

A review on the modeling based on political affiliation

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Abstract:

This study investigates voting trends by analyzing how individuals form political affiliations during a presidential campaign. We develop a system of ordinary differential equations (ODEs) based on a modified epidemiological model to represent the transitions of potential voters through varying levels of political engagement with either the Republican or Democratic Party. By exploring multiple variations of the model, we examine the influence of interactions between politically active and apathetic individuals over the course of the campaign. Furthermore, we compute and interpret threshold values to assess the stability of the model's steady-state solutions.

Keywords:

Mathematical modeling (MM), Political affiliation (PA), Differential equations (DE), Significant classification (SC).

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I. Understanding Political Affiliation through Mathematical Modeling:

For over a century, the Democratic and Republican parties have dominated the American political landscape, winning every presidential election since 1853. Despite their enduring prominence, neither party has been able to achieve a decisive or sustained advantage over the other in terms of membership or long-term control of the presidency. This competitive balance has prompted political scientists to investigate the underlying factors that influence individual party affiliation. In this context, we propose a mathematical model designed to analyze the formation of political identities and voting patterns, particularly during presidential election campaigns. Our model employs a system of ordinary differential equations (ODEs) to represent the social dynamics that lead individuals to transition among various political identity groups. Given that the overwhelming majority of voters in recent U.S. elections have cast their ballots for either the Democratic or Republican nominee, our model focuses exclusively on the dynamics of a two-party system [15]. Specifically, we explore how interactions—especially between politically engaged individuals and those who are apathetic or undecided—affect political alignment throughout the course of a campaign.

Types of Political Affiliations:

When analyzing the political system, it is essential to identify and quantify the individuals who participate in the electoral process. Since our focus is on a presidential election, we limit our analysis to the voting-age population (VAP). As of 2004, the estimated VAP in the United States was approximately 142 million individuals [6]. For the purposes of our mathematical model, we assume that all individuals in this category are eligible to vote, making them the total population under consideration. To mathematically model voting behavior, we begin with several foundational assumptions. First, we consider a two-party political system, focusing exclusively on the Democratic and Republican parties. The influence of third-party voters is assumed to be negligible in our model. While we acknowledge that third parties can have significant effects—as seen in the 2000 presidential election [15]—our goal is to understand the core dynamics of the dominant two-

party system. Before constructing the model, we must define the possible political affiliations an individual may adopt. Consider an individual forming an opinion about Political Party A, with Party B as the only alternative. This individual may:

Support Party A

Oppose Party A (i.e., support Party B)

Remain undecided, apathetic, or support a third party

We further assume that political support exists on two levels: moderate (mild support) and fanatical (strong and active support). This structure also applies to opposition. With these distinctions, we classify individuals into five possible states of political alignment:

Undecided / Apathetic / Other:

Moderately Supportive of Party A

Fanatically Supportive of Party A

Moderately Supportive of Party B

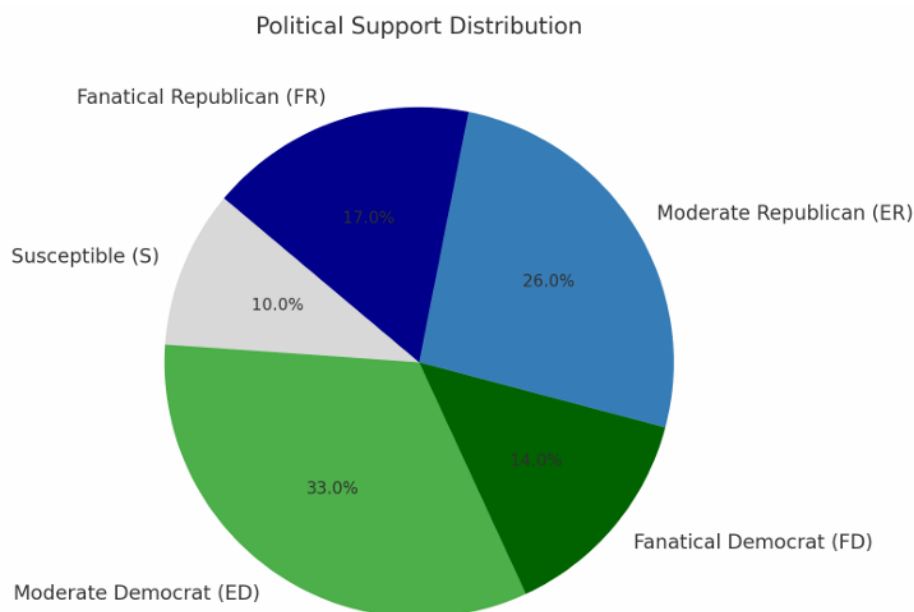
Fanatically Supportive of Party B

These five categories form the foundation of our model of political affiliation in the American context. Specifically:

- Susceptible (S): Individuals in this class are undecided, politically apathetic, or supporters of a third party. They are open to persuasion by either major party.
- Moderate Democrats (ED): These individuals plan to vote for the Democratic candidate but are not actively involved in campaigning. They may share their political views if asked but do not promote their stance publicly or engage in political activism.
- Moderate Republicans (ER): Analogous to Moderate Democrats, these individuals intend to vote for the Republican candidate but do not engage in active political advocacy.
- Fanatical Democrats (FD): These individuals are strongly supportive of the Democratic candidate and actively promote their views through campaigning, political debates, advertisements, rallies, and other means of influence.
- Fanatical Republicans (FR): These individuals exhibit strong support for the Republican candidate and, like Fanatical Democrats, are actively involved in promoting their political beliefs.

Summary of Political Affiliation Categories:

Category	Symbol	Description
Susceptible	S	Undecided, apathetic, or third-party supporters
Moderate Democrat	ED	Mild support for Democratic candidate
Fanatical Democrat	FD	Strong, active support for Democratic candidate
Moderate Republican	ER	Mild support for Republican candidate
Fanatical Republican	FR	Strong, active support for Republican candidate



Distribution of political support categories

These classifications provide a structured basis for our mathematical modeling of voter dynamics in a two-party presidential election system.

Factors that Influence the Formation and Change of Political Affiliations:

During the period between the conclusion of the presidential primaries and the November presidential election, potential voters transition between several political engagements categories. In our model, these categories include Susceptible Individuals (S), Moderate Democratic / Republican Voters (ED / ER), and Fanatical Democrats/Republicans (FD / FR). Although this period spans roughly two months, it is sufficient time for many individuals to change or strengthen their political affiliations. As noted by Holbrook [9], there is considerable evidence of significant shifts in public opinion during campaign seasons. These changes are often driven by campaign events and external stimuli. Accordingly, voters may either become more politically engaged or lose enthusiasm, reducing the support they previously had for a candidate. The factors influencing such shifts generally fall into two broad categories: personal influence and external influence.

Personal Influence:

Personal influence includes intrinsic factors such as:

Religious beliefs

Socioeconomic status

Family upbringing

Cultural background

Individual ideologies and values:

These elements shape a person's baseline political preferences and decisions. A notable aspect of personal influence is the incumbency factor—whether a candidate is an incumbent significantly affects voter perception [17]. In our model, when an individual decides to change their voting stance or strengthen support for a candidate independently, without any direct interaction with other voter groups, we attribute that change to personal motivation. These decisions are considered to arise from the individual's pre-existing values, beliefs, and obligations. Additionally, personal obligations—such as work, family responsibilities, or time constraints—can reduce a person's political engagement. For example, someone might become less active in political discourse or fail to vote simply due to being overwhelmed with personal duties. In our model, all these personal influences are represented by the π terms. These factors explicitly exclude the influence of interpersonal or media-based interactions.

External Influence:

External influence refers to interactions between individuals from different political groups and the broader spread of political messaging through telecommunication (e.g., television, email, social media, and radio) or person-to-person contact. In our model, external influence can be either positive or negative: A positive interaction occurs when an individual from a more politically active group persuades someone from a less active or neutral group to become more engaged. For example, if a Fanatical Democrat successfully convinces a Moderate Democrat to become more politically involved, the interaction has had a positive influence. A negative interaction is when contact between individual's leads to reduced political engagement or a shift in party allegiance. For instance, if a Republican fanatic (FR) turns off a Moderate Republican (ER) through an abrasive encounter, the ER individual may become disillusioned and revert to being Susceptible (S) or even switch to support the Democratic Party. Our model captures the dynamics of political affiliation shifts during the critical pre-election period by accounting for both individual-level motivations and interpersonal/group-level influences. By analyzing how individuals transition between political engagements groups, we aim to shed light on the mechanisms underlying the formation, reinforcement, and alteration of political affiliations in the United States during a presidential election cycle.

Formation of Our Mathematical Model:

To construct our model, it is essential to account for the various interactions that can occur between individuals, the rates at which these interactions happen, and their effects on the individuals involved. As previously outlined, we categorize the population into the following five classes:

S: Susceptible Individuals

ED: Moderate Democrats

ER: Moderate Republicans

FD: Fanatical Democrats

FR: Fanatical Republicans

We base our model on traditional epidemiological frameworks, such as those found in references [3] and [4], adapting them to analyze the formation and evolution of political affiliations. We make several simplifying assumptions to develop the model: No births or deaths occur within the system. This assumption is reasonable

given the relatively short two-month period before the presidential election, during which changes in the Voting-Age Population (VAP) are negligible. Homogeneity within classes: All individuals within a given class are assumed to behave similarly. Mass-action interaction: The probability that an individual interacts with someone from another class is proportional to the size of that class relative to the total population.

Example Interaction:

Consider the rate at which susceptible individuals (S) interact with moderate Republicans (ER) and then adopt the ER affiliation. If all susceptible individuals could interact with all moderate Republicans, the maximum potential interactions would be represented by the product

$$Rate_{S \rightarrow ER} = \frac{b_{14} S * ER}{N}$$

This expression represents the rate at which individual's transition from the S class to the ER class due to S-ER interactions.

Other Interaction Pathways:

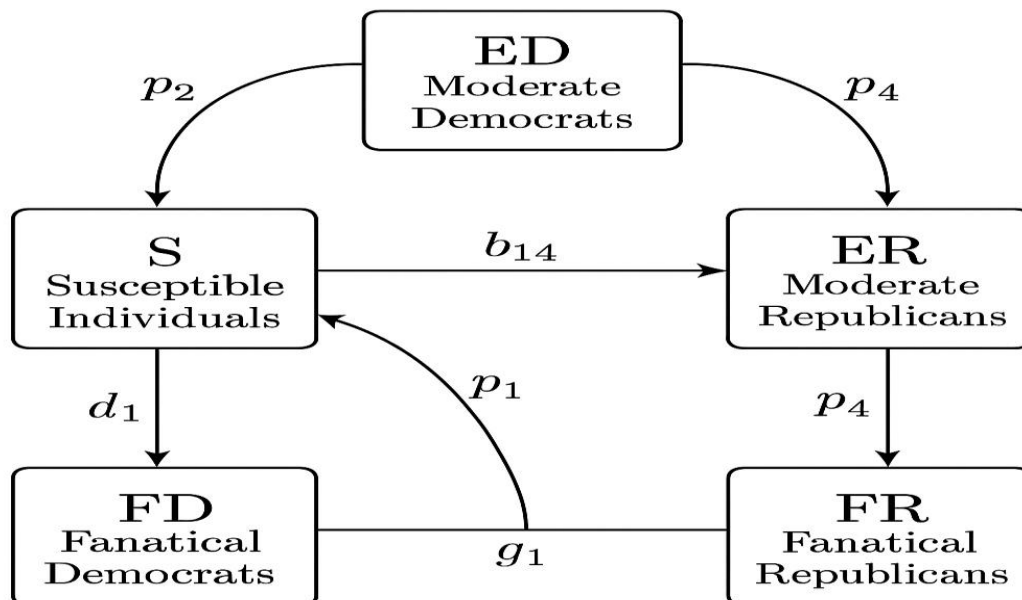
To fully describe the movement of susceptible individuals into the ER class, we must also account for interactions with other politically active groups, such as FD (Fanatical Democrats) and FR (Fanatical Republicans). The contribution of each interaction (e.g., S-FD, S-FR) follows an analogous derivation. Since each interaction may operate at a different intensity or effectiveness, we assign separate parameters—denoted b_i , c_i , d_i , g_i —to each interaction type.

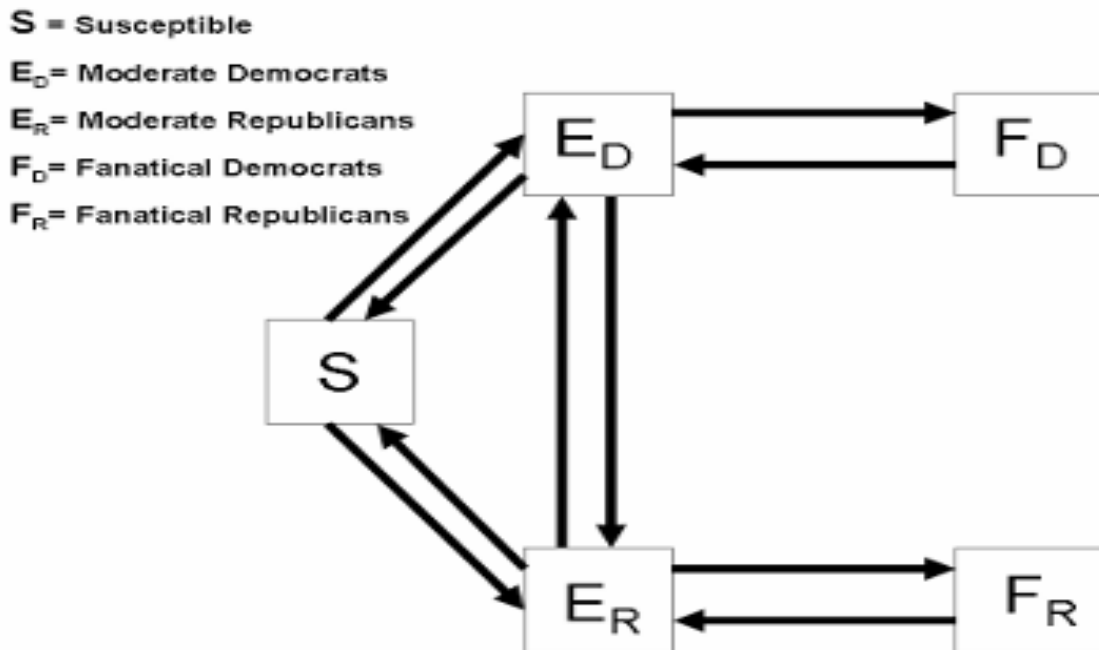
Personal Influence:

Another key component of our model is personal influence, denoted p_i . This term represents the effect of an individual's internal motivation or belief system in determining their political affiliation, independent of social interactions. For instance, an individual in the FR class may be influenced by personal convictions, represented as p_{FR} , which strengthen or reinforce their affiliation without requiring external interaction.

Model Framework:

These interaction terms and personal influence components form the foundation of our system of ordinary differential equations (ODEs). By systematically incorporating the effects of both social interactions and individual-level motivations, we construct a mathematical framework that captures the formation and development of political affiliation. This ideological model is thus governed by a system of ODEs representing the transitions among voter classes over time during a presidential election campaign.





These degrees of support apply equally to those who oppose the other party. Based on these distinctions, we define five possible states of political alignment:

Undecided / Apathetic / Other (S):

Individuals who are politically disengaged, undecided, or support a third-party candidate. This group is referred to as the Susceptible Class, denoted by S.

Moderate Democrat (ED):

Individuals who plan to vote for the Democratic candidate but do not actively campaign or promote their support. These individuals may share political opinions only when asked but otherwise refrain from political activism.

Fanatical Democrat (FD):

Individuals who are not only committed to voting Democrat but also actively promote the Democratic candidate through campaigning, advocacy, and political discourse.

Moderate Republican (ER):

Similar to Moderate Democrats, these individuals intend to vote for the Republican candidate but do not engage in active political campaigning.

Fanatical Republican (FR):

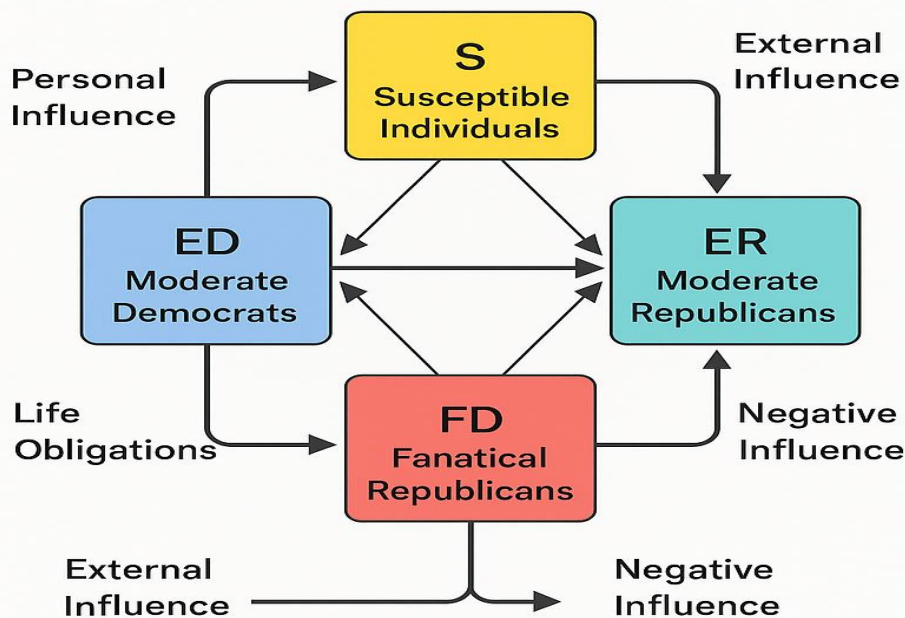
These individuals strongly support the Republican candidate and are actively involved in promoting their campaign. These five classifications form the foundation of our modeling framework for analyzing voter dynamics in a two-party political system.

Factors Influencing the Formation and Change of Political Affiliations:

During the period between the presidential primaries and the November general election, potential voters transition between various political categories: Susceptible Individuals (S), Moderate Democrats/Republicans (ED/ER), and Fanatical Democrats/Republicans (FD/FR). Although this period spans only a couple of months, it is sufficient for individuals to shift their political views due to ongoing influences. According to Holbrook, there is considerable evidence that public opinion changes significantly during campaign seasons, often influenced by campaign events [9]. Voters may become more engaged or, conversely, disillusioned, leading to decreased support for a candidate they had initially favored. These shifts are shaped by both interpersonal interactions and an individual's personal background and convictions. One key factor in changing political affiliation is personal influence. This includes a person's religious beliefs, socio-economic status, cultural background, family values, and individual ideology. Personal influence also encompasses factors such as incumbency, where the prior status of a candidate (e.g., as a sitting president) affects how voters perceive them [17]. These self-motivated decisions—those made independently of outside interactions—are based on pre-existing beliefs and opinions. When such intrinsic factors lead a person to change their support or level of engagement with a candidate, we describe this transition as driven by personal judgment. Another aspect of personal influence involves life obligations. For instance, individuals overwhelmed by work or family

responsibilities may withdraw from political engagement altogether, perhaps even choosing not to vote. In our model, these internal, personal factors are represented by the terms π_i , which account for self-motivation without regard to external group interaction. On the other hand, external influence stems from interactions between individuals of different political categories. These can occur via telecommunication (TV, email, radio, phone, etc.) or face-to-face conversations, where information and persuasion are exchanged. Such interactions can be either positive or negative: Positive influence occurs when someone encourages another person to become more politically engaged or loyal. For example, a Fanatical Democrat convincing a Moderate Democrat to become a fellow fanatic represents a positive influence. Negative influence refers to interactions that discourage political support. For instance, if a Fanatical Republican alienates a Moderate Republican, the latter may revert to being Susceptible or even switch support to the Democratic candidate. In summary, our model captures how individuals transition between political categories due to both personal and external influences. The extent to which someone becomes more or less politically committed depends on these two primary factors. Incorporate these elements into a mathematical model that provides insights into how political affiliations form and evolve during the final two months of a U.S. presidential campaign.

Factors Influencing the Formation and Change of Political Affiliations



Draw inspiration from traditional epidemiological models (e.g., [3], [4]) to develop our framework for analyzing political affiliation dynamics.

Assumptions:

We make the following simplifying assumptions:

No Births or Deaths: Over the two-month period prior to the presidential election, the net change in the voting-age population (VAP) is negligible, justifying the exclusion of births and deaths from the model.

Homogeneity Within Classes: All individuals within a class are assumed to behave identically.

Mass-Action Mixing: The probability of an individual interacting with someone from a given class is proportional to the size of that class relative to the total population. Therefore, interactions follow the mass-action law.

Interaction Example

As shown in the flow diagram (Figure 1), consider how individuals in the S class may interact with those in the ER class and subsequently adopt moderate Republican views. The potential maximum rate of interaction is proportional to the product $S \cdot ER$. However, it is unrealistic to assume that all individuals in these two groups interact.

To account for this, we introduce a parameter b_{14} , which reflects both the rate of interaction and the probability that an S individual transitions to the ER class following an interaction. Dividing by the total population N gives the per-capita transition rate:

$$(b_{14} * S * ER / N)$$

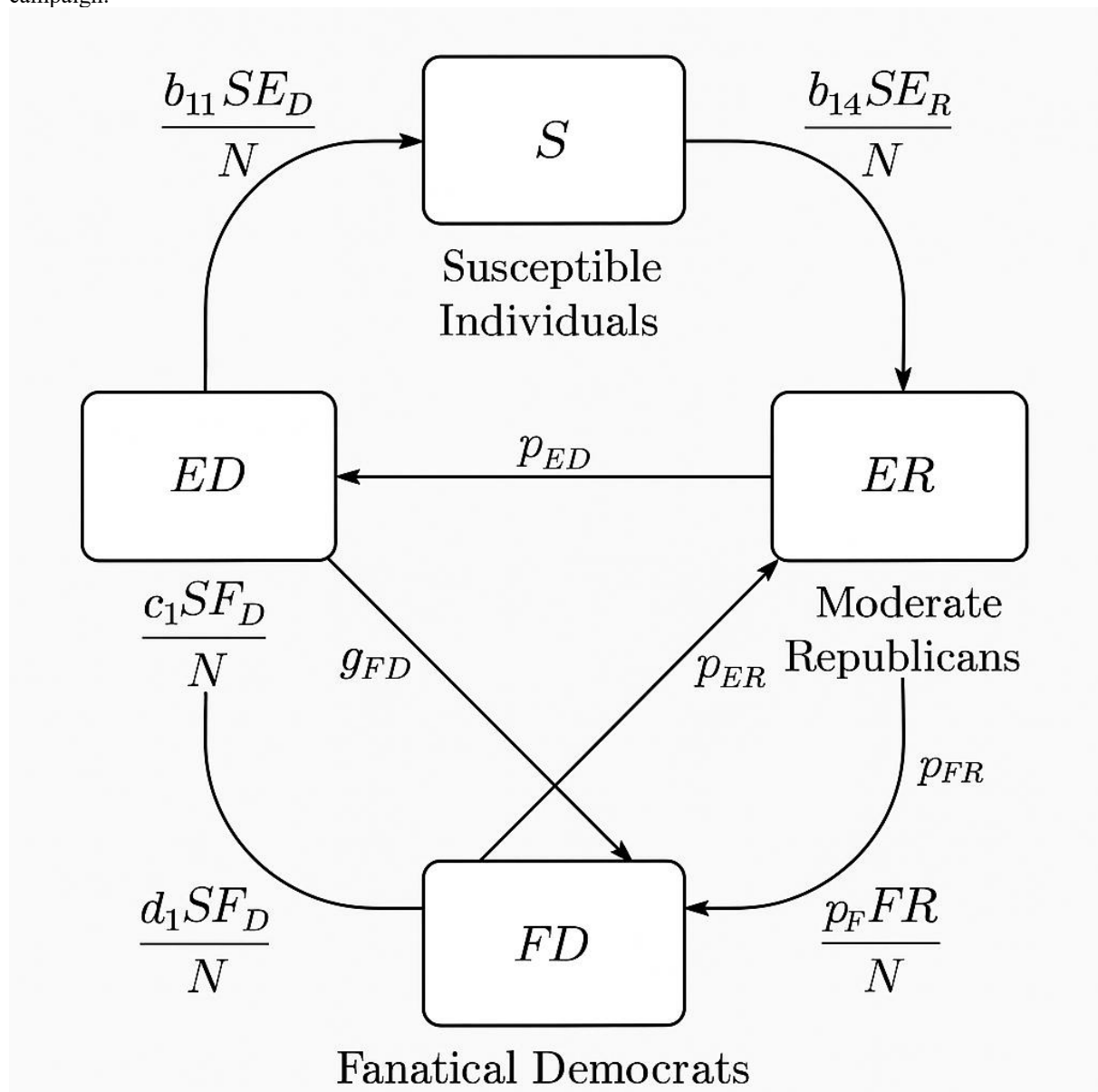
This expression quantifies the rate at which individuals move from S to ER due to interactions. Similar expressions are derived for other transitions involving the susceptible class, such as S-FD, S-FR, and so forth. Since not all interaction types lead to transitions at the same rate, we assign distinct parameters (b_i , c_i , d_i , g_i , etc.) to represent the influence of each specific interaction.

Personal Influence:

In addition to interpersonal interactions, we also include personal influence, denoted p_i , to capture the role of intrinsic motivation and pre-existing beliefs in shaping political affiliation. For instance, if an individual is in the FR class, p_{FR} represents the degree to which their continued affiliation is driven by personal conviction rather than external interaction.

Governing Equations:

These interaction-based and personal-influence expressions form the foundation of our system of ordinary differential equations (ODEs), which models the dynamic transition of individuals among the five political affiliation classes over time. Using this framework, we derive a mathematical ideological model that captures the formation and evolution of political affiliations within the eligible voter population during a presidential campaign.



$$\begin{aligned} \frac{dS}{dt} = & -\frac{S}{N} \{b_1 E_R + b_2 E_R + b_3 E_D + b_4 E_D\} + p_5 E_D + p_4 E_R - p_6 S - p_3 S \\ & + \frac{E_D}{N} \{b_6 E_D + b_7 E_R + b_8 F_R\} + \frac{E_R}{N} \{b_{10} F_R + b_{11} E_D + b_{12} F_D\} \end{aligned} \quad (1)$$

$$\begin{aligned} & -\frac{S}{N} \{b_{14} E_R + b_{15} F_R + b_{16} E_D + b_{17} F_D\} \\ \frac{dE_D}{dt} = & \frac{S}{N} \{b_1 E_R + b_2 F_R + b_3 E_D + b_4 F_D\} - p_8 E_D + p_9 F_D \\ & + \frac{E_R}{N} \{c_1 E_D + c_2 F_D + c_3 F_R\} - \frac{E_D}{N} \{c_5 F_R + c_6 F_R + c_7 F_D\} \end{aligned} \quad (2)$$

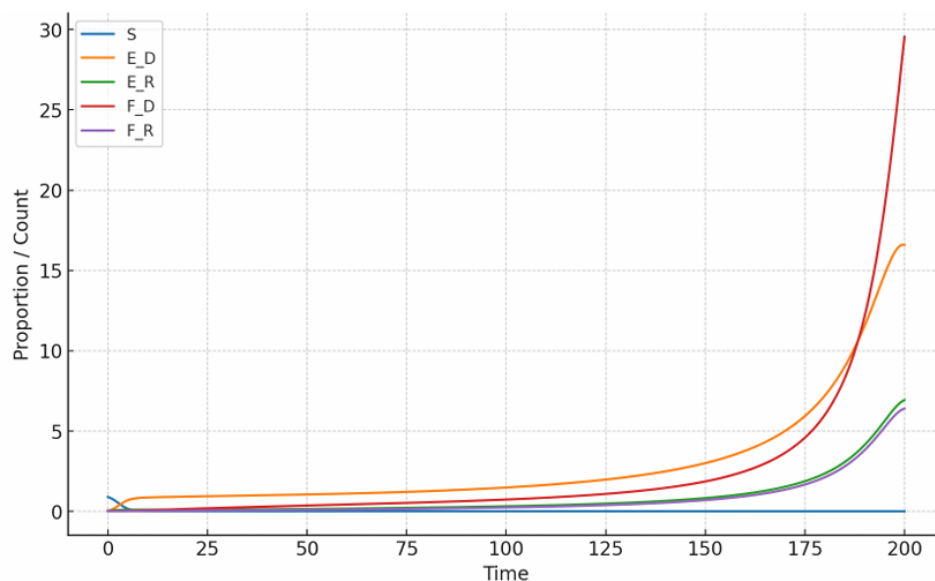
$$\begin{aligned} & + \frac{F_D}{N} \{c_9 E_R + c_{10} F_R\} - \frac{E_D}{N} \{c_{12} F_D - g_3 E_R + g_4 F_R\} \\ & - \frac{E_D}{N} \{b_6 F_D + b_7 E_R + b_8 F_R\} - p_5 E_D + p_7 E_R + p_6 S - p_{10} E_D \\ \frac{dE_R}{dt} = & \frac{S}{N} \{b_{14} E_R + b_{15} F_R + b_{16} E_D + b_{17} F_D\} + p_3 S - p_4 E_R - p_7 E_R \\ & - \frac{E_R}{N} \{d_1 F_R + g_1 F_D + g_2 F_D\} - \frac{E_R}{N} \{c_1 E_D + c_2 F_D + c_3 F_R\} \end{aligned} \quad (3)$$

$$\begin{aligned} & + \frac{E_D}{N} \{c_5 E_R + c_6 F_R + c_7 F_D\} + p_8 E_D + \frac{R_R}{N} \{d_3 E_D + d_4 F_D\} \\ & - \frac{E_R}{N} \{b_{10} F_R + b_{11} E_D + b_{12} F_D\} - p_{12} E_R + p_{13} E_R + p_{13} E_R \end{aligned}$$

$$\frac{dF_D}{dt} = \frac{E_D}{N} \{c_{12} F_D + g_3 E_R + g_4 F_R\} - p_9 E_D - \frac{F_D}{N} \{c_9 E_R + c_{10} F_R\} + p_{10} E_D \quad (4)$$

$$\frac{dF_R}{dt} = \frac{E_R}{N} \{d_1 F_R + g_1 E_D + g_2 F_D\} - p_{13} F_R - \frac{F_R}{N} \{d_3 E_D + d_4 F_D\} + p_{12} E_R \quad (5)$$

Graphical Solution:



The system in the image is nonlinear (S/N times linear combinations of other compartments) and coupled. Nonlinear systems like this are normally handled by:

1. Finding steady states (solve $f(X) = 0$ numerically),
2. Linearizing (Jacobian) at equilibria to test local stability,
3. Running forward-time numerical simulations to explore global behaviour and parameter dependence.

Normalizing the Governing Equations:

It is often convenient to use fractions of the population rather than absolute population numbers. This process mathematically normalizes the governing equations, making the variables represent the proportion of the total population rather than raw counts. Assuming the total population is constant and denoted by N we define the normalized variables as:

$$S = S' / N, I = I' / N, R = R' / N$$

where S' , I' and R' are the absolute numbers of susceptible, infected, and recovered individuals, respectively. The normalized variables S , I and R represent the fraction of the population in each compartment.

$$N = S + E_D + E_R + F_D + F_R$$

Summing equations (1) to (5)

$$\frac{dN}{dt} = \frac{dS}{dt} + \frac{dE_D}{dt} + \frac{dE_R}{dt} + \frac{dF_D}{dt} + \frac{dF_R}{dt} = 0$$

which provides that the population is constant. Thus, we can choose to ignore one of the variables. Define the quantity $s = S / N$ where s represents the proportion of the total population that belongs in the Susceptible State. Similarly, we can define $ed = ED / N$ to be the proportion of population in the Moderate Democrat class, (ED), $er = ER / N$ to be the proportion of the total population in the Moderate Republican Class (ER), $fd = FD / N$ to be the proportion in the Fanatical Democrat Group (FD) and $fr = FR / N$ to be the proportion in the Fanatical Republican Group (FR).

Substituting these normalized variables into the system and simplifying, the normalized susceptible expression

$$\begin{aligned} \frac{ds}{dt} = & -s[b_1e_r + b_2f_r + b_3e_d + b_4f_d] - p_6s + e_d[b_6f_d + b_7e_r + b_8f_r] \\ & + p_5e_d + e_r[b_{10}f_r + b_{11}e_d + b_{12}f_d] + p_4e_r - s[b_{14}e_r + b_{15}f_r + b_{16}e_d + b_{17}f_d] - p_3s \end{aligned}$$

The remaining substitutions have an analogous effect. For convenience, we rename the normalized variables such that $s \rightarrow S$, $e_d \rightarrow E_D$, $e_r \rightarrow E_R$, $f_d \rightarrow F_D$ and $f_r \rightarrow F_R$.

Preliminary Analysis of Our Mathematical Model:

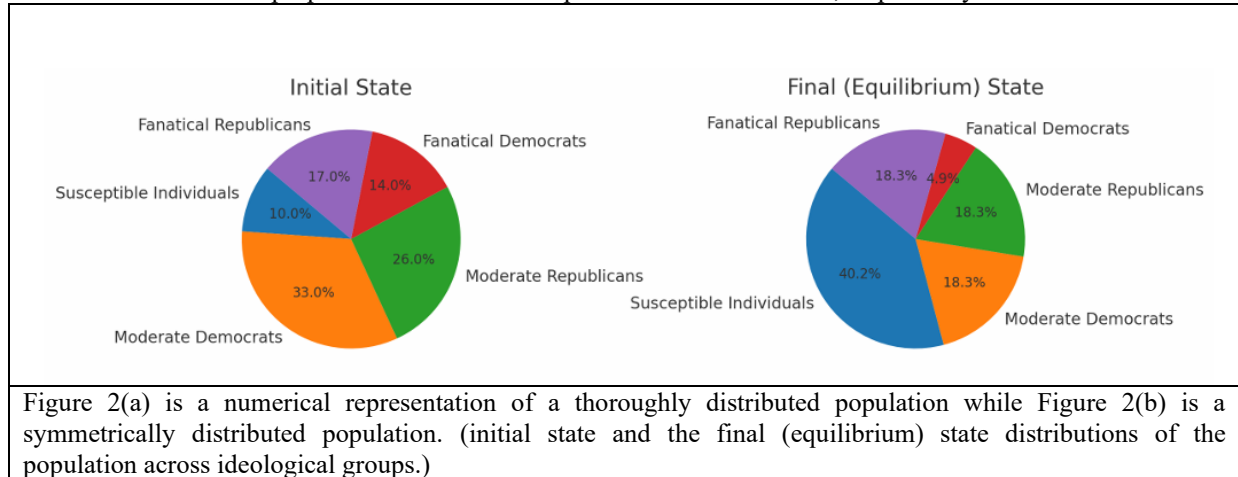
Developing a preliminary understanding of the dynamics of the proposed ODE model. As with many nonlinear dynamical systems, it is natural to investigate the long-term behavior of trajectories. Unlike standard epidemiological models, however, our system does not admit an Idea-Free Equilibrium (IFE)—a state in which the population consists exclusively of Susceptible individuals. This absence is a direct consequence of the personal influence (self-motivation) terms, which ensure that each class retains a baseline level of support even in the absence of external influence. Numerical simulations across a range of parameter values indicate the existence of non-zero stable equilibria for all classes. Interpreted in the context of our model, these equilibria correspond to the steady-state distribution of political support among competing candidates. The total population is thus partitioned into distinct ideological groups, each of which maintains a persistent proportion of supporters in the long run.

For example, consider Figure 2a:

- Initial state:
 - 10% Susceptible Individuals
 - 33% Moderate Democrats
 - 26% Moderate Republicans
 - 14% Fanatical Democrats

- 17% Fanatical Republicans
- Final (equilibrium) state:
- 33% Susceptible Individuals
- 15% Moderate Democrats
- 15% Moderate Republicans
- 4% Fanatical Democrats
- 15% Fanatical Republicans

In Figure 2b, we examine a scenario where the final voting populations are symmetric, a situation often observed in democratic countries with two dominant parties. Mathematically, we describe this symmetry as $ER = ED$ and $FR = FD$, where ER and ED are the equilibrium proportions of Moderate Republicans and Democrats, and FR and FD are the proportions of Fanatical Republicans and Democrats, respectively.



Symmetric Model: Origin of Symmetric Movement:

The 2000 U.S. presidential election provides a real-world example of such a symmetric outcome. Republican candidate George W. Bush narrowly won, while the Federal Election Commission reported that the popular vote was almost evenly split: approximately 49% for Democratic candidate Al Gore and 48% for Bush [6]. This nearly even division is a phenomenon our model seeks to capture. One interpretation is that both parties influence the population in similar ways and with equal success. To mathematically represent this, we equate analogous parameters within the model. For example, in the equation for the Susceptible class:

$$\frac{dS}{dt} = -b_1SER + \dots$$

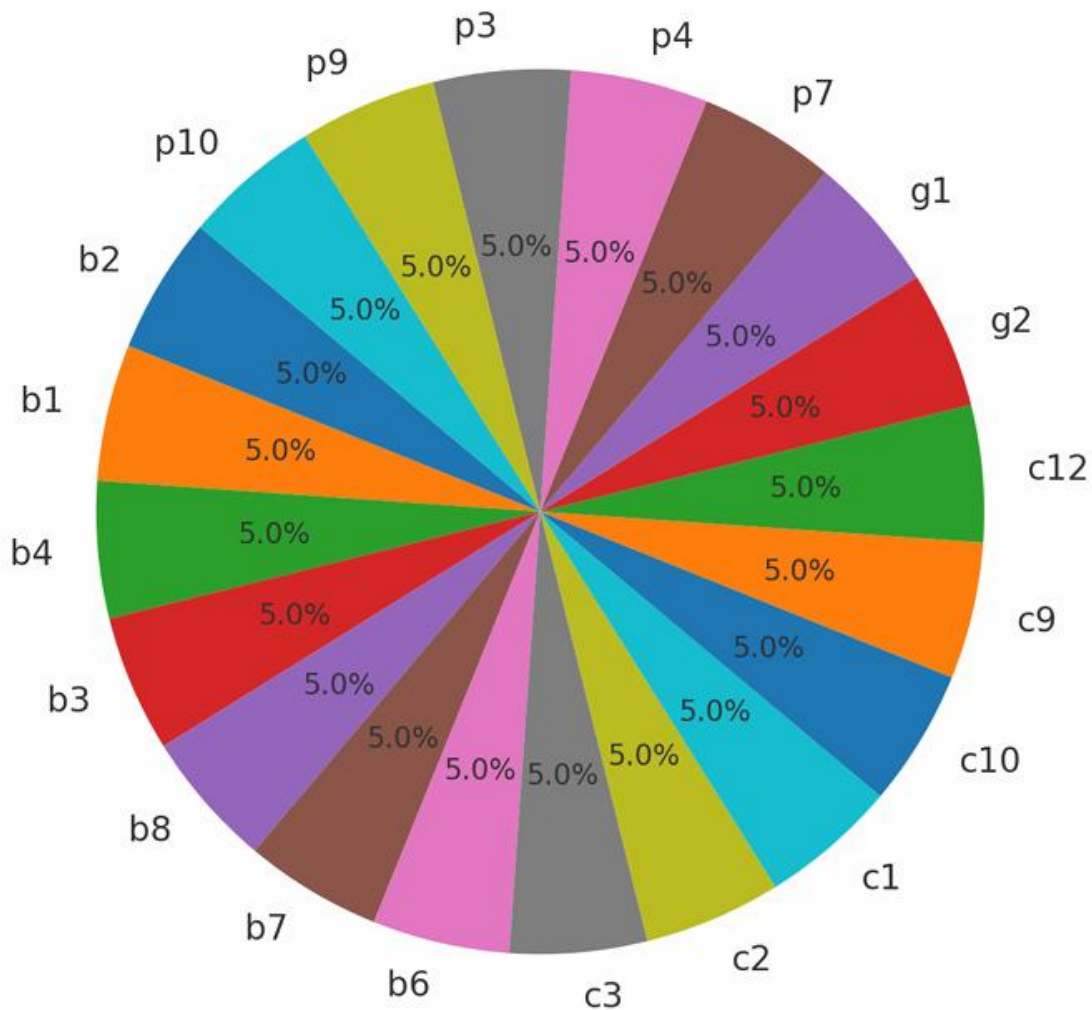
The term b_1SER represents the movement from Susceptible to ER due to interactions with Moderate Republicans. To reflect the symmetric influence from the Democratic side, we set:

$$b_1 = b_{16}$$

This approach was applied consistently across all analogous terms in the model. Following table shows how this assumption reduces the total number of independent parameters, simplifying the model while preserving its core dynamics.

Table of Reduced Parameters			
$b_{17}=b_2$	$b_{16}=b_1$	$b_{15}=b_4$	$b_{14}=b_3$
$b_{12}=b_8$	$b_{11}=b_7$	$b_{10}=b_6$	$c_7=c_3$
$c_6=c_2$	$c_5=c_1$	$d_4=c_{10}$	$d_3=c_9$
$d_1=c_{12}$	$g_4=g_2$	$g_3=g_1$	$p_8=p_7$
$p_5=p_4$	$p_6=p_3$	$p_{13}=p_9$	$p_{12}=p_{10}$

Reduced Parameters Distribution



II. Conclusions

Our analysis demonstrates that political affiliation dynamics depend strongly on the presence or absence of specific interactions and personal influences. Across multiple cases, equilibria and stability conditions varied significantly, yet a consistent finding was the outsized role of Moderates in shaping long-term political outcomes. When Moderates are persuasive, populations tend to remain engaged with the two major parties, while weak or ineffective interactions often drive disinterest. Conversely, scenarios dominated by personal conviction alone produced balanced distributions across classes rather than single-party dominance. These results suggest that effective, low-pressure engagement—especially through moderate discourse—may be more influential in sustaining party support than fanatical campaigning.

Future Work

Further research should focus on sensitivity analysis of key parameters to clarify which interactions most strongly influence stability. Our findings also suggest that disinterest in major parties is a natural equilibrium under many conditions, though the timescale is often much longer than an election cycle. Investigating parameter regimes that could accelerate disengagement within a two-month campaign window may shed light on the rare viability of third-party success in U.S. presidential elections. Numerical validation and graphical exploration of equilibria will also be crucial for connecting the model more directly to real-world voting dynamics.

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