PS 5

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2024-11-10

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): George Wang, gwang613
    - Partner 2 (name and cnet ID): Yuxuan Geng, yuxuan1123
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: **GW YG**
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: **2** Late coins left after submission: **1**
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 pandas as pd
import requests
from bs4 import BeautifulSoup

# Get web page through soup
url = "https://oig.hhs.gov/fraud/enforcement/"
response = requests.get(url)
soup = BeautifulSoup(response.content, 'lxml')

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

for action in soup.find_all('li', class_='usa-card card--list
↪  pep-card--minimal mobile:grid-col-12'):
    # Extract title
    title = action.find('h2',
↪  class_='usa-card__heading').get_text(strip=True)
    titles.append(title)

    # Extract link
    link = action.find('a')['href']
    links.append(f"https://oig.hhs.gov{link}")

    # Extract date
```

```
    date = action.find('span', class_='text-base-dark
↪   padding-right-105').get_text(strip=True)
    dates.append(date)

    # Extract category
    category = action.find('li', class_='display-inline-block usa-tag
↪   text-no-lowercase text-base-darkest bg-base-lightest
↪   margin-right-1').get_text(strip=True)
    categories.append(category)

# Create a df
data = pd.DataFrame({
    'Title': titles,
    'Date': dates,
    'Category': categories,
    'Link': links
})

data
```

	Title	Date	Category
0	Pharmacist and Brother Convicted of $15M Medic...	November 8, 2024	Criminal and Civil Action
1	Boise Nurse Practitioner Sentenced To 48 Month...	November 7, 2024	Criminal and Civil Action
2	Former Traveling Nurse Pleads Guilty To Tamper...	November 7, 2024	Criminal and Civil Action
3	Former Arlington Resident Sentenced To Prison ...	November 7, 2024	Criminal and Civil Action
4	Paroled Felon Sentenced To Six Years For Fraud...	November 7, 2024	Criminal and Civil Action
5	Former Licensed Counselor Sentenced For Defrau...	November 6, 2024	Criminal and Civil Action
6	Macomb County Doctor And Pharmacist Agree To P...	November 4, 2024	Criminal and Civil Action
7	Rocky Hill Pharmacy And Its Owners Indicted Fo...	November 4, 2024	Criminal and Civil Action
8	North Texas Medical Center Pays $14.2 Million ...	November 4, 2024	Criminal and Civil Action
9	New England Doctor Pleads Guilty To Drug Distr...	November 4, 2024	Criminal and Civil Action
10	Attorney General Alan Wilson Announces Upstate...	November 4, 2024	State Enforcement Agenci
11	St. Louis County Woman Accused Of $3 Million H...	November 1, 2024	Criminal and Civil Action
12	Lab Owner And Marketing Company Owner Both Fou...	November 1, 2024	Criminal and Civil Action
13	Compound Ingredient Supplier Medisca Inc., To ...	November 1, 2024	Criminal and Civil Action
14	The New Mexico Department Of Justice Charges F...	November 1, 2024	State Enforcement Agenci
15	Nashville Woman Indicted, Charged In TBI Medic...	November 1, 2024	State Enforcement Agenci
16	Michael DePalma, MD and Virginia I-Spine Physi...	October 31, 2024	CMP and Affirmative Exc
17	Columbus Doctor, His Clinic Convicted of $1.5 ...	October 31, 2024	State Enforcement Agenci
18	Mercy Health Youngstown Agreed to Pay $69,000 ...	October 30, 2024	Fraud Self-Disclosures
19	Quincy-Based Physician Group To Pay $650,000 T...	October 30, 2024	State Enforcement Agenci

Title	Date	Category

2. Crawling (PARTNER 1)

```
# Initialize
agencies = []
row_count = 0

# Loop trhough the dataframe to get agencies
for link in data['Link']:

    # Row counting
    row_count += 1
    print(f"Processing row {row_count}")

    # Make a request
    detail_response = requests.get(link)
    detail_soup = BeautifulSoup(detail_response.content, 'lxml')

    # Extract the agency NameError()
    agency_elements = detail_soup.find_all('span', class_='padding-right-2
 ↪  text-base')

    # Check if the second element exists
    if len(agency_elements) > 1:
        agency_li = agency_elements[1].next_sibling
        # Check if next_sibling is a string and strip it
        agency_name = agency_li.strip() if isinstance(agency_li, str) else
 ↪  str(agency_li).strip()
    else:
        agency_name = None

    # Append the extracted agency
    agencies.append(agency_li)

# Add the 'Agency' column
data['Agency'] = agencies

data
```

```
Processing row 1
Processing row 2
Processing row 3
Processing row 4
Processing row 5
Processing row 6
Processing row 7
Processing row 8
Processing row 9
Processing row 10
Processing row 11
Processing row 12
Processing row 13
Processing row 14
Processing row 15
Processing row 16
Processing row 17
Processing row 18
Processing row 19
Processing row 20
```

	Title	Date	Category
0	Pharmacist and Brother Convicted of $15M Medic...	November 8, 2024	Criminal and Civil Action
1	Boise Nurse Practitioner Sentenced To 48 Month...	November 7, 2024	Criminal and Civil Action
2	Former Traveling Nurse Pleads Guilty To Tamper...	November 7, 2024	Criminal and Civil Action
3	Former Arlington Resident Sentenced To Prison ...	November 7, 2024	Criminal and Civil Action
4	Paroled Felon Sentenced To Six Years For Fraud...	November 7, 2024	Criminal and Civil Action
5	Former Licensed Counselor Sentenced For Defrau...	November 6, 2024	Criminal and Civil Action
6	Macomb County Doctor And Pharmacist Agree To P...	November 4, 2024	Criminal and Civil Action
7	Rocky Hill Pharmacy And Its Owners Indicted Fo...	November 4, 2024	Criminal and Civil Action
8	North Texas Medical Center Pays $14.2 Million ...	November 4, 2024	Criminal and Civil Action
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11	St. Louis County Woman Accused Of $3 Million H...	November 1, 2024	Criminal and Civil Action
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Title	Date	Category

Step 2: Making the scraper dynamic

1. Turning the scraper into a function

- a. Pseudo-Code (PARTNER 2) To start, we define a function that takes month and year as input. If the year is before 2013, print a message that only years since are allowed, and then exit the function. Inside the function to intialize, set up an empty list to store the scraped data and a page variable starting at 1.

Use a while loop to keep scraping each page until there are no more enforcement actions. For each page, create a URL based on the page number and make a request to it. Parse the HTML content with BeautifulSoup and find all enforcement action items. If no items are found, stop the loop.

For each action, extract details like title, date, category, and link. Check if the date is within the specified range, and if not, skip it. Then, request the detail page for each action to get the agency name and add this data to the list.

After processing each page, increase the page number by 1 and pause for a second before moving. When finished, turn the list of data into a DataFrame and save it as enforcement_actions_year_month.csv.

- b. Create Dynamic Scraper (PARTNER 2)

```
import requests
from bs4 import BeautifulSoup
import pandas as pd
from urllib.parse import urljoin
from datetime import datetime
import time

# Define the scraper function to dynamically fetch
def scrape_enforcement_actions(start_year, start_month):
    # Base URL and start date for filtering actions
    base_url = "https://oig.hhs.gov/fraud/enforcement/"
    start_date = datetime(start_year, start_month, 1)

    # List to hold scraped data
    data = []
    page = 1
    keep_scraping = True
```

```
    detail_page_counter = 0

    while keep_scraping:
        # Construct page URL
        url = f"{base_url}?page={page}"

        # Request the page and parse the HTML
        response = requests.get(url)
        soup = BeautifulSoup(response.text, 'html.parser')

        # Find enforcement actions on the page
        actions = soup.find_all("div", class_="usa-card__container")

        # Break if no actions are found
        if not actions:
            break

        for action in actions:
            # Extract title, link, date, and category
            title_tag = action.find("h2",
↪   class_="usa-card__heading").find("a")
            title = title_tag.text.strip()
            link = urljoin(base_url, title_tag["href"])

            # Parse date and check if it's within the specified range
            date_text = action.find("span", class_="text-base-dark
↪   padding-right-105").text.strip()
            date = datetime.strptime(date_text, "%B %d, %Y")
            if date < start_date:
                keep_scraping = False  # Stop if the date is before
↪   start_date
                break

            category_list = action.find("ul", class_="display-inline
↪   add-list-reset")
            category = category_list.find("li").text.strip() if category_list
↪   else "Unknown"

            # Visit the detail page to extract agency information
            agency_response = requests.get(link)
            agency_soup = BeautifulSoup(agency_response.text, 'html.parser')
            agency_tag = agency_soup.find("span", text="Agency:")
```

```
            agency = agency_tag.find_next_sibling(text=True).strip() if
 ↪  agency_tag else "Unknown"

            # Append data including agency information
            data.append({
                "Title": title,
                "Date": date_text,
                "Category": category,
                "Link": link,
                "Agency": agency
            })

            # Batch delay: Apply delay after every 10 detail page requests
            detail_page_counter += 1
            if detail_page_counter % 10 == 0:
                time.sleep(1)  # Add a delay every 10 detail requests

        # Progress update and delay for next page
        print(f"Completed scraping page {page}")
        page += 1
        time.sleep(1)  # Delay between main pages

    # Convert to DataFrame
    df = pd.DataFrame(data)
    return df

# Run the scraper for January 2023
df_2023 = scrape_enforcement_actions(2023, 1)
```

Find the earliest date:

```
df_2023 = pd.read_csv("enforcement_actions_2023_01.csv")
earliest_action_2023 = df_2023.iloc[-1] if not df_2023.empty else None

# Display the results for both cases
len_2023 = len(df_2023)
earliest_date_2023 = earliest_action_2023['Date'] if earliest_action_2023 is
 ↪  not None else None
earliest_details_2023 = earliest_action_2023.to_dict() if
 ↪  earliest_action_2023 is not None else None

print(f"Total Records for 2023: {len_2023}")
```

```
print(f"Earliest Date in 2023: {earliest_date_2023}")
print("Details of the Earliest Enforcement Action in 2023:")
for key, value in earliest_details_2023.items():
    print(f"  {key}: {value}")
```

```
Total Records for 2023: 1534
Earliest Date in 2023: January 3, 2023
Details of the Earliest Enforcement Action in 2023:
  Title: Podiatrist Pays $90,000 To Settle False Billing Allegations
  Date: January 3, 2023
  Category: Criminal and Civil Actions
  Link:
  https://oig.hhs.gov/fraud/enforcement/podiatrist-pays-90000-to-settle-false-billing-allegat
  Agency: U.S. Attorney's Office, Southern District of Texas
```

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

```
# Get data since 2021
df_2021 = scrape_enforcement_actions(2021, 1)
```

Find the earliest date:

```
df_2021 = pd.read_csv("enforcement_actions_2021_01.csv")

# To get the earliest date
earliest_action_2021 = df_2021.iloc[-1] if not df_2021.empty else None

# Display the results for both cases
len_2021 = len(df_2021)
earliest_date_2021 = earliest_action_2021['Date'] if earliest_action_2021 is
 ↪  not None else None
earliest_details_2021 = earliest_action_2021.to_dict() if
 ↪  earliest_action_2021 is not None else None

# Display
print(f"Total Records for 2023: {len_2021}")
print(f"Earliest Date in 2023: {earliest_date_2021}")
print("Details of the Earliest Enforcement Action in 2023:")
for key, value in earliest_details_2021.items():
    print(f"  {key}: {value}")
```

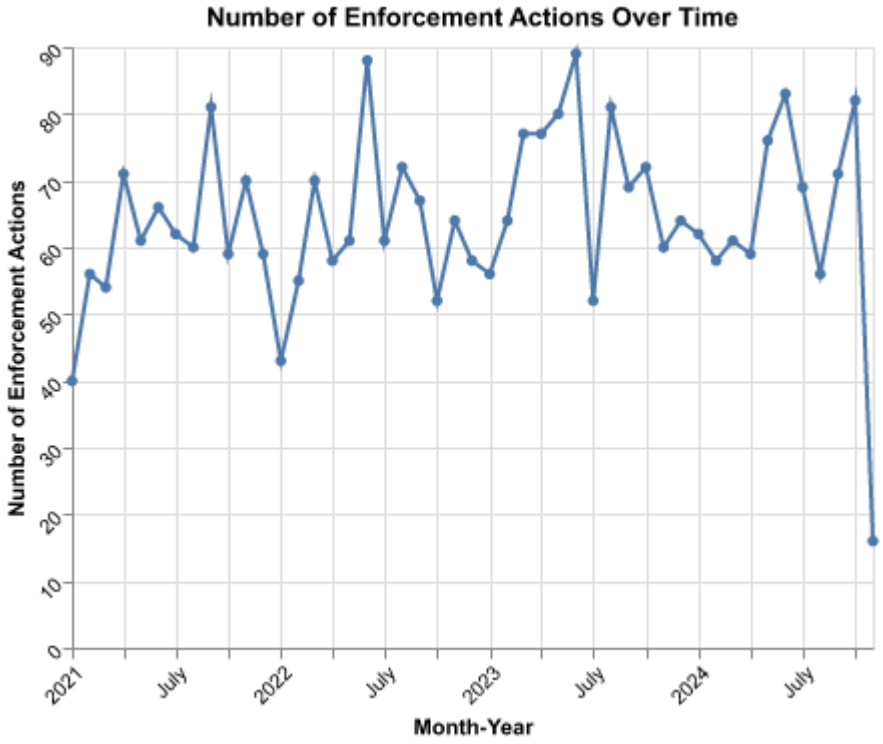
```
Total Records for 2023: 3022
Earliest Date in 2023: January 4, 2021
Details of the Earliest Enforcement Action in 2023:
  Title: The United States And Tennessee Resolve Claims With Three Providers
  For False Claims Act Liability Relating To ‘P-Stim’ Devices For A Total Of
  $1.72 Million
  Date: January 4, 2021
  Category: Criminal and Civil Actions
  Link:
  https://oig.hhs.gov/fraud/enforcement/the-united-states-and-tennessee-resolve-claims-with-t
  Agency: U.S. Attorney's Office, Middle District of Tennessee
```

Step 3: Plot data based on scraped data

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

```python
import matplotlib.pyplot as plt
import altair as alt
import pandas as pd

# Load and process the data
df_csv_2021 = pd.read_csv("enforcement_actions_2021_01.csv")
df_csv_2021['Date'] = pd.to_datetime(df_csv_2021['Date'], errors='coerce')

# Create 'YearMonth' column and count actions per month
df_csv_2021['YearMonth'] = df_csv_2021['Date'].dt.to_period('M').astype(str)
monthly_counts =
 ↪  df_csv_2021.groupby('YearMonth').size().reset_index(name='Enforcement_Actions')

# Plot with Altair
chart = alt.Chart(monthly_counts).mark_line(point=True).encode(
    x=alt.X('YearMonth:T', title='Month-Year'),
    y=alt.Y('Enforcement_Actions:Q', title='Number of Enforcement Actions'),
    tooltip=['YearMonth:T', 'Enforcement_Actions']
).properties(
    title="Number of Enforcement Actions Over Time",
    width=400,
    height=300
).configure_axis(
    labelAngle=-45
)
```

```
chart.show()
```

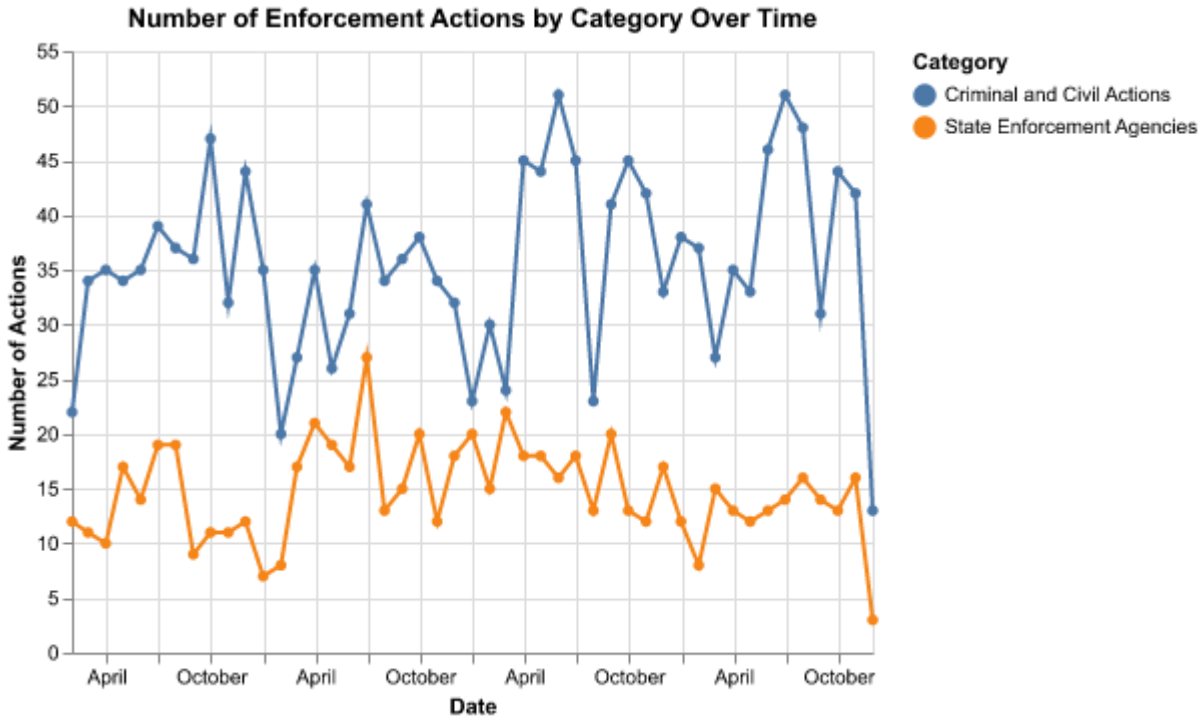


2. Plot the number of enforcement actions categorized: (PARTNER 1)

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

```
# Load data
df_csv_2021 = pd.read_csv("enforcement_actions_2021_01.csv")
df_csv_2021['Date'] = pd.to_datetime(df_csv_2021['Date'], errors='coerce')
df_csv_2021.set_index('Date', inplace=True)

def categorize_topic(title):
    title = title.lower()
    if 'health care' in title:
        return 'Health Care Fraud'
    elif 'financial' in title or 'bank' in title:
        return 'Financial Fraud'
    elif 'drug' in title:
```

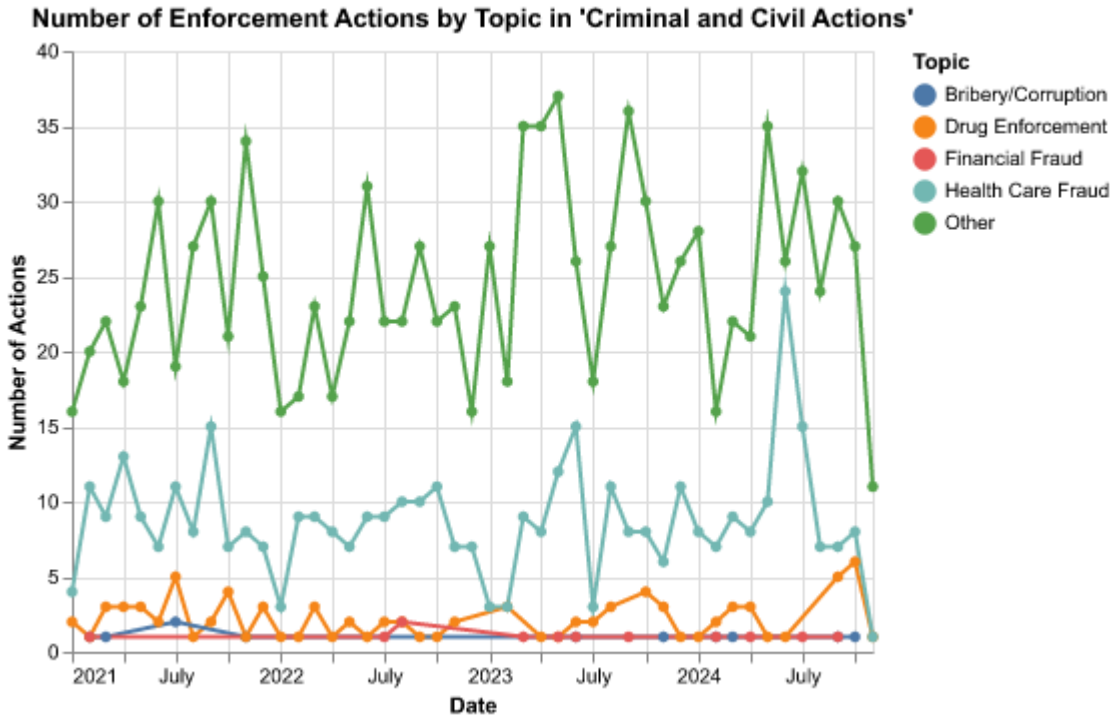
```
        return 'Drug Enforcement'
    elif 'bribery' in title or 'corruption' in title:
        return 'Bribery/Corruption'
    else:
        return 'Other'

df_csv_2021['Topic'] = df_csv_2021.apply(lambda x:
↪  categorize_topic(x['Title']) if x['Category'] == 'Criminal and Civil
↪  Actions' else None, axis=1)

# Split and resample
criminal_civil_df = df_csv_2021[df_csv_2021['Category'] == 'Criminal and
↪  Civil Actions'].resample('M').size().reset_index(name='Count')
criminal_civil_df['Category'] = 'Criminal and Civil Actions'

state_enforcement_df = df_csv_2021[df_csv_2021['Category'] == 'State
↪  Enforcement Agencies'].resample('M').size().reset_index(name='Count')
state_enforcement_df['Category'] = 'State Enforcement Agencies'

# Combine data
combined_df = pd.concat([criminal_civil_df, state_enforcement_df])

# Plot with Altair
chart = alt.Chart(combined_df).mark_line(point=True).encode(
    x=alt.X('Date:T', title='Date'),
    y=alt.Y('Count:Q', title='Number of Actions'),
    color='Category',
    tooltip=['Date:T', 'Count', 'Category']
).properties(
    title="Number of Enforcement Actions by Category Over Time",
    width=400,
    height=300
)

chart.show()
```



- based on five topics

```
import altair as alt
import pandas as pd

# Load and preprocess data
df_csv_2021 = pd.read_csv("enforcement_actions_2021_01.csv")
df_csv_2021['Date'] = pd.to_datetime(df_csv_2021['Date'], errors='coerce')
df_csv_2021.set_index('Date', inplace=True)

def categorize_topic(title):
    title = title.lower()
    if 'health care' in title:
        return 'Health Care Fraud'
    elif 'financial' in title or 'bank' in title:
        return 'Financial Fraud'
    elif 'drug' in title:
        return 'Drug Enforcement'
    elif 'bribery' in title or 'corruption' in title:
        return 'Bribery/Corruption'
    else:
```

```
        return 'Other'

df_csv_2021['Topic'] = df_csv_2021.apply(lambda x:
 ↪  categorize_topic(x['Title']) if x['Category'] == 'Criminal and Civil
 ↪  Actions' else None, axis=1)

# Filter and group data by month and topic
criminal_civil_df = df_csv_2021[df_csv_2021['Category'] == 'Criminal and
 ↪  Civil Actions']
topic_counts =
 ↪  criminal_civil_df.groupby([criminal_civil_df.index.to_period('M'),
 ↪  'Topic']).size().reset_index(name='Count')
topic_counts['Date'] = topic_counts['Date'].dt.to_timestamp()

# Plot with Altair
chart = alt.Chart(topic_counts).mark_line(point=True).encode(
    x=alt.X('Date:T', title='Date'),
    y=alt.Y('Count:Q', title='Number of Actions'),
    color='Topic',
    tooltip=['Date:T', 'Count', 'Topic']
).properties(
    title="Number of Enforcement Actions by Topic in 'Criminal and Civil
 ↪  Actions'",
    width=400,
    height=300
)

chart.show()
```



Step 4: Create maps of enforcement activity

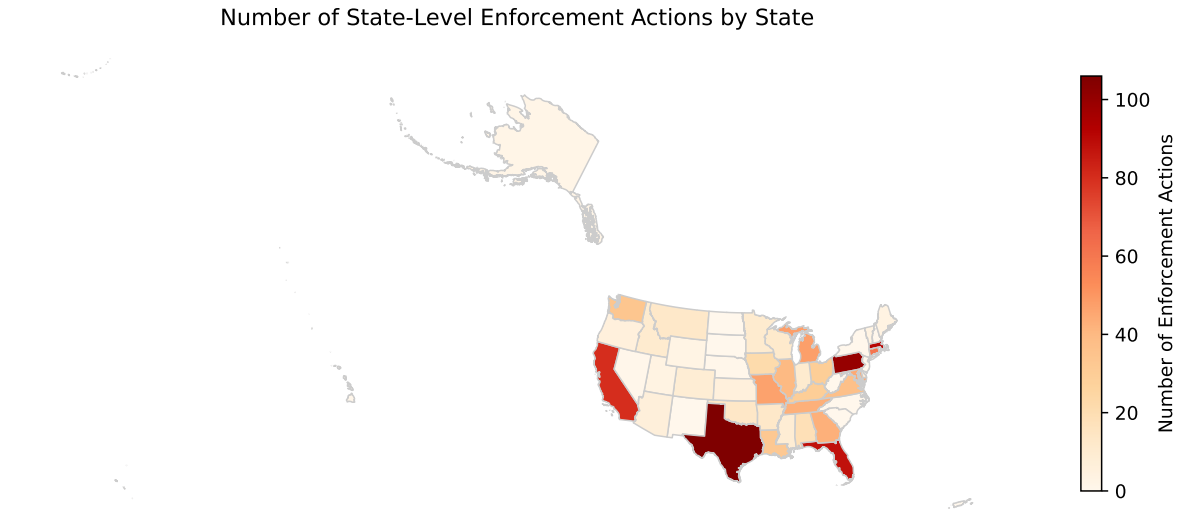
1. Map by State (PARTNER 1)

```
import pandas as pd
import geopandas as gpd
import matplotlib.pyplot as plt
import re

# Extract state name from the 'Agency' column
def extract_state(agency):
    if pd.notnull(agency):
        match = re.search(r"of\s+(\w+)$", agency)
        if match:
            return match.group(1)
    return None

df_csv_2021['State'] = df_csv_2021['Agency'].apply(extract_state)

# Filter rows with valid state names
```

```
state_actions = df_csv_2021.dropna(subset=['State'])

# Count actions by state
state_counts = state_actions['State'].value_counts().reset_index()
state_counts.columns = ['State', 'Count']

# Standardize
state_counts['State'] = state_counts['State'].str.title()

# Load Census state
census_states = gpd.read_file("/Users/georgew/Desktop/Fall 2024/PPHA
 ↪  30538/ps5/cb_2018_us_state_500k")

# Standardize shapefile state names to title case
census_states['NAME'] = census_states['NAME'].str.title()

# Merge state counts with shapefile data
choropleth_data = census_states.merge(state_counts, left_on='NAME',
 ↪  right_on='State', how='left')

# Fill missing values
choropleth_data['Count'] = choropleth_data['Count'].fillna(0)

# Print states with no data
missing_states = choropleth_data[choropleth_data['Count'] == 0]['NAME']
print("States with no data (potential mismatch):", missing_states.tolist())

# Plot the choropleth map
choropleth_data = choropleth_data.to_crs("EPSG:5070")
fig, ax = plt.subplots(1, 1, figsize=(12, 8))
choropleth_data.plot(
    column='Count',
        cmap='OrRd',
    linewidth=0.8,
    ax=ax,
    edgecolor='0.8',
    legend=True,
    legend_kwds={
        'label': "Number of Enforcement Actions",
        'shrink': 0.5
    }
)
```

```
# Customize the plot
ax.set_title("Number of State-Level Enforcement Actions by State")
ax.axis('off')
plt.show()
```

```
States with no data (potential mismatch): ['North Carolina', 'West Virginia',
'New Mexico', 'Puerto Rico', 'South Dakota', 'New York', 'South Carolina',
'New Hampshire', 'District Of Columbia', 'American Samoa', 'United States
Virgin Islands', 'New Jersey', 'Guam', 'Commonwealth Of The Northern Mariana
Islands', 'Rhode Island', 'North Dakota']
```

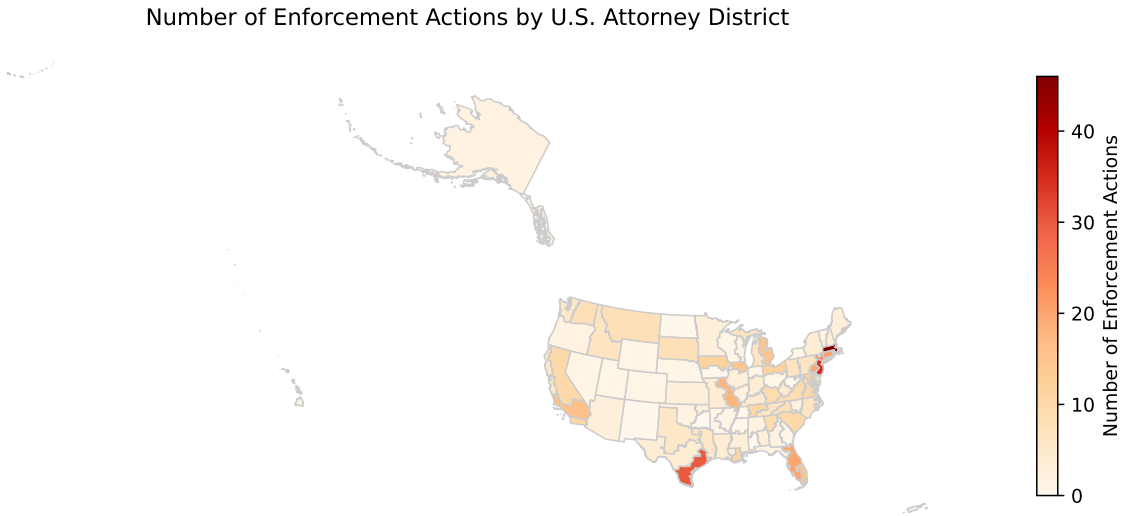


2. Map by District (PARTNER 2)

```
import pandas as pd
import geopandas as gpd
import matplotlib.pyplot as plt
import re

# Define paths for the US Attorney Districts
district_shapefile_path = "/Users/georgew/Desktop/Fall 2024/PPHA 30538/ps5/US
 ↪  Attorney Districts Shapefile simplified_20241109"

# Define the function to extract district
```

```
def extract_district(agency):
    if pd.notnull(agency) and "U.S. Attorney's Office" in agency:
        # Capture district name after "U.S. Attorney's Office"
        match = re.search(r"U\.S\. Attorney's Office, ((?:[A-Za-z]+
 ↪  )?District of [A-Za-z\s]+)", agency)
        if match:
            return match.group(1).strip()
    return None

# Apply the function to extract
df_csv_2021['District'] = df_csv_2021['Agency'].apply(extract_district)

# Drop rows without a valid district name
district_actions = df_csv_2021.dropna(subset=['District'])

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

# Standardize
district_counts['District'] = district_counts['District'].str.title()

# Load the US Attorney District shapefile
district_shapefile = gpd.read_file(district_shapefile_path)

# Standardize district names in the shapefile
district_shapefile['District'] = district_shapefile['judicial_d'].str.title()

# Merge the district counts with the shapefile
choropleth_data = district_shapefile.merge(district_counts, on='District',
 ↪  how='left')

# Fill missing count values
choropleth_data['Count'] = choropleth_data['Count'].fillna(0)

# Plot
choropleth_data = choropleth_data.to_crs("EPSG:5070")

# Plot with Albers USA projection
fig, ax = plt.subplots(1, 1, figsize=(12, 8))
choropleth_data.plot(
    column='Count',
```

```
    cmap='OrRd',
    linewidth=0.8,
    ax=ax,
    edgecolor='0.8',
    legend=True,
    legend_kwds={
        'label': "Number of Enforcement Actions",
        'shrink': 0.5
    }
)

# Customize the plot
ax.set_title("Number of Enforcement Actions by U.S. Attorney District")
ax.axis('off')
plt.show()
```



Extra Credit

1. Merge zip code shapefile with population

```
import geopandas as gpd
import pandas as pd

# Load ZIP code shapefile
```

```
zip_shapefile_path = "/Users/georgew/Desktop/Fall 2024/PPHA
 ↪  30538/ps5/cb_2018_us_zcta510_500k/cb_2018_us_zcta510_500k.shp"
zip_shapefile = gpd.read_file(zip_shapefile_path)

# Load population data CSV
population_data_path = "/Users/georgew/Desktop/Fall 2024/PPHA
 ↪  30538/ps5/DECENNIALDHC2020.P1_2024-11-09T180943/DECENNIALDHC2020.P1-Data.csv"
population_data = pd.read_csv(population_data_path)

# Extract 5-digit ZIP codes
population_data['ZIP'] = population_data['NAME'].str.replace('ZCTA5 ',
 ↪  '').str.zfill(5)
zip_shapefile['ZIP'] = zip_shapefile['ZCTA5CE10'].astype(str).str.zfill(5)

# Merge shapefile with population data on ZIP code
zip_population = zip_shapefile.merge(population_data[['ZIP', 'P1_001N']],
 ↪  on='ZIP', how='left')

# Fill missing population values with 0
zip_population['P1_001N'] = zip_population['P1_001N'].fillna(0)

# Preview merged data
print(zip_population.head())
```

```
  ZCTA5CE10      AFFGEOID10 GEOID10    ALAND10  AWATER10  \
0     36083  8600000US36083   36083  659750662   5522919
1     35441  8600000US35441   35441  172850429   8749105
2     35051  8600000US35051   35051  280236456   5427285
3     35121  8600000US35121   35121  372736030   5349303
4     35058  8600000US35058   35058  178039922   3109259

                                            geometry    ZIP P1_001N
0  MULTIPOLYGON (((-85.63225 32.28098, -85.62439 ...  36083    9367
1  MULTIPOLYGON (((-87.83287 32.84437, -87.83184 ...  35441    1077
2  POLYGON ((-86.74384 33.25002, -86.73802 33.251...  35051    9173
3  POLYGON ((-86.58527 33.94743, -86.58033 33.948...  35121   16016
4  MULTIPOLYGON (((-86.87884 34.21196, -86.87649 ...  35058   11098
```

2. Conduct spatial join

```
import geopandas as gpd

# Load the district shapefile
district_shapefile_path = "/Users/georgew/Desktop/Fall 2024/PPHA 30538/ps5/US
 ↪  Attorney Districts Shapefile simplified_20241109"
district_shapefile = gpd.read_file(district_shapefile_path)

# Ensure both GeoDataFrames use the same CRS
zip_population = zip_population.to_crs(district_shapefile.crs)

# Conduct the spatial join
zip_district_join = gpd.sjoin(zip_population, district_shapefile,
 ↪  how="inner", predicate="intersects")

# Preview the result of the spatial join
print(zip_district_join.head())
```

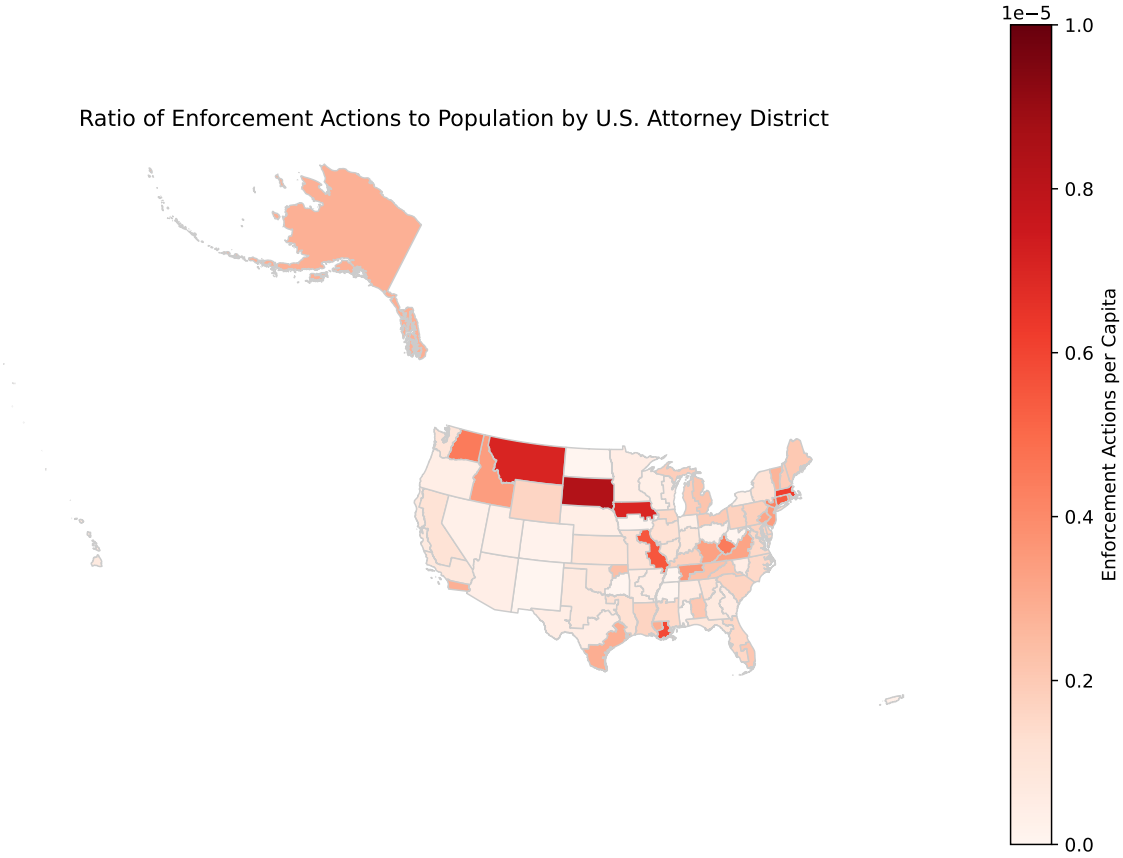
```
  ZCTA5CE10      AFFGEOID10 GEOID10    ALAND10  AWATER10  \
0     36083  8600000US36083   36083  659750662   5522919
1     35441  8600000US35441   35441  172850429   8749105
1     35441  8600000US35441   35441  172850429   8749105
2     35051  8600000US35051   35051  280236456   5427285
3     35121  8600000US35121   35121  372736030   5349303

                                            geometry    ZIP P1_001N  \
0  MULTIPOLYGON (((-85.63225 32.28098, -85.62439 ...  36083    9367
1  MULTIPOLYGON (((-87.83287 32.84437, -87.83184 ...  35441    1077
1  MULTIPOLYGON (((-87.83287 32.84437, -87.83184 ...  35441    1077
2  POLYGON ((-86.74384 33.25002, -86.73802 33.251...  35051    9173
3  POLYGON ((-86.58527 33.94743, -86.58033 33.948...  35121   16016

   index_right statefp  ...    state         chief_judg          nominating
   \
0            3      01  ...  Alabama  Emily Coody Marks    Donald Trump (R)
1            4      01  ...  Alabama      Kristi DuBose  George W. Bush (R)
1           80      01  ...  Alabama      Scott Coogler  George W. Bush (R)
2           80      01  ...  Alabama      Scott Coogler  George W. Bush (R)
3           80      01  ...  Alabama      Scott Coogler  George W. Bush (R)

  term_as_ch shape_leng shape_area  abbr  district_n    shape__are  \
```

```
0     2019.0  10.235799   3.858442   ALM          11  5.645450e+10
1     2017.0  12.976906   3.278871   ALS          11  4.772733e+10
1     2020.0  12.563893   5.754560   ALN          11  8.593125e+10
2     2020.0  12.563893   5.754560   ALN          11  8.593125e+10
3     2020.0  12.563893   5.754560   ALN          11  8.593125e+10

     shape__len
0  1.236201e+06
1  1.567095e+06
1  1.529854e+06
2  1.529854e+06
3  1.529854e+06

[5 rows x 23 columns]
```

3. Map the action ratio in each district

```
import geopandas as gpd
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.colors as mcolors
import re

# Convert 'P1_001N' to numeric, coercing errors to NaN and then filling with
 ↪  0
zip_district_join['P1_001N'] = pd.to_numeric(zip_district_join['P1_001N'],
 ↪  errors='coerce').fillna(0)

# Aggregate population by district
district_population =
 ↪  zip_district_join.groupby('judicial_d')['P1_001N'].sum().reset_index()
district_population.columns = ['judicial_d', 'Total_Population']

# Load and filter
enforcement_data_path = "enforcement_actions_2021_01.csv"
enforcement_data = pd.read_csv(enforcement_data_path)
enforcement_data['Date'] = pd.to_datetime(enforcement_data['Date'],
 ↪  errors='coerce')
enforcement_data = enforcement_data[enforcement_data['Date'] >= '2021-01-01']

# Extract district names
```

```
enforcement_data['District'] =
 ↪  enforcement_data['Agency'].apply(extract_district)
district_actions = (enforcement_data.dropna(subset=['District'])

 ↪  .groupby('District').size().reset_index(name='Action_Count'))

# Merge population and action counts
district_data = district_population.merge(district_actions,
 ↪  left_on='judicial_d', right_on='District', how='left')
district_data['Action_Count'] = district_data['Action_Count'].fillna(0)
district_data['Enforcement_Ratio'] = district_data['Action_Count'] /
 ↪  district_data['Total_Population']

# Merge with district shapefile for plotting
choropleth_data = district_shapefile.merge(district_data,
 ↪  left_on='judicial_d', right_on='judicial_d', how='left')

# Change projection
choropleth_data = choropleth_data.to_crs("EPSG:5070")

# Chnage maximum
norm = mcolors.Normalize(vmin=0, vmax=0.00001)

# Plot the choropleth map
fig, ax = plt.subplots(1, 1, figsize=(12, 8))
choropleth_data.plot(
    column='Enforcement_Ratio',
    cmap='Reds',
    linewidth=0.8,
    ax=ax,
    edgecolor='0.8',
    legend=True,
    norm=norm,
    legend_kwds={'label': "Enforcement Actions per Capita"}
)

ax.set_title("Ratio of Enforcement Actions to Population by U.S. Attorney
 ↪  District")
ax.axis('off')

plt.show()
```


Ratio of Enforcement Actions to Population by U.S. Attorney District
1e−5
1.0
0.8
0.6
0.4
0.2
0.0
Enforcement Actions per Capita