Applied Math 50 Final Project:

How Polarization Has Changed Before and After the 2016 Presidential Election

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I. Abstract

This project uses adjacency matrices and heat maps to analyze how similarly legislators in the Senate and the House of Representatives vote on bills based on their political affiliation. By comparing the number of agreements and disagreements between Republican-to-Republican, Democrat-to-Democrat, and Republican-to-Democrat party lines, this project visualizes how the Democratic and Republican parties have increasingly diverged in legislative voting patterns since the 2016 Presidential election. This project utilizes data from the 113th, 115th, and 117th sessions, which correspond to 2013-2015, 2017-2019, and 2021-2023, respectively. In the end, we found that polarization did generally increase in the Senate and some parts of the House, but there was also an increase in bipartisan efforts between the 113th and 117th sessions of the House. In addition, intra-party polarization for Democrats in both chambers of Congress consistently decreased over time. The results of this study may have important implications for understanding the current political climate and the ability of legislators to work across party lines.

II. Introduction

Motivation

Polarization, which is the "divergence of political attitudes to ideological extremes,"[1] creates strife by its very nature; heightened polarization creates tension at the dinner table and slows down the legislative process by dividing politicians into two uncompromising sides.[2] Alarmingly, several news articles indicate that polarization has increased after President Donald Trump's term, including the Washington Post's article *Party polarization hit a high under Trump. Can Biden reel it back?*.[3] To check the validity of this statement, this project uses mathematical

modeling tools, such as adjacency matrices and heat maps, to analyze the voting behavior of the Senate and U.S. House of Representatives before and after the 2016 election.

Background Information

To provide background information, each session analyzed in this project is a series of annual meetings by Congress to vote on legislation.[4] This project analyzes the 113th (2013-2015), 115th (2017-2019), and 117th (2021-2023) sessions by dividing Congressional voting patterns between the Senate and the House of Representatives. There are two senators elected from each state for a term of 6 years.[5] Every two years, around a third of senators are re-elected or newly elected.[5] Constitutionally, there are 435 legislators in the House of Representatives, which are all elected every two years.[6] The number of Representatives from each state depends proportionally on the state's population.[6] In the 113th Session, when Barack Obama was president, the Senate had a Democratic majority, while the House of Representatives had a Republican majority.[7] In the 115th Session, when Donald J. Trump was president, both the Senate and the House of Representatives had a Republican majority.[8] In the 117th Session, when Joe Biden was president, the Senate had a 50-50 split of Democrats and Republicans, while the House of Representatives had a Democratic majority.[9]

Purpose

The purpose of this project is to analyze the voting patterns of legislators before and after the 2016 US presidential election to determine whether there has been a decline or increase in voting similarity between Democrats and Republicans. The project seeks to investigate whether the current political climate has affected the willingness of legislators to work across party lines. Inter-party polarization refers to the ideological distance between the two major political parties, while intra-party polarization refers to the ideological diversity within each party. By nature of

the methodology, this project reflects the dynamics of inter-party and intra-party polarization before and after the 2016 election.

III. Methods

Dataset Information

The dataset that we are using was from *Voteview.com*, which was created by the University of California, Los Angeles's Department of Political Science.[10] The website allows downloads of CSVs of different sessions of Congress containing data on the voting records of Congress on bills. There are also CSVs available for download featuring each member of Congress and their political affiliation.

In order to create our dataset, we downloaded House and Senate roll call voting data and political affiliation data from the 113th, the 115th, and the 117th sessions of Congress. The reason these two sessions were picked is to analyze the effects of the 2016 election. The 113th session of Congress is best for analyzing the state of polarization prior to the 2016 election because it convened on January 3, 2015.[7] This was roughly 6 months before Donald Trump's formal campaign began on July 16, 2015. The 115th session of Congress is best for analyzing the immediate effects of polarization that the 2016 election had as it ran from 2017-2019.[8] Finally, the 117th session of Congress is best for analyzing the lasting effects of polarization since it is the most recent, fully convened session of Congress.[9]

We also decided to use both House and Senate data because they can serve to balance the shortcomings of the other. Since seats of the House are up for re-election every election cycle, members of the House of Representatives are more likely to vote according to their constituents' preferences because they need strong public appeal in order to be re-elected. While this can be good, it also means that members of the House are often swayed by popular demands. Senators,

on the other hand, must consider the needs of a larger constituency and have a longer term to carry out their agenda. They are not held to the same pressure as members of the House because they only need to worry about elections every 6 years. By including both data from the House and the Senate, these limitations and strengths will serve to balance each other out.

Once we had these datasets, we merged and cleaned them by the session of Congress such that the rows represented unique Congresspeople while the columns represented different pieces of legislation that passed through Congress during that session. Values of *1* indicated a passing vote, *6* indicated a failing vote and *9* indicated abstentions. We then sorted the dataset by party affiliation such that all the Democrats were at the top, then Republicans, then independents. This would later be helpful in visualizing how members of different parties voted with each other.

Mathematical Modeling

Our mathematical model used adjacency matrices to map out the relationship between bipartisan efforts and polarization in voting. The adjacency matrix represented the total number of votes that each member of Congress voted with another member of Congress. For example, if the [*i, j*]th entry of the matrix was *10*, this means that the *i*th member of Congress agreed with the *j*th member of Congress *10* times. Once the adjacency matrix was made, we created a heat map to visualize the bipartisan efforts and polarizing effects.

Additionally, we calculated a metric of agreement for the Senate and House between and among both Democrats and Republicans. To do so, we found the average number of agreements on legislation for Democrats-to-Democrats, Republicans-to-Republicans, and Democrats-to-Republicans for both the House and Senate for each session. To standardize the averages, we divided each average number of agreements on bill voting by the number of bills

voted on in each Congressional session. This ensured that all metrics of agreement fell on a scale between *0* and *1*, where *0* meant that there was no agreement on bill voting, while *1* meant that there was absolute agreement on bill voting.

Finally, in order to test the significance and effect size of these samples, we conducted and calculated several two-sample *t*-tests and Cohen's *d* scores. We ran tests for every session by the Senate and House in pairs (Democrats-Democrats, Republicans-Republicans, Democrats-Republicans). We found that using both of these tests was a better alternative to only using a two-sample *t*-test because our sample sizes were so large that the *p*-values returned were incredibly low (some just output as *0* while others were as low as *0.3e-306*). By using Cohen's *d* score, we can analyze the effect size (a value that measures the strength of the relationship between two variables). Cohen's *d* can range from *0* to *2* with *0* meaning no difference between the datasets and a larger Cohen's *d* indicating a larger difference in the samples. Some other benchmarks that are frequently used are *0.2*, which is a small effect size, and *0.5*, which is a medium effect size. We will be using this value along with our *p*-value, which we will analyze with an $a = 0.05$.

IV. Results

Overall, our results indicate that in the Senate, inter-party polarization has increased over time, while Democratic intra-party polarization has decreased and Republican intra-party polarization has fluctuated, initially decreasing and then increasing. In the House, inter-party polarization has decreased over time, while Democratic intra-party polarization has also decreased and Republican intra-party polarization has increased.

We are able to easily interpret our dataset because it is sorted by party affiliation such that all the Democrats are ordered from *0* to the total number of Democrats and Republicans are

ordered after the total number of Democrats along both axes. As a result, in *Figure 1, Figure 2, Figure 3, Figure 5, Figure 6,* and *Figure* 7, the top-left quadrant gives information about Democratic intra-party polarization; the bottom-right quadrant displays Republican intra-party polarization; and the top-right and bottom-left quadrant shows intra-party polarization with alternating axes. More specifically, the top-right quadrant has the information of Republicans lined up along the *x*-axis and the Democrats across the *y*-axis, while the bottom-left quadrant has the information of the Democrats lined up along the *y*-axis and the Republicans across the *x*-axis. Without loss of generality, we will analyze the top-right quadrant as opposed to the bottom-left quadrant to explain the trends of inter-party polarization over time.

Senate Results

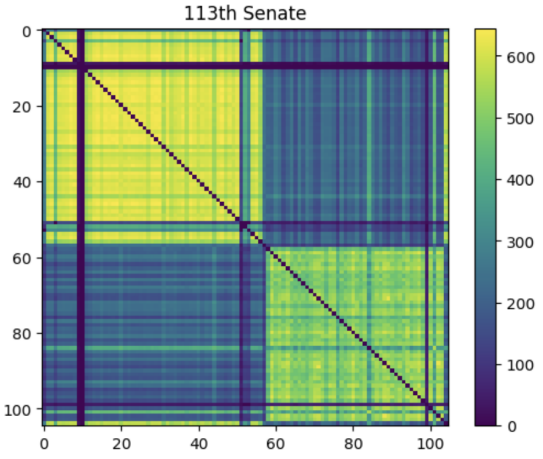

Figure 1: Heat Map of 113th Senate (2013-2015)

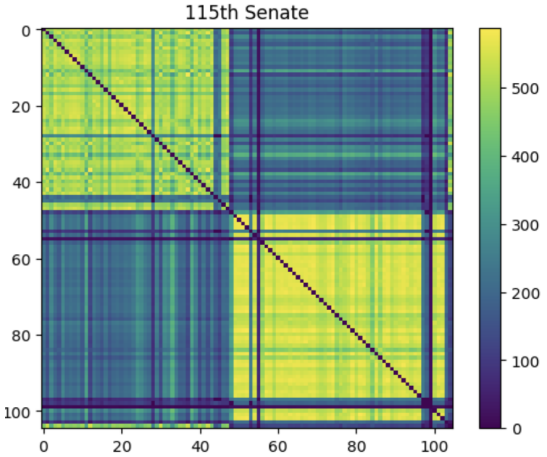

Figure 2: Heat Map of 115th Senate (2017-2019)

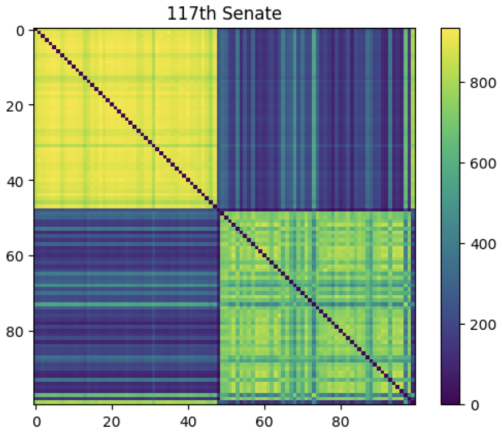

Figure 3: Heat Map of 117th Senate (2021-2023)

According to our metric of Senate agreement displayed in *Figure 4*, on a scale of *0* to *1*, *0* represents no agreement and *1* means complete agreement; in other words, *0* means complete polarization while *1* means no polarization. Since the top-left quadrant contains information about intra-party polarization for the Democratic Party in the Senate in *Figure 1, Figure 2, and Figure 3*, we can analyze the trends across the 113th, 115th, and 117th Senate sessions using our metric of agreement. Between Democrat-to-Democrat in the 113th Senate, the metric of agreement was *0.7326*; in the 115th Senate, the metric was *0.7179*; in the 117th Senate, the metric was *0.8455*. This reveals an increase in intra-party agreement—or a decrease in intra-party polarization—in the Senate after the 2016 election.

Between Republican-to-Republican, represented in the bottom right quadrant of *Figure 1, Figure 2,* and *Figure 3*, in the 113th Senate, the metric of agreement was *0.7084*; in the 115th Senate, the metric was *0.7660*; in the 117th Senate, the metric was *0.7122*. While intra-party agreement for Republicans increased from the 113th Senate to the 115th Senate—which was during President Trump's term—agreement decreased for the 117th Senate session.

Between Democrat-to-Republican, represented in the top right quadrant of *Figure 1, Figure 2,* and *Figure 3*, in the 113th Senate, the metric of agreement was *0.3189*; in the 115th Senate, the metric was *0.3499*; in the 117th Senate, the metric was *0.2539*. Therefore, inter-party polarization in the Senate decreased from the 113th to 115th Senate, but increased from the 115th to 117th Senate. As a result, the overall trend was an increase in inter-party polarization.

	Democrat-to-Democrat	Republican-to-Republican	Democrat-to-Republican
113th Senate	*0.7326*	*0.7084*	*0.3189*
115th Senate	*0.7179*	*0.7660*	*0.3499*
117th Senate	*0.8455*	*0.7122*	*0.2539*

Figure 4: Metric of Senate Agreement (standardized for the number of legislation per session)

House of Representatives Results

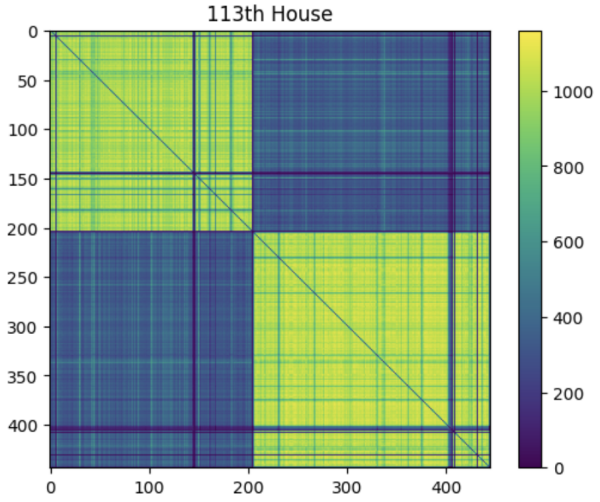

Figure 5: Heat Map of 113th House (2013-2015)

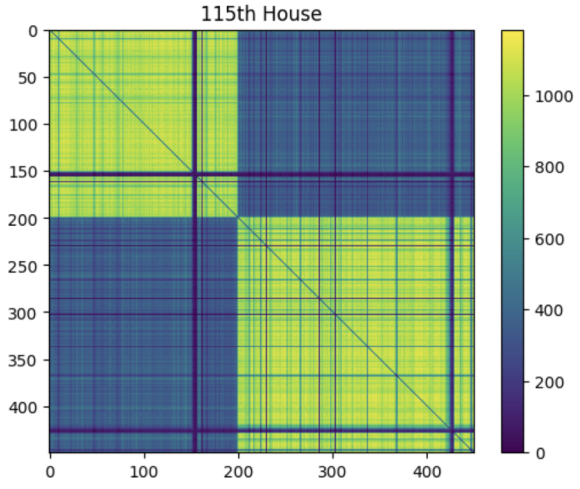

Figure 6: Heat Map of 115th House (2017-2019)

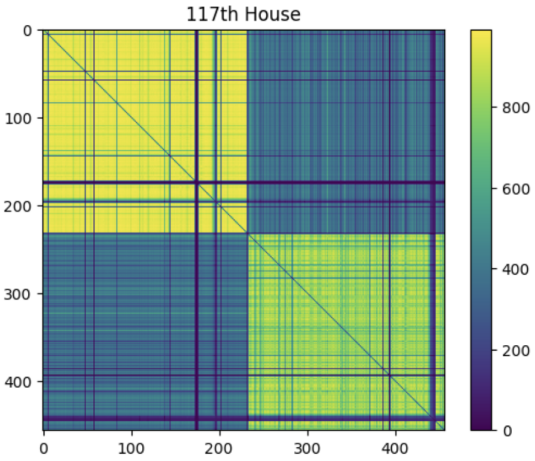

Figure 7: Heat Map of 117th House (2021-2023)

Our metric of House agreement is displayed in *Figure 7*. Between Democrat-to-Democrat, represented in the top left quadrant of *Figure 5, Figure 6*, and *Figure 7*, in the 113th House, the metric of agreement was *0.7511*; in the 115th House, the metric was *0.7773*; in the 117th House, the metric was *0.8362*. This reveals an increase in intra-party agreement—or a decrease in intra-party polarization—in the House of Representatives after the 2016 election; furthermore, this finding is consistent with our results for the analogous Senate sessions.

Between Republican-to-Republican, represented in the bottom right quadrant of *Figure 5, Figure 6*, and *Figure 7*, in the 113th House, the metric of agreement was *0.7909*; in the 115th House, the metric was *0.7628*; in the 117th House, the metric was *0.7455*. These results demonstrate a decrease in intra-party agreement—or an increase in intra-party polarization—for the Republicans in the House of Representatives after the 2016 election.

Between Democrat-to-Republican, represented in the top right quadrant of *Figure 5, Figure 6*, and *Figure 7*, in the 113th House, the metric of agreement was *0.2825*; in the 115th House, the metric was *0.2818*; in the 117th Senate, the metric was *0.3454*. Therefore, inter-party polarization in the House overall decreased from the 113th to 117th Senate.

	Democrat-to-Democrat	Republican-to-Republican	Democrat-to-Republican
113th House	*0.7511*	*0.7909*	*0.2825*
115th House	*0.7773*	*0.7628*	*0.2818*
117th House	*0.8362*	*0.7405*	*0.3454*

Figure 8: Metric of House Agreement (standardized for the number of legislation per session)

Results of Significance Tests

Figure 9 displays the results of two types of significance tests: *t*-tests and Cohen's *d* scores. Using $a = 0.05$ for our *p*-value, all of our results are statistically significant, except for our findings between Republican-to-Republican in the 113th and 117th Senate session as well as between Democrat-to-Republican in the 113th and 117th House of Representatives session. However, since *p*-values might be lower than they should be due to the large sample size of our datasets, we can also look at Cohen's *d* for the effect size between the two sample sizes. This could be especially useful for some of our *p*-values which are incredibly low; for example, the Republican-to-Republican *p*-value between the 113th to 117th House is *1.6182e-306* which is way lower than a *p*-value normally is. This helps us to deduce that we should be looking at

alternative forms of measuring the significance of the *t*-test. In this case, Cohen's *d* value was *0.2354* which indicates a small difference between the datasets. We can also do this for the *p*-values that scored *0*, likely because it was lower than the threshold that Python could calculate. For Democrat-to-Democrat in the 113th to the 117th House, Cohen's *d* was *0.3377* which is roughly between a small and medium difference between the datasets. Then, for Democrats to Republicans for 113th to the 117th and the 115th to the 117th, we see that Cohen's *d* calculates to *0.5379* and *0.5324*, respectively. This indicates a medium effect size meaning the difference in the datasets was reasonable.

	Democrat-to-Democrat		Republican-to-Republican		Democrat-to-Republican	
	p-value	Cohen's *d*	*p*-value	Cohen's *d*	*p*-value	Cohen's *d*
113th - 115th Senate	*0.0353*	*0.0530*	*3.3110e-16*	*0.2281*	*4.9990e-14*	*0.2108*
113th - 117th Senate	*5.9063e-57*	*0.4043*	*0.4967*	*0.0219*	*2.5362e-48*	*0.4247*
115th - 117th Senate	*1.5442e-79*	*0.5492*	*1.1910e-17*	*0.2287*	*1.3481e-79*	*0.6200*
113th - 115th House	*1.0011e-74*	*0.1275*	*4.6666e-109*	*0.1285*	*0.2697*	*0.0070*
113th - 117th House	*0.0*	*0.3377*	*1.6182e-306*	*0.2354*	*0.0*	*0.5379*
115th - 117th House	*1.1698e-286*	*0.2280*	*5.9042e-55*	*0.0945*	*0.0*	*0.5324*

Figure 9: Significance Test Results (p-value and Cohen's d)

V. Discussion

Main Discussion

The 113th, 115th, and 117th Senate and House sessions provide insights into how polarization has changed before and after the 2016 presidential election by examining the voting

patterns and behaviors of Senators and House of Representatives from both political parties. In the 113th Senate session, there was more bipartisanship in voting patterns, with Senators from both parties more likely to vote together on certain issues. However, in the 115th and 117th Senate sessions, there was a greater divide between Democrats and Republicans, with fewer instances of bipartisan voting. One possibility of this increase in inter-party polarization is that the political climate has become more polarized in recent years, with issues becoming increasingly contentious. As a result, there were fewer instances of bipartisan voting, as politicians feel more pressure to stick to their party's positions and avoid appearing to cross party lines. Specifically, during the 115th and 117th Senate sessions, there were several highly contentious issues that highlighted the polarization between the two parties, such as the confirmation of Supreme Court Justice Brett Kavanaugh and the impeachment trials of President Donald Trump.[11] In both cases, Senators voted almost entirely along party lines, especially for Democrats as shown by our results, with few exceptions.

Another possibility is that party leadership has become more rigid in recent years, with leaders on both sides of the aisle pushing their members to vote along party lines. This could create a situation where there is less room for compromise and cooperation between the two parties, leading to fewer instances of bipartisan voting. Furthermore, the election of President Donald Trump in 2016 may have played a role in increasing polarization in Congress. Trump's presidency was marked by a number of controversial policies and statements, which may have galvanized members of both parties and led to increased partisanship.[12]

Although the 117th Senate session had a 50-50 split, Vice President Kamala Harris held the tie-breaking vote as the President of the Senate, meaning the Democrats had a slim majority.[13] This has created a situation where the Democrats needed to maintain strict party

discipline to pass legislation, as they could afford to lose a single vote. Furthermore, after the 2016 election with a Republican president in the White House and the Republican Party in control of both the House and the Senate, Democrats may have felt a greater need to present a united front and work together to advance their legislative priorities. As a result, according to our results, intra-party polarization for Democrats in both the Senate and House decreased after the 2016 election.

The increase in intra-party polarization for Republicans in the House and Senate could be driven by several factors as well. One possible explanation is that the election of President Trump in 2016 may have created a greater sense of loyalty and unity among Republicans, but also contributed to more extreme and polarized positions within the party. Furthermore, the Republican Party has seen a shift in its base over the past decade, with a rise in support for more conservative movements. This shift may have led to increased polarization within the party as members seek to align themselves with their constituents and the broader ideological trends within the party.

Limitations

One surprising finding from the House data was the decrease in inter-party polarization, even though the Senate results explained otherwise. A plausible explanation for the decrease in inter-party polarization is the fact that members of the House of Representatives serve for a shorter term of 2 years, while Senators serve for 6-year terms. Consequently, members of the House of Representatives may be more concerned about re-election and thereby adapt their public-facing image. This makes sense as many electoral accountability models indicate that there is a trade-off between incentives and selection of politicians; as such, especially under the

117th House during Biden's term, both Republicans and Democrats in the House may have wanted to cooperate more to improve their prospects of re-election.[14]

Although our model effectively captures the voting patterns of Senators and the House of Representatives, it has a noteworthy limitation. Specifically, our analysis is limited to the behaviors of these politicians alone, which may not always reflect the true preferences of their constituents. While we expect that elected officials act in accordance with their constituents' interests, factors such as corruption may cause them to vote in ways that do not align with public opinion. As a result, it is essential to recognize that our model's accuracy may be limited by the complexities of real-world politics.

Existing Research

Our findings for an increase in inter-party polarization, especially in the Senate, are consistent with existing scholarly research. For example, "American Political Party Polarization: The 2016 Presidential Election Cycle in Comparison" by Ragan Robichaux is a study that examines the polarization of American politics in the lead-up to the 2016 presidential election using a proportion-based content analysis technique.[15] The study finds that there has been a significant increase in inter-party polarization in American politics over the past several decades. In particular, this study found that the 2016 presidential election was marked by high levels of polarization, with both major political parties adopting increasingly extreme positions on key issues. The election was also characterized by a high degree of partisanship, with voters being more likely to vote based on their party affiliation than on the issues themselves.

Another study that affirms our results is "Polarization in 2016" by Stanford economics professor Matthew Gentzkow. Using public opinion data to graph the distribution of voter preferences, Gentzkow similarly found an increase in inter-party polarization as "we are less

likely to find people holding liberal views on some issues and conservative views on others, or to meet a liberal Republican or conservative Democrat."[6]

Thus, our paper utilized a unique and original mathematical modeling approach that involved the use of adjacency matrices and heat maps. Unlike other studies that focused on different methods to analyze party polarization, our approach was distinct and innovative. However, despite the novelty of our methodology, we were able to confirm the findings of previously published scholarly works on the subject. This convergence of results underscores the robustness of our research approach and supports the validity of our conclusions. In summary, our study contributes to the literature on party polarization by offering a fresh perspective and demonstrating the utility of our unique modeling approach.

VI. Conclusion

Future Steps

In conclusion, while our study provides important insights into the polarization of American politics, there are several areas that require further investigation. One such area is the analysis of specific issues that are highly contentious and have a significant impact on the political landscape. For instance, issues such as immigration, gun control, and climate change have been highly debated in recent years and could benefit from a more in-depth analysis of how politicians vote and behave in relation to these topics.

Moreover, an analysis based on policy subject areas could provide a more nuanced understanding of polarization in Congress. By examining the voting behavior of lawmakers on different policy issues, we could gain more insight into which areas of policymaking are most divisive and which are more likely to foster bipartisanship. For example, a study focused on the

health policy area could examine whether there is more polarization on issues related to access to healthcare or on funding for medical research.

Additionally, our study has focused primarily on the polarization of Congress at the national level, but it would be beneficial to explore how this polarization differs at the state level. By analyzing state legislatures, we can examine how politicians and constituents differ at different levels of government. This could reveal important insights into how the political climate differs across regions and how state-level policies are influenced by national politics.

Furthermore, the implications for research are that scholars should continue to monitor and analyze trends in inter-party and intra-party polarization over time and explore the underlying causes of these trends. For example, future research could examine the role of gerrymandering, media fragmentation, and other factors that may contribute to the increasing polarization of American politics.

Therefore, while this study provides a valuable perspective on the polarization of American politics, there are numerous avenues for future research. By exploring these areas in more detail, we can gain a deeper understanding of the underlying causes of polarization and how it affects policymaking at different levels of government.

Final Remarks

The significance of these findings is that they provide insights into the changing dynamics of American politics over time. The increasing inter-party polarization, especially in the Senate, may make it more difficult for Congress to pass legislation, as the two parties become more entrenched in their respective ideological positions.

The results of our study show the significant impact of the 2016 election on American politics. By using adjacency matrices, heat maps, mean comparisons, two-sample *t*-tests, and

Cohen's *d*, we were able to measure the voting patterns of Democrats and Republicans in the House and the Senate. More than anything, our paper showed the rich potential of research on political polarization in the United States.

VII. Code[17]

R Code for Creating Datasets

```
# Reading all CSV

senatevotes113 <- read.csv("S113_votes.csv")
senatemembers113 <- read.csv("S113_members.csv")

housevotes113 <- read.csv("H113_votes.csv")
housemembers113 <- read.csv("H113_members.csv")

senatevotes115 <- read.csv("S115_votes.csv")
senatemembers115 <- read.csv("S115_members.csv")

housevotes115 <- read.csv("H115_votes.csv")
housemembers115 <- read.csv("H115_members.csv")

senatevotes117 <- read.csv("S117_votes.csv")
senatemembers117 <- read.csv("S117_members.csv")

housevotes117 <- read.csv("H117_votes.csv")
housemembers117 <- read.csv("H117_members.csv")

# Function to clean up data
process_senate_data <- function(votes_data, members_data) {
  # Merge the two data frames
  senate <- merge(votes_data, members_data, by = "icpsr")
  senate$congress <- senate$congress.x

  senate <- senate[c("congress", "rollnumber", "cast_code",
                     "party_code", "bioname")]

  senate <- senate[senate$rollnumber > 2, ]

  senate <- senate[order(senate$party_code), ]
  # Reshape data
  senate <- reshape(senate, direction = "wide", idvar = "bioname",
                    timevar = "rollnumber", v.names = "cast_code",
                    drop = c("congress", "party_code"))
```

```
  # Clean up column names
  colnames(senate)[-1] <- paste0(colnames(senate)[-1])

  return(senate)
}

# Creating the Processed Data
senate113_processed <- process_senate_data(senatevotes113, senatemembers113)
house113_processed <- process_senate_data(housevotes113, housemembers113)
senate115_processed <- process_senate_data(senatevotes115, senatemembers115)
house115_processed <- process_senate_data(housevotes115, housemembers115)
senate117_processed <- process_senate_data(senatevotes117, senatemembers117)
house117_processed <- process_senate_data(housevotes117, housemembers117)

# Exporting the Processed Data
write.csv(senate113_processed, "senate113.csv")
write.csv(house113_processed, "house113.csv")
write.csv(senate115_processed, "senate115.csv")
write.csv(house115_processed, "house115.csv")
write.csv(senate117_processed, "senate117.csv")
write.csv(house117_processed, "house117.csv")
```

Python Code for Creating Adjacency Matrices and Heat Maps

```
# Importing packages
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import csv
from scipy import stats

# Reading CSVs
sen113 = pd.read_csv('senate113.csv')
house113 = pd.read_csv('house113.csv')
sen115 = pd.read_csv('senate115.csv')
house115 = pd.read_csv('house115.csv')
sen117 = pd.read_csv('senate117.csv')
house117 = pd.read_csv('house117.csv')

# Printing Shapes
print(np.shape(sen113))
print(np.shape(house113))
print(np.shape(sen115))
print(np.shape(house115))
print(np.shape(sen117))
print(np.shape(house117))
```

```
# Creating a Function that turns dataframe into Adjacency Matrix
def data_to_mat(data):
 data = data.to_numpy()
 data = data[:-1, 2:]

 dims = np.shape(data)

 # Creating Adjacency Matrix
 A = np.zeros((dims[0], dims[0]))

 # Loop through bills:
 for i in range(dims[1]):

   # Loop through senators:
   for j in range(dims[0]):

       # Loop through senators in column k
       for k in range(dims[0]):
         # Check for senators in column k that co-sponsored bill i
         if (data[j, i] == data[k, i]) and (j != k) and (data[j, i] != 9.0):
           A[k, j] += 1
 return A

# Creating Adjacency Matrix
sen113 = data_to_mat(sen113)
house113 = data_to_mat(house113)
sen115 = data_to_mat(sen115)
house115 = data_to_mat(house115)
sen117 = data_to_mat(sen117)
house117 = data_to_mat(house117)

# Plots
plt.plot(figsize = (6,6))
plt.title("113th Senate")
plt.imshow(sen113)
plt.colorbar()
plt.show()

plt.plot(figsize = (6,6))
plt.title("115th Senate")
plt.imshow(sen115)
plt.colorbar()
plt.show()

plt.plot(figsize = (6,6))
```

```
plt.title("117th Senate")
plt.imshow(sen117)
plt.colorbar()
plt.show()

plt.plot(figsize = (6,6))
plt.title("113th House")
plt.imshow(house113)
plt.colorbar()
plt.show()

plt.plot(figsize = (6,6))
plt.title("115th House")
plt.imshow(house115)
plt.colorbar()
plt.show()

plt.plot(figsize = (6,6))
plt.title("117th House")
plt.imshow(house117)
plt.colorbar()
plt.show()
```

Python Code for Metric of Agreement and Significance Testing

```
# 113th Session - Senators
sen113 = sen113/655
sen113_dems = sen113[1:60,1:60]
sen113_reps = sen113[60:-2,60:-2]
sen113_demstoreps = sen113[1:60, 60:-2]

# 113th Session - House of Representatives
house113 = house113/1200
house113_dems = house113[1:207,1:207]
house113_reps = house113[207:,207:]
house113_demstoreps = house113[1:207, 207:]

# 115th Session - Senators
sen115 = sen115/597
sen115_dems = sen115[1:50,1:50]
sen115_reps = sen115[50:-2,50:-2]
sen115_demstoreps = sen115[1:50, 50:-2]

# 115th Session - House of Representatives
house115 = house115/1205
house115_dems = house115[1:202,1:202]
```

```
house115_reps = house115[202:,202:]
house115_demstoreps = house115[1:202, 202:]

# 117th Session - Senators
sen117 = sen117/947
sen117_dems = sen117[1:51,1:51]
sen117_reps = sen117[51:-2,51:-2]
sen117_demstoreps = sen117[1:51, 51:-2]

# 117th Session - House of Representatives
house117 = house117/994
house117_dems = house117[1:235,1:235]
house117_reps = house117[235:,235:]
house117_demstoreps = house117[1:235, 235:]

# Matrix to Array
sen113_demsarray = sen113_dems.flatten()
sen113_repsarray = sen113_reps.flatten()
sen113_demstorepsarray = sen113_demstoreps.flatten()

house113_demsarray = house113_dems.flatten()
house113_repsarray = house113_reps.flatten()
house113_demstorepsarray = house113_demstoreps.flatten()

sen115_demsarray = sen115_dems.flatten()
sen115_repsarray = sen115_reps.flatten()
sen115_demstorepsarray = sen115_demstoreps.flatten()

house115_demsarray = house115_dems.flatten()
house115_repsarray = house115_reps.flatten()
house115_demstorepsarray = house115_demstoreps.flatten()

sen117_demsarray = sen117_dems.flatten()
sen117_repsarray = sen117_reps.flatten()
sen117_demstorepsarray = sen117_demstoreps.flatten()

house117_demsarray = house117_dems.flatten()
house117_repsarray = house117_reps.flatten()
house117_demstorepsarray = house117_demstoreps.flatten()

# Senate t - test
senate_t1, senate_p1 = stats.ttest_ind(sen113_repsarray, sen115_repsarray,
equal_var = False)
senate_t2, senate_p2 = stats.ttest_ind(sen113_repsarray, sen117_repsarray,
equal_var = False)
senate_t3, senate_p3 = stats.ttest_ind(sen115_repsarray, sen117_repsarray,
```

```
equal_var = False)

senate_t4, senate_p4 = stats.ttest_ind(sen113_demsarray, sen115_demsarray,
equal_var = False)
senate_t5, senate_p5 = stats.ttest_ind(sen113_demsarray, sen117_demsarray,
equal_var = False)
senate_t6, senate_p6 = stats.ttest_ind(sen115_demsarray, sen117_demsarray,
equal_var = False)

senate_t7, senate_p7 = stats.ttest_ind(sen113_demstorepsarray,
sen115_demstorepsarray, equal_var = False)
senate_t8, senate_p8 = stats.ttest_ind(sen113_demstorepsarray,
sen117_demstorepsarray, equal_var = False)
senate_t9, senate_p9 = stats.ttest_ind(sen115_demstorepsarray,
sen117_demstorepsarray, equal_var = False)

# House t - test
house_t1, house_p1 = stats.ttest_ind(house113_repsarray, house115_repsarray,
equal_var = False)
house_t2, house_p2 = stats.ttest_ind(house113_repsarray, house117_repsarray,
equal_var = False)
house_t3, house_p3 = stats.ttest_ind(house115_repsarray, house117_repsarray,
equal_var = False)

house_t4, house_p4 = stats.ttest_ind(house113_demsarray, house115_demsarray,
equal_var = False)
house_t5, house_p5 = stats.ttest_ind(house113_demsarray, house117_demsarray,
equal_var = False)
house_t6, house_p6 = stats.ttest_ind(house115_demsarray, house117_demsarray,
equal_var = False)

house_t7, house_p7 = stats.ttest_ind(house113_demstorepsarray,
house115_demstorepsarray, equal_var = False)
house_t8, house_p8 = stats.ttest_ind(house113_demstorepsarray,
house117_demstorepsarray, equal_var = False)
house_t9, house_p9 = stats.ttest_ind(house115_demstorepsarray,
house117_demstorepsarray, equal_var = False)

# Cohens Function
def cohens_d(group1, group2):
   mean1, mean2 = np.mean(group1), np.mean(group2)
   sd1, sd2 = np.std(group1, ddof=1), np.std(group2, ddof=1)
   n1, n2 = len(group1), len(group2)

   pooled_sd = np.sqrt(((n1 - 1) * sd1 ** 2 + (n2 - 1) * sd2 ** 2) / (n1 + n2 - 2))
   d = (mean1 - mean2) / pooled_sd
```

```
   return np.abs(d)

# Senate Cohens - test
senate_d1 = cohens_d(sen113_repsarray, sen115_repsarray)
senate_d2 = cohens_d(sen113_repsarray, sen117_repsarray)
senate_d3 = cohens_d(sen115_repsarray, sen117_repsarray)

senate_d4 = cohens_d(sen113_demsarray, sen115_demsarray)
senate_d5 = cohens_d(sen113_demsarray, sen117_demsarray)
senate_d6 = cohens_d(sen115_demsarray, sen117_demsarray)

senate_d7 = cohens_d(sen113_demstorepsarray, sen115_demstorepsarray)
senate_d8 = cohens_d(sen113_demstorepsarray, sen117_demstorepsarray)
senate_d9 = cohens_d(sen115_demstorepsarray, sen117_demstorepsarray)

# House Cohens - test
house_d1 = cohens_d(house113_repsarray, house115_repsarray)
house_d2 = cohens_d(house113_repsarray, house117_repsarray)
house_d3 = cohens_d(house115_repsarray, house117_repsarray)

house_d4 = cohens_d(house113_demsarray, house115_demsarray)
house_d5 = cohens_d(house113_demsarray, house117_demsarray)
house_d6 = cohens_d(house115_demsarray, house117_demsarray)

house_d7 = cohens_d(house113_demstorepsarray, house115_demstorepsarray)
house_d8 = cohens_d(house113_demstorepsarray, house117_demstorepsarray)
house_d9 = cohens_d(house115_demstorepsarray, house117_demstorepsarray)
```

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