# title

author

Invalid Date

**Due 11/9 at 5:00PM Central. Worth 100 points + 10 points extra credit.**

## Submission Steps (10 pts)

1. This problem set is a paired problem set.
2. Play paper, scissors, rock to determine who goes first. Call that person *Partner 1*.
    - Partner 1 (name and cnet ID): Guillermina Marto - gmarto
    - Partner 2 (name and cnet ID): Alejandra Silva - aosilva
3. Partner 1 will accept the `ps5` and then share the link it creates with their partner. You can only share it with one partner so you will not be able to change it after your partner has accepted.
4. "This submission is our work alone and complies with the 30538 integrity policy." Add your initials to indicate your agreement: **GM** **___**
5. "I have uploaded the names of anyone else other than my partner and I worked with on the problem set **here**" (1 point)
6. Late coins used this pset: **___** Late coins left after submission: **___**
7. Knit your `ps5.qmd` to an PDF file to make `ps5.pdf`,
    - The PDF should not be more than 25 pages. Use `head()` and re-size figures when appropriate.
8. (Partner 1): push `ps5.qmd` and `ps5.pdf` to your github repo.
9. (Partner 1): submit `ps5.pdf` via Gradescope. Add your partner on Gradescope.
10. (Partner 1): tag your submission in Gradescope

```
import pandas as pd
import altair as alt
import time

import warnings
warnings.filterwarnings('ignore')
alt.renderers.enable("png")
```

```
RendererRegistry.enable('png')
```

## Step 1: Develop initial scraper and crawler

### 1. Scraping (PARTNER 1)

```
import requests
from bs4 import BeautifulSoup

# URL of the HHS OIG Enforcement Actions page
url = "https://oig.hhs.gov/fraud/enforcement/"

# Send a GET request to the page
response = requests.get(url)
response.raise_for_status()

# Parse the HTML with BeautifulSoup
soup = BeautifulSoup(response.text, "html.parser")

# Lists to store the extracted data
titles = []
dates = []
categories = []
links = []

# Find all enforcement action items
for item in soup.select("li.usa-card"):
    # Extract the title
    title_element = item.select_one("h2.usa-card__heading a")
    if title_element:
        titles.append(title_element.get_text(strip=True))
        links.append("https://oig.hhs.gov" + title_element["href"])
```

```
    else:
        titles.append(None)
        links.append(None)

    # Extract the date
    date_element = item.select_one("span.text-base-dark")
    dates.append(date_element.get_text(strip=True) if date_element else None)

    # Extract the category
    category_element = item.select_one("ul li.usa-tag")
    categories.append(category_element.get_text(strip=True) if
↪   category_element else None)

# Create a DataFrame with the extracted data
data = pd.DataFrame({
    "Title": titles,
    "Date": dates,
    "Category": categories,
    "Link": links
})

# Save the DataFrame to a CSV file
data.to_csv("hhs_oig_enforcement_actions.csv", index=False)

# Display the DataFrame
print(data.head())
```

```
                                               Title              Date  \
0  Pharmacist and Brother Convicted of $15M Medic...  November 8, 2024
1  Boise Nurse Practitioner Sentenced To 48 Month...  November 7, 2024
2  Former Traveling Nurse Pleads Guilty To Tamper...  November 7, 2024
3  Former Arlington Resident Sentenced To Prison ...  November 7, 2024
4  Paroled Felon Sentenced To Six Years For Fraud...  November 7, 2024

                     Category  \
0  Criminal and Civil Actions
1  Criminal and Civil Actions
2  Criminal and Civil Actions
3  Criminal and Civil Actions
4  Criminal and Civil Actions

                                                Link
```

```
0  https://oig.hhs.gov/fraud/enforcement/pharmaci...
1  https://oig.hhs.gov/fraud/enforcement/boise-nu...
2  https://oig.hhs.gov/fraud/enforcement/former-t...
3  https://oig.hhs.gov/fraud/enforcement/former-a...
4  https://oig.hhs.gov/fraud/enforcement/paroled-...
```

### 2. Crawling (PARTNER 1)

```
import time

# Initialize an empty list to store agency names
agencies = []

# Loop through each link in the DataFrame to extract agency information
for link in data["Link"]:
    action_response = requests.get(link)
    action_response.raise_for_status()
    action_soup = BeautifulSoup(action_response.text, "html.parser")

    # Extract agency information - usually the second <li> element
    agency_element = action_soup.select("ul.usa-list--unstyled li")
    if len(agency_element) > 1:
        agency_text = agency_element[1].get_text(strip=True)
        agency_name = agency_text.split(":", 1)[-1].strip()  # Extract text
 ↪  after "Agency:"
        agencies.append(agency_name)
    else:
        agencies.append(None)

    # Optional: Pause to avoid too many rapid requests
    time.sleep(1)

# Update the DataFrame with the new 'Agency' column
data["Agency"] = agencies

# Print the first few rows to verify
print(data.head())
```

```
                                               Title              Date  \
0  Pharmacist and Brother Convicted of $15M Medic...  November 8, 2024
1  Boise Nurse Practitioner Sentenced To 48 Month...  November 7, 2024
```

```
2  Former Traveling Nurse Pleads Guilty To Tamper...  November 7, 2024
3  Former Arlington Resident Sentenced To Prison ...  November 7, 2024
4  Paroled Felon Sentenced To Six Years For Fraud...  November 7, 2024

                    Category  \
0  Criminal and Civil Actions
1  Criminal and Civil Actions
2  Criminal and Civil Actions
3  Criminal and Civil Actions
4  Criminal and Civil Actions

                                                 Link  \
0  https://oig.hhs.gov/fraud/enforcement/pharmaci...
1  https://oig.hhs.gov/fraud/enforcement/boise-nu...
2  https://oig.hhs.gov/fraud/enforcement/former-t...
3  https://oig.hhs.gov/fraud/enforcement/former-a...
4  https://oig.hhs.gov/fraud/enforcement/paroled-...

                                              Agency
0                          U.S. Department of Justice
1  November 7, 2024; U.S. Attorney's Office, Dist...
2  U.S. Attorney's Office, District of Massachusetts
3  U.S. Attorney's Office, Eastern District of Vi...
4  U.S. Attorney's Office, Middle District of Flo...
```

## Step 2: Making the scraper dynamic

### 1. Turning the scraper into a function

- a. Pseudo-Code (PARTNER 2)

1. **Define the Function** `scrape_enforcement_actions(start_month, start_year)`:
    - **Inputs**:
        - `start_month`: The month to start scraping from (1 to 12).
        - `start_year`: The year to start scraping from (should be >= 2013).
2. **Initial Validity Check**:
    - If `start_year` is less than 2013, **print a message**: "Please enter a year >= 2013, as data before 2013 is not available."
    - **Exit the function** if the condition is not met.
3. **Setup**:

- Define the **base URL** for the HHS OIG enforcement actions page.
- **Initialize lists** to store scraped data for each action (e.g., `titles`, `dates`, `categories`, `links`).
- Set `page = 1` to start from the first page of the site.
- Get the **current date** to compare against as the end condition.

4. **Loop Through Pages Until Date Condition is Met**:
   - Start a `while` loop:
     - **Construct URL** with the current `page` number.
     - **Request the page** content and parse it with `BeautifulSoup`.
     - **Find all enforcement action items** on the page (e.g., by selecting specific HTML elements).
     - **Check for End of Pages**:
       * If no items are found (end of content), **break** the loop.
5. **Extract Data for Each Action**:
   - For each item on the page:
     - Extract and **store the title**, **link**, **date**, and **category**.
     - **Parse the date** to check if it's within the specified `start_year` and `start_month`.
       * If the action's date is earlier than the specified date, **break** the loop to stop scraping.
6. **Append Data to Lists**:
   - Append the extracted data for title, date, category, and link to the respective lists.
7. **Move to the Next Page**:
   - Increment `page` by 1 to load the next set of actions.
   - Use `time.sleep(1)` to pause between requests to avoid overloading the server.
8. **Create a DataFrame and Save to CSV**:
   - After exiting the loop, **create a DataFrame** from the lists.
   - **Save** the DataFrame to a CSV file.
9. **End Function**:
   - Print a confirmation message that data has been saved.

This structure uses a `while` loop to handle pagination dynamically and ensures the scraper stops early if it encounters data before the specified start date.

- b. Create Dynamic Scraper (PARTNER 2)

```
from datetime import datetime
import requests
from bs4 import BeautifulSoup
import pandas as pd

def scrape_enforcement_actions(start_month, start_year):
    start_date = datetime(start_year, start_month, 1)

    # Check if the input year is valid (>= 2013)
    if start_year < 2013:
        print("Please enter a year >= 2013, as data before 2013 is not
        ↪  available.")
        return

    base_url = "https://oig.hhs.gov/fraud/enforcement/"
    all_titles, all_dates, all_categories, all_links, all_agencies = [], [],
↪   [], [], []
    page = 1
    stop_scraping = False

    while not stop_scraping:
        response = requests.get(f"{base_url}?page={page}")
        response.raise_for_status()
        soup = BeautifulSoup(response.text, "html.parser")

        for item in soup.select("li.usa-card"):
            title_element = item.select_one("h2.usa-card__heading a")
            title = title_element.get_text(strip=True) if title_element else
↪   None
            link = "https://oig.hhs.gov" + title_element["href"] if
↪   title_element else None

            date_element = item.select_one("span.text-base-dark")
            date_text = date_element.get_text(strip=True) if date_element
↪   else None
            date_obj = datetime.strptime(date_text, "%B %d, %Y") if date_text
↪   else None

            # Stop if the date is before start_date
            if date_obj and date_obj < start_date:
                stop_scraping = True
                break
```

```
            category_element = item.select_one("ul li.usa-tag")
            category = category_element.get_text(strip=True) if
↪   category_element else None

            all_titles.append(title)
            all_dates.append(date_text)
            all_categories.append(category)
            all_links.append(link)

            # Optional: Pause to avoid too many rapid requests
            time.sleep(0.05)

        page += 1

    # Extract agency information from each link
    for link in all_links:
        action_response = requests.get(link)
        action_response.raise_for_status()
        action_soup = BeautifulSoup(action_response.text, "html.parser")

        agency_element = action_soup.select("ul.usa-list--unstyled li")
        if len(agency_element) > 1:
            agency_text = agency_element[1].get_text(strip=True)
            all_agencies.append(agency_text.split(":", 1)[-1].strip())
        else:
            all_agencies.append(None)

    # Create DataFrame
    data = pd.DataFrame({
        "Title": all_titles,
        "Date": all_dates,
        "Category": all_categories,
        "Link": all_links,
        "Agency": all_agencies
    })

    # Save the DataFrame to a CSV file
    filename = f"enforcement_actions_{start_year}_{start_month}.csv"
    data.to_csv(filename, index=False)
    print(f"Data saved to {filename}")
```

```
    return data

# Example usage:
data = scrape_enforcement_actions(1, 2023)
#print(data.head())

print(f"Total enforcement actions collected: {len(data)}")
data["Date"] = pd.to_datetime(data["Date"], errors="coerce")
earliest_action = data.sort_values("Date").iloc[0]
print("Earliest enforcement action collected:")
print(earliest_action)
```

```
Data saved to enforcement_actions_2023_1.csv
Total enforcement actions collected: 1534
Earliest enforcement action collected:
Title       Podiatrist Pays $90,000 To Settle False Billin...
Date                                      2023-01-03 00:00:00
Category                            Criminal and Civil Actions
Link        https://oig.hhs.gov/fraud/enforcement/podiatri...
Agency      U.S. Attorney's Office, Southern District of T...
Name: 1533, dtype: object
```

- c. Test Partner's Code (PARTNER 1)

```
# Collect data from January 2021 to today
data = scrape_enforcement_actions(1, 2021)

# Check the number of enforcement actions collected

print(f"Total enforcement actions collected: {len(data)}")

# Display the earliest enforcement action by date
data["Date"] = pd.to_datetime(data["Date"], errors="coerce")
earliest_action = data.sort_values("Date").iloc[0]
print("Earliest enforcement action collected:")
print(earliest_action)
```

```
Data saved to enforcement_actions_2021_1.csv
Total enforcement actions collected: 3022
Earliest enforcement action collected:
Title       The United States And Tennessee Resolve Claims...
Date                                      2021-01-04 00:00:00
```

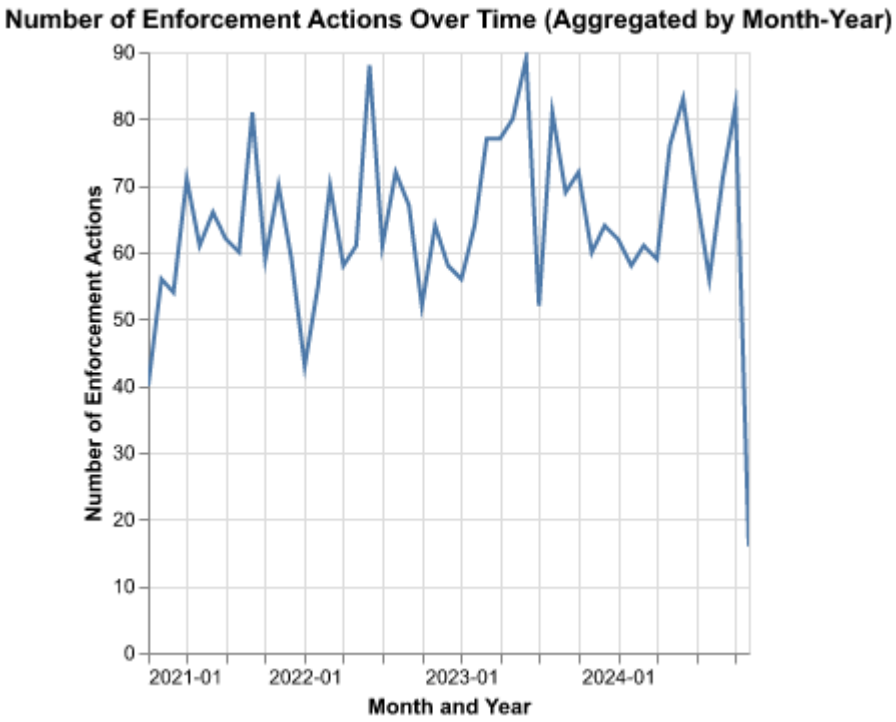
```
Category                              Criminal and Civil Actions
Link          https://oig.hhs.gov/fraud/enforcement/the-unit...
Agency        U.S. Attorney's Office, Middle District of Ten...
Name: 3021, dtype: object
```

### Step 3: Plot data based on scraped data

#### 1. Plot the number of enforcement actions over time (PARTNER 2)

```
import altair as alt

# Assuming your data is loaded as 'data' and processed similarly
data = pd.read_csv("enforcement_actions_2021_1.csv")

# Convert 'Date' column to datetime format to enable time-based operations
data["Date"] = pd.to_datetime(data["Date"], errors="coerce")

# Drop rows with NaT in Date (if any) after conversion
data = data.dropna(subset=["Date"])

# Extract month-year for aggregation
data["Year_Month"] = data["Date"].dt.to_period("M")

# Group by month-year and count the number of actions
monthly_counts = data.groupby("Year_Month").size().reset_index(name="Count")

# Convert Year_Month to datetime for Altair plotting
monthly_counts["Year_Month"] = monthly_counts["Year_Month"].dt.to_timestamp()

# Plot the line chart using Altair with improved tick formatting
chart = alt.Chart(monthly_counts).mark_line().encode(
    x=alt.X("Year_Month:T", title="Month and Year",
 ↪  axis=alt.Axis(format="%Y-%m")),
    y=alt.Y("Count:Q", title="Number of Enforcement Actions"),
    tooltip=["Year_Month:T", "Count:Q"]
).properties(
    title="Number of Enforcement Actions Over Time (Aggregated by
 ↪  Month-Year)",
    width=300,
    height=300
).interactive()
```

```
chart
```

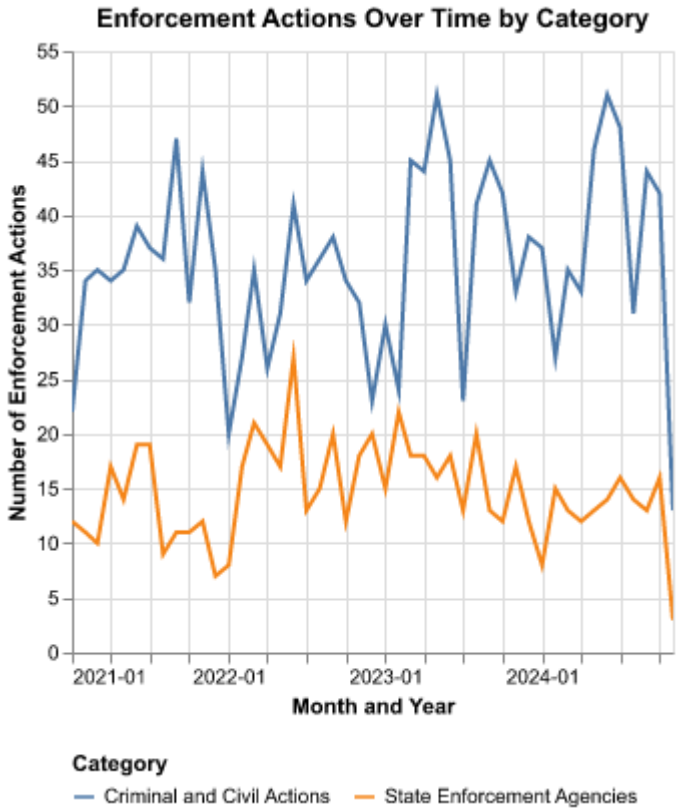



## 2. Plot the number of enforcement actions categorized: (PARTNER 1)

- based on "Criminal and Civil Actions" vs. "State Enforcement Agencies"

```
# Assuming your data is loaded as 'data' and processed similarly
data = pd.read_csv("enforcement_actions_2021_1.csv")

# Convert 'Date' column to datetime format
data["Date"] = pd.to_datetime(data["Date"], errors="coerce")

# Drop rows with NaT in Date (if any)
data = data.dropna(subset=["Date"])

# Extract month-year for aggregation
data["Year_Month"] = data["Date"].dt.to_period("M")
```

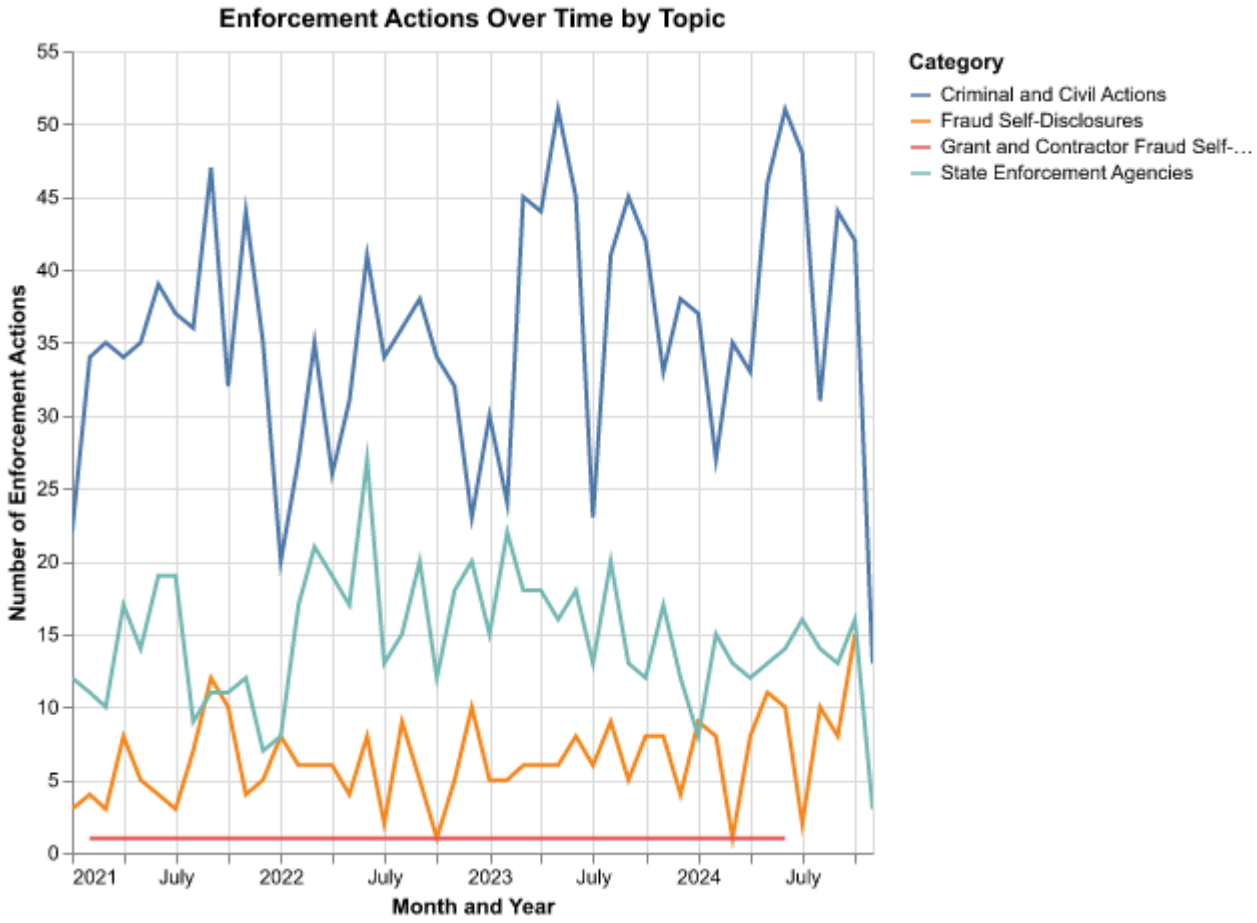
```
# Filter for specific categories
categories_of_interest = ["Criminal and Civil Actions", "State Enforcement
 ↪  Agencies"]
filtered_data = data[data["Category"].isin(categories_of_interest)]

# Group by month-year and category, then count the number of actions
monthly_category_counts = (
    filtered_data.groupby(["Year_Month", "Category"])
    .size()
    .reset_index(name="Count")
)

# Convert Year_Month to datetime for Altair plotting
monthly_category_counts["Year_Month"] =
 ↪  monthly_category_counts["Year_Month"].dt.to_timestamp()

# Plot the line chart by category with improved tick formatting
category_chart = alt.Chart(monthly_category_counts).mark_line().encode(
    x=alt.X("Year_Month:T", title="Month and Year",
 ↪  axis=alt.Axis(format="%Y-%m")),
    y=alt.Y("Count:Q", title="Number of Enforcement Actions"),
    color=alt.Color("Category", legend=alt.Legend(orient="bottom")),
    tooltip=["Year_Month:T", "Category", "Count"]
).properties(
    title="Enforcement Actions Over Time by Category",
    width=300,
    height=300
).interactive()

category_chart
```




- based on five topics

```
# Define five specific topics to categorize actions
topics_of_interest = [
    "Criminal and Civil Actions",
    "State Enforcement Agencies",
    "Fraud Self-Disclosures",
    "Grant and Contractor Fraud Self-Disclosures",
    "Medicare Fraud Strike Force"
]

# Filter data for these topics
topic_filtered_data = data[data["Category"].isin(topics_of_interest)]

# Group by month-year and topic, then count the actions
monthly_topic_counts = (
    topic_filtered_data.groupby(["Year_Month", "Category"])
    .size()
    .reset_index(name="Count")
```

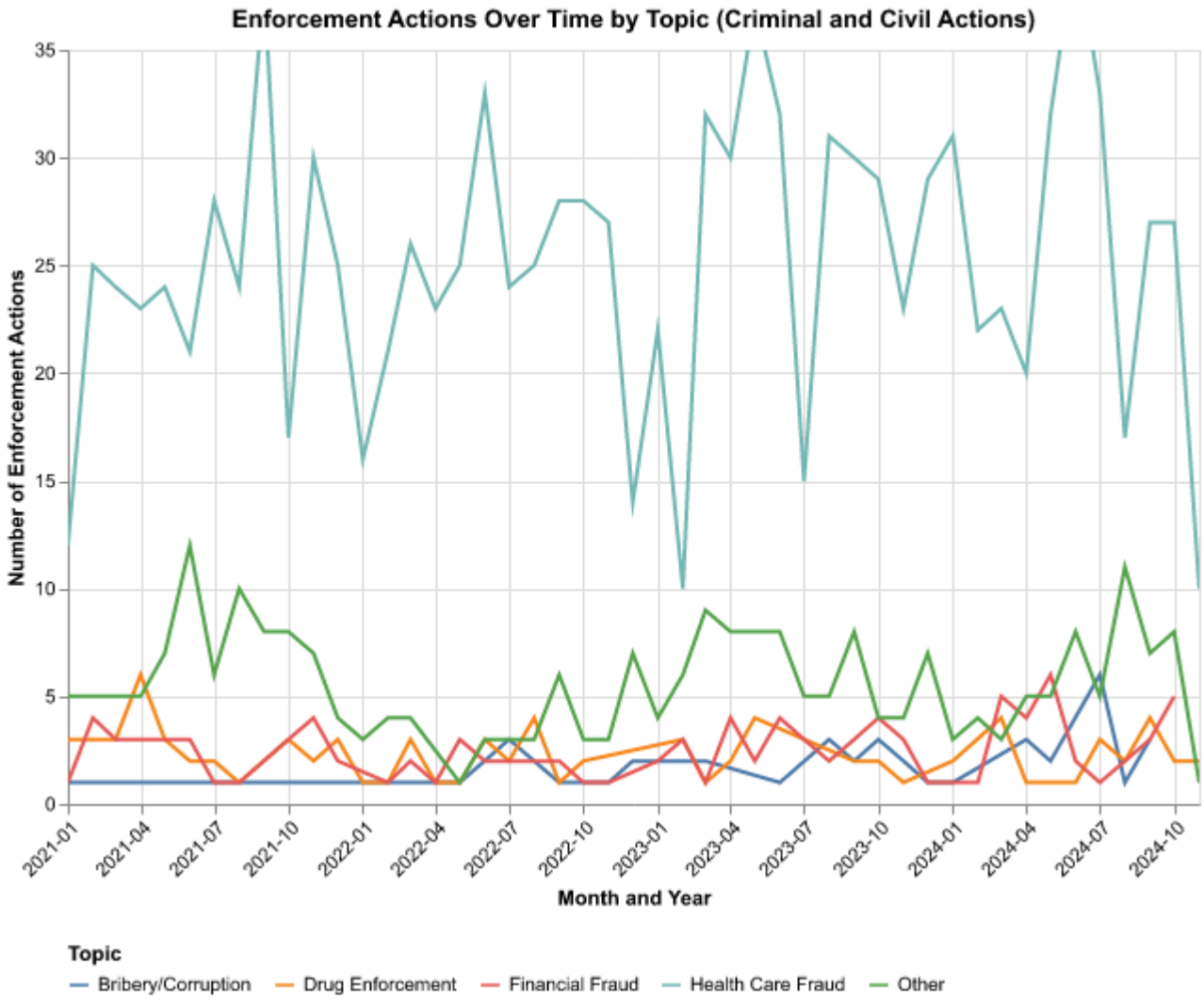
```
)

# Convert Year_Month to datetime for plotting
monthly_topic_counts["Year_Month"] =
 ↪  monthly_topic_counts["Year_Month"].dt.to_timestamp()

# Plot the line chart by topic
topic_chart = alt.Chart(monthly_topic_counts).mark_line().encode(
    x=alt.X("Year_Month:T", title="Month and Year"),
    y=alt.Y("Count:Q", title="Number of Enforcement Actions"),
    color="Category",
    tooltip=["Year_Month:T", "Category", "Count"]
).properties(
    title="Enforcement Actions Over Time by Topic",
    width=400,
    height=400
).interactive()

topic_chart
```




```
# Assuming your data is processed as shown earlier
data = pd.read_csv("enforcement_actions_2021_1.csv")

# Convert 'Date' column to datetime format
data["Date"] = pd.to_datetime(data["Date"], errors="coerce")
data = data.dropna(subset=["Date"])
data["Year_Month"] = data["Date"].dt.to_period("M")

# Filter and assign topics
categories_of_interest = ["Criminal and Civil Actions"]
filtered_data = data[data["Category"] == "Criminal and Civil Actions"]

def assign_topic(title):
    title = title.lower()
    if any(keyword in title for keyword in ["health", "medical", "hospital",
     ↪  "clinic", "insurance", "medicare", "medicaid", "patient",
     ↪  "pharmaceutical", "doctor", "nurse"]):
```

```
        return "Health Care Fraud"
    elif any(keyword in title for keyword in ["bank", "financial",
     ↪  "investment", "securities", "loan", "mortgage", "credit", "fund",
     ↪  "money laundering", "asset", "accounting", "tax", "ponzi",
     ↪  "scheme"]):
        return "Financial Fraud"
    elif any(keyword in title for keyword in ["drug", "narcotic", "opioid",
     ↪  "cocaine", "heroin", "methamphetamine", "prescription", "pharmacy",
     ↪  "substance abuse", "dea"]):
        return "Drug Enforcement"
    elif any(keyword in title for keyword in ["bribery", "corruption",
     ↪  "kickback", "lobbying", "graft", "illegal payment", "under the
     ↪  table", "influence", "official", "misconduct", "embezzlement"]):
        return "Bribery/Corruption"
    else:
        return "Other"

filtered_data["Topic"] = filtered_data["Title"].apply(assign_topic)

# Group by month-year and topic
monthly_topic_counts = (
    filtered_data.groupby(["Year_Month", "Topic"])
    .size()
    .reset_index(name="Count")
)
monthly_topic_counts["Year_Month"] =
 ↪  monthly_topic_counts["Year_Month"].dt.to_timestamp()

# Plot with adjustments for axes
topic_chart = alt.Chart(monthly_topic_counts).mark_line().encode(
    x=alt.X("Year_Month:T", title="Month and Year",
 ↪  axis=alt.Axis(format="%Y-%m", labelAngle=-45)),
    y=alt.Y("Count:Q", title="Number of Enforcement Actions",
 ↪  scale=alt.Scale(domain=(0, 35))),
    color=alt.Color("Topic", legend=alt.Legend(orient="bottom")),
    tooltip=["Year_Month:T", "Topic", "Count"]
).properties(
    title="Enforcement Actions Over Time by Topic (Criminal and Civil
 ↪  Actions)",
    width=600,
    height=400
).configure_axisX(
```

```
    labelFontSize=10
).interactive()

topic_chart
```

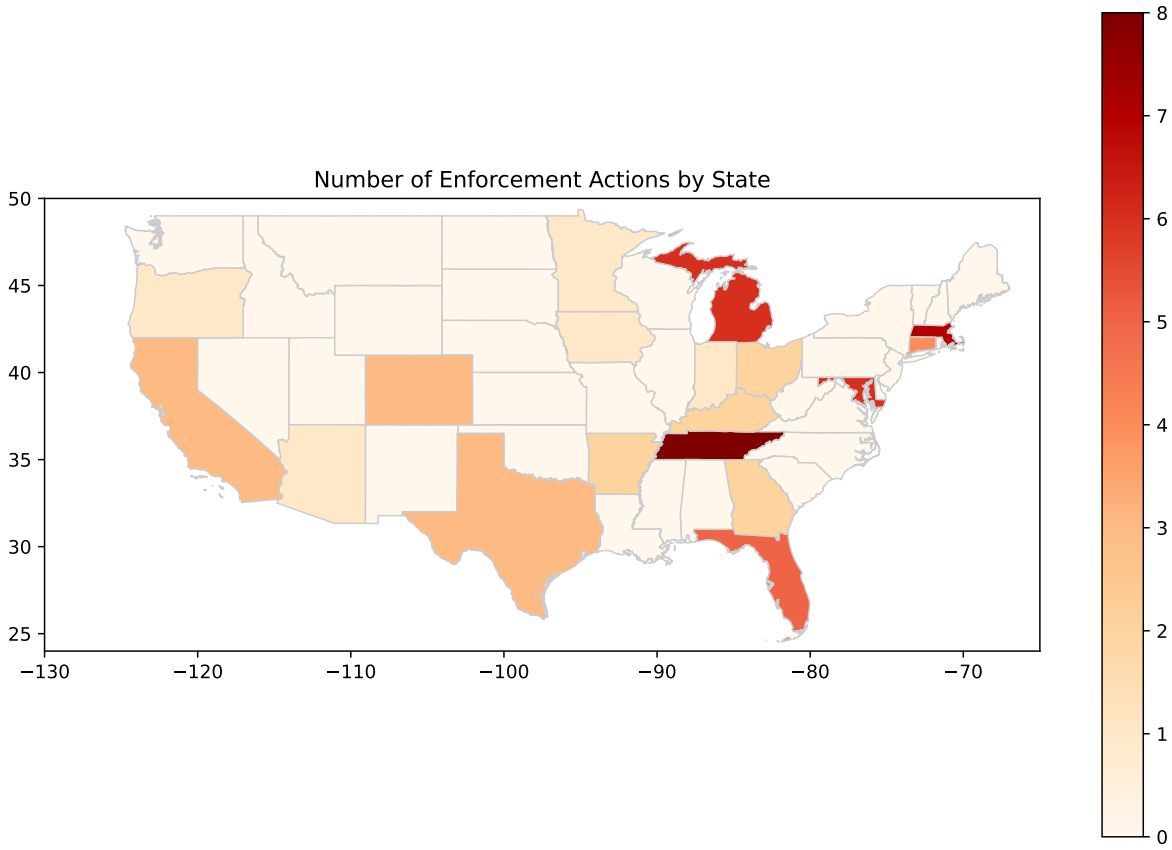


### Step 4: Create maps of enforcement activity

#### 1. Map by State (PARTNER 1)

```
import geopandas as gpd
import matplotlib.pyplot as plt

# Load the enforcement actions data
data = pd.read_csv("enforcement_actions_2021_1.csv")

# Update the path to the .shp file with either double backslashes or a raw
 ↪  string
#shapefile_path = r'US Attorney Districts Shapefile
 ↪  simplified_20241105\geo_export_863694bc-2e85-424f-96a2-1598bf583e4c.shp'

shapefile_path_us = r'US Attorney Districts Shapefile
 ↪  simplified_20241108/geo_export_f7b8e2a6-7a91-4743-8cde-a71cb95af3e2.shp'

shapefile_path_census = r'cb_2018_us_state_500k/cb_2018_us_state_500k.shp'

# Load the shapefiles
district_shapefile = gpd.read_file(shapefile_path_us)
census_shapefile = gpd.read_file(shapefile_path_census)

# Filter for state-level actions and extract state names
state_level_enforcements = data[data['Agency'].str.contains("State of",
 ↪  na=False)]
state_level_enforcements['State'] =
 ↪  state_level_enforcements['Agency'].str.extract(r'State of (\w+)')

# Count the number of enforcement actions per state
state_counts = state_level_enforcements['State'].value_counts().reset_index()
state_counts.columns = ['State', 'Enforcement_Actions']

# Remove Alaska, Hawaii, and other territories
census_shapefile = census_shapefile.rename(columns={'NAME': 'State'})

# Merge the enforcement counts with the census shapefile
merged = census_shapefile.merge(state_counts, on='State', how='left')
merged['Enforcement_Actions'] = merged['Enforcement_Actions'].fillna(0)
```

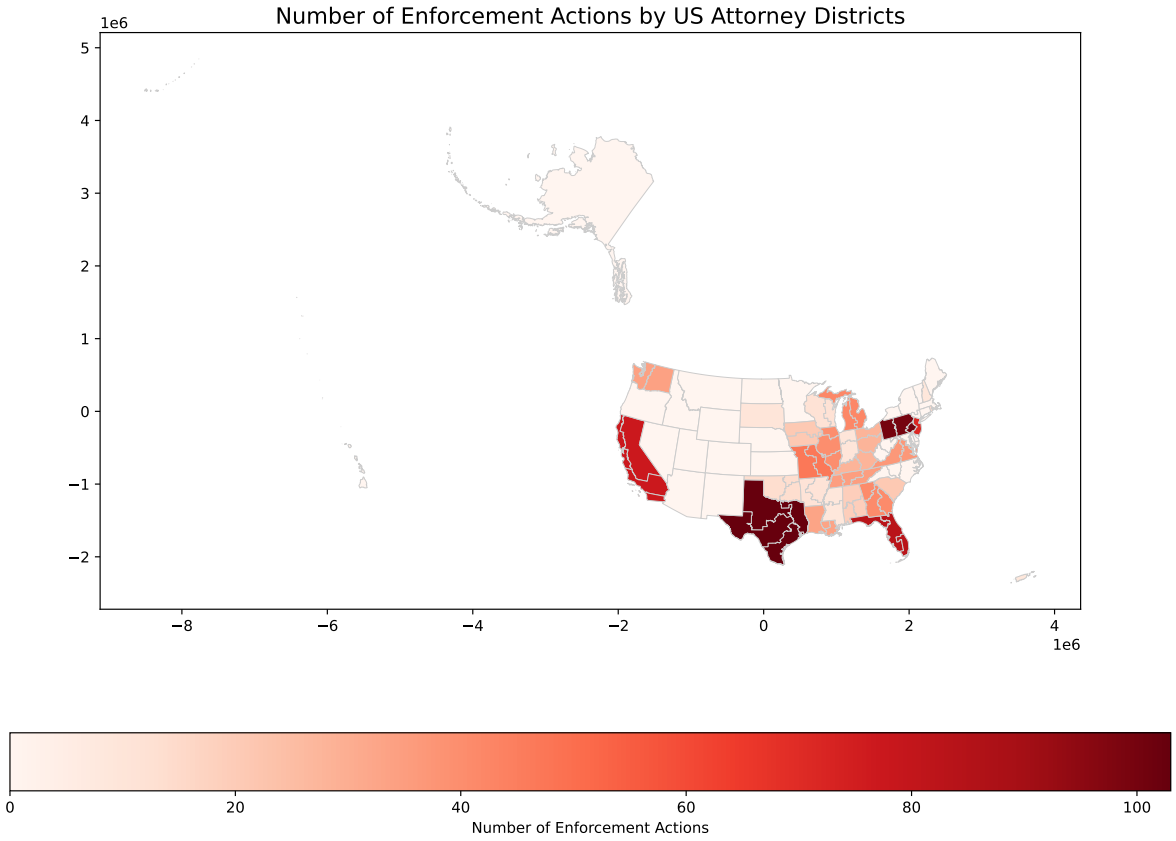
```
# Plot the choropleth map with axis limits focused on the contiguous U.S.
fig, ax = plt.subplots(1, 1, figsize=(12, 8))
merged.plot(column='Enforcement_Actions', cmap='OrRd', linewidth=0.8, ax=ax,
 ↪  edgecolor='0.8', legend=True)
ax.set_title("Number of Enforcement Actions by State")

# Set axis limits to focus on the contiguous U.S.
ax.set_xlim(-130, -65)
ax.set_ylim(24, 50)

plt.show()
```




## 2. Map by District (PARTNER 2)

```
# Load the shapefile
district_shapefile = gpd.read_file(shapefile_path_us)
census_shapefile = gpd.read_file(shapefile_path_census)

# Load the enforcement actions data
data = pd.read_csv("enforcement_actions_2021_1.csv")

# Filter for US Attorney District-level agencies by looking for "District" in
 ↪  the Agency column
district_data = data[data["Agency"].str.contains("District",
 ↪  na=False)].copy()

# Keep only the last three words in the District column of enforcement data
district_data["District"] = district_data["Agency"].apply(lambda x: '
 ↪  '.join(x.split()[-3:]))

# Count the number of enforcement actions per district
district_counts = district_data["District"].value_counts().reset_index()
district_counts.columns = ["District", "Count"]

# Remove Alaska, Hawaii, and other territories
census_shapefile = census_shapefile.rename(columns={'NAME': 'State'})
census_shapefile =
 ↪  census_shapefile[~census_shapefile['State'].isin(['Alaska', 'Hawaii'])]

# Remove the first word from each entry in the judicial_d column
district_shapefile["cleaned_judicial_d"] =
 ↪  district_shapefile["judicial_d"].apply(lambda x: ' '.join(x.split()[1:]))

# Merge the district counts with the shapefile data on 'cleaned_judicial_d'
 ↪  and 'District'
district_map_data = district_shapefile.merge(district_counts,
 ↪  left_on="cleaned_judicial_d", right_on="District", how="left")

# Fill NaN values in the 'Count' column with 0 for districts with no actions
district_map_data["Count"].fillna(0, inplace=True)

# Plot without axis limits to see all areas
fig, ax = plt.subplots(1, 1, figsize=(14, 10))
district_map_data.to_crs("EPSG:2163").plot(  # Albers Equal Area projection
 ↪  for the US
```

```
    column="Count", cmap="Reds", linewidth=0.5, ax=ax, edgecolor="0.8",
 ↪  legend=True,
    legend_kwds={"label": "Number of Enforcement Actions", "orientation":
 ↪  "horizontal"}
)
ax.set_title("Number of Enforcement Actions by US Attorney Districts",
 ↪  fontsize=15)

plt.show()
```




## Extra Credit

### 1. Merge zip code shapefile with population

```
# Load the population data
#population_data_path =
 ↪  "DECENNIALDHC2020.P1_2024-11-08T134537\DECENNIALDHC2020.P1-Data.csv"

population_data_path =
 ↪  "DECENNIALDHC2020.P1_2024-11-10T141341/DECENNIALDHC2020.P1-Data.csv"
population_df = pd.read_csv(population_data_path)

# Check the first few rows
print(population_df.head())

# Ensure `ZIP_Code` is formatted as a string (if necessary)
population_df["ZIP_Code"] =
 ↪  population_df["GEO_ID"].str.extract(r'(\d{5})')[0]
population_df["Population"] = pd.to_numeric(population_df["P1_001N"],
 ↪  errors="coerce")

# Drop rows with missing ZIP codes or population data
population_df = population_df.dropna(subset=["ZIP_Code", "Population"])

# Load the ZIP code shapefile
#zip_shapefile_path = "gz_2010_us_860_00_500k\gz_2010_us_860_00_500k.shp"
zip_shapefile_path = "gz_2010_us_860_00_500k/gz_2010_us_860_00_500k.shp"
zip_gdf = gpd.read_file(zip_shapefile_path)

# Rename the ZIP column in the shapefile data for consistency
zip_gdf = zip_gdf.rename(columns={"ZCTA5": "ZIP_Code"})
 # Adjust this if your column name is different

# Merge population data with ZIP code shapefile on ZIP_Code
merged_gdf = zip_gdf.merge(population_df[['ZIP_Code', 'Population']],
 ↪  on="ZIP_Code", how="left")

# Check merged data
print(merged_gdf.head())
```

```
           GEO_ID                  NAME   P1_001N  Unnamed: 3
0       Geography  Geographic Area Name   !!Total         NaN
1  860Z200US00601           ZCTA5 00601     17242         NaN
2  860Z200US00602           ZCTA5 00602     37548         NaN
3  860Z200US00603           ZCTA5 00603     49804         NaN
```

```
4  860Z200US00606           ZCTA5 00606      5009         NaN
           GEO_ID ZIP_Code   NAME   LSAD  CENSUSAREA  \
0  8600000US01040    01040  01040  ZCTA5      21.281
1  8600000US01050    01050  01050  ZCTA5      38.329
2  8600000US01053    01053  01053  ZCTA5       5.131
3  8600000US01056    01056  01056  ZCTA5      27.205
4  8600000US01057    01057  01057  ZCTA5      44.907

                                              geometry  Population
0  POLYGON ((-72.62734 42.16203, -72.62764 42.162...     38238.0
1  POLYGON ((-72.95393 42.34379, -72.95385 42.343...      2467.0
2  POLYGON ((-72.68286 42.37002, -72.68287 42.369...      2031.0
3  POLYGON ((-72.39529 42.18476, -72.39653 42.183...     21002.0
4  MULTIPOLYGON (((-72.39191 42.08066, -72.39077 ...      8152.0
```

**2. Conduct spatial join**

```
# Ensure both GeoDataFrames (merged_gdf and district_shapefile) are in the
 ↪  same CRS
merged_gdf = merged_gdf.to_crs(district_shapefile.crs)

# Perform a spatial join between ZIP codes and districts
zip_district_join = gpd.sjoin(merged_gdf, district_shapefile, how="inner",
 ↪  predicate="intersects")

print(zip_district_join.columns)

# Aggregate the population for each district
population_by_district =
 ↪  zip_district_join.groupby("judicial_d")["Population"].sum().reset_index()

# Check the aggregated data
print(population_by_district.head())
```

```
Index(['GEO_ID', 'ZIP_Code', 'NAME', 'LSAD', 'CENSUSAREA', 'geometry',
       'Population', 'index_right', 'statefp', 'judicial_d', 'aland',
       'awater',
       'state', 'chief_judg', 'nominating', 'term_as_ch', 'shape_leng',
       'shape_area', 'abbr', 'district_n', 'shape__are', 'shape__len',
       'cleaned_judicial_d'],
      dtype='object')
```

```
                       judicial_d  Population
0  Central District of California  19621862.0
1    Central District of Illinois   2684528.0
2              District of Alaska    707199.0
3             District of Arizona   7334666.0
4            District of Colorado   5935657.0
```

### 3. Map the action ratio in each district

```
import re

# Load enforcement actions data
enforcement_data = pd.read_csv("enforcement_actions_2021_1.csv")

# Convert 'Date' column to datetime format and filter for actions since
 ↪  January 2021
enforcement_data["Date"] = pd.to_datetime(enforcement_data["Date"],
 ↪  errors="coerce")
enforcement_data = enforcement_data[enforcement_data["Date"] >= "2021-01-01"]

# Filter for district-level actions and extract district names with improved
 ↪  regex
def extract_district_name(agency):
    match =
 ↪  re.search(r"(Eastern|Western|Northern|Southern|Middle)?\s*District
 ↪  of\s+[A-Za-z\s]+", agency)
    return match.group(0).strip() if match else agency

# Apply the function to extract district names from 'Agency'
enforcement_data["District"] =
 ↪  enforcement_data["Agency"].apply(extract_district_name)

# Count the number of enforcement actions per district
actions_per_district =
 ↪  enforcement_data["District"].value_counts().reset_index()
actions_per_district.columns = ["judicial_d", "Enforcement_Actions"]

# Load the population data and calculate the population per district
population_data_path =
 ↪  "DECENNIALDHC2020.P1_2024-11-10T141341/DECENNIALDHC2020.P1-Data.csv"
population_df = pd.read_csv(population_data_path)
```

```
# Extract ZIP code and population, ensuring 'ZIP_Code' is a string
population_df["ZIP_Code"] =
 ↪  population_df["GEO_ID"].str.extract(r'(\d{5})')[0]
population_df["Population"] = pd.to_numeric(population_df["P1_001N"],
 ↪  errors="coerce")
population_df = population_df.dropna(subset=["ZIP_Code", "Population"])

# Load the ZIP code shapefile and merge with population data
zip_shapefile_path = "gz_2010_us_860_00_500k/gz_2010_us_860_00_500k.shp"
zip_gdf = gpd.read_file(zip_shapefile_path)
zip_gdf = zip_gdf.rename(columns={"ZCTA5": "ZIP_Code"})

# Merge population data with ZIP code shapefile on ZIP_Code
merged_gdf = zip_gdf.merge(population_df[['ZIP_Code', 'Population']],
 ↪  on="ZIP_Code", how="left")

# Load the district shapefile
district_shapefile_path = r'US Attorney Districts Shapefile
 ↪  simplified_20241108/geo_export_f7b8e2a6-7a91-4743-8cde-a71cb95af3e2.shp'
district_shapefile = gpd.read_file(district_shapefile_path)

# Ensure both GeoDataFrames are in the same CRS
merged_gdf = merged_gdf.to_crs(district_shapefile.crs)

# Perform a spatial join between ZIP codes and districts
zip_district_join = gpd.sjoin(merged_gdf, district_shapefile, how="inner",
 ↪  predicate="intersects")

# Aggregate the population for each district
population_by_district =
 ↪  zip_district_join.groupby("judicial_d")["Population"].sum().reset_index()

# Merge enforcement actions with population data
district_ratios = actions_per_district.merge(population_by_district,
 ↪  on="judicial_d", how="left")

# Calculate the ratio of enforcement actions per capita (per population)
district_ratios["Enforcement_Ratio"] = district_ratios["Enforcement_Actions"]
 ↪  / district_ratios["Population"]

# Merge with the district shapefile for mapping
```

```
district_map_data = district_shapefile.merge(district_ratios,
 ↪  on="judicial_d", how="left")

# Plot the choropleth map
fig, ax = plt.subplots(1, 1, figsize=(14, 10))
district_map_data.to_crs("EPSG:2163").plot(
    column="Enforcement_Ratio", cmap="Blues", linewidth=0.5, ax=ax,
 ↪  edgecolor="0.8", legend=True,
    legend_kwds={"label": "Enforcement Actions per Capita", "orientation":
 ↪  "horizontal"}
)
ax.set_title("Ratio of Enforcement Actions per Population by US Attorney
 ↪  District", fontsize=15)

plt.show()
```