    if not isinstance(month, (list, tuple)):
        month = [month]

    # Filter data for the specified month
    if len(month) == 1:
        monthly_rainfall = df[df.index.month == month[0]]['PRCP'].resample('Y').
    else:
        monthly_rainfall = df[df.index.month.isin(month)]['PRCP'].resample('Y').

    # Create a figure and set the size
    plt.figure(figsize=(10, 6))

    # Scatter plot for average monthly rainfall
    plt.scatter(x=monthly_rainfall['DATE'].dt.year, y=monthly_rainfall['PRCP'],

    # Fit a linear trend line
    X = monthly_rainfall['DATE'].dt.year.values.reshape(-1, 1)
    y = monthly_rainfall['PRCP'].values
    model = LinearRegression().fit(X, y)
    trend_line = model.predict(X)

    # Calculate R-squared value
    r_squared = r2_score(y, trend_line)

    # Plot the linear trend line
    plt.plot(monthly_rainfall['DATE'].dt.year, trend_line, color='red', label=f'

    # Setting x and y-axis labels
    plt.xlabel('Year')
    plt.ylabel(y_label)

    # Set the title and show legend
    plt.title(title)
    plt.legend()

    # Show the plot
    plt.show()

plot_rainfall_trend(filtered_df, 7, 'July Rainfall (mm)', 'Average July Rainfall

# Performing statistical test using two-sample t-test
earlier_period = perth_df.loc['1951-01-01':'1980-12-31']['PRCP']
later_period = perth_df.loc['1981-01-01':'2010-12-31']['PRCP']

t_statistic, p_value = ttest_ind(earlier_period, later_period)

print(f'Two-Sample T-Test Results:')
print(f'T-statistic: {t_statistic}')
print(f'P-value: {p_value}')

# Check significance at a 95% confidence interval
alpha = 0.05
if p_value < alpha:
    print(f'Difference between the two periods is statistically significant (rej
else:
    print(f'Difference between the two periods is not statistically significant
```

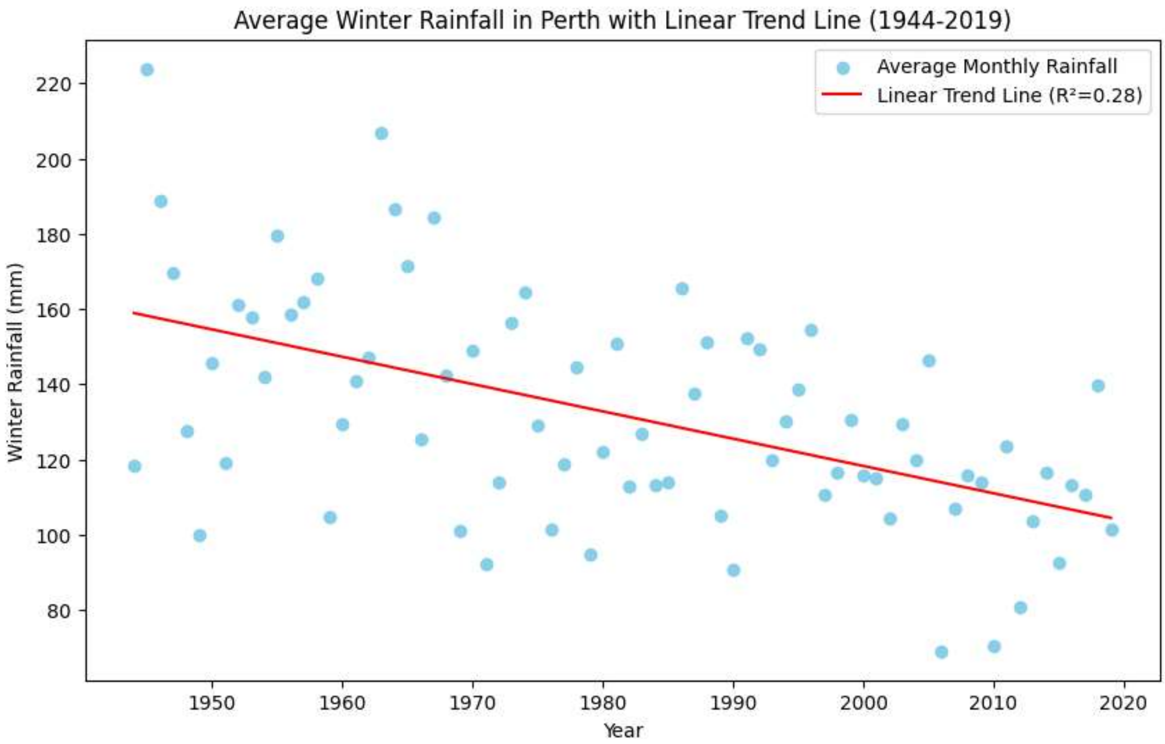



```
Two-Sample T-Test Results:
T-statistic: 1.3581011168763193
P-value: 0.17485819704852887
Difference between the two periods is not statistically significant (fail to reje
ct H0).
```

Q2. c)

In [ ]:

```
plot_rainfall_trend(filtered_df, [5, 6, 7, 8], 'Winter Rainfall (mm)', 'Average

# Filter data for winter months (May-August)
winter_rainfall = perth_df[perth_df.index.month.isin(range(5, 9))]['PRCP'].resam

# Performing statistical test using two-sample t-test for average winter rainfal
early_period = winter_rainfall[(winter_rainfall['DATE'].dt.year >= 1951) & (wint
later_period = winter_rainfall[(winter_rainfall['DATE'].dt.year >= 1981) & (wint

t_statistic, p_value = ttest_ind(early_period, later_period)

print(f'Two-Sample T-Test Results for Average Winter Rainfall Trend:')
print(f'T-statistic: {t_statistic}')
print(f'P-value: {p_value}')

# Check significance at a 95% confidence interval
alpha = 0.05
if p_value < alpha:
    print(f'Difference in average winter rainfall trend is statistically signifi
else:
    print(f'Difference in average winter rainfall trend is not statistically sig
```




```
Two-Sample T-Test Results for Average Winter Rainfall Trend:
T-statistic: 2.905853284992847
P-value: 0.005177858501204699
Difference in average winter rainfall trend is statistically significant (reject
H0).
```

Q3. Climate change and inequality

In [ ]:
```
county_income = pd.read_csv(os.path.join(path,
                                          'indiv1_us_counties_incomes.csv'), engi
county_temp = pd.read_csv(os.path.join(path,
                                        'indiv1_us_counties_temperature.csv'), en

display(county_income.shape)
display(county_income.head(10))

display(county_temp.shape)
display(county_temp.head(10))
```

```
(3112, 2)
```

	fips	income_per_capita_2018
0	1001	41618
1	1003	45596
2	1005	35199
3	1007	30254
4	1009	34976
5	1011	28797
6	1013	36450
7	1015	37120
8	1017	33859
9	1019	35505

```
(3112, 9)
```

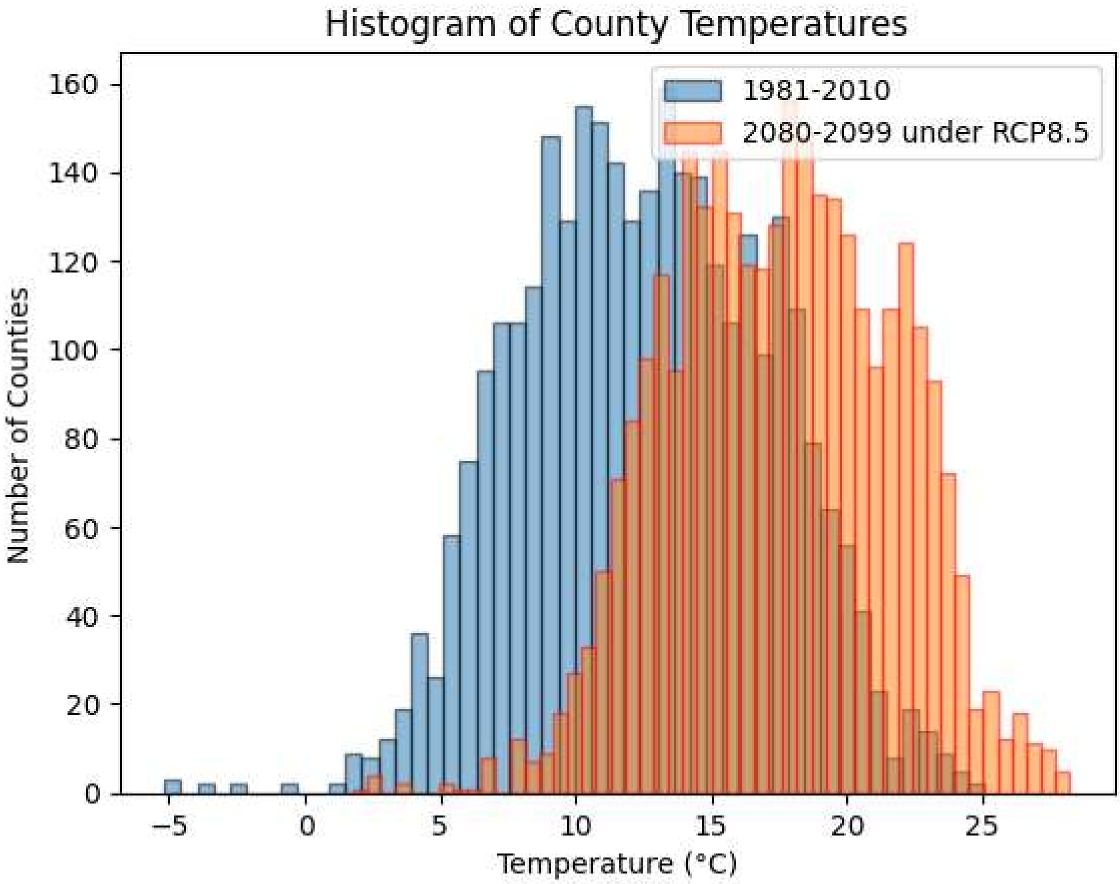
	fips	county	state	lat	lon	normal_1981_2010	rcp85_2020_2039	rc
0	1001	Autauga County	AL	32.535000	-86.642998	18.361113	19.527779	
1	1003	Baldwin County	AL	30.736000	-87.723000	19.211113	20.288887	
2	1005	Barbour County	AL	31.870001	-85.392998	17.283333	18.438890	
3	1007	Bibb County	AL	32.999001	-87.125999	16.433334	17.633335	
4	1009	Blount County	AL	33.980999	-86.567001	15.961111	17.166668	
5	1011	Bullock County	AL	32.099998	-85.716003	17.283333	18.438890	
6	1013	Butler County	AL	31.752001	-86.680000	17.444445	18.588888	
7	1015	Calhoun County	AL	33.771000	-85.825996	16.894444	18.083336	
8	1017	Chambers County	AL	32.914001	-85.391998	16.505554	17.638889	
9	1019	Cherokee County	AL	34.175999	-85.603996	15.177777	16.355555	

Q3. a)

In [ ]:

```
# Histogram based on 1981-2010 temperatures
plt.hist(county_temp['normal_1981_2010'], bins=50, alpha=0.5, label='1981-2010',

# Histogram based temperature estimates for 2080-2099 under RCP8.5 emissions
```

```
plt.hist(county_temp['rcp85_2080_2099'], bins=50, alpha=0.5, label='2080-2099 un

plt.xlabel('Temperature (°C)')
plt.ylabel('Number of Counties')
plt.title('Histogram of County Temperatures')
plt.legend(loc='upper right')
plt.show()
```



Q3 b)

In [ ]:

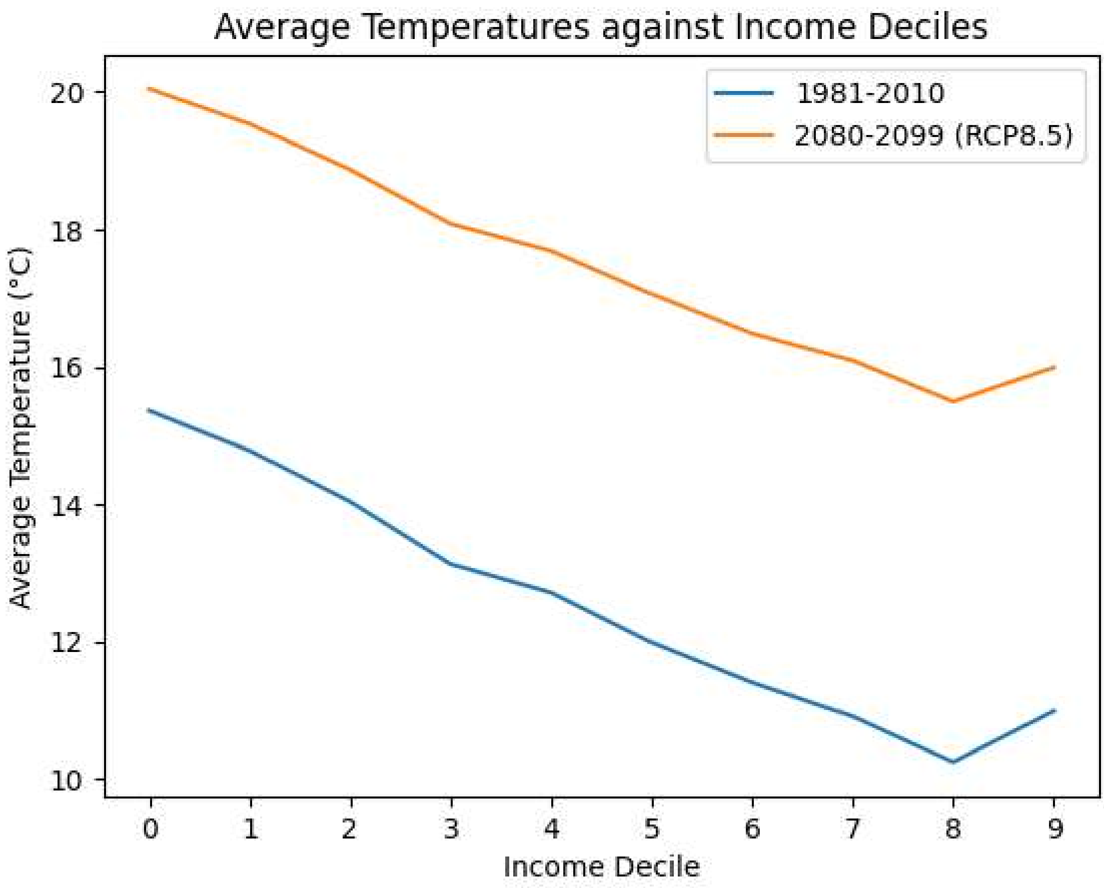
```
# Creating a merged dataset from the temperature and income datasets
county_merge = pd.merge(county_income, county_temp, on='fips')

# Calculating income deciles
county_merge['Income Decile'] = pd.qcut(county_merge['income_per_capita_2018'],

# Calculating average temperatures for each time period for these income deciles
average_temps = county_merge.groupby('Income Decile').agg({
    'normal_1981_2010': 'mean',
    'rcp85_2020_2039': 'mean',
    'rcp85_2040_2059': 'mean',
    'rcp85_2080_2099': 'mean'
})
average_temps = average_temps.round(3)
display(average_temps)
```

Income Decile	normal_1981_2010	rcp85_2020_2039	rcp85_2040_2059	rcp85_2080_2099
0	15.358	16.634	17.692	20.046
1	14.776	16.072	17.147	19.539
2	14.035	15.345	16.438	18.872
3	13.124	14.474	15.595	18.083
4	12.707	14.067	15.180	17.686
5	11.979	13.351	14.497	17.057
6	11.395	12.767	13.908	16.481
7	10.902	12.292	13.458	16.086
8	10.237	11.644	12.826	15.490
9	10.981	12.333	13.455	15.986

Q3. c)

In [ ]:

```
plt.figure()

# Plot average temperatures for both time periods
plt.plot(average_temps.index, average_temps['normal_1981_2010'], label='1981-201
plt.plot(average_temps.index, average_temps['rcp85_2080_2099'], label='2080-2099

plt.xlabel('Income Decile')
plt.ylabel('Average Temperature (°C)')
plt.title('Average Temperatures against Income Deciles')
plt.xticks(range(0, 10))
plt.legend()
plt.show()
```



Q3. e)

```
In [ ]: # Calculating change in temperature
county_merge['temp_change'] = county_merge['rcp85_2080_2099'] - county_merge['no

# Calculating average temperature change for each income decile
average_temp_change = county_merge.groupby('Income Decile')['temp_change'].mean(

# Finding income decile with the most change
highest_change = average_temp_change.idxmax()
display(f"The income decile that will experience the most change is: {highest_ch
```

```
'The income decile that will experience the most change is: 8'
```

```
In [ ]: # Analysis of spatial pattern changes

spatial_df = pd.DataFrame({
    'lat': county_merge['lat'],
    'lon': county_merge['lon'],
    'temp_change': county_merge['temp_change'],
    'Income Decile': county_merge['Income Decile']
})

# Create a scatter plot on a map
fig = px.scatter_geo(spatial_df, lat='lat', lon='lon', color='temp_change',
                     projection='natural earth',
                     title='Spatial pattern of temperature changes (RCP8.5)',
                     color_continuous_scale=px.colors.sequential.YlOrRd)
fig.update_geos(resolution=110, showcoastlines=True, coastlinecolor="Black",
                showocean=True, oceancolor="lightblue")
fig.update_layout(coloraxis_colorbar=dict(title="Temperature Change (°C)"))
```

```
fig.show()

fig = px.scatter_geo(spatial_df, lat='lat', lon='lon', color='Income Decile',
                     projection='natural earth',
                     title='Spatial pattern of income deciles')
fig.update_geos(resolution=110, showcoastlines=True, coastlinecolor="Black",
                showocean=True, oceancolor="lightblue")
fig.show()
```

Spatial pattern of temperature changes (RCP8.5)

Spatial pattern of income deciles

In [ ]:
```
filtered_df = spatial_df[spatial_df['Income Decile'] == 8]
display(filtered_df.describe())
display(spatial_df.describe())
```

	lat	lon	temp_change	Income Decile
count	311.000000	311.000000	311.000000	311.0
mean	41.422765	-94.289058	5.252269	8.0
std	5.196372	15.202604	0.623615	0.0
min	26.576000	-170.279010	3.255556	8.0
25%	38.767499	-99.708000	4.919444	8.0
50%	41.771999	-95.309998	5.322222	8.0
75%	44.309000	-84.686500	5.666666	8.0
max	65.017998	-68.345001	7.722222	8.0

	lat	lon	temp_change	Income Decile
count	3112.000000	3112.000000	3112.000000	3112.000000
mean	38.470611	-92.389624	4.983169	4.500000
std	5.328819	12.876852	0.594605	2.874085
min	19.598000	-170.279010	2.877775	0.000000
25%	34.659499	-98.347500	4.677780	2.000000
50%	38.417999	-90.495498	5.072222	4.500000
75%	41.852001	-83.602497	5.361110	7.000000
max	69.306000	-67.638000	7.722222	9.000000

In [ ]:
```
fig = px.scatter_geo(filtered_df, lat='lat', lon='lon', color='temp_change',
                     projection='natural earth',
                     title='Spatial pattern of temperature changes for decile 8
                     color_continuous_scale=px.colors.sequential.YlOrRd)

fig.update_geos(resolution=110, showcoastlines=True, coastlinecolor="Black",
                showocean=True, oceancolor="lightblue")
fig.update_layout(coloraxis_colorbar=dict(title="Temperature Change (°C)"))

fig.show()
```

Spatial pattern of temperature changes for decile 8 c

Q4. Climate change communication

Q4. a)

In [ ]:
```
ts_data = pd.read_csv(os.path.join(path,
                                   'timeseries_data.csv'), engine='python', skip
```

In [ ]:
```
# Converting year to proper date-time format for plotting
ts_data['Year'] = ts_data['Year'].astype(str)
ts_data['Year'] = pd.to_datetime(ts_data['Year'].str.slice(0,4) + '-' + ts_data[
```

In [ ]:
```
plt.figure(figsize=(15, 7))
plt.plot(ts_data['Year'], ts_data['Anomaly'])
plt.xlabel('Year')
plt.ylabel('Temperature Anomaly (°C)')
plt.title('Global Land and Ocean Temperature Anomalies Over Time (base period: 1
plt.xlim([pd.Timestamp('1850-01-01'), pd.Timestamp('2023-12-31')])
```

Out[ ]:
```
(-43829.0, 19722.0)
```