THE INTERACTION BETWEEN HETEROGENEOUS VOTING STRATEGIES AND DYNAMIC VOTE-SEEKING CAMPAIGNS: AN AGENT-BASED MODEL

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ABSTRACT

Political candidates in a democracy articulate positions on the issues of the day, but they are also highly aware of voter sentiment on those issues, and tailor their campaigns accordingly as they seek to win elections. Voters, too, adjust their political opinions based on (among other things) interactions with others in their social network. We present an agent-based simulation that models this dynamic interplay between candidates and voters, in order to shed light on what outcomes candidates can expect to result from a policy of "chasing" votes. The voters in our simulation differ from one another in the decision procedure they use in choosing who to vote for – these voting algorithms are modeled on results from the political science literature about the different ways voters make decisions. Our model can thus be used to experiment with a virtual electorate, to determine the conditions under which vote-chasing candidates gain an advantage or perhaps even cause the election outcome to be objectively irrational.

Keywords: opinion dynamics, ABM, election, voting

1 INTRODUCTION

Many factors are known to influence voters in democratic elections, including their own background characteristics (demographics, ideology, partisanship, personality traits, *etc.*), the distinctiveness of the candidates, the availability of information, and the voter's perception of their identity.[1, pp.3-4] But another major factor – and one we would argue *should* be the most important, if citizens are casting their votes rationally – is the candidates' stances on the issues of the day. At least in principle, voters are electing the candidate who will enact policies most favorable to them if elected to office.

Voters are known to adjust their positions on issues over time, in response to influence from their peers[2, 3, 4] among other sources. They are also known to prefer interactions with those who are similar to them in some respect (the well-known effect of "homophily"[5, 6]) and prone to sever social ties with those who believe differently[7, 8].

Further, political parties and candidates are known to adjust their positions on issues in a strategic attempt to appeal to greater numbers of voters.[9] This phenomenon, termed "policy positioning"[10] or "issue adaptation"[11] means that, like voters, candidates dynamically vary their articulated political opinions over time. Neither voters nor candidates occupy a fixed position in opinion space.

This dynamic interplay between voters influencing one another and candidates seeking to gain their allegiance is worth studying, in part because the results it will produce are unknown at the outset. Will candidates who "chase" voters in this way succeed in winning more elections? Or will they alienate their base by deserting policy positions they previously held, wiping out these gains? If voters' opinions are "drifting" in

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response to one another between election cycles, will candidates be chasing a moving target and thus outfox themselves?

We purport to answer such questions with an agent-based model that reproduces this dance in opinion space between voters and candidates. Opinions on issues are represented as vectors of values in a continuous n-dimensional space (as in works like [12, 13]), and voters interact with one another on a randomly-generated social network, influencing each other on these issues. Concurrently, candidates evaluate their estimated vote totals and adjust their policy positions in an attempt to maximize them. Voters are each equipped with one of a variety of empirically-verified voting strategies, and cast their ballots according to that algorithm. With this model, we can study the effects of different voting algorithms within the electorate, and different strategic choices on the part of candidates, on election results.

2 RELATED WORK

2.1 Factors that influence voting

To model a political system, the nuanced psychological factors that influence voting decisions need to be meaningfully consolidated down to only the most significant components. It is a complex field of study; prior to even choosing a candidate, citizens must first decide whether or not they will even turn out, which entails its own distinct psychological process. To narrow the scope of our study, we assume all agents will vote, allowing us to focus on the dynamics and minds of politically active citizens.

Redlawsk and Habegger[1] consolidated the findings of political psychologists to coin several ideal-type voters that illustrate how different strategies of information processing manifest in voters' decisions. The driving mechanism that dictates how citizens make voting decisions can be described by the natural trade-off that exists between making a good decision and an easy decision. We explore the effect voters have on a political system when they sacrifice a full assessment of the information environment for a quick, uncomplicated decision.

2.2 Modeling voter opinions

In many approaches to modeling opinion dynamics, each agent's opinion comprises merely a valence and possibly a magnitude, rather than involving a more complex amalgamation of issue positions. The original binary voter model, for example, utilized only a single "issue" upon which an individual could hold a position.[14, 15]. Even in Kottonau and Paul-Wohstl's much more recent seminal work[16], citizens maintain a "mental accounting" of only a single variable over the course of an election season – namely, which of the two parties they favor. The campaigns for these parties then attempt to optimize their advertising resources to influence would-be voters at opportune times. Burke and Searle[17] followed Sobkowicz's emotion/information/opinion (E/I/O) approach[18] in making agents' mental states more complex and realistic: in addition to holding a certain opinion about a party (or candidate), an agent is, at any moment, in either a "calm" or "agitated" state, which controls how they influence and are influenced by other agents (and by campaign messaging). Here, too, the object of analysis is a single "issue" (pro party A or B), not an array of them.

Various researchers have probed the idea of voters possessing an array of issue positions (or other attributes)[19, 12, 20, 21, 22, 23, 24] but we know of few on applying these ideas specifically to elections.

2.3 Modeling the election process

One election-centric study that did employ agents with an array of opinions is the older but seminal work by Kollman *et al*[25]. This work explored similar themes to ours, but with discrete-valued opinions, no variation in voting algorithms among voters, and exactly two parties (incumbent and challenger) whose strategies encompassed an entire sequence of consecutive elections. Our multi-party model, by contrast, features a heterogeneous electorate in which different voters use different decision procedures for candidate selection. Parties have visibility into voter issue positions (an analogy to opinion polls) and can adjust their party's platform in between elections in order to woo them, but face the wild card of an unknown proportion of agents not voting rationally. The interplay between these campaign choices and the diverse ways in which voters actually choose how to vote is a novel contribution of this paper.

Other existing agent-based election models focus on the continuous dynamics of political systems in which all voters have fixed opinions and are assumed to always support the candidate closest to them in the opinion space [25, 26, 27, 28]. In his formative work, Laver[26] studies how candidates can use different issue adjustment campaign strategies to gain more support. Lehrer and Schumacher[27] build upon Laver's foundation by modeling party formations and coalition governments, and Wright and Sengupta[28] study the impact of oligarchs on a democratic model.

Recently, Gao *et al*[29] have presented a promising approach to election forecasting. They combine current demographic attributes of the population with historical results of past election outcomes in order to determine how much each attribute is likely to influence voters, and in which direction. This is very different from our model, both in purpose (actually forecasting upcoming elections, rather than exploring "what if?" voting strategy scenarios) and in approach (the agents in [29] do not influence one another on a social network.)

3 THE MODEL

3.1 Overview

An abstract **opinion space** is represented as a continuous I_N-dimensional Euclidean space, where I_N is the number of issues. An **opinion** O_i on **issue** I_i is a value in the real interval $[0,1]$, for $1 \leq i \leq I_N$.

There are two kinds of agents in the model: C_N **candidates**, and V_N **voters**. Agents of either type each have a dynamic **opinion vector** $(O_{i_1}, O_{i_2}, O_{i_3}, ..., O_{i_{I_N}})$ comprising one opinion on each issue; in other words, a point in the opinion space.

A random Erdős-Rényi graph[30] is generated with V_N nodes and uniform edge probability of p_e. We chose an Erdős-Rényi graph since it is the earliest and simplest random network generation algorithm, though it would be an interesting future work activity to compare the model's behavior with different starting networks. During each iteration of the simulation, voters interact randomly with their graph neighbors in pairwise fashion, as explained below. This often results in one of the opinions of one voter in the pair being moved either higher or lower in the interval. We term this movement of voter opinions "**drifting**."

Every E ("election interval") iterations, each candidate adjusts (within constraints) its opinion vector to the point in opinion space that would produce the maximum number of votes assuming (1) all voter agents vote rationally (*i.e.* they will vote for the candidate whose opinion vector is closest to theirs in opinion space) and (2) no other candidates' opinion vector changes. We term this movement of candidate opinions "**chasing**."

Finally, each agent is endowed with a **party** variable, indicating which party they are affiliated with at simulation's start. Voters may switch parties to reflect their new opinions as they drift, but candidates' party affiliations remain fixed.

3.2 Voter agents

At each iteration of the simulation, each agent V_i (in randomly-chosen order) has the opportunity to be influenced according to the **cross-issue influence** (CI2) algorithm[31]. To do so, it chooses one of its graph neighbors V_j at random. It also selects two of the I_N issues, I_c and I_f (with $I_c \neq I_f$) as the **comparison issue** and the **influenced issue**, respectively.

Agent V_i then compares its opinion on issue I_c (O_{i_c}) with agent V_j's opinion on that issue (O_{j_c}). If $|O_{i_c} - O_{j_c}| < T_o$, where T_o is the **openness threshold**, agent V_i considers V_j to be homophilous and therefore trustworthy. It will then move its opinion on I_f (O_{i_f}) to be the average of its current value and agent V_j's value on I_f (O_{j_f}). (For example, suppose issue 9 is chosen as the comparison issue and issue 2 is chosen as the influenced issue. Then suppose $O_{i_9} = .2, O_{j_9} = .3$, and $T_o = .15$. Since $|O_{i_9} - O_{j_9}| = .1 < .15$, O_{i_2} will be influenced midway towards O_{j_2}. So, if $O_{i_2} = .6$ and $O_{j_2} = .9$, then O_{i_2} becomes .75.)

On the other hand, if $|V_i - V_j| > T_p$, where T_p is the **pushaway threshold**, agent V_i considers V_j to be so dissimilar that its opinion on the influenced issue I_f will be repelled. In this case, agent V_i will move its opinion on I_f to be midway between its current position and that of the pole (either 0 or 1). (For example, suppose issue 4 is chosen as the comparison issue and issue 5 is chosen as the influenced issue. Then suppose $O_{i_4} = .2, O_{j_4} = .9$, and $T_p = .6$. Since $|O_{i_4} - O_{j_4}| = .7 > .6$, O_{i_5} will be pushed away from O_{j_5}. If $O_{i_5} = .4$ and $O_{j_5} = .7$, then O_{i_5} will be repelled to .2)

3.3 Parties

Party affiliations are initialized by simply assigning each agent the party whose candidate is closest to them in opinion space. Each party has a **centroid**, which is the average opinion vector of all agents affiliated with that party, and is recomputed at each step of the simulation.

As the simulation progresses, and both voters and candidates adjust their opinions, an agent may drift closer to the agents in a different party than the one they are currently assigned to. A **party switch threshold** T_s establishes a hysteresis effect: an agent's Euclidean distance to a different party's centroid must be at least T_s smaller than their distance to their current party's centroid in order for a party switch to occur. In this case, the agent is simply reassigned to the new party. This adds a sense of party loyalty to the model in which agents do not hastily switch parties. Party affiliation only affects the behavior of party-line voter agents.

3.4 Candidate agents

Immediately following every election interval, E, each **chasing candidate** adjusts their opinions such that they would receive the maximum number of votes possible if all agents were to vote rationally at that time. Chasing candidates' information environments are restricted to the opinions of voters one election previous to the current one. They do not know how agents will actually vote, nor do they know how agents' opinions have changed during the most recent election interval. To ensure candidates are not abandoning their party ideologically, their movement is constrained within a "**chase radius**" of R_C. Candidates may not move more than R_C away from their party's centroid in Euclidean distance. **Non-chasing candidates** never adjust their opinions to chase votes.

3.5 Elections

To study the political impact of the CI2 mechanism and further explore issue-based campaigning and voting, we introduce elections to the model. Elections are held every $E = 50$ iterations and results are tabulated to determine both the winner and the rationality of the outcome. An election outcome is considered **rational** if the winning candidate is the candidate that best represents the population in opinion space. Put another way, an election outcome is rational if the candidate who actually wins is the same candidate who *would* have won if all agents had been using the rational voting algorithm (see section 3.5.1, below). This is in line with how Redlawsk and Habegger describe an individual "**voting correctly**, or matching their values to the candidate who represents them most accurately,"[1, p.8] (emphasis original) except that we look at the outcome of the entire election instead of just a single voter.

3.5.1 Voting algorithms

Each voter agent is assigned one of several voting algorithms at initialization, which model the discrepancies in the thinking patterns and decision-making strategies of real voters. At election time, a voter uses this algorithm to cast their ballot for a candidate. Derived from the literature on voter psychology[1, ch.2], our four voting algorithms are as follows: **rational**, **party-line**, **fast & frugal #1** (F&F1), and **fast & frugal #2** (F&F2). The simulation makes it possible to adjust what proportion of the electorate's voters will be assigned each of the four algorithms, enabling the "**voting algorithm distribution**" to be treated as an independent variable.

Rational agents simply vote for the candidate they are closest to in Euclidean opinion space. They are an ideal-type voter, representing someone with perfect information and the ability to maximize utility.

Party-line agents vote for the candidate that belongs to the party they themselves are affiliated with. Thus they vote in a manner that simply reaffirms their identity as a party member, ignoring candidates' specific positions on issues.

F&F1 agents are each randomly assigned one "core issue" at initialization. This remains their core issue through the entire simulation, and solely determines how they vote: instead of choosing the candidate closest in I_N-dimensional opinion space, as rational voters do, F&F1 voters simply choose the candidate closest to them on their core issue.

F&F2 agents similarly vote based on a single issue, but it is a "hot topic" issue that all F&F2 agents share, and which changes randomly with each election cycle. Thus in contrast to F&F1, all F&F2 voters use the same issue to make their decision.

Both kinds of F&F agents represent voters who make a calculated trade-off between a good decision and an easy decision. They do not consider all information, only that which is most important to them, and cast their votes based on that limited information, seeing as it is "good enough" (or "satisficing"[32]).

4 EXPERIMENTATION

4.1 Verification

To confirm the model's basic operations, we ran it interactively with a wide variety of values for every parameter. We verified, among other things, that the CI2 mechanism does asymptote towards a fixed point as expected. Figure 1 (left) depicts the average amount that each agent's opinion was either "pushed" (or "pulled") towards an agent similar enough (or dissimilar enough) on the comparison issue. These drift distances decay over the course of about four hundred iterations until an equilibrium is reached. Empirically, we discovered that an **openness** parameter value of **.1**, and a **pushaway** of **.6**, worked well for leading the CI2 mechanism to an eventual equilibrium.

Similarly, as expected, the distances in opinion space that candidates traversed in "chasing" voters also trend downward to zero. After reaping the nearby "low-hanging fruit" (voters not locked in by any other

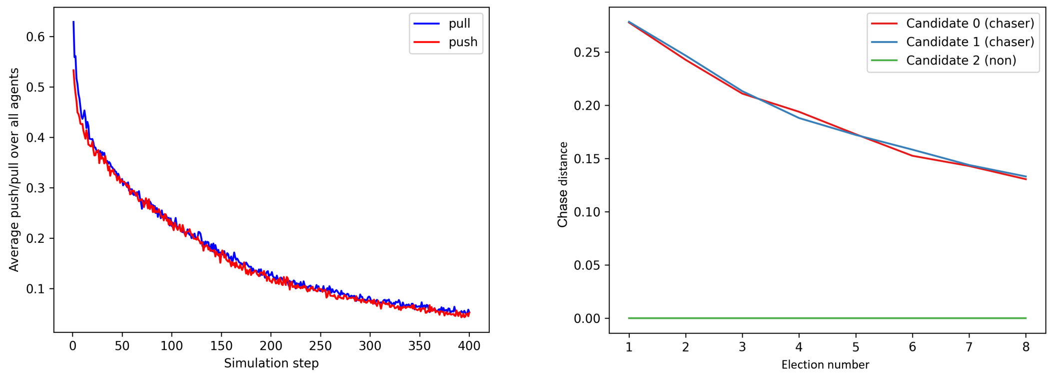

Figure 1: Both voters' drift movements (due to the CI2 mechanism approaching steady state) and candidates' chase movements (due to all candidates reaching local maxima in state space) asymptote to zero.

candidate and thus prime for poaching), candidates face diminishing returns when chasing any further would jeopardize their existing voters. See Figure 1 (right) for an illustration with two chasing candidates and one non-chasing candidate. Note that the voters approach zero mean drift distance more quickly than the candidates approach zero mean chase distance. This is to be expected since candidates are (1) only chasing each election (every E iterations) instead of every iteration, (2) self-imposing a limit (the chase radius) on how aggressively they will pursue voters, and (3) reacting to changes in voter opinions only after voters have made them.

4.2 Independent variables

The important independent variables we focus on in this paper center around the action choices of the two kinds of agents. Candidates can be either chasers or non-chasers, and can alter how far they are willing to move in opinion space in the pursuit of additional voters. Voters adopt different voting algorithms, and thus the electorate can be divided up into groups of varying sizes: for example, all rational; half rational and half party; half party and one-fourth of each of the two Fast and Frugal variants; and so on.

4.3 Dependent variables

The main dependent variables we examine are the rationality of election outcomes (how often the winner is the same candidate who would have been elected if all voters had voted rationally) and, in the case of heterogeneous candidates (some chasers and some non-chasers, and/or chasers with different chase radii) how often they win elections at different stages of the simulation.

5 RESULTS

5.1 Parameter settings

In all of the following results, we use a suite size of 1200 (that is, 1200 independent simulations with different random number seeds for *each* combination of distinct independent variable values) and run each simulation for 400 iterations. We set $V_N = 20$ voters, $C_N = 3$ candidates, $I_N = 3$ issues, $p_e = .2$ edge probability, and $E = 50$ for eight consecutive elections in the 400 iteration time period.

5.2 Multiple chasers impede one another

Using the default voting algorithm distribution ($\frac{1}{3}$ rational, $\frac{1}{3}$ party, $\frac{1}{6}$ F&F1, $\frac{1}{6}$ F&F2) When only one of three candidates is chasing votes, it reaches its "sweet spot" early on, and quickly encounters diminishing returns to further chasing. When two candidates are chasing, they fail to reach this "sweet spot" after 8 election cycles and continue chasing votes. (See Figure 2.) We speculate that this is because the chasers are interfering with one another as they court voters in opinion space, dampening the gains of their rival by moving into regions that might have been unspoken for.

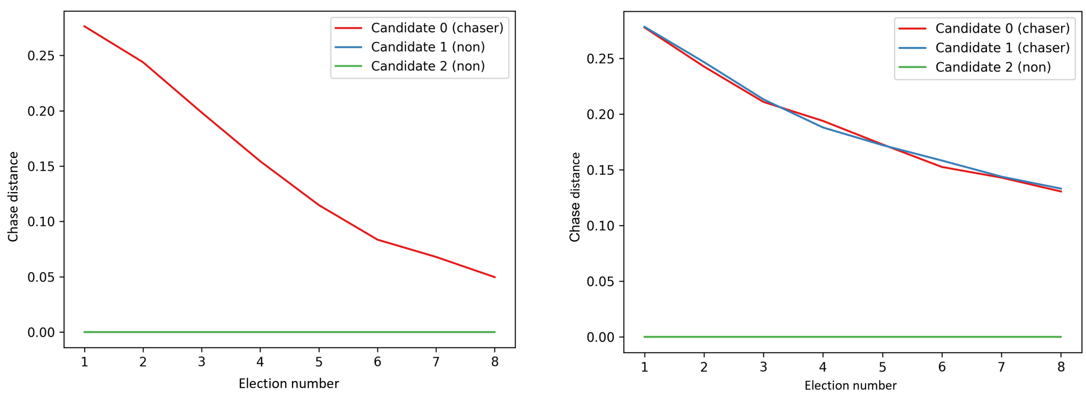

Figure 2: A single chasing candidate maxes out its gains more quickly than two competing chasers do.

5.3 Multiple chasers reduce one another's gains

The above effect can be further illustrated by looking at how many elections are actually won by chasing vs. non-chasing candidates. Figure 3 shows the proportion of elections won by each candidate in a three-candidate race with one chaser (left side) and with two (right side). (Error bars are 95% confidence intervals for a proportion, assuming normality.) As you can see, when only one candidate chases voters, it has a tremendous advantage over the other candidates, and this advantage increases the longer that the drifting/chasing mechanism continues. Two chasers, however, interfere with one another such that each gets only a modest benefit.

5.4 The chase radius

Recall that the chase radius sets a limit on how far candidates can wander in opinion space every time they chase voters. Interestingly, the value of this parameter has little effect on election outcomes. Figure 4 shows winner outcomes in two-chaser elections for three different values of the chase radius (the same value is shared by both chasing candidates): 0.1, 0.2, and 0.3.

More interesting is when we make one chaser more aggressive than the other (*i.e.* more willing to take risky positions, and perhaps to abandon their base and traditional platform). Figure 5 shows the chase distances and election win totals for two chasing candidates with different chase radii: candidate 0's (red) is .1, and candidate 1's (blue) is .2. As can be seen, at first candidate 1 makes much larger leaps in opinion space in an effort to appeal to voters, but after six or seven election cycles approaches candidate 0's distances. In the right half of the figure, we see that the more aggressively-chasing candidate now ekes out election victories its rival in all elections but the first, even with candidate 0 being awarded ties.

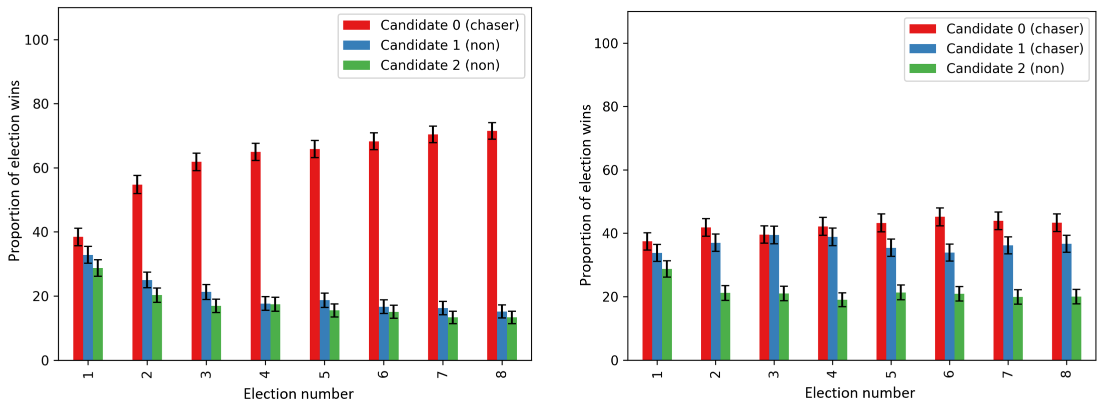

Figure 3: Using the default voting algorithm distribution, a single chasing candidate (red) has an enormous advantage over its competitors. If two candidates (both red and blue) are chasing voters, however, neither gains nearly as much benefit. (Note: the small advantages that red consistently has over blue are an artifact of how the simulation handles ties – it awards victory to the lowest-numbered tied candidate. This is miniscule in comparison with the main effect illustrated here, however.)

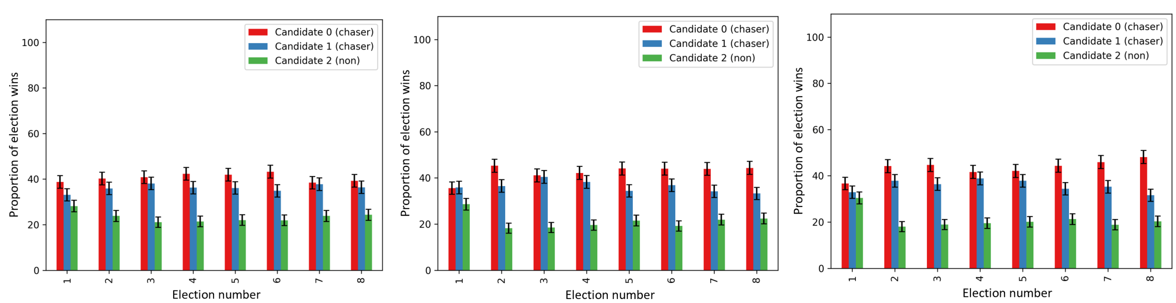

Figure 4: Election winners when two chasers' chase radii are varied from .1 to .2 to .3. The outcomes show negligible difference.

5.5 The impact of voting algorithm distribution

All of the above results were obtained with the default voting algorithm distribution ($\frac{1}{3}$ rational, $\frac{1}{3}$ party, $\frac{1}{6}$ F&F1, $\frac{1}{6}$ F&F2) and it turns out they are highly sensitive to it. In an electorate with *no* rational voters, by contrast, chasers get little to no benefit. They are trying to appeal to the issue positions of voters who will not in fact be voting based on those positions. Chasing candidates have no advantage even if there are many, or even all, F&F voters. This is somewhat surprising since F&F voters do "noisily" vote based on their issue positions (they consider only one of them, instead of all three). Compare Figure 6 (the left side has all party-line voters, the right side has all F&F voters) with the left side of Figure 3 (which has the default voting algorithm distribution) to see the difference.

At the other extreme, an electorate of all rational voters gives the maximum benefit to chasing candidates (see Figure 7). In this scenario, even when two candidates are chasers, they do not interfere with one another enough to nullify their effects – both easily eclipse the single non-chasing candidate (Figure 7, right side.)

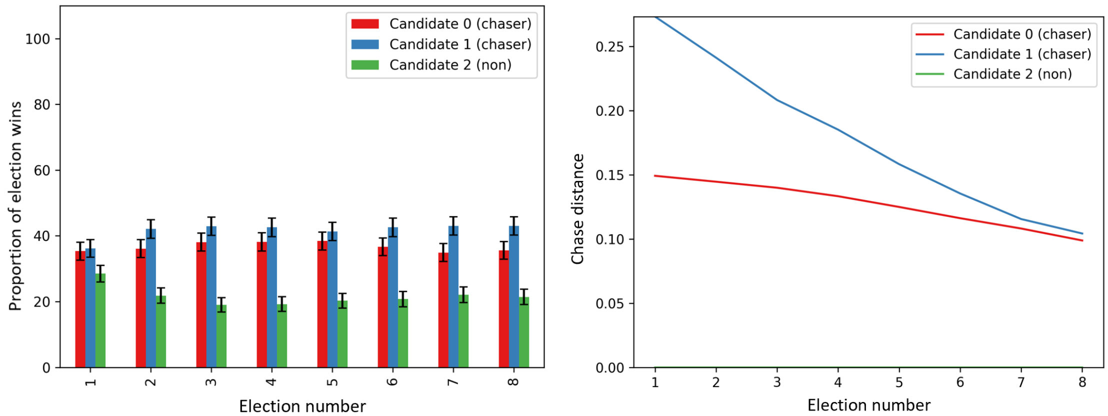

Figure 5: Total chase distances, and election outcomes, for two chasing candidates with different chase radii (candidate 0: radius 0.1; candidate 1: radius 0.2) plus a non-chasing candidate.

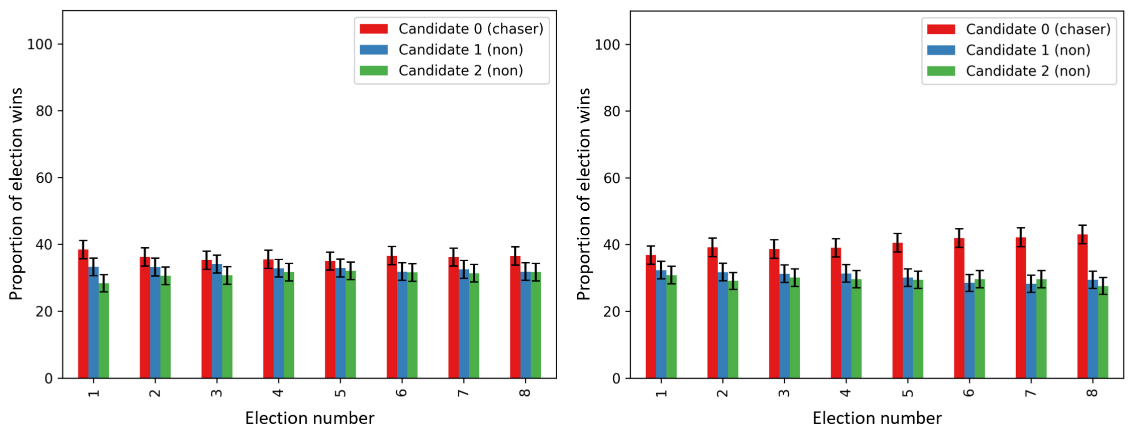

Figure 6: When the electorate is changed to have all party-line voters (left) or all fast & frugal voters (right), chasing candidates have little appreciable advantage.

5.6 The rationality of election outcomes

Now, using an electorate of all party-line voters, we can measure the impact of blind party voters on the rationality of election outcomes. Recall that an election is considered rational if the candidate who actually wins is the same candidate who would have won if all agents had voted rationally.

Based on the fact that party affiliations are in line with voters' and candidates' opinions, we would expect party-based electorates to produce frequent rational outcomes. However, voters' "stubbornness" in remaining with their current parties, as modeled modestly by the party switch threshold ($T_s = 0.2$), becomes surprisingly detrimental to the rationality of elections. Voters only adopt a new party if their opinions are within a T_s radius of the new party's centroid. Figure 8 (left) shows that when no candidates are chasing votes and all agents are party-line voters, only 60% of election outcomes are rational.

When candidates are chasing party-line voters, not only does it fail to provide an advantage (as determined above), but it actually decreases the rationality of elections, as shown in Figure 8 with one chaser (middle) and three chasers (left). These plots show the proportion of elections with rational outcomes from a suite of 1200 independent simulation iterations.

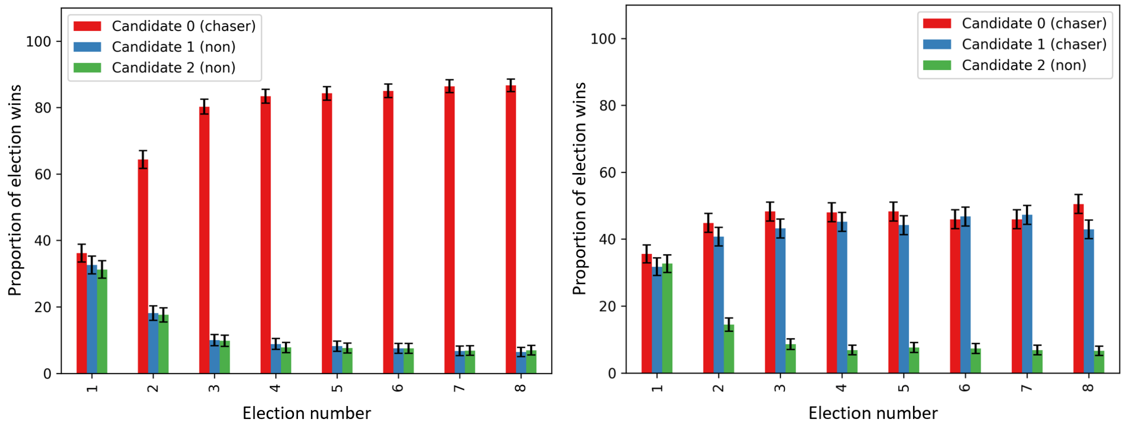

Figure 7: An electorate of all rational voters confers maximum benefit to chasing. Even when there are two chasers (right side) they each receive an advantage.

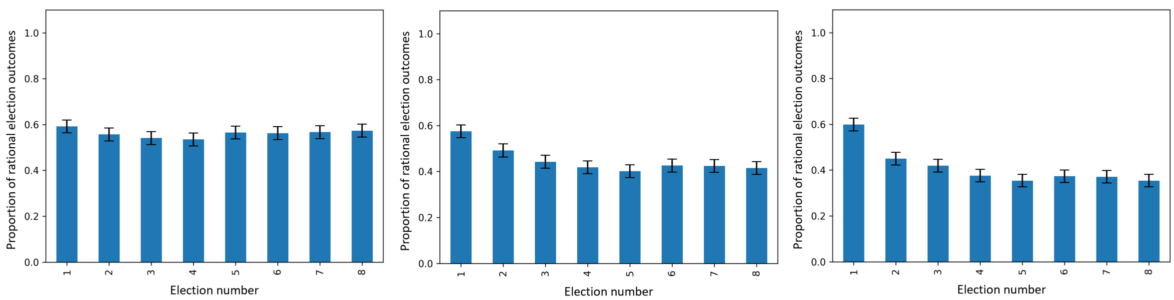

Figure 8: The percentage of rational election outcomes remains constant over time when there are no chasers (left). When there is one chaser (middle) or three chasers (right), the rationality of elections decreases over time. The more chasers there are, the more the rationality decreases.

6 DISCUSSION

In our model, both the rationality of elections and the efficacy of candidate chasing depend crucially on the makeup of the electorate. Chasing votes through opinion adjustment proves to be an extremely beneficial campaigning strategy when the electorate is comprised of rational voters. In this environment, any number of chasers stand to gain a significant number of votes by chasing, proving this algorithm is effective in an ideal system.

We find that a balanced distribution of rational, party-line, and fast & frugal voters in the model is conducive to benefiting one chasing candidate. If two candidates are chasing votes, we observe a much more modest advantage. As we see with real political campaigns, adopting centrist-leaning opinions to appeal to the masses is a sound strategy. However, our model shows this strategy has a diminishing return on investment as two candidates fight over the same voters who aren't guaranteed to vote rationally, providing an unexpected advantage to a third candidate who has a solidified voter base.

We predicted a modest increase in the model's rationality over time when initialized with all party-line or fast & frugal voters and all chasing candidates. It seemed probable that party-line and fast & frugal voters would vote for the rational candidate more often upon being "chased". However, the voters and candidates end up engaging in a blind dance of sorts, where neither candidates nor voters know what is best for them. We in fact observe a decrease in the rationality of elections over time under these conditions. The blind dance becomes a race to the bottom in which candidates are fruitlessly chasing votes and voters are unknowingly electing candidates that don't represent their beliefs. This effect is a bit more modest with fast & frugal voters than it is with party-line, but the trend remains in any voter distribution that is not rational.

These results may offer an explanation as to why real campaigns rely on strategies like emotional messaging and playing up hot topic issues. Despite the fact that matching voters where they are opinion-wise is an optimal strategy to *represent* the greatest number of voters, the real electorate is not rational. Oftentimes, they will not elect the candidate that most closely represents their beliefs. Rather, they will make the easy, and "good enough" decision by single-issue voting or party voting. The model shows that while chasing is an exceptional strategy for a rational, or even partially rational electorate, there comes a point where if enough voters are making trade-offs for a quick decision, chasing only serves to make matters worse.

7 FUTURE WORK

One future point of exploration is testing the sensitivity of the model to network variance. We used an Erdős-Rényi graph, but would like to test our model with different networks and edge probabilities.

Our next major step is to fit the model to empirical data by calibrating the initial conditions and validating the outcomes with polling data. This would allow us to model the effectiveness of vote-seeking campaigns in a real democratic system, and arguably more importantly, identify feasible strategies to increase the rationality of elections.

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