

Computational Social Science Summative

Research Brief: QCA Method in Developed Democracies

April 22, 2024

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ABSTRACT

This research brief uses Qualitative Comparative Analysis (QCA) to explore how factors like social media use and political polarization affect political satisfaction in developed democracies. It highlights the importance of voting and the potential drawbacks of excessive social media engagement, offering strategic insights for enhancing democratic health.

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1. Introduction

1.1. Self-role Setting in Research

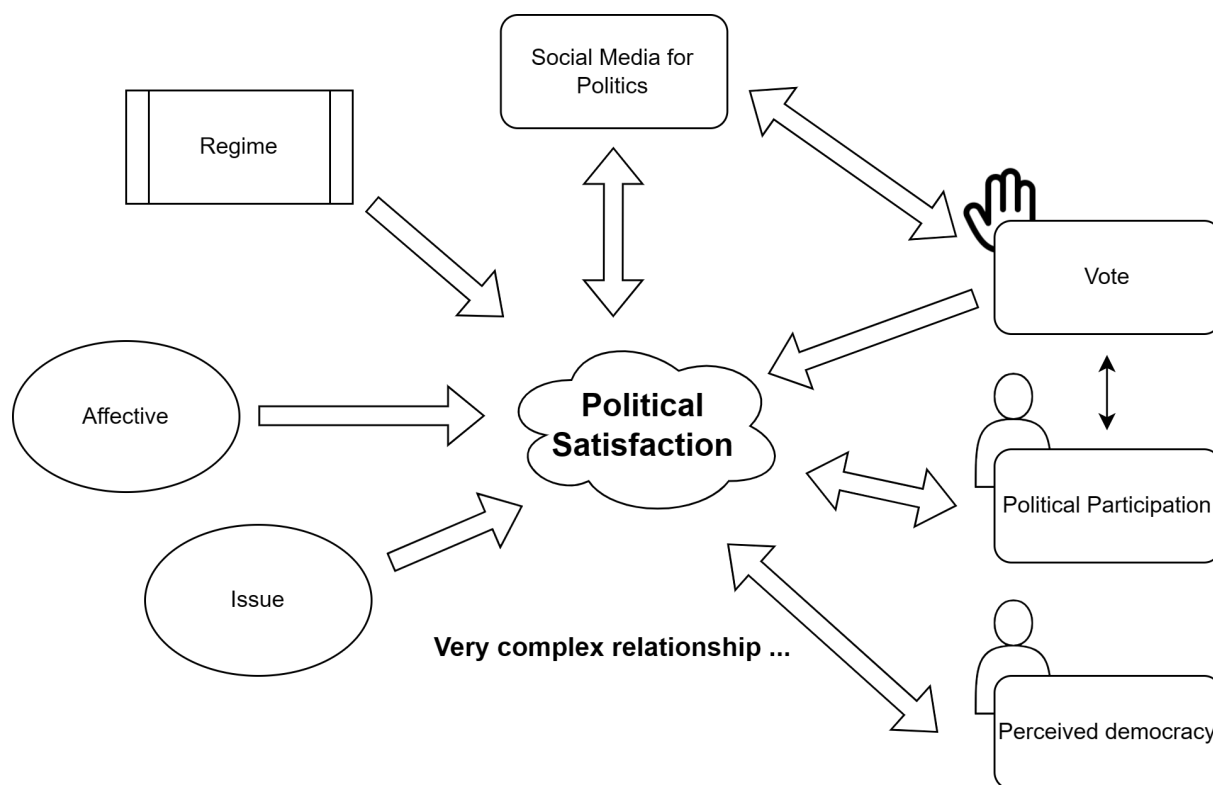
Assume that we are a group of researchers in the government think tank. We investigate the factors that influence political satisfaction in developed democracies. Our research aims to provide insights to policymakers on how to enhance democratic health and citizen satisfaction in developed democracies. Influenced by our leadership, we have been particularly interested in the **Qualitative Comparative Analysis** (QCA) approach in recent studies.

1.2. Application in Social Policy Research

- Tailored Interventions: By identifying specific conditions under which social media positively or negatively affects political engagement with QCA, policymakers can design more targeted interventions.
- Inclusive Policy Making: QCA's ability to consider multiple combinations of conditions can ensure that diverse demographic and political contexts are considered in policy-making, preventing one-size-fits-all solutions.

2. The Social Policy Context in Democracy Satisfaction

The democratic satisfaction of citizens in developed democracies is a multifaceted issue influenced by various factors. Understanding the complex interplay between these factors is crucial for policymakers seeking to enhance democratic satisfaction and governance effectiveness. In this context, I refer to the research of M. Chan in "Social Media Use and Political Engagement in Polarized Times"[1].



2.1. The Rise of Social Media in Political Action

In the past decade, social media has transformed from a platform for social interaction into a significant political tool. It has enabled political parties, advocacy groups, and individual politicians to communicate directly with the public, bypass debates in traditional media, and mobilize political action. The penetration of social media in developed democracies has raised crucial questions regarding its impact on political engagement and democratic health.

2.2. Affective and Issue Polarization

Affective polarization refers to the increasing hostility and negative feelings between members of different political parties or ideologies. Issue polarization, on the other hand, involves the widening gap between the policy preferences of different political groups. Both forms of polarization can contribute to political dissatisfaction and hinder effective governance in democracies.

2.3. Political Engagement and Democracy Satisfaction

Political engagement encompasses various activities that allow citizens to influence governmental policies or the selection of government officials. These activities include voting, participating in political discussions, joining political parties or movements, and engaging in protests. In a healthy democracy, high levels of political engagement suggest a population that is actively involved in shaping its governance, which is vital for the legitimacy and function of democratic institutions.

2.4. Complexity in Social Media and Political Engagement

The relationship between social media use and political engagement is inherently complex, influenced by a myriad of factors [2] including but not limited to **(In this part I do some descriptive statistical work, and the results confirme the social complexity of the problem we are studying):**

2.4.1. Multiple Scales and Levels

Political engagement operates across multiple scales and levels, from individual tweets to country level. Actions at one level can influence outcomes at another, making it essential to consider multiple layers of interaction when analyzing political movements and their effectiveness.



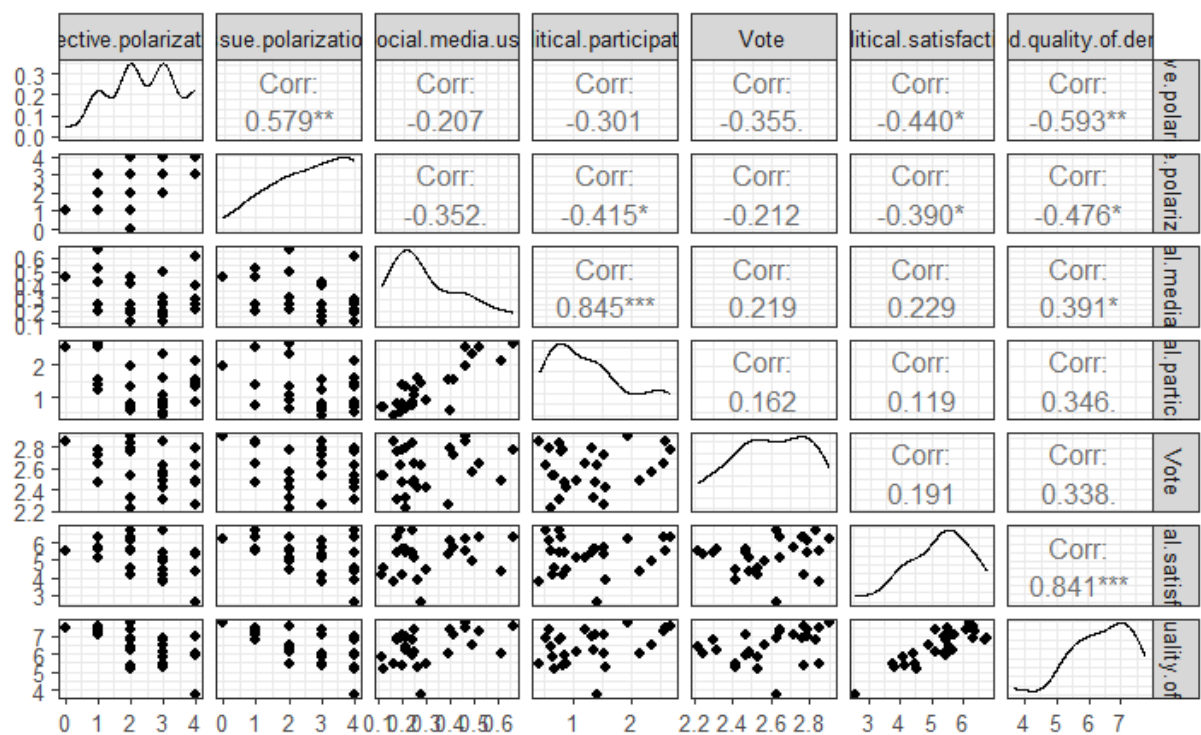
If we divide the discussion into countries and individuals during the study, we will find that when we study the state system, the political satisfaction of countries with complete democracy is higher (Appendix 3.4).

2.4.2. Distributed Control

Control over political narratives and movements is distributed among many users and entities, with no single actor able to command complete control. This distributed nature can lead to diverse and sometimes conflicting messages within the same political camp, complicating efforts to present a unified stance.

2.4.3. Unknowns

There are many unknown factors in social media interactions that can unexpectedly influence political engagement and outcomes.



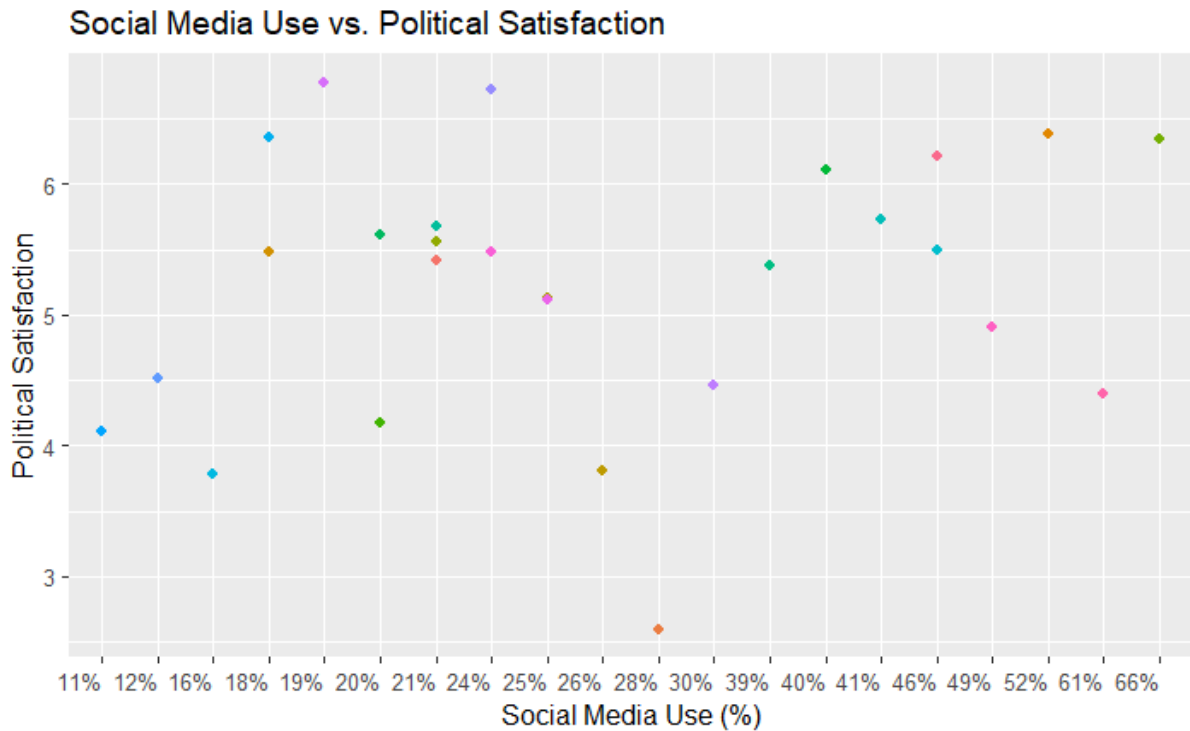
Although some variables have a low correlation with each other, it does not mean that there is no interaction between them (Appendix 3.6).

2.4.4. Unpredictability

The complexity and openness of political systems make them fundamentally unpredictable. The vast number of interactions and the continuous introduction of new content and users mean that predicting specific outcomes, such as the impact of a particular political message or campaign, is fraught with uncertainty.

2.4.5. Non-linear Relationships

We cannot simply obtain democratic satisfaction through multi-level linear model fitting. And the interaction between variables is so complex that you can't manually try all the possibilities.



Theoretically more information on social networks about political elections will increase more turnout, and in turn will allow democracy satisfaction decreases, however. There is no linear relationship directly from the scatter plot (Appendix 3.5).

2.4.6. Feedback Loops

Political campaigns use social media feedback to adjust their strategies, creating an ongoing loop of action and reaction between political entities and the public.

3. Research Question

Therefore, based on our own background and research contexts, we propose the following research questions:

“How does the combination of social media use, affective and issue polarization, and other socio-political factors influence political satisfaction in developed democracies?”

This question seeks to explore the complex interplay between social media, regime and various dimensions of political engagement and satisfaction.

4. Introduction to the Dem-Dataset and QCA Method

4.1. The Dem-Dataset

Dem-Dataset is obtained by processing and integrating two datasets, namely Varieties of Democracy (V-Dem) [3] and World Values Survey (WVS) [4]. In Appendix 1.2 there is a flowchart for the integration of the two datasets.

- **Varieties of Democracy (V-Dem):** Provides comprehensive indicators on various dimensions of democracy, which can be used to measure aspects like issue and affective polarization at the country level.

- **World Values Survey (WVS):** Offers extensive survey data on values, norms, and political behaviors of individuals across various countries, likely providing individual-level data on political engagement, social media use, and perceptions of democracy.

Here's a breakdown of the types of data used in the analysis:

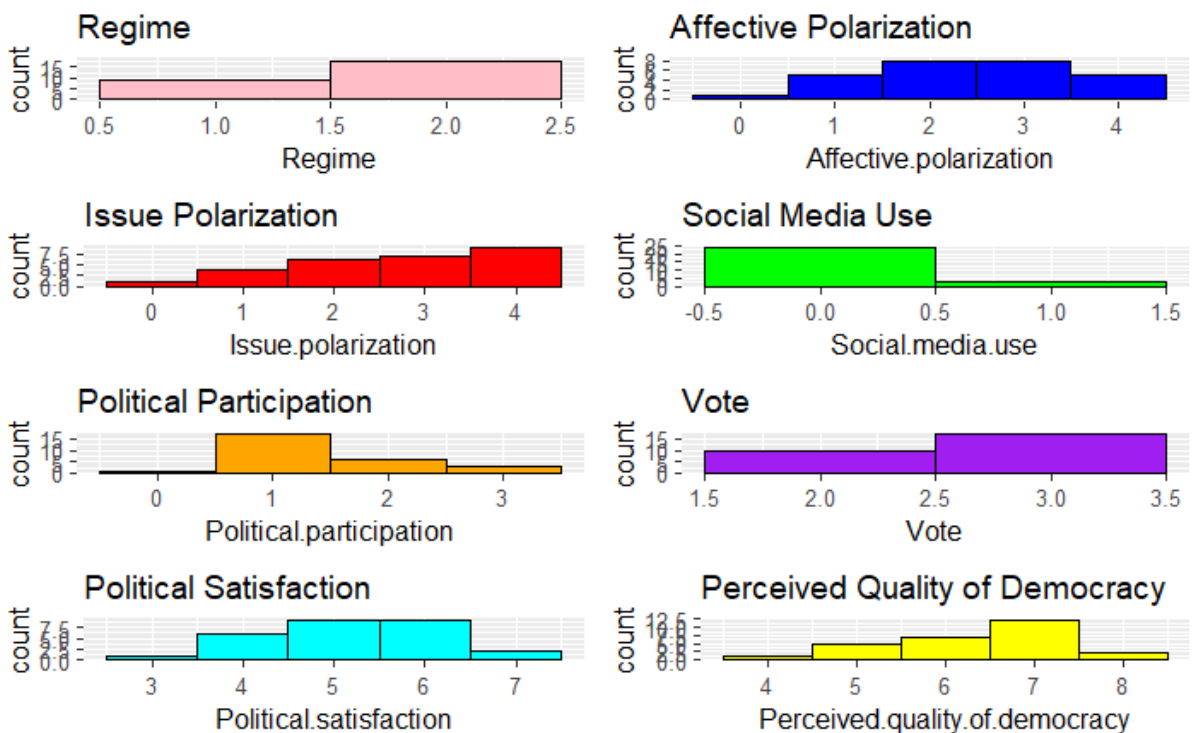
1. Individual-Level Data

- **Social Media Use for Political Information:** Frequency of using platforms like Facebook and Twitter for political information.
- **Political Participation and Voting:** Engagement in political activities, including voting and attending political events.
- **Demographic and Socioeconomic Variables:** Variables such as age, education, and income.

2. Country-Level Data

- **Polarization Measures:** Affective and issue polarization scores.
- **Political, Economic Indicators and Other Macro-level Variables**

The Dem-Dataset is loaded in **Appendix 2**.



4.2. Qualitative Comparative Analysis (QCA)

QCA is a method that allows for the systematic analysis of complex causal relationships in small to medium-N datasets. It is particularly useful when dealing with multiple causal conditions that can lead to an outcome of interest. QCA is based on Boolean algebra and set theory, which enables researchers to identify necessary and sufficient conditions for an outcome to occur.

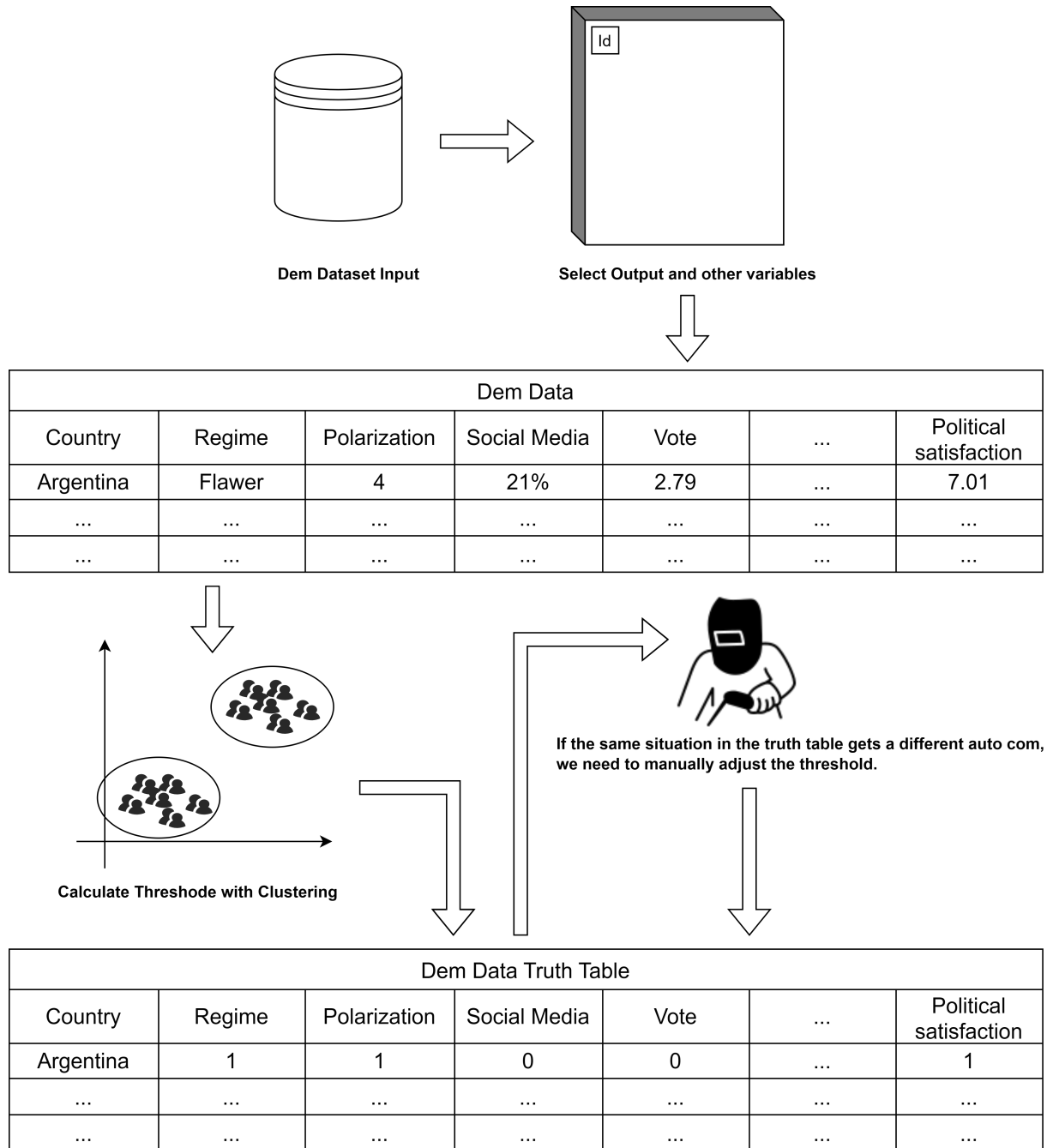
4.2.1. Steps for QCA

1. Define the Outcome: Identify the outcome of interest, in our case, political satisfaction.
2. Select Conditions: Choose the causal conditions that may influence the outcome (Regime, Vote, and etc.).
3. Calibrate Conditions: Assign values to the conditions based on empirical data.
4. Truth Table: Generate a truth table that lists all possible combinations of conditions and outcomes.

5. Analysis: Use software like QCA package in R to analyze the truth table and identify necessary and sufficient conditions for the outcome.

4.2.2. Flowchart of QCA Method

For better understanding, I provide a flowchart of the QCA method below (I make it with draw.io).



5. Justification of Data and Model Choice

5.1. Appropriateness of QCA for the Research Question

QCA is highly suitable for this research due to several factors:

- **Complex Causal Relationships**: It explores how interdependent variables and contingent conditions, such as social media impact under various levels of polarization and regime types, interact to affect political satisfaction.

- **Configurational Comparative Approach:** QCA differs from traditional methods by examining how unique combinations of conditions lead to outcomes, rather than assuming independent causal effects. This is critical for understanding the multifaceted role of social media in political engagement.
- **Identification of Conditions:** QCA pinpoints necessary and sufficient conditions for outcomes, offering valuable insights for policy-making, especially in understanding how specific settings influence political satisfaction.

5.2. Suitable Dataset Selection

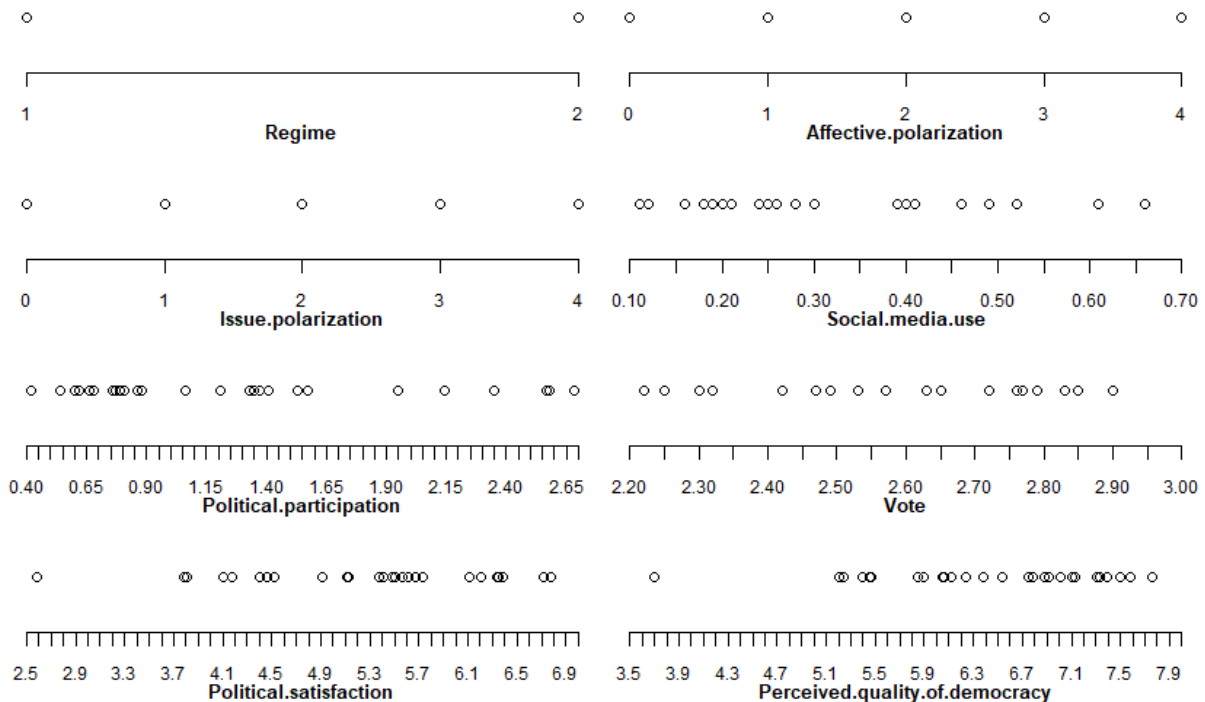
- **Suitability for QCA:** The dataset contains both continuous and categorical data suitable for transformation into the binary or multi-value sets required for QCA analysis.
- **Relevance:** The dataset includes variables directly relevant to the research question, such as levels of social media use, affective and issue polarization, political participation, voting behavior, and perceptions of democratic quality.
- **Comprehensiveness:** It spans a broad range of developed democracies, providing a diverse context that enhances the generalizability and relevance of the findings.

6. Application of QCA Method in Developed Democracies

In this part, I use the QCA package of R language and tidyverse to process the dem data set and perform QCA calculations. And place all codes and running results in the **Appendix 4**. (The appendix is built using Rmarkdown and exported to PDF and attached to the end of this research brief).

6.1. Steps by Steps QCA Analysis

- **Step 1: Data Preprocessing:** Clean and prepare the Dem-Dataset for QCA analysis. In **Appendix 4.1**, I provide the code for data cleaning and transformation by changing the Social Media Use from percentage number to float and Regime to numeric format.
- **Step 2: Check the histogram of the data:** In **Appendix 4.2**, I provide the code (Xplot) for checking the histogram of the data. It is a reference to adjust the Calibrate Conditions in the future.



- Step 3: Calculate the threshold of the data: In **Appendix 4.3**, Auto Calculating the thresholds for Crisp Set is used with **QCA::findTh** (findTh via clustering method to get the thresholds). The initial thresholds are showing below.

Regime: 1.500, **Affective Polarization:** 2.000, **Issue Polarization:** 2.000, **Social Media Use:** 0.400, **Political Participation:** 1.760, **Vote:** 2.400, **Political Satisfaction:** 6.500, **Perceived Quality of Democracy:** 7.000,

- Step 4: Generate the Truth Table: In **Appendix 4.4**, the truth table is a matrix that lists all possible combinations of conditions and outcomes.
- Step 5: Check the Truth Table: If the truth table with the same conditions but different outcomes, it means that the Calculated data is not enough to support the QCA analysis. If so, try to adjust the thresholds and repeat the Step 4 and 5 until the truth table is unique.

6.2. Final Model of QCA

After several iterations of adjusting the thresholds (It takes me about 2 hours to find the thresholds), the final truth table is unique. The final model is shown below:

Regime: 1.500, **Affective Polarization:** 1.500, **Issue Polarization:** 1.500, **Social Media Use:** 0.345, **Political Participation:** 1.760, **Vote:** 2.685, **Political Satisfaction:** 4.285, **Perceived Quality of Democracy:** 4.450,

Then, In **Appendix 4.6** I use the **QCA::truthTable** to generate the final truth table and use the **QCA::minimize** to analyze the truth table. The results are shown in **Appendix 4.7**.

7. Conclusions

7.1. The Findings of the QCA results

The causal recipes leading to political satisfaction are as follows (the **QCA::minimize** Output of **Appendix 4.7**):

1. **Regime * AffectPol * ~IssuePol * ~SocialMedia * PolPart * Vote * ~QualDem**
 - Regime and AffectPol are present.
 - IssuePol, SocialMedia, PolPart, and QualDem are absent.
 - Vote is present.
 - This configuration suggests that political satisfaction is likely when there is a certain regime type coupled with affective polarization, absence of issue-based polarization, less use of social media, lower political participation outside voting, active voting, and lower perceived quality of democracy.
 - Covers 50% of the cases with political satisfaction (20 cases).
2. **~Regime * AffectPol * IssuePol * ~SocialMedia * ~PolPart * Vote * ~QualDem**
 - Regime is absent, but AffectPol and IssuePol are present.
 - SocialMedia, PolPart, and QualDem are absent.
 - Vote is present.
 - This configuration indicates that political satisfaction can also occur in the absence of a certain regime type when both forms of polarization (affective and issue-based) are present, alongside active voting, with lower usage of social media, lesser non-voting political participation, and lower perceived quality of democracy.
 - Also covers 50% of the cases with political satisfaction (22 cases).

Interpretation and Implications

- **Complex Relationships:** The presence of polarization (affective and sometimes issue-based) combined with active voting and specific political contexts (related to regime type and perception of democracy) are critical for political satisfaction.
- **Role of Voting:** Voting appears as a crucial condition in both configurations, underscoring its significance in contributing to political satisfaction.
- **Influence of Media and Participation:** Lesser engagement with social media and political activities beyond voting seems to contribute to political satisfaction, suggesting that over-engagement might have negative impacts or distract from factors that truly drive satisfaction.

Model Comparison

In **Appendix 5**, I use multiple models to compare the results of QCA. The results show that the same conclusion as we get from QCA.

7.2. Challenges, Limitations and Management

Challenges and Limitations: Using Qualitative Comparative Analysis (QCA) to investigate political engagement through social data involves several challenges and limitations (Even so, it took me a long time to find the unique collection). The calibration of data into sets can be subjective and prone to misclassification, potentially leading to incorrect conclusions about causal relationships. The method also faces issues with limited empirical diversity, where the possible configurations of variables may exceed the number of cases available, resulting in logical remainders without empirical support. Additionally, QCA's sensitivity to case selection can affect the generalizability of the findings, particularly if the selection isn't representative of a broader scenario. Finally, the configurational nature of QCA introduces causal complexity, where multiple combinations of conditions might lead to the same outcome (equifinality), making the interpretation of results particularly challenging for those unfamiliar with such analytical approaches.

Strategies for Management: Increasing the diversity of cases can help cover more potential configurations, and transparency in how cases are selected can enhance the representativeness and relevance of the study (when few variables, I find it is too hard to set the thresholds). Furthermore, providing clear explanations of the QCA methodology and its interpretation challenges, supplemented by visual aids like truth tables and Venn diagrams, can aid stakeholders in understanding the results.

7.3. Summary of the Research Brief

This QCA has provided insights into the complex interplay of political behaviors, attitudes, and satisfaction. The findings can inform policymakers and political scientists about the key factors that contribute to or detract from political satisfaction in different political regimes and environments.

QCA dealing with the Social Complexity by Capturing Complex Causal Relationships: QCA is designed to handle cases where outcomes are the result of multiple, interacting conditions. This method is particularly adept at identifying how different combinations of factors contribute to a specific result. Unlike traditional methods that often look for average effects of isolated variables, QCA recognizes that the same outcome can arise from different pathways or combinations of factors.

Finally, according to our research, voting consistently emerges as essential, indicating its foundational role in democratic satisfaction. Meanwhile, the findings suggest potential drawbacks of excessive social media engagement and political participation, which might not always enhance satisfaction and could lead to political fatigue. Thus, promoting balanced political discourse and encouraging informed voting are crucial strategies for improving political satisfaction in developed democracies.

Bibliography

- [1] M. Chan and J. Yi, “Social Media Use and Political Engagement in Polarized Times. Examining the Contextual Roles of Issue and Affective Polarization in Developed Democracies,” *Political Communication*, vol. 0, no. 0, pp. 1–20, 2024, doi: [10.1080/10584609.2024.2325423](https://doi.org/10.1080/10584609.2024.2325423).
- [2] A. Penn, P. Barbrook-Johnson, M. Bicket, D. Hills, and J. Boehnert, “THE VISUAL REPRESENTATION OF COMPLEXITY Definitions, Examples & Learning Points,” p. , 2018, doi: [10.13140/RG.2.2.12496.15369](https://doi.org/10.13140/RG.2.2.12496.15369).
- [3] “Varieties of Democracy (V-Dem) Dataset.” 2022.
- [4] C. Haerpfer *et al.*, Eds., *World Values Survey: Round Seven - Country-Pooled Datafile*, Version 5.0 ed. Madrid, Spain & Vienna, Austria: JD Systems Institute & WVSA Secretariat, 2022. doi: [10.14281/18241.20](https://doi.org/10.14281/18241.20).

Appendix for Computaional Social Science Summative

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2024-04-22

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Appendix 1 Dataset Pre-processing

Dataset World Values Survey Wave 7 (2017-2022)

Link: <https://www.worldvaluessurvey.org/WVSDocumentationWV7.jsp>

Dataset V-Dem (2022)

Link: <https://www.v-dem.net/data/dataset-archive/>

It contains data files and original questionnaire.

I download the dataset from this link and put it in “./data” directory.

1.1 Read the data from the RData and RDS file

```
current_directory = getwd()
# print(current_directory)
# actual_path = current_directory
setwd(current_directory)
# load("./data/WVS_Cross-National_Wave_7_rData_v5_0.rdata")
# WVS.origin = `WVS_Cross-National_Wave_7_v5_0`
# v_dem_2022 = readRDS("./data/2022_CPD_V_Party_R_v2/V-Dem-CPD-Party-V2.rds")
```

1.2 Steps for Pre-processing

Appendix 2 Read Democracy Dataset Directly

```
dem_data = read.csv("./data/country_level_dem.csv")
```

```
head(dem_data)
```

```
##      Country Regime Sample Affective.polarization Issue.polarization
## 1 Argentina Flawed   1003                4                4
## 2  Brazil Flawed   1762                4                4
## 3   Canada  Full   4018                1                1
## 4   Chile Flawed   1000                3                4
## 5 Colombia Flawed   1520                3                4
## 6  Cyprus Flawed   1000                3                2
##  Social.media.use Political.participation Vote Political.satisfaction
## 1              21%              1.33 2.79              5.41
## 2              28%              1.41 2.63              2.59
## 3              52%              2.57 2.65              6.38
## 4              18%              0.77 2.30              5.48
## 5              26%              1.57 2.42              3.81
## 6              25%              1.06 2.49              5.13
##  Perceived.quality.of.democracy
## 1              7.01
## 2              3.70
## 3              7.31
```

```
## 4          6.79
## 5          5.24
## 6          6.12
```

```
# Using dim() to get both rows and columns
# Prints c(number_of_rows, number_of_columns)
print(dim(dem_data))
```

```
## [1] 27 10
```

Appendix 3 Basic EDA for dem_data

3.1 Summarize the Data

```
print(summary(dem_data))
```

```
##      Country          Regime          Sample  Affective.polarization
## Length:27          Length:27      Min.    :1000      Min.    :0.000
## Class :character   Class :character 1st Qu.:1200      1st Qu.:2.000
## Mode  :character   Mode  :character Median :1313      Median :2.000
##                                     Mean  :1601      Mean  :2.407
##                                     3rd Qu.:1700      3rd Qu.:3.000
##                                     Max.   :4018      Max.   :4.000
## Issue.polarization Social.media.use Political.participation      Vote
## Min.    :0.000      Length:27      Min.    :0.420      Min.    :2.220
## 1st Qu.:2.000      Class :character 1st Qu.:0.765      1st Qu.:2.470
## Median :3.000      Mode  :character Median :1.210      Median :2.630
## Mean    :2.704      Mean    :1.297      Mean    :2.595
## 3rd Qu.:4.000      3rd Qu.:1.550      3rd Qu.:2.770
## Max.    :4.000      Max.    :2.680      Max.    :2.900
## Political.satisfaction Perceived.quality.of.democracy
## Min.    :2.590      Min.    :3.700
## 1st Qu.:4.490      1st Qu.:5.875
## Median :5.480      Median :6.530
## Mean    :5.248      Mean    :6.409
## 3rd Qu.:5.920      3rd Qu.:7.115
## Max.    :6.780      Max.    :7.760
```

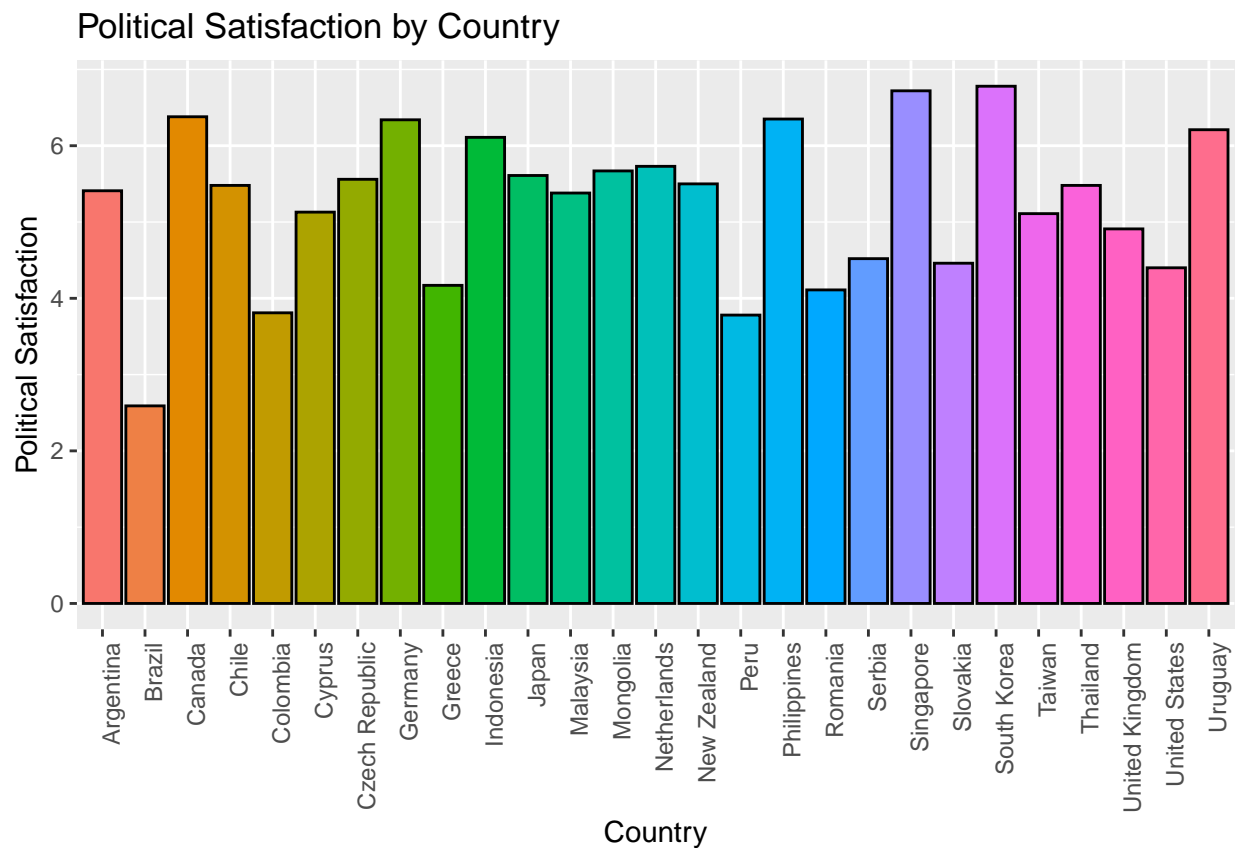
3.2 Check for Missing Values

```
# Check if it exists missing value
any_missing_values = any(is.na(dem_data))
# Will print TRUE if there are any NAs, otherwise FALSE
print(any_missing_values)
```

```
## [1] FALSE
```

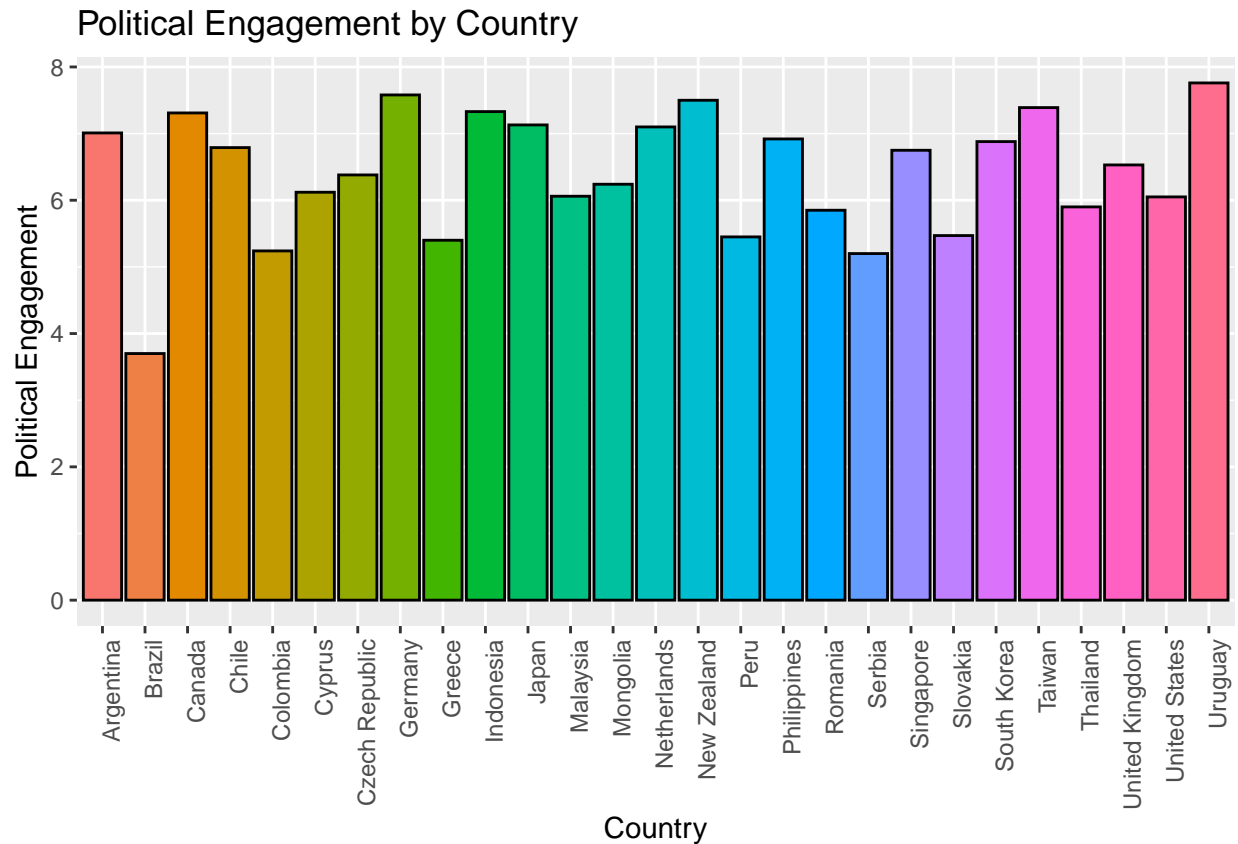
3.3 Bar Plots for Political Satisfaction and Engagement

```
# install.packages("ggplot2")
library(ggplot2)
ggplot(dem_data,
       aes(x = Country, y = Political.satisfaction,
           fill = Country
       )) +
  # Use identity to use the actual values from the data
  geom_bar(stat = "identity", color = "black") +
  labs(title = "Political Satisfaction by Country",
       x = "Country",
       y = "Political Satisfaction") +
  # Rotate x labels for better readability
  theme(axis.text.x = element_text(angle = 90, hjust = 1),
        legend.position = "none")
```



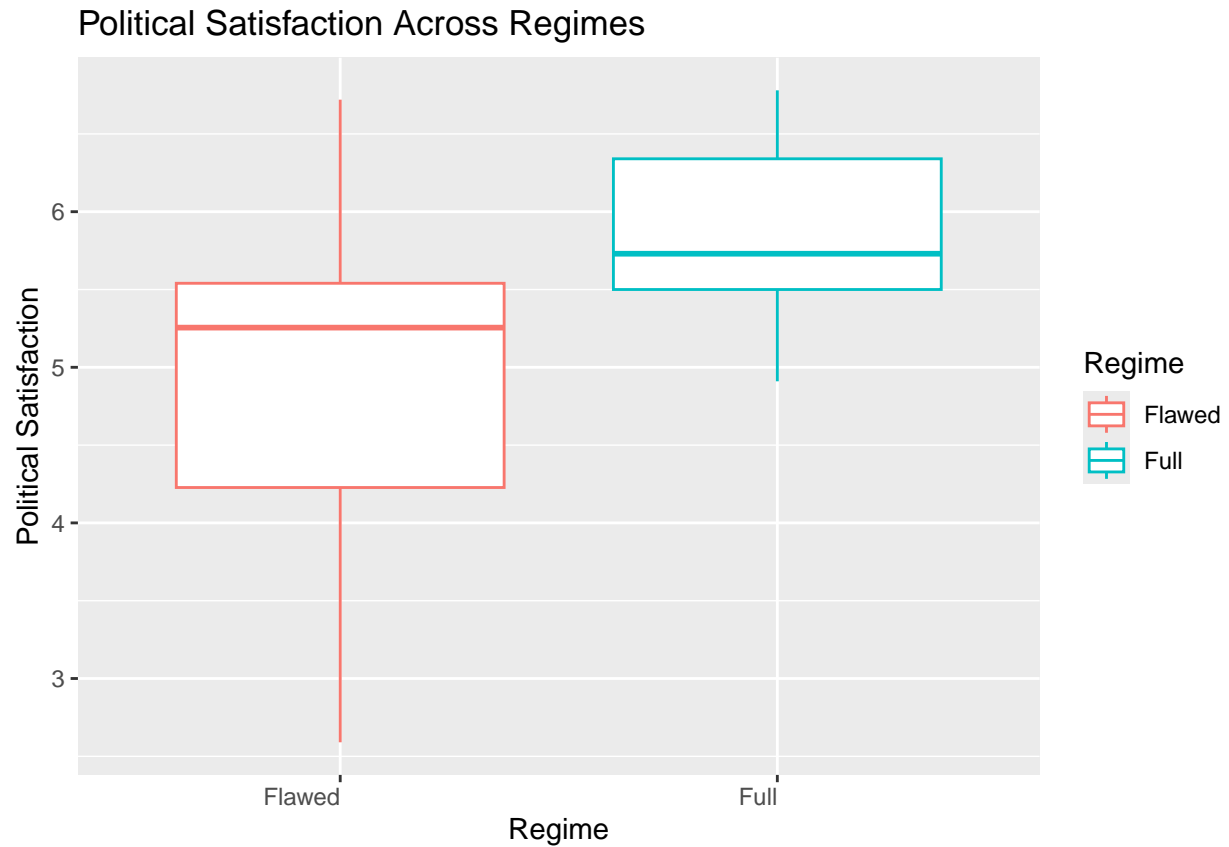
```
ggplot(dem_data,
       aes(x = Country,
           y = Perceived.quality.of.democracy,
           fill = Country
       )) +
  # Use identity to use the actual values from the data
  geom_bar(stat = "identity", color = "black") +
```

```
labs(title = "Political Engagement by Country",
     x = "Country",
     y = "Political Engagement") +
# Rotate x labels for better readability
theme(axis.text.x = element_text(angle = 90, hjust = 1),
      legend.position = "none")
```

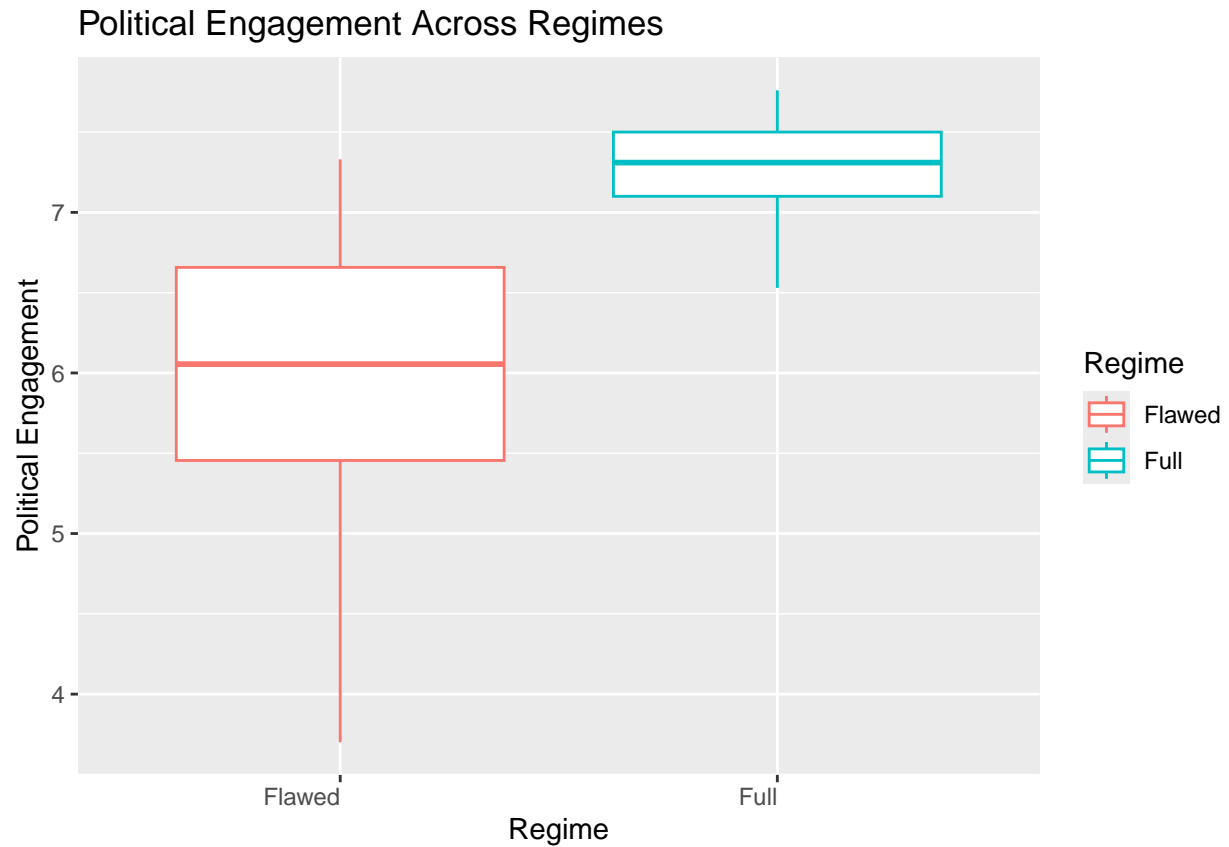


3.4 Political Satisfaction and Engagement across Regime

```
ggplot(dem_data, aes(x = Regime, y = Political.satisfaction)) +
# geom_boxplot(fill = "tomato") +
geom_boxplot(aes(color = Regime)) +
labs(title = "Political Satisfaction Across Regimes",
     x = "Regime",
     y = "Political Satisfaction") +
theme(axis.text.x = element_text(angle = 0, hjust = 1))
```

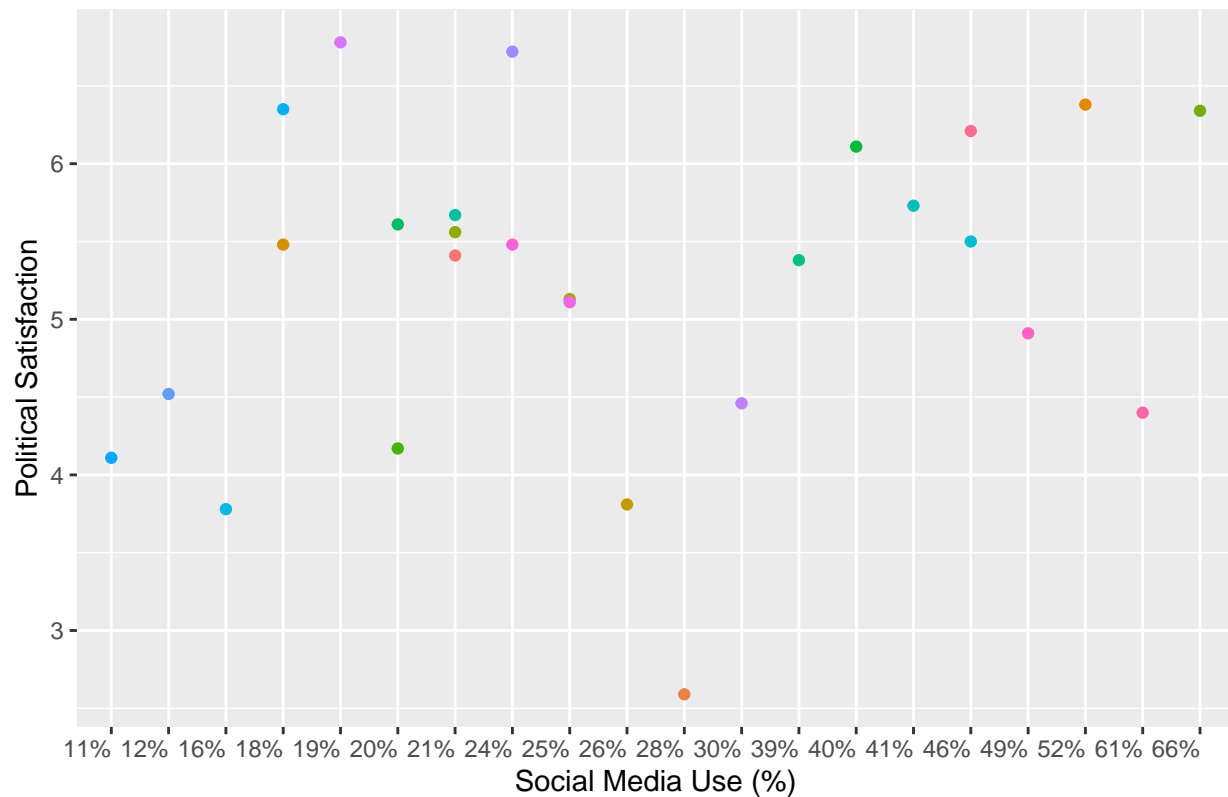
```
ggplot(dem_data, aes(x = Regime, y = Perceived.quality.of.democracy)) +  
  geom_boxplot(aes(color = Regime)) +  
  labs(title = "Political Engagement Across Regimes",  
        x = "Regime",  
        y = "Political Engagement") +  
  theme(axis.text.x = element_text(angle = 0, hjust = 1))
```



3.5 Relationship between Political Satisfaction and Social Media Use

```
ggplot(dem_data, aes(x = Social.media.use, y = Political.satisfaction)) +
  # Color points by Regime to add another layer of information
  geom_point(aes(color = Country)) +
  labs(title = "Social Media Use vs. Political Satisfaction",
       x = "Social Media Use (%)",
       y = "Political Satisfaction") +
  theme(axis.text.x = element_text(angle = 0, hjust = 1),
        legend.position = "none")
```

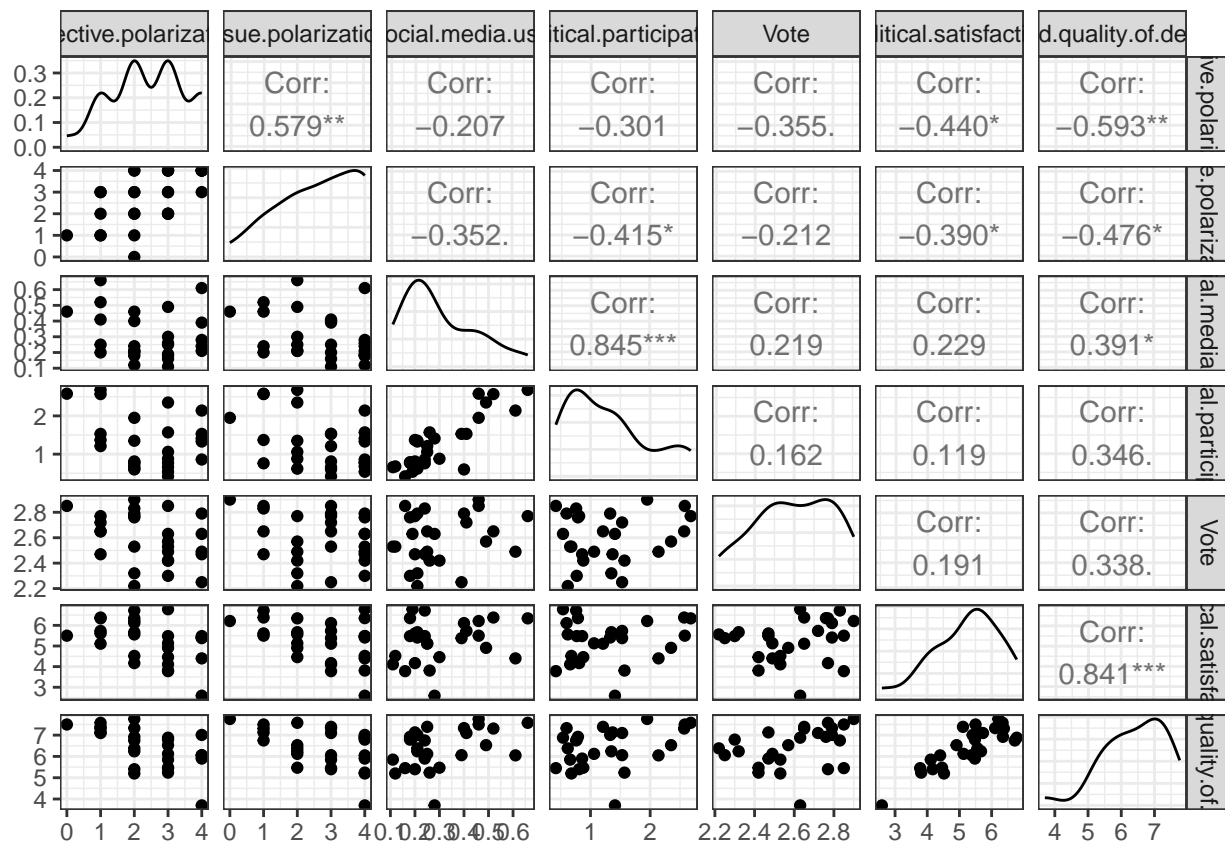
Social Media Use vs. Political Satisfaction



3.6 Correlations between Variables

```
# install.packages("dplyr")
library(dplyr)
library(stringr)
dem_data_cor = dem_data %>%
  mutate(Social.media.use = str_remove(Social.media.use, "%") %>%
    as.numeric() %>%
    `/(100))
```

```
# install.packages("GGally")
library("GGally")
ggpairs(dem_data_cor[, c("Affective.polarization",
  "Issue.polarization",
  "Social.media.use",
  "Political.participation",
  "Vote",
  "Political.satisfaction",
  "Perceived.quality.of.democracy"])] +
  theme_bw())
```



Appendix 4 Processing with QCA

```
# install QCA from CRAN
# install.packages("QCA")
```

4.1 Change the format of Social.media.use and Regime

```
dem_data_new = dem_data %>%
  mutate(Social.media.use = str_remove(Social.media.use, "%") %>%
    as.numeric() %>%
    `/(100),
    Regime = case_when(
      Regime == "Full" ~ 1,
      Regime == "Flawed" ~ 2,
      # Handles any unexpected categories
      TRUE ~ NA_real_
    ))
```

4.2 Histogram for Variables

```
# ref: Computational Social Science Week 5: QCA Workshop
library(QCA)

# Crisp set QCA
# Calibration discussion
# -----
# Sorting and printing for each variable
# example for Printing and sorting for Affective Polarization
print("Affective Polarization")

## [1] "Affective Polarization"

sorted_AffectivePolarization <- sort(dem_data_new$Affective.polarization)
print(sorted_AffectivePolarization)

## [1] 0 1 1 1 1 1 2 2 2 2 2 2 2 3 3 3 3 3 3 3 3 4 4 4 4 4

# Printing and sorting for Issue Polarization
print("Issue Polarization")

## [1] "Issue Polarization"

sorted_IssuePolarization <- sort(dem_data_new$Issue.polarization)
print(sorted_IssuePolarization)

## [1] 0 1 1 1 1 1 2 2 2 2 2 2 3 3 3 3 3 3 3 4 4 4 4 4 4 4 4 4

# Printing and sorting for Social Media Use
print("Social Media Use")

## [1] "Social Media Use"

sorted_SocialMediaUse <- sort(dem_data_new$Social.media.use)
print(sorted_SocialMediaUse)

## [1] 0.11 0.12 0.16 0.18 0.18 0.19 0.20 0.20 0.21 0.21 0.21 0.24 0.24 0.25 0.25
## [16] 0.26 0.28 0.30 0.39 0.40 0.41 0.46 0.46 0.49 0.52 0.61 0.66

remove(sorted_AffectivePolarization,
        sorted_IssuePolarization,
        sorted_SocialMediaUse)

library(gridExtra)

##
## 'gridExtra'
```

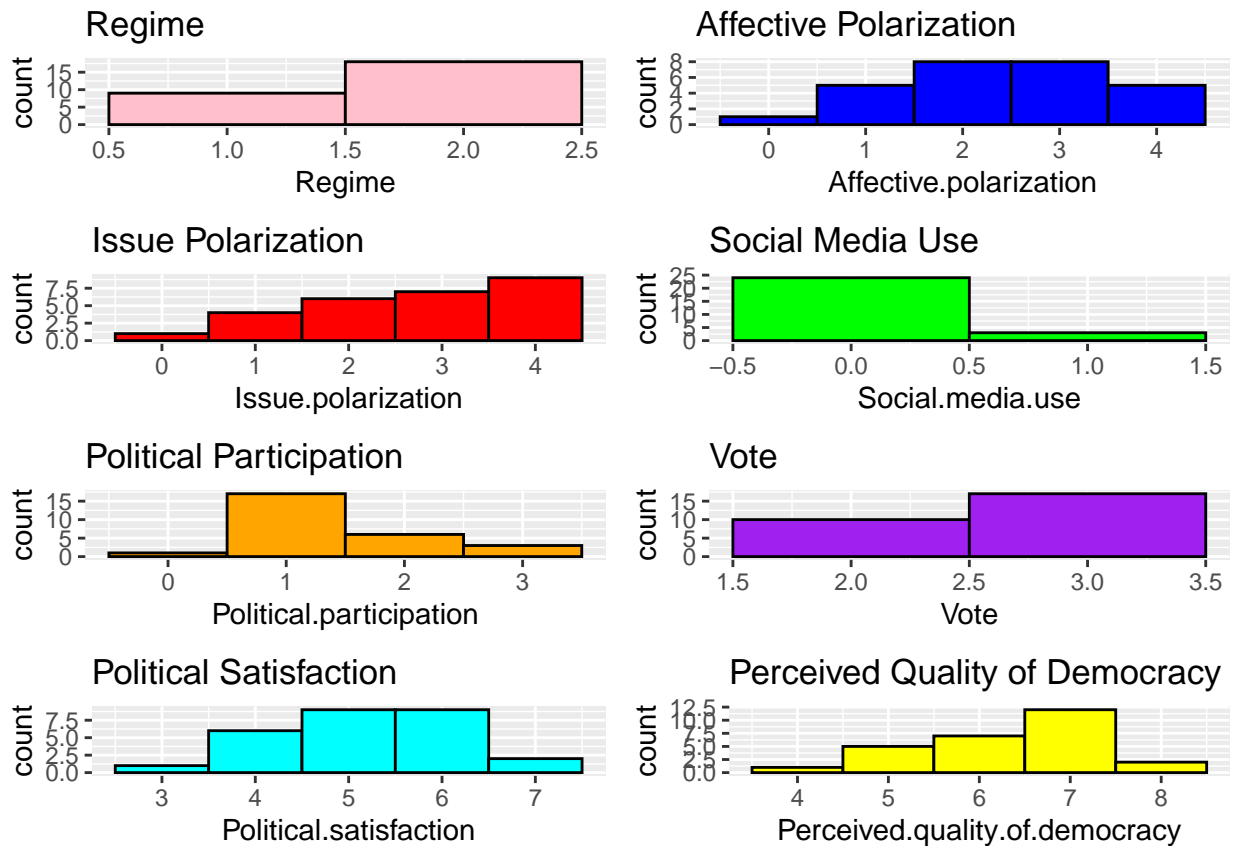
```
## The following object is masked from 'package:dplyr':  
##  
##      combine
```

```
# library(patchwork)  
# Assuming dem_data_new is your dataset and variables are formatted as below  
# Create and rename plot objects  
Regime <-  
  ggplot(dem_data_new, aes(x = Regime)) +  
    geom_histogram(binwidth = 1,  
                  fill = "pink",  
                  color = "black") +  
    ggtitle("Regime")  
AffectivePolarization <-  
  ggplot(dem_data_new, aes(x = Affective.polarization)) +  
    geom_histogram(binwidth = 1,  
                  fill = "blue",  
                  color = "black") +  
    ggtitle("Affective Polarization")  
IssuePolarization <-  
  ggplot(dem_data_new, aes(x = Issue.polarization)) +  
    geom_histogram(binwidth = 1,  
                  fill = "red",  
                  color = "black") +  
    ggtitle("Issue Polarization")  
SocialMediaUse <- ggplot(dem_data_new, aes(x = Social.media.use)) +  
  geom_histogram(binwidth = 1,  
                fill = "green",  
                color = "black") +  
  ggtitle("Social Media Use")  
PoliticalParticipation <-  
  ggplot(dem_data_new, aes(x = Political.participation)) +  
    geom_histogram(binwidth = 1,  
                  fill = "orange",  
                  color = "black") +  
    ggtitle("Political Participation")  
VoteHistogram <- ggplot(dem_data_new, aes(x = Vote)) +  
  geom_histogram(binwidth = 1,  
                fill = "purple",  
                color = "black") +  
  ggtitle("Vote")  
PoliticalSatisfaction <-  
  ggplot(dem_data_new, aes(x = Political.satisfaction)) +  
    geom_histogram(binwidth = 1,  
                  fill = "cyan",  
                  color = "black") +  
    ggtitle("Political Satisfaction")  
QualityOfDemocracy <-
```

```

ggplot(dem_data_new, aes(x = Perceived.quality.of.democracy)) +
  geom_histogram(binwidth = 1,
                fill = "yellow",
                color = "black") +
  ggtitle("Perceived Quality of Democracy")
# Arrange the plots
grid.arrange(
  Regime,
  AffectivePolarization,
  IssuePolarization,
  SocialMediaUse,
  PoliticalParticipation,
  VoteHistogram,
  PoliticalSatisfaction,
  QualityOfDemocracy,
  ncol = 2,
  nrow = 4
)

```



```

remove(
  AffectivePolarization,
  IssuePolarization,
  SocialMediaUse,
  PoliticalParticipation,
  VoteHistogram,

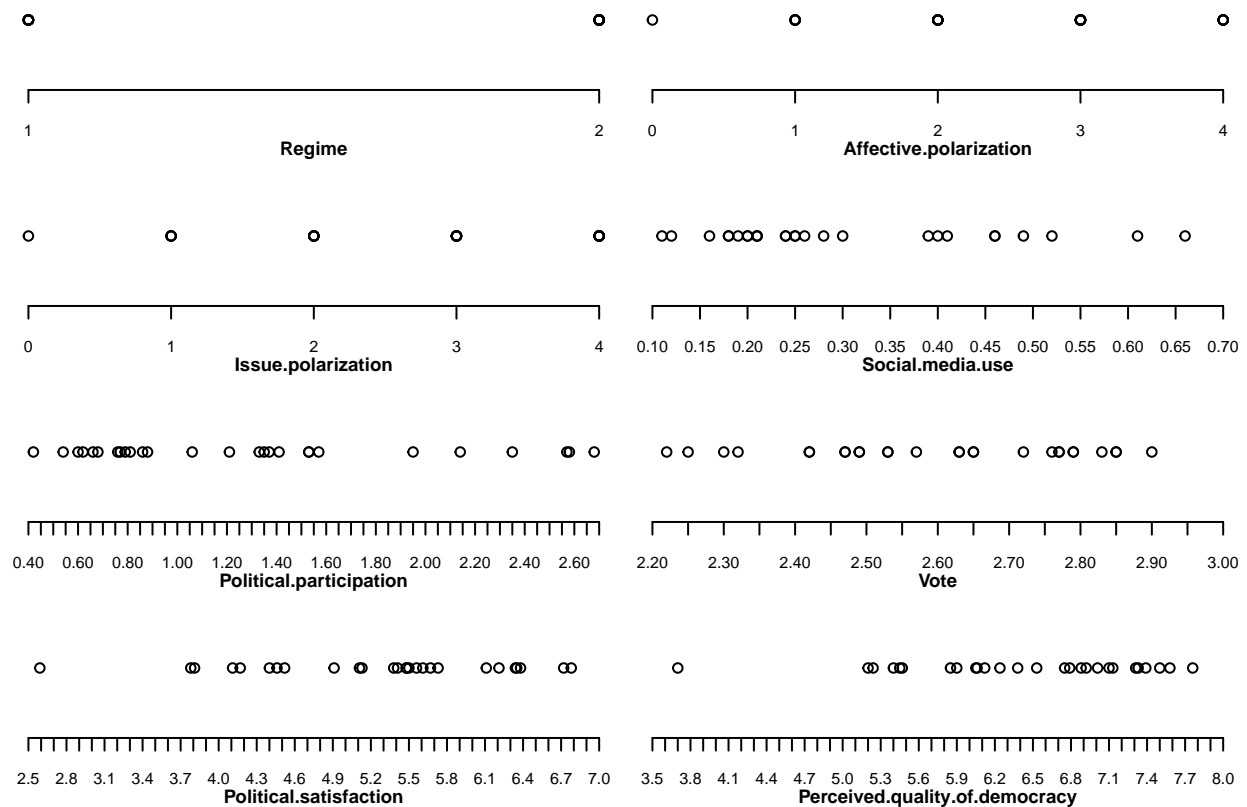
```

```

    PoliticalSatisfaction,
    QualityOfDemocracy,
    Regime
)

# Set up the plot layout
# Adjust the numbers as needed to fit all your plots
par(mfrow = c(4, 2))
# Now call Xplot for each variable, they will be plotted in the layout
Xplot(
  dem_data_new$Regime,
  at = seq(from = 1, to = 2, by = 1),
)
Xplot(
  dem_data_new$Affective.polarization,
  at = seq(from = 0, to = 4, by = 1),
)
Xplot(
  dem_data_new$Issue.polarization,
  at = seq(from = 0, to = 4, by = 1),
)
Xplot(
  dem_data_new$Social.media.use,
  at = seq(from = 0.1, to = 0.7, by = 0.05),
)
Xplot(
  dem_data_new$Political.participation,
  at = seq(from = 0.4, to = 2.7, by = 0.05),
)
Xplot(dem_data_new$Vote,
      at = seq(from = 2.2, to = 3, by = 0.05),
)
Xplot(
  dem_data_new$Political.satisfaction,
  at = seq(from = 2.5, to = 7, by = 0.1),
)
Xplot(
  dem_data_new$Perceived.quality.of.democracy,
  at = seq(from = 3.5, to = 8, by = 0.1),
)

```

```
par(mfrow = c(1, 1))
```

4.3 Auto Calculating the thresholds for Crisp Set (Init)

```
# Auto thresholds
# Finding threshold for Regime
Regime_Th <- findTh(
  dem_data_new$Regime,
  n = 1,
  hclustm = "complete",
  distm = "manhattan"
)

# Finding threshold for Affective Polarization
Affective_polarization_Th <- findTh(
  dem_data_new$Affective.polarization,
  n = 1, # number of thresholds
  hclustm = "complete", # hierarchical clustering method
  distm = "manhattan" # distance measure
)

# Finding threshold for Issue Polarization
Issue_polarization_Th <- findTh(
  dem_data_new$Issue.polarization,
  n = 1,
```

```

    hclustm = "complete",
    distm = "manhattan"
)

# Finding threshold for Social Media Use
Social_media_use_Th <- findTh(
  dem_data_new$Social.media.use,
  n = 1,
  hclustm = "complete",
  distm = "manhattan"
)

# Finding threshold for Political Participation
Political_participation_Th <- findTh(
  dem_data_new$Political.participation,
  n = 1,
  hclustm = "complete",
  distm = "manhattan"
)

# Finding threshold for Vote
Vote_Th <- findTh(
  dem_data_new$Vote,
  n = 1,
  hclustm = "complete",
  distm = "manhattan"
)

# Finding threshold for Political Satisfaction
Political_satisfaction_Th <- findTh(
  dem_data_new$Political.satisfaction,
  n = 1,
  hclustm = "complete",
  distm = "manhattan"
)

# Finding threshold for Perceived Quality of Democracy
Perceived_quality_of_democracy_Th <- findTh(
  dem_data_new$Perceived.quality.of.democracy,
  n = 1,
  hclustm = "complete",
  distm = "manhattan"
)

# organize thresholds
thresholds <- data.frame(
  Variable = c(
    "Regime",
    "Affective Polarization",
    "Issue Polarization",
    "Social Media Use",
    "Political Participation",
    "Vote",

```

```

    "Political Satisfaction",
    "Perceived Quality of Democracy"
),
Threshold = c(
  Regime_Th,
  Affective_polarization_Th,
  Issue_polarization_Th,
  Social_media_use_Th,
  Political_participation_Th,
  Vote_Th,
  Political_satisfaction_Th,
  Perceived_quality_of_democracy_Th
)
)
print(thresholds)

```

```

##                Variable Threshold
## 1                Regime      1.500
## 2      Affective Polarization    1.500
## 3            Issue Polarization    1.500
## 4            Social Media Use     0.345
## 5      Political Participation    1.760
## 6                Vote      2.685
## 7      Political Satisfaction    4.285
## 8 Perceived Quality of Democracy    4.450

```

```
remove(thresholds)
```

4.4 Calibrate the Data with thresholds

```

# Regime
dem_data_new$Regime_cs = calibrate(
  dem_data_new$Regime,
  type = "crisp",
  thresholds = Regime_Th
)
# Affective polarization
dem_data_new$Affective_polarization_cs = calibrate(
  dem_data_new$Affective.polarization,
  type = "crisp",
  # thresholds = Affective_polarization_Th # 1.5
  thresholds = 2
)
# Issue Polarization
dem_data_new$Issue_polarization_cs = calibrate(
  dem_data_new$Issue.polarization,
  type = "crisp",
  # thresholds = Issue_polarization_Th # 1.5
  thresholds = 2
)
# Social Media Use

```

```

dem_data_new$Social_media_use_cs = calibrate(
  dem_data_new$Social.media.use,
  type = "crisp",
  # thresholds = Social_media_use_Th # 0.345
  thresholds = 0.4
)

# Political Participation
dem_data_new$Political_participation_cs = calibrate(
  dem_data_new$Political.participation,
  type = "crisp",
  thresholds = Political_participation_Th
)

# Vote
dem_data_new$Vote_cs = calibrate(
  dem_data_new$Vote,
  type = "crisp",
  # thresholds = Vote_Th # 2.685
  thresholds = 2.4
)

# Political Satisfaction
dem_data_new$Political_satisfaction_cs = calibrate(
  dem_data_new$Political.satisfaction,
  type = "crisp",
  # thresholds = Political_satisfaction_Th # 4.285
  thresholds = 6.5
)

# Perceived Quality of Democracy
dem_data_new$Perceived_quality_of_democracy_cs = calibrate(
  dem_data_new$Perceived.quality.of.democracy,
  type = "crisp",
  # thresholds = Perceived_quality_of_democracy_Th # 4.45
  thresholds = 7
)

remove(
  Affective_polarization_Th,
  Issue_polarization_Th,
  Social_media_use_Th,
  Political_participation_Th,
  Vote_Th,
  Political_satisfaction_Th,
  Perceived_quality_of_democracy_Th,
  Regime_Th
)

```

4.5 Construct Truth Tables

```

DemCrisp <- dem_data_new[, c(
  "Regime_cs",
  "Affective_polarization_cs",

```

```

"Issue_polarization_cs",
"Social_media_use_cs",
"Political_participation_cs",
"Vote_cs",
"Political_satisfaction_cs",
"Perceived_quality_of_democracy_cs"
)]
DemCrisp.sim = DemCrisp
# Assigning new simpler names
names(DemCrisp.sim) <- c(
  "Regime",
  "AffectPol",
  "IssuePol",
  "SocialMedia",
  "PolPart",
  "Vote",
  "PolSat",
  "QualDem"
)

```

```

conditionCounts <- as.data.frame(DemCrisp.sim) %>%
  mutate(conditions = paste0(Regime,
                              AffectPol,
                              IssuePol,
                              SocialMedia,
                              PolPart,
                              Vote,
                              QualDem
                              )) %>%
  group_by(conditions, PolSat) %>%
  summarise(cases = n())
print(conditionCounts)

```

```

## # A tibble: 14 x 3
## # Groups:   conditions [14]
##   conditions PolSat cases
##   <chr>      <int> <int>
## 1 0000011      0      1
## 2 0001111      0      2
## 3 0010011      0      1
## 4 0011011      0      1
## 5 0011111      0      1
## 6 0101111      0      1
## 7 0110010      1      1
## 8 0111110      0      1
## 9 1100010      1      1
## 10 1110000      0      4
## 11 1110010      0     10
## 12 1110011      0      1
## 13 1111011      0      1
## 14 1111110      0      1

```

4.6 Extracting causal recipes

```
TTDem = truthTable(  
  DemCrisp.sim,  
  outcome = "PolSat",  
  complete = TRUE,  
  show.cases = TRUE  
)
```

4.7 Minimize Truth Tables

```
complexDemCrisp = minimize(TTDem, details = TRUE)
complexDemCrisp
```

```
##
## M1: Regime*AffectPol*~IssuePol*~SocialMedia*~PolPart*Vote*~QualDem +
## ~Regime*AffectPol*IssuePol*~SocialMedia*~PolPart*Vote*~QualDem <-> PolSat
##
##
## inclS PRI covS covU
## -----
## 1 Regime*AffectPol*~IssuePol*~SocialMedia*~PolPart*Vote*~QualDem 1.000 1.000 0.500 0.500
## 2 ~Regime*AffectPol*IssuePol*~SocialMedia*~PolPart*Vote*~QualDem 1.000 1.000 0.500 0.500
## -----
## M1 1.000 1.000 1.000
##
## cases
## -----
## 1 Regime*AffectPol*~IssuePol*~SocialMedia*~PolPart*Vote*~QualDem 20
## 2 ~Regime*AffectPol*IssuePol*~SocialMedia*~PolPart*Vote*~QualDem 22
## -----
```

```
complexDemCrisp$PIchart
```

```
##
##
## Regime* AffectPol*~IssuePol*~SocialMedia*~PolPart*Vote*~QualDem - x
## ~Regime* AffectPol*IssuePol*~SocialMedia*~PolPart*Vote*~QualDem x -
```

Parsimonious ComplexDemCrisp

```
ParComplexDemCrisp <- minimize(TTDem, include = "?", details = TRUE)
ParComplexDemCrisp
```

```
##
## M01: Regime*~IssuePol + ~Regime*AffectPol*~SocialMedia <-> PolSat
## M02: Regime*~IssuePol + ~Regime*AffectPol*~PolPart <-> PolSat
## M03: Regime*~IssuePol + ~Regime*~SocialMedia*~QualDem <-> PolSat
## M04: Regime*~IssuePol + ~Regime*~PolPart*~QualDem <-> PolSat
## M05: ~IssuePol*~QualDem + ~Regime*AffectPol*~SocialMedia <-> PolSat
## M06: ~IssuePol*~QualDem + ~Regime*AffectPol*~PolPart <-> PolSat
```

```

## M07: ~IssuePol*~QualDem + ~Regime*~SocialMedia*~QualDem <-> PolSat
## M08: ~IssuePol*~QualDem + ~Regime*~PolPart*~QualDem <-> PolSat
## M09: ~Regime*AffectPol*~SocialMedia + AffectPol*~IssuePol*~SocialMedia
##      <-> PolSat
## M10: ~Regime*AffectPol*~SocialMedia + AffectPol*~IssuePol*~PolPart <-> PolSat
## M11: ~Regime*AffectPol*~PolPart + AffectPol*~IssuePol*~SocialMedia <-> PolSat
## M12: ~Regime*AffectPol*~PolPart + AffectPol*~IssuePol*~PolPart <-> PolSat
## M13: ~Regime*~SocialMedia*~QualDem + AffectPol*~IssuePol*~SocialMedia
##      <-> PolSat
## M14: ~Regime*~SocialMedia*~QualDem + AffectPol*~IssuePol*~PolPart <-> PolSat
## M15: ~Regime*~PolPart*~QualDem + AffectPol*~IssuePol*~SocialMedia <-> PolSat
## M16: ~Regime*~PolPart*~QualDem + AffectPol*~IssuePol*~PolPart <-> PolSat

```

| | | inclS | PRI | covS | covU | (M1) | (M2) |
|------|----------------------------------|-------|-------|-------|-------|-------|-------|
| ## 1 | Regime*~IssuePol | 1.000 | 1.000 | 0.500 | 0.000 | 0.500 | 0.500 |
| ## 2 | ~IssuePol*~QualDem | 1.000 | 1.000 | 0.500 | 0.000 | | |
| ## 3 | ~Regime*AffectPol*~SocialMedia | 1.000 | 1.000 | 0.500 | 0.000 | 0.500 | |
| ## 4 | ~Regime*AffectPol*~PolPart | 1.000 | 1.000 | 0.500 | 0.000 | | 0.500 |
| ## 5 | ~Regime*~SocialMedia*~QualDem | 1.000 | 1.000 | 0.500 | 0.000 | | |
| ## 6 | ~Regime*~PolPart*~QualDem | 1.000 | 1.000 | 0.500 | 0.000 | | |
| ## 7 | AffectPol*~IssuePol*~SocialMedia | 1.000 | 1.000 | 0.500 | 0.000 | | |
| ## 8 | AffectPol*~IssuePol*~PolPart | 1.000 | 1.000 | 0.500 | 0.000 | | |
| ## | M1 | 1.000 | 1.000 | 1.000 | | | |
| ## | M2 | 1.000 | 1.000 | 1.000 | | | |
| ## | M3 | 1.000 | 1.000 | 1.000 | | | |
| ## | M4 | 1.000 | 1.000 | 1.000 | | | |
| ## | M5 | 1.000 | 1.000 | 1.000 | | | |
| ## | M6 | 1.000 | 1.000 | 1.000 | | | |
| ## | M7 | 1.000 | 1.000 | 1.000 | | | |
| ## | M8 | 1.000 | 1.000 | 1.000 | | | |
| ## | M9 | 1.000 | 1.000 | 1.000 | | | |
| ## | M10 | 1.000 | 1.000 | 1.000 | | | |
| ## | M11 | 1.000 | 1.000 | 1.000 | | | |
| ## | M12 | 1.000 | 1.000 | 1.000 | | | |
| ## | M13 | 1.000 | 1.000 | 1.000 | | | |
| ## | M14 | 1.000 | 1.000 | 1.000 | | | |
| ## | M15 | 1.000 | 1.000 | 1.000 | | | |
| ## | M16 | 1.000 | 1.000 | 1.000 | | | |
| ## | | | | | | | |
| ## | | (M3) | (M4) | (M5) | (M6) | (M7) | (M8) |
| ## 1 | Regime*~IssuePol | 0.500 | 0.500 | | | | |
| ## 2 | ~IssuePol*~QualDem | | | 0.500 | 0.500 | 0.500 | 0.500 |
| ## 3 | ~Regime*AffectPol*~SocialMedia | | | 0.500 | | | |
| ## 4 | ~Regime*AffectPol*~PolPart | | | | 0.500 | | |
| ## 5 | ~Regime*~SocialMedia*~QualDem | 0.500 | | | | 0.500 | |
| ## 6 | ~Regime*~PolPart*~QualDem | | 0.500 | | | | 0.500 |
| ## 7 | AffectPol*~IssuePol*~SocialMedia | | | | | | |

```
## 8      AffectPol*~IssuePol*~PolPart
## -----
##
## -----
##              (M9)   (M10)  (M11)  (M12)  (M13)  (M14)
## -----
## 1          Regime*~IssuePol
## 2          ~IssuePol*~QualDem
## 3      ~Regime*AffectPol*~SocialMedia  0.500  0.500
## 4          ~Regime*AffectPol*~PolPart          0.500  0.500
## 5          ~Regime*~SocialMedia*~QualDem              0.500  0.500
## 6          ~Regime*~PolPart*~QualDem
## 7  AffectPol*~IssuePol*~SocialMedia  0.500          0.500          0.500
## 8      AffectPol*~IssuePol*~PolPart          0.500          0.500          0.500
## -----
##
## -----
##              (M15)  (M16)  cases
## -----
## 1          Regime*~IssuePol          20
## 2          ~IssuePol*~QualDem          20
## 3      ~Regime*AffectPol*~SocialMedia          22
## 4          ~Regime*AffectPol*~PolPart          22
## 5          ~Regime*~SocialMedia*~QualDem          22
## 6          ~Regime*~PolPart*~QualDem  0.500  0.500  22
## 7  AffectPol*~IssuePol*~SocialMedia  0.500          20
## 8      AffectPol*~IssuePol*~PolPart          0.500  20
## -----
```

```
ParComplexDemCrisp$PIchart
```

```
##
##              51 99
## Regime*~IssuePol      -  x
## ~IssuePol*~QualDem    -  x
## ~Regime*AffectPol*~SocialMedia  x  -
## ~Regime*AffectPol*~PolPart      x  -
## ~Regime*~SocialMedia*~QualDem    x  -
## ~Regime*~PolPart*~QualDem        x  -
## AffectPol*~IssuePol*~SocialMedia -  x
## AffectPol*~IssuePol*~PolPart      -  x
```

Appendix 5 Comparison

```
dem_data_reg = dem_data_cor
dem_data_reg$Country = as.factor(dem_data_reg$Country)
dem_data_reg$Regime = as.factor(dem_data_reg$Regime)
```



```

# install.packages("lme4")
# install.packages("lmerTest")
library(lme4)
library(lmerTest)
model = lmer(
  Political.satisfaction ~
    Regime +
    Affective.polarization +
    Issue.polarization +
    Social.media.use +
    Political.participation +
    Vote +
    Perceived.quality.of.democracy +
    (1 | Regime),
  data = dem_data_new
)

```

```
summary(model)
```

```

## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula:
## Political.satisfaction ~ Regime + Affective.polarization + Issue.polarization +
##   Social.media.use + Political.participation + Vote + Perceived.quality.of.democracy +
##   (1 | Regime)
##   Data: dem_data_new
##
## REML criterion at convergence: 46.6
##
## Scaled residuals:
##   Min       1Q   Median       3Q      Max
## -1.6441 -0.4878 -0.2210  0.6714  1.6942
##
## Random effects:
##   Groups   Name                Variance Std.Dev.
##   Regime    (Intercept)  0.004524  0.06726
##   Residual                  0.332347  0.57650
## Number of obs: 27, groups:  Regime, 2
##
## Fixed effects:
##
##              Estimate Std. Error    df t value Pr(>|t|)
## (Intercept)    0.36551    2.40671  19.00000    0.152    0.881
## Regime          0.08949    0.40449  19.00000    0.221    0.827
## Affective.polarization  0.03652    0.15321  19.00000    0.238    0.814
## Issue.polarization  -0.07334    0.12263  19.00000   -0.598    0.557
## Social.media.use    0.97911    1.52119  19.00000    0.644    0.527
## Political.participation -0.45544    0.35581  19.00000   -1.280    0.216
## Vote            -0.49216    0.63620  19.00000   -0.774    0.449
## Perceived.quality.of.democracy  1.00093    0.17535  19.00000    5.708 1.68e-05
##
## (Intercept)
## Regime
## Affective.polarization

```

```

## Issue.polarization
## Social.media.use
## Political.participation
## Vote
## Perceived.quality.of.democracy ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##          (Intr) Regime Affct. Iss.pl Scl.m. Pltcl. Vote
## Regime      -0.546
## Affctv.plrz -0.237 -0.293
## Issu.plrztn -0.146  0.009 -0.379
## Social.md.s  0.280 -0.121 -0.209  0.025
## Pltcl.prtcp -0.405  0.388  0.064  0.128 -0.799
## Vote        -0.716  0.129  0.176 -0.038 -0.175  0.156
## Prcvd.qlt.. -0.586  0.365  0.269  0.130 -0.292  0.264 -0.054

```