GRAZSCHUMPETERCENTRE

GSC Discussion Paper Series

Paper No. 32

Simulating Party Competition in Dynamic Voter Distributions

Leonie Geyer[1] and Patrick Mellacher[2]

[1] Zeppelin University Friedrichshafen,
Am Seemoser Horn, 88045 Friedrichshafen
[2] University of Graz, Graz Schumpeter Centre,
Universitätsstraße 15/FE, A-8010 Graz

Abstract

We study strategic party interaction in a spatial voting model where voters' ideological positions may change. Building on a rich empirical and theoretical literature, we assume that voters align their ideology with others who are sufficiently close to them (social influence with bounded confidence) as well as with the party that they support (party attraction). We show that these changes have strong implications on the results of the party competition model by Laver (2005). Two strategies stand out in our simulations: Aggregators, who always follow the mean policy of their supporters, and predators, who always chase the strongest party. Aggregators are most likely to win in a large corridor of the parameter space. However, predators can outperform them if party attraction is strong. This is interesting because predators are on average the worst-performing parties in the static voter distribution benchmark. We argue that these results are connected to real-world debates about how mainstream parties should react to the rise of extremist parties, as the two strategies epitomize debates about focusing on own strengths and supporters (aggregators) vs. adapting towards successful extremists (predators). We also demonstrate that the level of polarization and fragmentation of parties and voters is strongly affected by social influence and party attraction. While medium-sized confidence bounds and party attraction increase the polarization of voters and parties, unconstrained social influence decreases it.

Keywords: Spatial voting model, opinion dynamics, agent-based model

JEL-Codes: C63, D71, D72

Simulating Party Competition in Dynamic Voter Distributions

Leonie Geyer[1] and Patrick Mellacher[2]

[1]Zeppelin University Friedrichshafen, leonie.geyer@zu.de
[2]University of Graz, Graz Schumpeter Centre, patrick.mellacher@uni-graz.at

November 20, 2024

Abstract

We study strategic party interaction in a spatial voting model where voters' ideological positions may change. Building on a rich empirical and theoretical literature, we assume that voters align their ideology with others who are sufficiently close to them (social influence with bounded confidence) as well as with the party that they support (party attraction). We show that these changes have strong implications on the results of the party competition model by Laver (2005). Two strategies stand out in our simulations: Aggregators, who always follow the mean policy of their supporters, and predators, who always chase the strongest party. Aggregators are most likely to win in a large corridor of the parameter space. However, predators can outperform them if party attraction is strong. This is interesting because predators are on average the worst-performing parties in the static voter distribution benchmark. We argue that these results are connected to real-world debates about how mainstream parties should react to the rise of extremist parties, as the two strategies epitomize debates about focusing on own strengths and supporters (aggregators) vs. adapting towards successful extremists (predators). We also demonstrate that the level of polarization and fragmentation of parties and voters is strongly affected by social influence and party attraction. While medium-sized confidence bounds and party attraction increase the polarization of voters and parties, unconstrained social influence decreases it.

Keywords: Spatial voting model, opinion dynamics, agent-based model

1 Introduction

How should political parties position themselves in order to win elections? Spatial voting models have long been used to study this question (e.g., Hotelling, 1929; Downs, 1957a; Cox, 1987; Adams et al., 2005; Laver, 2005). While most scholars using these models agree that the ideological distribution of voters changes over time in the real world (see, e.g., Downs, 1957b, p. 140) and it would be highly important to study the implications of this fact (e.g., Laver, 2005, p. 280), almost all of them focus on static voter distribution in their modeling efforts.

We address this gap by focusing on two key sources of political change which are both empirically well-supported: i) social influence, which causes voters do adapt their policy positions in response to other voters' opinions (see, e.g., Brandts et al., 2015; Druckman et al., 2018), and ii) party attraction, which promotes a party's position among its supporters (see, e.g., Markus and Converse, 1979; Sanders et al., 2008; Brader and Tucker, 2012; Druckman et al., 2013; Bechtel et al., 2015; Grewenig et al., 2020). Both sources seem to be even more important nowadays than in the days of, e.g., Downs (1957a), since social media allows information to be transmitted very quickly between voters and from parties or candidates to voters. For example, Donald Trump, who centered his presidential campaign in 2016 around Twitter (Francia, 2018), excessively uses the platform to spread his views among potential voters.[1] His supporters

---

[1] His account was suspended in the aftermath of the attack on the US capitol in January 2022, but later reinstated by the new owner Elon Musk. As of the writing of this article in October 2024, he has returned to the platform, which now operates under the name X.

then "retweet" his messages, thus multiplying their impact (this is why social influence is also known as "social multiplyer" Glaeser et al., 2003).

A further indication that voter landscapes are not exogenous to political parties is given by the co-evolution of elite and mass polarization in the US. While Fiorina and Abrams (2008) conclude that elite polarization in the US has been on the rise for decades, i.e., representatives of Republicans and Democrats have moved further apart, there had been little evidence of mass polarization as of 2008. However, a survey experiment by Druckman et al. (2013) shows that elite polarization has the potential to trigger mass polarization. Indeed, Enders (2021) observes that this tendency has since materialized on an aggregate-level by showing a shrinking difference between elite and mass polarization, with the masses "catching up" to the elites. This general trend is quite possibly entangled with and amplified by the rise in social media. On a micro-level, Druckman et al. (2018) show experimentally that the effects of partisan media consumption can spread in subsequent group discussions, an effect which is known as "social influence" (Brandts et al., 2015) or "social multiplier" (Glaeser et al., 2003).

While both social influence and party attraction seem to be highly important empirically, they have so far only been studied separately by a few papers (Gerber and Jackson, 1993; Jackson, 2003; Ward, 2006; Sadiraj et al., 2006).

Our framework combines two very well-known models. The first is by Laver (2005), who investigate the strategic competition between parties that follow boundedly rational rules. This model features four different party types that follow simple heuristics: i) stickers stay at their initial position, ii) aggregators follow the mean position of their current supporters, iii) predators chase the strongest party and iv) hunters move in a random direction and continue in that direction if the move proves beneficial. If not, they change course and try a different random direction. This framework is particularly promising for our research question, as heuristics have proven to be to be effective tools to navigate complex systems in other disciplines, making the model an ideal starting point of our analysis (see, e.g., Dosi et al., 2020).

The second model that we draw on is the opinion dynamics model with bounded confidence (Hegselmann and Krause, 2002). In this model, agents are influenced by other agents, but only if they are significantly close to each other (as measured by the confidence bound). Depending on the confidence bound, the model produces either fragmentation, polarization or consensus in the resulting distribution of opinions.

In studying our model, we focus on two questions: First, which party strategies are successful in dynamic voter distributions? Second, how does the interaction between the competition of parties and opinion dynamics shape the resulting distribution of voters and parties within the policy space? We show that this combination proves to be highly fruitful by providing new insights and qualifications to both original models. We show that the "hunter" strategy, which has proven to be highly successful in static voter distributions (see Laver, 2005) performs much worse in dynamic environments in our baseline specification. However, their performance increases if we assume that opinion dynamics are a noisy process (in contrast to Hegselmann and Krause, 2002). Stickers gain from party attraction, but lose from social influence. However, the most successful parties in dynamic environments that we studied are aggregators and predators. Incidentally, these two strategies epitomize the potential responses of mainstream parties to the recent successes of radical parties in Europe: While aggregators focus on their own supporters, predators adapt their policy towards the most successful party. In most of our simulations, the aggregator strategy outperformed all other strategies. However, predators were able to outperform aggregators in a subset of simulations where party attraction is very high relative to social influence. This result is not robust to the introduction of noise, in which case aggregators perform best in nearly all specifications. Hence, our model suggests a nuanced view, as the success of strategies depends on the model parameters, and in particular the relative strength of social influence vs. party attraction.

However, our model also refines the results of opinion dynamics with bounded confidence: We show that party attraction creates polarization and fragmentation in situations where a model purely based on social influence (such as the original model by Hegselmann and Krause, 2002) would lead to consensus. Hence, we show in our paper that social influence and party attraction do not only affect the success of parties, but also the ideological distribution of voters (and parties).

The rest of this paper is organized in the following way: We provide a brief overview of the literature on spatial voting models and opinion dynamics in section 2. Section 3 describes the model and 4 presents the results of our simulations. Finally, we discuss our findings in section 5 and conclude in section 6.

2 Background

The first in the long tradition of spatial models is Hotelling's (1929) model of competition. In this model, initially framed as an economic one, suppliers want to position themselves within a space to maximize their market share. Consumers have a fixed position within this space and prefer suppliers who are located close to them. His famous takeaway is that two competitors would place themselves at the center of the distribution of consumers, creating a socially suboptimal outcome in which consumers do not really have a meaningful choice. He also mentions the competition between Democrats and Republicans as one example of the significance of his work. Building on Hotelling's work, Downs (1957b; 1957a) focuses exclusively on the political competition between office-seeking political parties and candidates who endeavor to position themselves in an ideology space such that they maximize their vote share. He expounds in detail the conditions under which the median voter result holds (and under which it does not hold). While Downs acknowledges that parties will try to pull voters toward their ideologies, he argues that analyzing dynamic voter distributions would be "vast beyond our scope" (Downs, 1957a, p.140). Many other studies follow the tradition of fully rational and perfectly informed parties (or candidates) in a static voter distribution that aim to maximize a utility function that may, e.g., incorporate different target functions (see, e.g., Hinich and Ordeshook, 1970, for a discussion of vote-share maximizing versus plurality-maximizing parties) or ideological ambitions (see, e.g., Osborne and Slivinski, 1996; Duggan and Fey, 2005, for policy-motivated candidates). Furthermore, the (non-)existence of multiparty equilibria in such models has attracted significant scholarly attention (Cox, 1987; Feddersen et al., 1990; Osborne, 1993, 1995).

Some authors have since moved beyond static voter distributions. Most assume that party policy influences voters' policy preferences (Gerber and Jackson, 1993; Jackson, 2003; Ward, 2006). We call this effect "party attraction" and incorporate it into our model. The view that voter preferences are shaped by "their" party has a long tradition in political science and has been supported by the empirical literature using, e.g., panel survey data (Markus and Converse, 1979) and more recently in experimental settings (Sanders et al., 2008; Brader and Tucker, 2012; Druckman et al., 2013; Bechtel et al., 2015; Grewenig et al., 2020) as well as in natural experiments (Slothuus, 2010; Mellacher, 2023).

On the other hand, there is only one paper that we are aware of endogenizing voter preferences by letting voters influence other voters: The model by Sadiraj et al. (2006) assumes that voters want to hold the same views of a certain share of others, leading to a clustering of the population over time. However, in their model, the distribution of voter ideology is not influenced by the platform pursued by the political parties.

Another tradition in the literature on spatial voting models considers parties that follow different simple behavioral rules to compete against each other (Kollman et al., 1992, 1998; Marchi, 1999; Laver and Schilperoord, 2007; Laver and Sergenti, 2012; Laver, 2011; Lehrer and Schumacher, 2018; Fowler and Laver, 2008), but operate in a static distribution of voters. We build on this tradition by replicating the model by Laver (2005) and combining it with a different, albeit equally rich strand of the literature, namely opinion dynamics (French Jr., 1956; Hegselmann and Krause, 2002, 2015; Deffuant et al., 2000, 2002).

The basic idea of opinion dynamics models is that people exchange their views and take the opinions of others into account, hence usually "meeting in the middle". The idea that people's decisions and preferences are shaped by others is widely supported empirically (see, e.g., Glaeser et al., 2003; Maurin and Moschion, 2009; Bond et al., 2012; Muchnik et al., 2013; Ma et al., 2015) and more recent studies have shown that these models can be calibrated to fit empirical patterns quite well (Gestefeld and Lorenz, 2023; Lackner et al., 2024). Hegselmann and Krause (2002) famously introduced bounded confidence into opinion dynamics models, meaning that people would only listen to others who are sufficiently close to them.[2] Depending on the confidence bound, their model produces a fragmented society (for very low confidence bounds), a polarized one (for intermediate confidence bounds) or a consensus (for relatively large ones). Scheller (2019) uses a modified version of this model to study the strategic use of fear appeals by political parties. We describe our model in the next section 3.

---

[2] Independently of Hegselmann and Krause (2002), Deffuant et al. (2000) also developed a model of continuous opinion dynamics under bounded confidence. In the model by Hegselmann and Krause (2002) agents move toward the average of their contacts' opinions (many-to-one communication). By contrast, in Deffuant et al. (2000) two agents are selected, one of which influences the other (one-to-one communication).

3 Model

3.1 Overview

The aim of our model is to serve as a computational laboratory for studying the interplay between opinion dynamics and strategic party competition with boundedly rational actors in the tradition of Laver (2005) and Hegselmann and Krause (2002). Like in these papers, we develop an agent-based model (ABM), i.e., a model that features heterogeneous interacting agents (Delli Gatti et al., 2005; Dosi et al., 2020). In ABMs, agents typically follow simple behavioral rules that often create macro-level outcomes that are difficult to predict from simply looking at the micro-rules, as the interaction between agents can give rise to complex, potentially non-linear dynamics.

Our model is populated by two types of agents who are located on a continuous two-dimensional ideology landscape: voters and parties. The numbers of voters n_v and parties n_p stay constant over time. However, parties and voters may change their ideology following boundedly rational rules which are based on established scientific literature.

The model contains various stochastic processes and is hence not deterministic. To rigorously explore the behavior of our model, we thus follow a dual strategy. On the one hand, we use single illustrative simulation runs to showcase how voters and parties behave in various parameter configurations. On the other hand, in line with the literature on agent-based modelling (see, e.g., Dosi et al., 2010), we use a large number of simulations over an ensemble of parameter configurations to understand under which conditions our model produces, on average, which outcomes. The model is available as an open source NetLogo implementation.[3]

In the initialization period $t = 0$, the simulation code creates two types of agents: n_v voters and n_p parties which are located on a two-dimensional ideology landscape which is bounded by $x_{min} = -0.5$, $x_{max} = +0.5$, $y_{min} = -0.5$ and $y_{max} = +0.5$. Agents' initial positions on this landscape are given by $x_{i,t=0}$ and $y_{i,t=0}$, both of which are drawn from a uniform distribution $U \sim (-0.5, 0.5)$ for each agent.

The model then runs for n_t periods. In each of these periods, the following sequence of events is computed:

1. Voters decide for which party they want to vote based on ideological congruence.
2. Voters adapt their ideology based on social influence and party attraction (described in section 3.2).
3. Parties may change their ideology following their strategy (see section 3.3).
4. Aggregate statistics are computed.

3.2 Voters

We follow the long tradition of proximity-based spatial voting models (see, e.g., Hotelling, 1929; Downs, 1957a; Laver, 2005). These models assume that people cast their vote for the ideologically closest party. In our case, ideological proximity is measured by the Euclidean distance between the voter and the party ideology, putting equal weight on both ideology axes.

In contrast to the established literature, however, agents in our model may change their ideology over time by reacting to other voters (social influence), as well as the platform pursued by the party which they currently support (party attraction), following ample empirical evidence mentioned in the second section of this paper.

Following Hegselmann and Krause (2002), we model social influence as a process in which agents adapt their opinion towards the mean opinion held by those other agents whose ideologies are not "too far away" from the own ideology. Hegselmann and Krause (2002) call this "bounded confidence". Voters also adapt their ideology towards the ideology of the political party that they support.

Formally, voter i adapts her ideology according to eq. 1, where $x_{i,t}$ and $y_{i,t}$ characterize the two-dimensional ideology of the agent after accounting for opinion dynamics, α is a parameter between 0 and 1 that governs how much voters are influenced by other voters, β a parameter between 0 and 1 which determines the strength of party attraction, $x_{i,t-1}$ and $y_{i,t-1}$ are the ideology of voter i in the

---

[3] Available on github at https://github.com/patrickmellacher/dynamicpartycompetition.

previous period, $x^{party}_{i,t}$ and $y^{party}_{i,t}$ characterize the ideology of the party (before parties change their ideology) that the voter currently supports, $\bar{x}_{i,t-1}$ and $\bar{x}_{i,t-1}$ is the average ideological position on the respective axis of all other voters who are within the confidence bound ϵ of the agent. In line with the literature (Hegselmann and Krause, 2002), the confidence bound is assumed to be between 0 and 1. An agent is considered to be within the confidence bound of another agent if the confidence bound is larger than (or equal to) the Euclidean distance between the two agents divided by the square root of 2. This configuration ensures that all voters are influenced by all other voters if $\epsilon = 1$.

$$\begin{aligned} x_{i,t} &= (1-\alpha-\beta)x_{i,t-1} + \alpha\bar{x}_{i,t} + \beta x^{party}_{i,t-1} \\ y_{i,t} &= (1-\alpha-\beta)y_{i,t-1} + \alpha\bar{y}_{i,t} + \beta y^{party}_{i,t-1} \end{aligned} \tag{1}$$

This equation describes opinion dynamics without noise, as in Hegselmann and Krause (2002). In an extension proposed in section 4.6, we introduce a noise term to account for all other influences on opnion and discuss its implications on our results.

3.3 Parties

Each party belongs to one of four types introduced by Laver (2005). Each party's type is fixed and governs the behavior of the party in the following way:

- **Sticker**: Parties that follow the sticker strategy remain steady in their ideological positions regardless of changing political circumstances. They do not move during the simulation. We could understand these parties to be highly idealistic (or policy-oriented), as they do not want to compromise with regard to their policy stance in order to become more "electable".
- **Aggregator**: Aggregators determine the mean coordinate on each dimension of the current party supporters' ideal points and adopt this position. We could think of this party type as one where the supporters democratically decide on the stance of their party, hence representing the interests of the current voters of the party in the best possible way. A different interpretation of their behavior is that aggregators aim to defend their voter base against their competitors and hence set up a position where they are well-equipped against attacks from any side. However, please note that an aggregator which is attacked, e.g., from the right (i.e., a competitor moves towards the aggregator from the right and picks up the right-most voters of the aggregator) will react by moving to the *left*. This is because the remaining supporters of the party will be more left-wing than in the previous period. If we consider policy-motivation vs. office-motivation as a continuum, the aggregators are hence arguably less policy-motivated than stickers, but more policy-motivated than predators and hunters, taking up an intermediate position.
- **Predator**: Predators incrementally change their ideology by a step size of at maximum γ towards the strongest party.[4] If they are the strongest party or are at the same position as the strongest party, they do not move. We could think of these parties as office-motivated or opportunistic - they want to adapt towards the policy stance that seems to be most successful.
- **Hunter**: Hunters randomly move incrementally by γ in a given direction. If that move has resulted in an increase in the number of their voters, they continue to move in the same direction as in the previous round. If not, the hunter will randomly move in a different direction. Parties that exhibit such a behavior are likely office-motivated, vote-seeking parties that do not possess strong ideological convictions.

4 Results

As in most simulation models, the choice of parameters crucially affects the model dynamics. In order to rigorously explore voter and party dynamics, we studied the model dynamics over a wide range of

---

[4] In the original model by Laver (2005), predators who are not the strongest party would always move, even if that would cause them to overshoot. This created an unrealistic behavior already documented and called "pathological" by (Laver and Sergenti, 2012, p.134), where predators would first converge towards the ideal point and then continuously overshoot, leaving a single predator as the winner.

the parameter space. We then selected five illustrative scenarios which are summmarized in Table 1 and described in more detail here. We chose the parameter values for our scenarios such that they reflect ideal types. Although we also show the full analysis over the much broader parameter space later on.

- **Static voter distribution**: In this scenario, which serves as our benchmark, we replicate the model by Laver (2005). This means that social influence and party attraction are absent and the voter distribution accordingly is static.
- **Social influence only**: Here, the dynamics of voter distribution closely follow the opinion dynamics model with bounded confidence by Hegselmann and Krause (2002), except that we use a two-dimensional ideology space. Hence, party attraction is absent in this scenario, while we set the social influence parameter α to 0.1.
- **Strong social influence**: We build on the preceding scenario where $\alpha = 0.1$, but add a party attraction of $\beta = 0.01$. This serves to better understand how introducing a relatively small party attraction effect changes the dynamics of a model primarily determined by social influence.
- **party attraction effect**: Here, we want to study the impact of a "pure" party attraction effect. Accordingly, we set $\alpha = 0$ and $\beta = 0.1$.
- **Strong party attraction**: Finally, we combine a small social influence effect of $\alpha = 0.01$ with a strong party attraction effect of $\beta = 0.1$. This scenario thus allows us to understand how an additional, modest social influence effect may affect model dynamics compared to the scenario that only entails party attraction

Scenario	**Parameter values**
Static voter distribution (Benchmark)	$\alpha = 0$, $\beta = 0$
Social influence only	$\alpha = 0.1$, $\beta = 0$
Strong social influence	$\alpha = 0.1$, $\beta = 0.01$
Party attraction only	$\alpha = 0$, $\beta = 0.1$
Strong party attraction	$\alpha = 0.01$, $\beta = 0.1$

Table 1: Scenarios

We study how our model behaves in each scenario using a battery of different parameter configurations. More precisely, we study 620 different party constellations which are inhabited with 0-4 parties of each type, but at least two parties in total.[5] Furthermore, we test four different values (0.05, 0.15, 0.25 and 1) for the confidence bound for each party constellation and scenario.[6] Finally, we run each parameter configuration (i.e., the combination between party constellation, confidence bound and scenario) 100 times in order to understand the mean outcome of a given parameter configuration in the face of a stochastic model.

Notably, we use fixed random seeds to initialize and run the model. This has two main advantages: First, all of our results are fully reproducible. Second, this implies that we can test the effect of different scenarios and confidence bounds for the same initial distribution of voters and parties, hence providing an ideal virtual laboratory where the control group is ex ante the same. All parameters used are described in Table 2.

---

[5] The total number of party constellations for 0-4 parties of each type is $5^4 = 625$, but we disregard those five constellations where there is at maximum one party.

[6] If we only activate social influence, a confidence bound of 0.25 is usually high enough to reach a consensus for the given initial voter distribution, where each position is – as explained – drawn from a uniform distribution. In order to focus on presenting "interesting" results, we hence disregard intermediate values between 0.25 and 1.

Symbol	Parameter	Values
n_v	Number of voters	1000
n_p	Number of parties	2-16
	Number of hunters	0-4
	Number of stickers	0-4
	Number of aggregators	0-4
	Number of predators	0-4
γ	Step size	0.02 [7]
ϵ	Confidence bound	0.05/0.15/0.25/1
α	Social influence	see Table 1
β	Party attraction	see Table 1
χ	Polarization sensitivity [8]	1.6 (Esteban and Ray, 1994)

Table 2: Parameter settings

4.1 Individual runs

We start our analysis by studying single illustrative runs. Fig. 1 plots the ideological positions of voters and parties on both dimensions over the first 150 periods.[9] This serves to better showcase how voters and parties behave in various scenarios. For the sake of clarity, we set the party constellation as well as the initial distribution of ideologies of voters and parties fixed across these runs. In order to keep the analysis simple and to illustrate the competitive behavior associated with different party strategies, we initialize the model with one party of each type only.

We observe that the ideological dynamics of voters and parties crucially depend on the scenario. We hence depict them to illustrate the mechanisms that generate the overall patterns. Fig. 1 shows on the left-hand side the x-coordinate and on the right-hand side the y-coordinate of our two-dimensional party model.

In a static voter distribution, the parties exhibit their well-known behavior (see Laver, 2005): while the sticker party does not move but still obtains a certain share of votes, all other parties constantly change their ideological positions. The hunter persistently seeks an optimal position, while the predator responds by shifting towards the hunter's location if the latter becomes the strongest party. Finally, aggregators react by moving in the same direction as the closest party (either hunter or predator) to represent its mean voter.

If we activate party attraction (but not social influence), in the beginning, four distinct clusters in the voter distribution emerge, each of which has a party that perfectly represents the ideology of this cluster.[10]. Then, the predator moves towards the aggregator, which is the strongest party, and also carries its voters towards the new point, thus causing the two clusters to merge. However, even though it is now of larger size, the newly merged cluster is not large enough to allow both parties to achieve a plurality if they have to split their votes. Hence, the predator is locked between moving towards the hunter (which wins if aggregator and predator share a position) and back to the aggregator (which wins once the hunter moved away from it).

If we activate social influence (but not party attraction), then the results depend on the value of ϵ. For $\epsilon = 1$, we observe the well-known consensus of voters on the mean initial ideology (see Hegselmann and Krause, 2002). Accordingly, the aggregator and the predator both pursue the consensus ideology, whereas the sticker (after a couple of periods) and the hunter (after ca. 10 periods) operate in a political vacuum. Finally, social influence with an $\epsilon = 0.15$ creates multiple clusters within the population. In

---

[7] This is the rounded step size relative to the size of the policy/ideology space chosen by Laver (2005), which is $\frac{1}{61} \approx 0.0164$.

[8] This parameter is used in eq. 2 and eq. 3 and is necessary to calculate the level of polarization according to Esteban and Ray (1994).

[9] We simulated the model for 500 periods, but did not find any qualitative differences between period 150 and period 500. In order to better highlight the opinion dynamics occurring in the first periods, we thus decided to only show the results of the first 150 periods.

[10] By "clusters" we mean, following Esteban and Ray (1994), groups of the population which are homogeneous with respect to their ideological views within their group, but markedly different from the views held by other groups.

the illustrative run shown in Fig. 1, four clusters emerge. Two clusters vote for the predator, and one cluster each for the hunter and aggregator. In contrast to the “party attraction only” scenario, however, only the aggregator perfectly represents its mean voter.

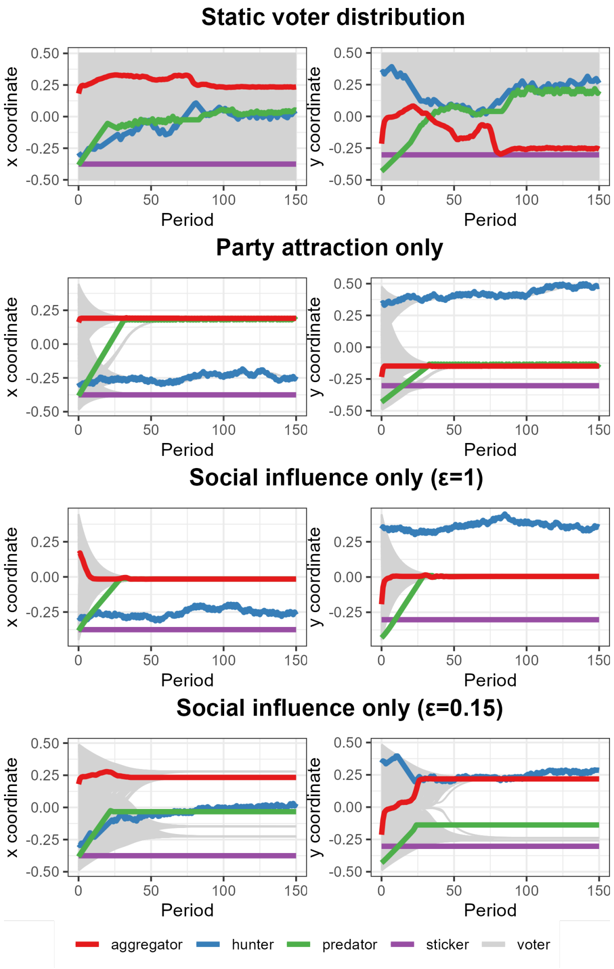

Figure 1: Evolution of voter and party ideology (single illustrative runs).

4.2 Quantitative analysis

After having established how parties and voters behave in various illustrative simulation runs, we aim to investigate the mean behavior of our model across a broader range of the parameter space.

We are particularly interested in two questions. First, which party strategies are successful if opinions are dynamic rather than static? Second, what are the welfare implications of a dynamic voter distribution?

Depending on the electoral system, parties may either be interested in reaching the first place (as in a plurality system used, e.g., in the UK) or in maximizing their vote share (as in proportional representation systems used, e.g., in Nordic countries). Accordingly, Fig. 2 shows both how likely it is for a given type of party to win an election after 500 periods,[11] as well as the size of the vote share of an average party of a given type. We plot only the mean over 100 simulation runs because the confidence intervals (as calculated with a t-test) are very small and would not be visible in this figure. The mean values, standard deviations and confidence intervals are also shown in Tables 7–10 in the Appendix.

---

[11] In our illustrative runs, we did not observe qualitative differences between the outcome after 250 periods vs. the outcome after 500 periods. However, to ensure that we do not miss any dynamics across our 125,000 simulation runs, we chose to report the results after 500 periods.

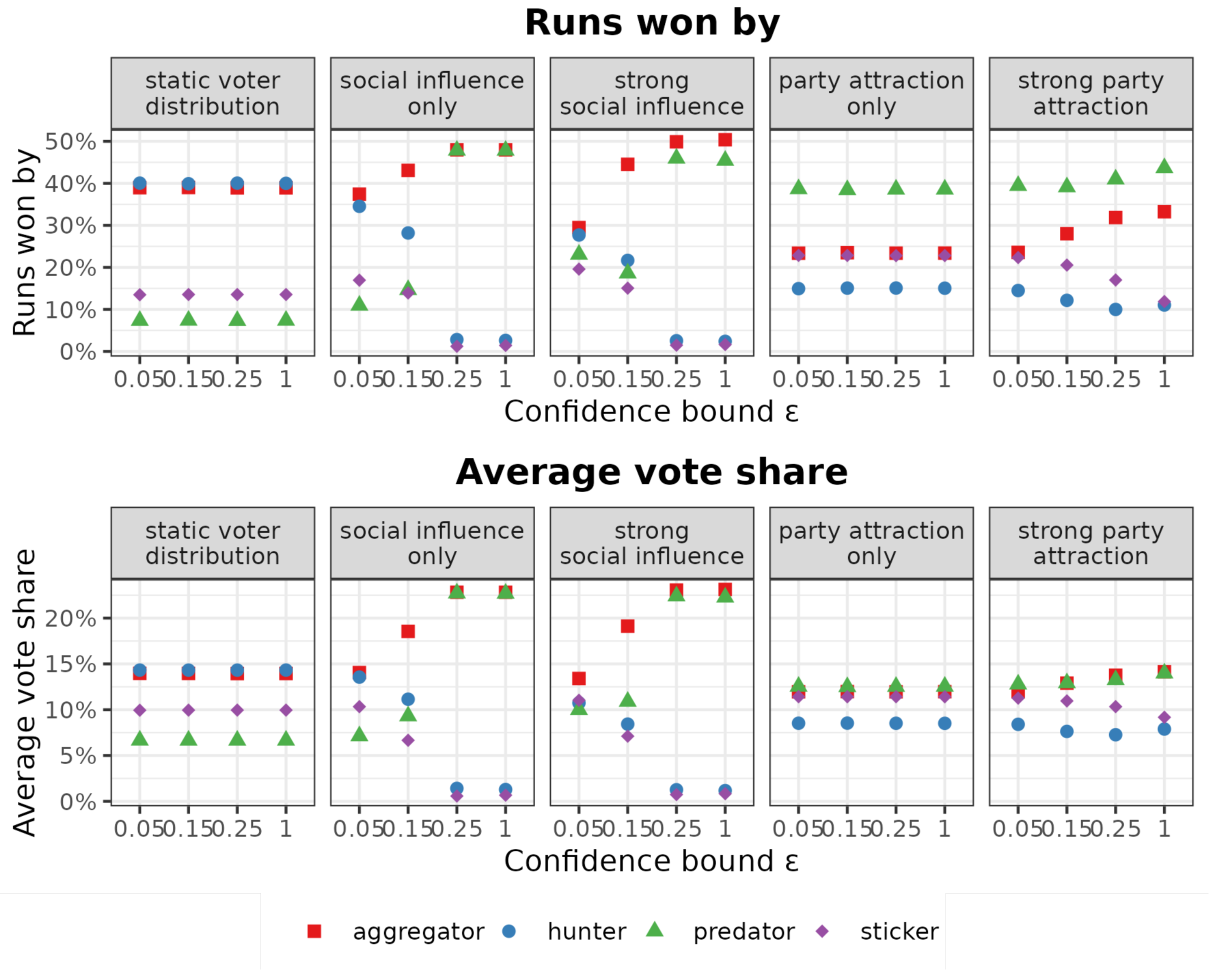

Figure 2: Winning probability and average vote share for the four party types in our simulation runs.

A static voter distribution replicates the well-known results of Laver (2005). The hunter proves to be a highly successful strategy both in terms of winning probability and in terms of average vote share, with the aggregator being virtually tied for the first place. They are then followed, by a large margin, by the sticker and the predator. In the scenario that only incorporates social influence, the final distribution of voters is either fragmented ($\epsilon = 0.05$), polarized ($\epsilon = 0.15$) or forms a consensus ($\epsilon = 0.25$ or $\epsilon = 1$). Hence, this scenario effectively simply studies how well parties are able to navigate in a political landscape that becomes increasingly rugged. In this scenario, hunters become less successful compared to the benchmark as the confidence bound ϵ increases. This is because the more rugged the landscape, the less "feedback" they will receive. In an extreme case, all voters and at least one other party would be located at a single position. In this case, the hunter would have to randomly find exactly one position from an extremely large number of possibilities. For stickers, we observe a non-linear effect: their probability to win increases compared to the baseline if ϵ is small, but decreases if it is large. In terms of the average vote share, we only observe a marginal increase for $\epsilon = 0.05$ and a decrease for larger values of ϵ. Aggregators and predators, on the other hand, become more successful – in particular for large values of ϵ. If $\epsilon \geq 0.25$, all voters, aggregators and predators will locate at a single position, which is why aggregators and predators fare equally well in such a case.

In the remaining three scenarios, the parties are not merely observers of changes in the voter landscapes, but actively change them as well by attracting supporters towards the party position. The "strong social influence" scenario exhibits similar dynamics as the "social influence only" scenario for aggregators and stickers, although the latter benefit more from lower values of ϵ, as voters of sticker parties are in such cases less likely influenced by voters of other parties, but are drawn towards the stickers by party attraction. Hunters also achieve highly similar outcomes compared to the preceding scenario. Predators derive an advantage from the party attraction effect and their performance exhibits a slight improvement, particularly at low and moderate values of ϵ. However, hunters still win more runs on average as predators at low and moderate bounded confidence levels. In the "party attraction only" scenario, predators are most successful in terms of the probability to win, followed by aggregators, stickers, and hunters. However, the differences between the first three party types in terms of the average vote share is very small. This result may be influenced by the assumption (borrowed from Laver, 2005) that parties and voters are randomly placed within the ideological space according to a uniform distribution. Hence, every party has a similar starting position on average. It is unlikely that stickers would perform similarly to other parties if the initial party ideologies were drawn from a uniform distribution, but the initial voter distribution was to be drawn from, e.g., a normal distribution. Finally, activating a weak social influence effect in the "strong party attraction" scenario causes the prospects of stickers and hunters to decline when ϵ becomes larger, while aggregators and predators benefit with an increase in ϵ.

4.3 Fragmentation and Polarization

We use two measures to assess the resulting ideological landscape quantitatively. First, we compute the standard deviation of voters and parties respectively in the two ideology dimensions to measure the fragmentation of voters and parties. Second, following Esteban and Ray (1994) we measure the polarization of voters P_t^{voters} according to eq. 2 and the polarization of parties $P_t^{parties}$ according to eq. 3. In these equations, n_o denotes the number of ideologies (as given by x and y coordinates) occupied by voters or parties, $\pi_{a,t}$ is the share of voters (or parties) at a given ideology a (as given by x and y coordinates) at time step t, $\delta(a, b)$ is the Euclidean distance between the ideologies a and b, and χ is a parameter that describes the "polarization sensitivity" (see Esteban and Ray, 1994).[12]

$$P_t^{voters} = \sum_{a=1}^{n_o}\sum_{b=1}^{n_o} \pi_{a,t}^{1+\chi}\pi_{b,t}\delta(a,b) \tag{2}$$

$$P_t^{parties} = \sum_{a=1}^{n_o}\sum_{b=1}^{n_o} \pi_{a,t}^{1+\chi}\pi_{b,t}\delta(a,b) \tag{3}$$

We show both polarization metrics, as well as the standard deviation of parties and voters in Fig. 3.[13]

Compared with the static voter distribution baseline studied in the related literature, social influence reduces the fragmentation of voters, particularly for large values of ϵ, where social influence tends to create a consensus around the mean opinion. Moreover, social influence produces polarization of voters for a confidence bound of around $\epsilon = 0.15$. Both findings match the results of Hegselmann and Krause (2002) on which the "social influence only" scenario is based.

When coupled with weak party attraction, the fragmentation of voters tends to be *lower* for low values of ϵ, but the polarization of voters is *higher*. Pure party attraction reduces the fragmentation of voters but increases the fragmentation of parties. Compared to the static voter distribution baseline, polarization of both voters and parties increases. In combination with weak social influence (strong party attraction), both the fragmentation and polarization of parties and voters are lower for large values of ϵ than for pure party attraction.

---

[12] Esteban and Ray (1994) multiply the measure with a constant K which only changes the magnitude of the polarization index, but not the order between any two distributions. We thus implicitly set K to 1 for simplicity.

[13] In line with our expectations, we did not find any significant differences between the standard deviation in the x-axis and in the y-axis, and thus decided to plot the standard deviation in the y-axis only in the appendix (see Fig. 9).

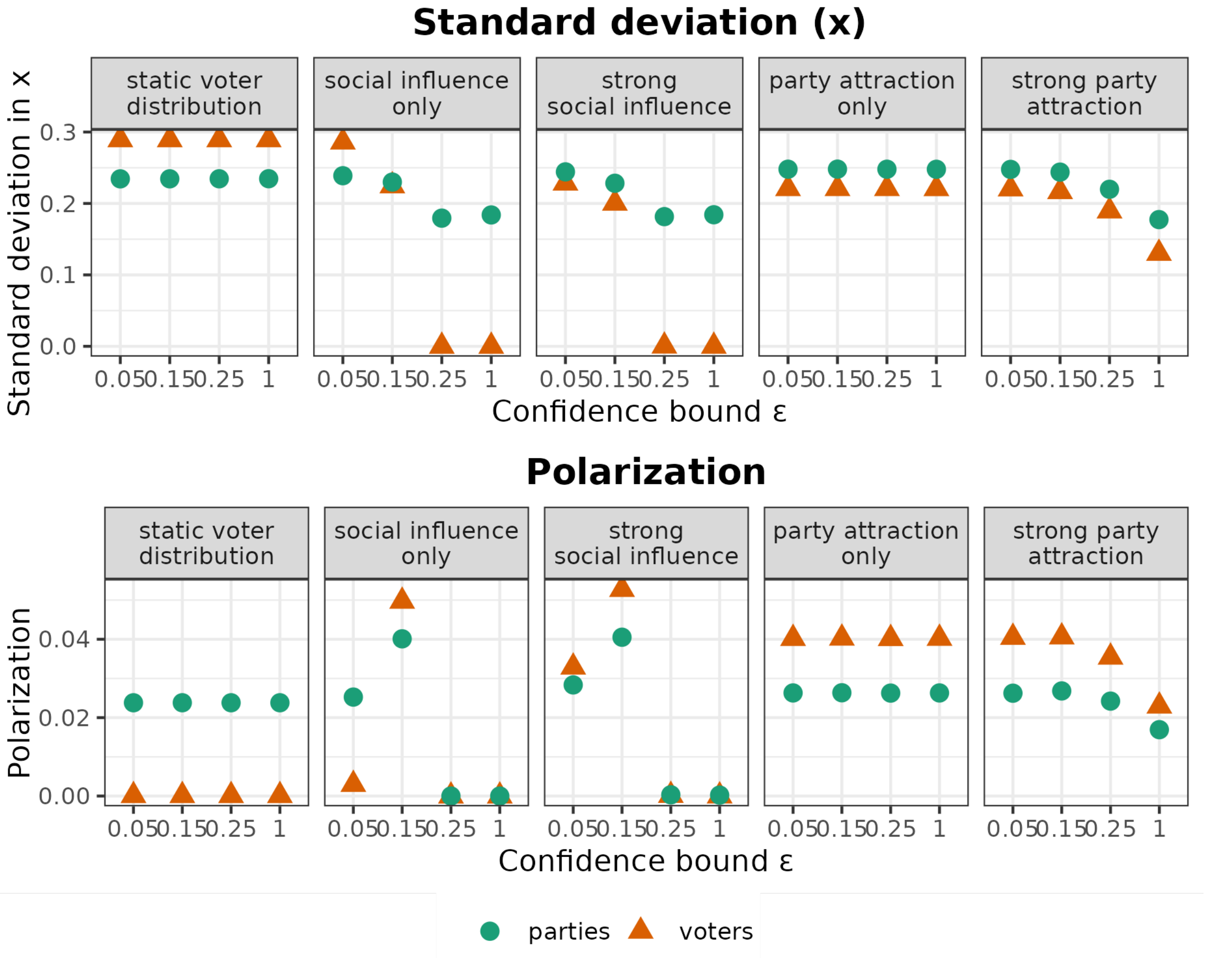

Figure 3: Fragmentation and polarization of voters and parties in our five scenarios and varying confidence bounds.

4.4 Party System Representativeness and Party Extremism

We assess the relationship between the ideology of parties and their voters using three measures: voter misery, mean party policy eccentricity (both in line with the previous literature, see Laver and Sergenti, 2012; Lehrer and Schumacher, 2018), as well as a new measure that we introduce, namely, weighted party policy eccentricity.

Voter misery:

Ideally, voters would like to be represented by a party that is as close as possible to the voter's ideology. To evaluate the discrepancy between voter and party ideology, Laver and Sergenti (2012) and Laver (2011) measure the representativeness of the party system using the mean squared distance between party and voter ideology. They call this measure voter misery M_t, given by eq. 4, where $d(i,p,t)$ is the Euclidean distance between the ideology of the voter i and the ideology of the party p which she votes for in time step t.[14]

$$M_t = \frac{\sum_{i=1}^{n_v} d(i,p,t)^2}{n_v} \tag{4}$$

---

[14] Please note the difference in notation to the Euclidean distance between two ideologies a and b ($\delta(a,b)$) mentioned previously, which is time-invariant. To highlight that voter misery represents a disutility to voters, Laver (2011) multiplies this measure by -1. We adhere to the definition used in the code provided by Laver and Sergenti (2012).

Smaller values of M_t imply that the party system better represents the voter distribution.

Mean party eccentricity:

A second measure used by Laver and Sergenti (2012); Laver (2011); Lehrer and Schumacher (2018) to assess the relationship between voter and party ideology is party eccentricity. This index measures how ideologically "extreme" parties are relative to the mean voter. Each party's eccentricity is measured as its Euclidean distance from the mean voter position, where $\bar{x}_t^v$ and $\bar{y}_t^v$ are the mean positions of voters on the two ideology dimensions.

We aggregate the party-level measures in two different ways: First, mean party eccentricity is given by eq. 5:

$$E_t^{mean} = \frac{1}{n_p} \sum_{p=1}^{n_p} \sqrt{(x_{p,t} - \bar{x}_t^v)^2 + (y_{p,t} - \bar{y}_t^v)^2} \tag{5}$$

This means that the higher E_t^{mean} is, the greater the mean distance between the mean voter and the parties.

Weighted party eccentricity:

Second, we also use weighted party eccentricity. Here, we weight the party eccentricity according to their vote share s_p. We believe that this is important because some parties may be very "extreme", but only attract few votes, hence making their extremism arguably less important. Weighted party eccentricity is given by eq. 6:

$$E_t^{weighted} = \sum_{p=1}^{n_p} s_p \sqrt{(x_{p,t} - \bar{x}_t^v)^2 + (y_{p,t} - \bar{y}_t^v)^2} \tag{6}$$

Fig. 4 shows the results of this analysis. Compared to the benchmark scenario in which the voter distribution is static, social influence and party attraction generally reduce voter misery, hence making the party system more "representative" of the will of the voters. This is because opinion dynamics tend to create one to many homogeneous clusters in the voter distribution, hence making it easier for parties to adopt the position of one cluster.[15] Party attraction is even more successful than social influence in combating voter misery, as party attraction causes voters to be pulled ideologically towards the party that they support, hence making voters feel less miserable. If each cluster of voters is represented by a party, voter misery could reach 0.

---

[15] As shown by Hegselmann and Krause (2002), opinion dynamics with bounded confidence creates a fragmented, polarized or consensual distribution of opinions, depending on the confidence bound.

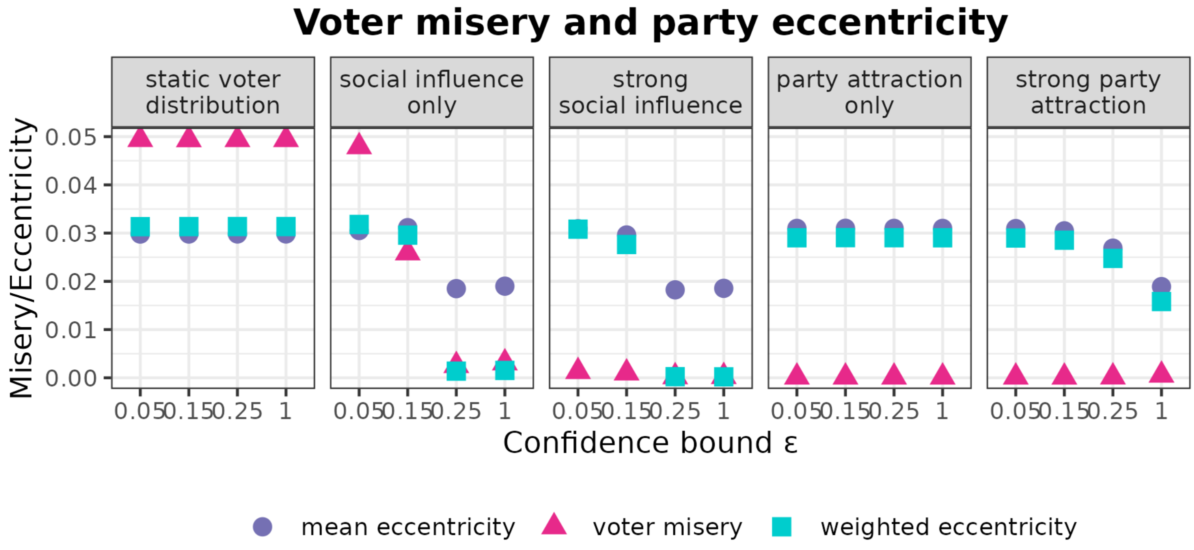

Figure 4: Voter Misery and party eccentricity for our five scenarios for different values of ϵ.

Party eccentricity, on the other hand, is primarily determined by social influence. Fig. 4 shows that mean and – in particular – weighted party eccentricity decreases drastically if the confidence bounds are large. This is because social influence without confidence bounds and without party attraction tends to create a consensus at the mean of the initial voter distribution, hence creating a strong incentive of parties to converge to the center. Since stickers do not react to changes in the voter landscape and hunter parties do not necessarily "find" the population mean, not all parties will be located at the resulting consensus opinion. However, any such divergent parties are punished by the voters accordingly, as can be seen by the difference between mean eccentricity and weighted eccentricity.

4.5 Party constellations

In this subsection, we analyze the impact of party constellations on various outcome metrics. To this end, we conduct a regression analysis using the "fixest" package for R (Bergé, 2018) with fixed effects for each combination between the scenario and the confidence bound parameter ϵ. Standard errors are clustered for these combinations.

The polarization of voters decreases with the number of parties and the share of aggregators, and increases with the share of predators. Parties become more polarized when the share of stickers and hunters increases, and less polarized when the share of predators and the total number of parties increases. The fragmentation of voters and of parties increases with the number of parties, the share of stickers and hunters, and decreases with the share of predators. The share of aggregators increases the fragmentation of voters, but does not have any significant impact on the fragmentation of parties. The share of stickers increases the mean eccentricity and weighted eccentricity. The mean eccentricity also significantly increases with the share of hunters. Both measures decrease when the share of predators increases. Finally, a larger number of parties and a larger share of aggregators decreases voter misery, while the share of predators increases it.

	polarization of voters	polarization of parties	fragmentation of voters	fragmentation of parties	mean eccentricity	weighted eccentricity	voter misery
N_p	-0.001***	-0.002***	0.004***	0.006***	0.001***	0.001***	-0.003**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Share of stickers	0.000	0.009***	0.036**	0.098***	0.015***	0.008***	0.005**
	(0.002)	(0.001)	(0.009)	(0.009)	(0.001)	(0.001)	(0.002)
R2	0.688	0.486	0.816	0.209	0.398	0.754	0.529
R2 Within	0.048	0.161	0.064	0.110	0.160	0.110	0.131

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Fixed effect models with the share of stickers as dependent variable.

	polarization of voters	polarization of parties	fragmentation of voters	fragmentation of parties	mean eccentricity	weighted eccentricity	voter misery
N_p	-0.001***	-0.002***	0.004***	0.006***	0.001***	0.001***	-0.003**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Share of predators	0.007**	-0.020***	-0.081***	-0.171***	-0.024***	-0.016***	0.023*
	(0.002)	(0.003)	(0.019)	(0.003)	(0.001)	(0.002)	(0.008)
R2	0.691	0.515	0.830	0.320	0.527	0.790	0.546
R2 Within	0.055	0.209	0.137	0.235	0.339	0.239	0.164

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Fixed effect models with the share of predators as dependent variable.

	polarization of voters	polarization of parties	fragmentation of voters	fragmentation of parties	mean eccentricity	weighted eccentricity	voter misery
N_p	-0.001***	-0.002***	0.004***	0.006***	0.001***	0.001***	-0.003**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Share of hunters	0.002	0.008*	0.024**	0.052**	0.008***	0.003	-0.002
	(0.001)	(0.003)	(0.007)	(0.014)	(0.002)	(0.001)	(0.001)
R2	0.689	0.484	0.814	0.170	0.342	0.743	0.528
R2 Within	0.049	0.158	0.054	0.066	0.082	0.070	0.129

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Fixed effect models with the share of hunters as dependent variable.

	polarization of voters	polarization of parties	fragmentation of voters	fragmentation of parties	mean eccentricity	weighted eccentricity	voter misery
N_p	-0.001***	-0.002***	0.004***	0.006***	0.001***	0.001***	-0.003**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Share of aggregators	-0.009**	0.003	0.021	0.021	0.001	0.005*	-0.027**
	(0.003)	(0.002)	(0.011)	(0.024)	(0.003)	(0.002)	(0.008)
R2	0.693	0.479	0.814	0.157	0.316	0.746	0.553
R2 Within	0.062	0.149	0.053	0.052	0.046	0.081	0.175

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Fixed effect models with the share of aggregators as dependent variable.

4.6 Robustness Checks

4.6.1 Noisy opinion dynamics

In our first robustness check, we present a model extension which changes the equation governing opinion dynamics to include two noise terms $e^x_{i,t}$ and $e^y_{i,t}$ – one for each ideology dimension. The new equation is given by 7 and similar to the specification proposed by Mäs et al. (2010).

$$\begin{aligned} x_{i,t} &= (1-\alpha-\beta)x_{i,t-1} + \alpha\bar{x}_{i,t} + \beta x^{party}_{i,t-1} + e^x_{i,t} \\ y_{i,t} &= (1-\alpha-\beta)y_{i,t-1} + \alpha\bar{y}_{i,t} + \beta y^{party}_{i,t-1} + e^y_{i,t} \end{aligned} \tag{7}$$

These noise terms represent all other impacts on opinion and are drawn from a normal distribution in each period for each voter. Their mean is given by μ and the standard deviation by σ. Formally, $e^x_{i,t} \sim \mathcal{N}(\mu, \sigma^2)$ and $e^y_{i,t} \sim \mathcal{N}(\mu, \sigma^2)$.

To illustrate how the new equation affects opinion formation, we plot the evolution of opinions, as well as locations of parties and voters on the two-dimensional plane for the "social influence only" scenarios for $\mu = 0$ and $\sigma = 0.01$ and confidence bounds of 0.15 and 1 in Fig. 5

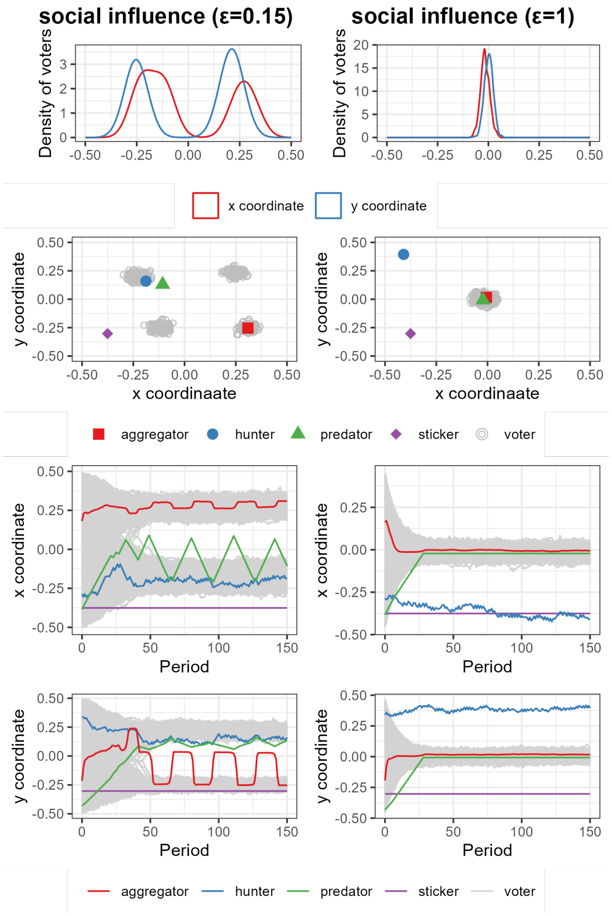

Figure 5: Density of voters at period 150 (top), location of voters and parties at period 150 (upper middle), evolution of party and voter locations at the x coordinate (lower middle) and evolution of party and voter locations at the y coordinate (bottom).

We then re-run the main analysis comprising of our five scenarios to investigate the impact of this change for values of $\mu = 0$ and $\sigma = 0.01$ and plot the results in Fig. 6.

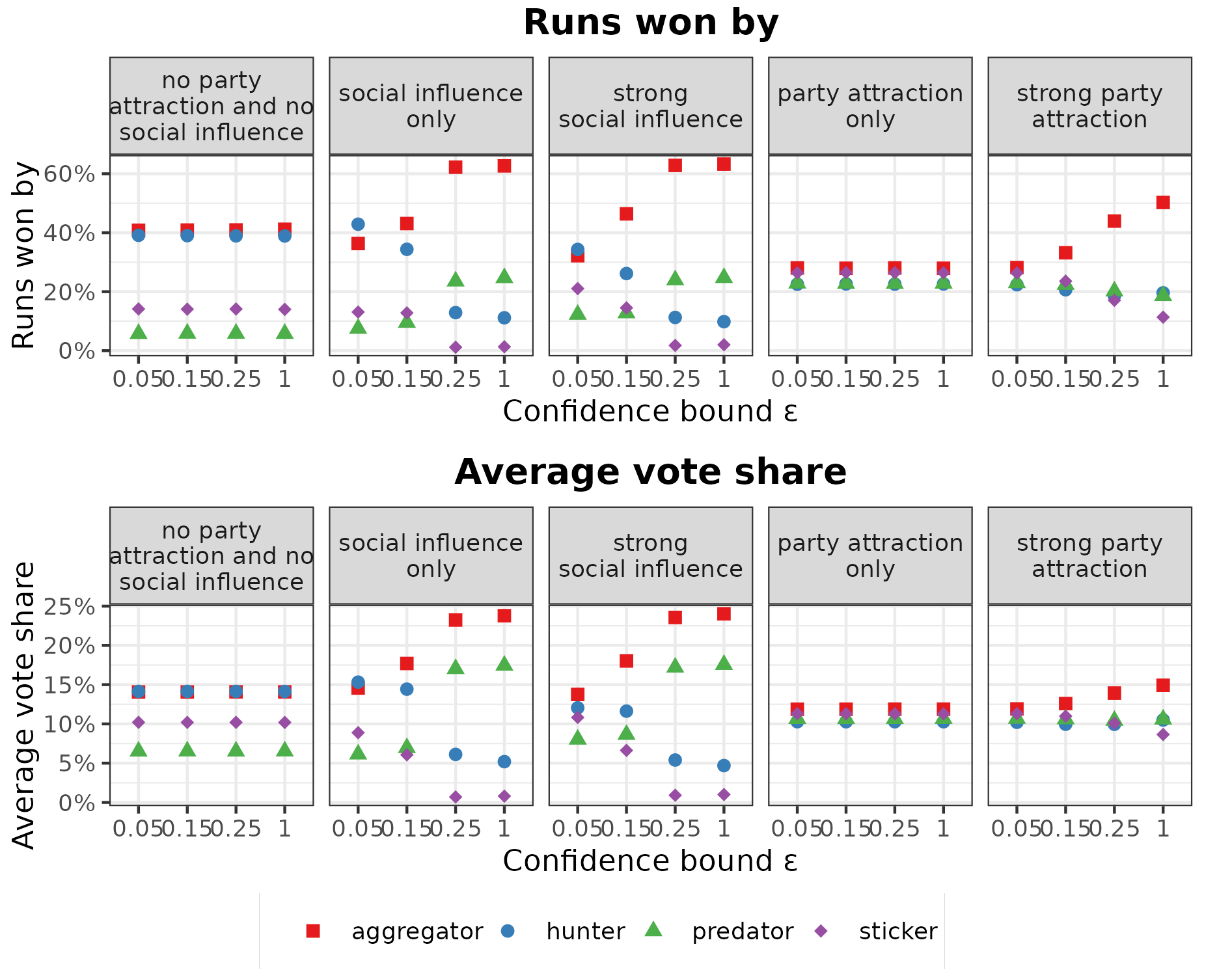

Figure 6: Winning probability and average vote share for the four party types in our simulation runs with noise.

Noise mainly affects the outcomes of three party types. First, it improves the shares and winning probabilities of hunters – in particular, they are now the best-performing party type when there is only social influence and a very low confidence bound. This is because the hunter strategy is a sort-of minimally intelligent hill-climbing mechanism. Since the introduction of noise introduces "hills" even in dynamic voter distributions, hunters are now a more viable strategy. Second, predators perform worse in this model extension and are no longer the best-performing strategy in any of our scenarios.

In order to understand why this is the case, consider the "social influence only" scenario with two aggregators and two predators. In the absence of noise, all voters follow a single opinion. Since the aggregators follow their voters to this opinion and the predators follow the strongest party, all parties share the votes equally and tie for the win (as shown in section 4.2). However, if opinion dynamics are noisy, the resulting opinion distribution will follow a normal distribution and both aggregators will take up slightly different (if close) positions. The predators then want to move between those two parties because whenever the predators take up the position of one of the aggregators, the other aggregator will win (since the former aggregator has to share its voters with two other parties – namely, the predators).

Finally, aggregators are now the best-performing party type in virtually all parameter combinations, except in the "social influence only" scenario if the confidence bound is very low.

4.6.2 Sensitivity analysis

To ensure that the results illustrated in the five scenarios are generalizable over a broader range of the parameter space, we further conduct an extensive sensitivity analysis shown in Fig. 7 and 8. For these simulations, we again use the baseline specification without noise. These simulations involved testing each 21x21 parameter combination for social influence and party attraction, with both parameters ranging from 0 to 0.2 in increments of 0.01. To facilitate the computation of the 110.25 million simulation runs, we limited our agent population to 200 voters.[16]

Subsequently, we examined the vote share and winning probabilities of each party type across this expanded parameter space, as depicted in Fig. 7.

The average share and the winning probability of aggregators increases with social influence α and confidence bound ϵ (the latter holds, of course, only if $\alpha > 0.0$). Furthermore, it decreases with party attraction.

Hunters are most effective when social influence and party attraction are very low. In other words, the hunter is the most successful strategy in the static voter distribution scenario, as already shown in Fig. 2. In addition to that, average share and winning probability decrease with higher values of ϵ, as a higher confidence bound implies a more rugged voter landscape that voters find difficult to navigate.

---

[16] We verified that the results for the scenarios presented above are approximately consistent for populations of 200 and 1000 voters.

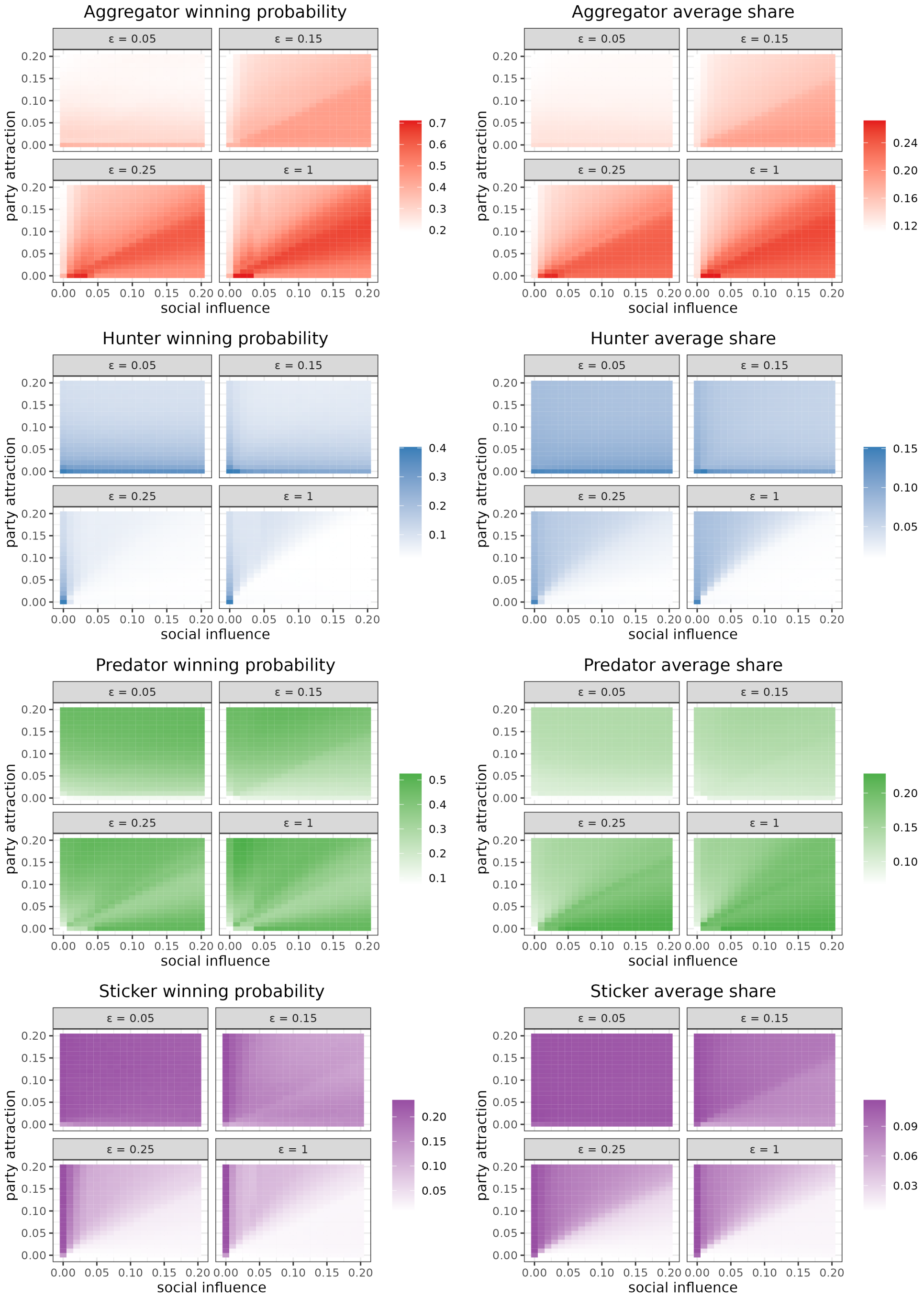

Figure 7: Sensitivity analysis for the share and winning probabilities of each party type.

For predators, the analysis is more intricate. Since the success of the predator hinges on the performance of the other parties, we observe non-linearities in the outcomes. For larger confidence bounds, the average vote share of predators is highest if social influence is strong. They also observe the largest probability to win (in absolute terms) in such a scenario. However, as we already saw in the five illustrative scenarios discussed above, they tie with the aggregators for the first place in such a case. Their winning probability increases furthermore when moving above the diagonal where $\alpha = \beta$ (where the winning probability is the lowest) for larger values of party attraction, up to a point where the predator is the strongest strategy.

Finally, stickers are most successful if the party attraction is high and social influence is low. Furthermore, stickers benefit from a low confidence bound. Party attraction without social influence causes stickers to "pull" their initial voters towards their party ideology, hence consolidating their voter base. Activating social influence potentially causes problems for stickers, as their voters may be "pulled away" from the party policy. However, the problem is less acute for lower values of ϵ, because this makes it more likely that the clusters arising in the population are ideologically distinct and do not influence each other, hence leaving ideological primacy to the party.

We then investigate the resulting distribution of voters and parties over this larger parameter space in Fig. 8. The polarization of parties typically increases with party attraction and decreases with social influence, except for the bounded confidence level $\epsilon = 0.15$, where the opposite is true. The polarization of voters increases with party attraction. Furthermore, it increases with social influence if $\epsilon = 0.15$. The polarization of voters decreases with social influence, on the other hand, for $\epsilon = 0.25$ and $\epsilon = 1$. The analysis confirms the well-known result that social influence tends to create a consensus for larger values of ϵ.

Finally, we look at the party system representativeness and party extremism, also shown in Fig. 8. For party eccentricity, we see pronounced differences for $\epsilon = 0.25$ and $\epsilon = 1$, where party eccentricity generally increases with party attraction, but decreases with social influence. There is a small non-linearity to this general trend in the mean party eccentricity, which is absent from the weighted party eccentricity. As discussed above, this result is driven by hunters and stickers which are extreme, but do not receive many or even any votes. Voter misery is highest in the static voter distribution, because the mean distance between parties and their voters is highest in this scenario. Party attraction causes voter misery to become drastically lower, as this causes voters to move closer to "their" party. Social influence also reduces voter misery for $\epsilon > 0.05$, as this causes the population to form clusters. Aggregators and hunters, as well as – depending on the party constellation – predators are able to react to this dynamic and adapt their position accordingly.

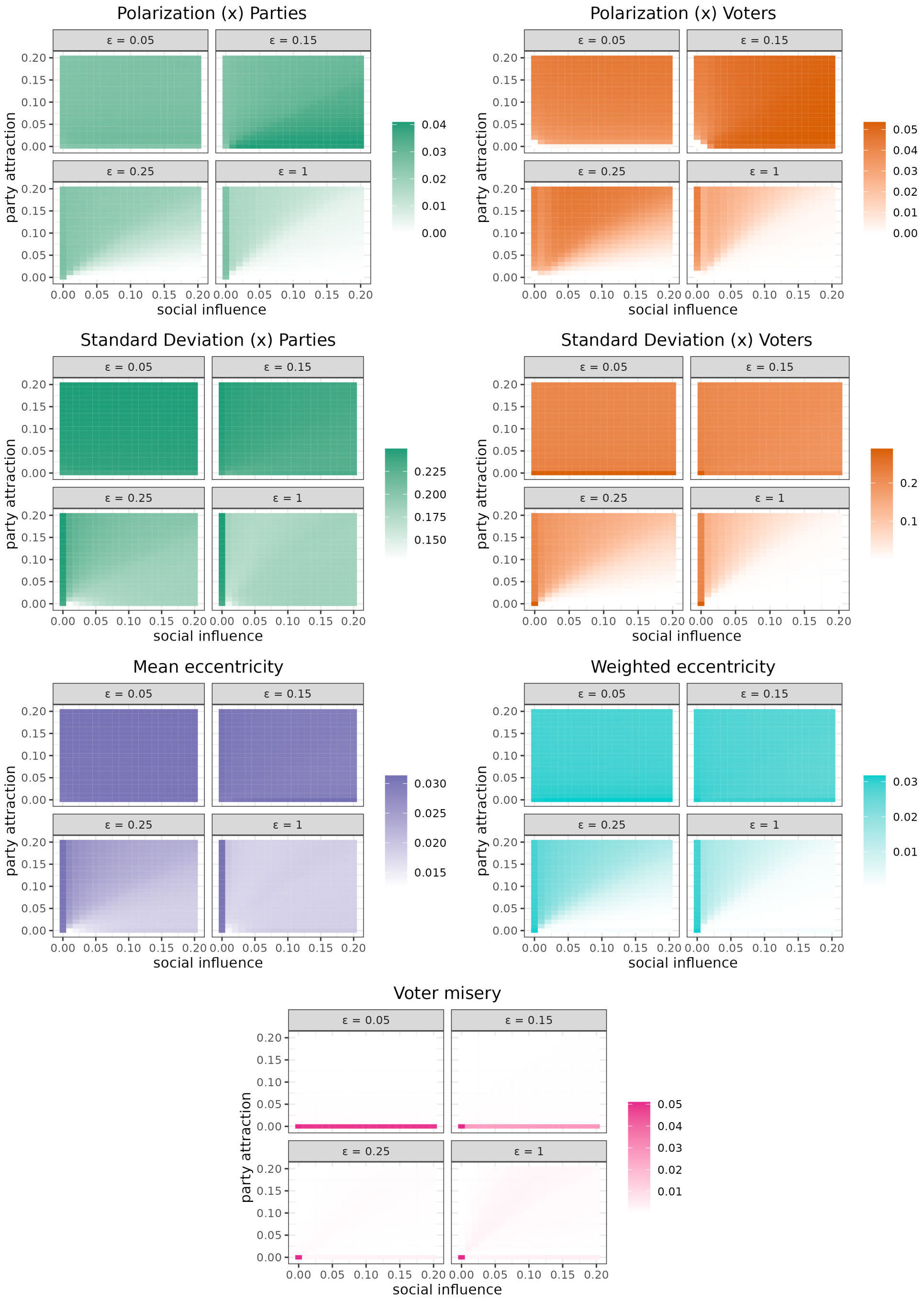

Figure 8: Sensitivity analysis for the polarization and fragmentation of voters and parties, as well as the mean and weighted party eccentricity and voter misery.

5 Discussion

While our model is more general than the model by Laver (2005) in the sense that it allows for both dynamic and static voter distributions, it still exhibits many simplifications. Being aware of these simplifications helps to better understand how the model results should be interpreted. In the following, we provide a list of limitations that we think are most important and conjecture how relaxing them could affect the results.

In our model, parties are able to attract voters towards their policy platform as soon as the voter is located closest to this party. There is empirical support for the idea that party attraction is influenced by party identification, where people who identify more strongly with a given party are more strongly influenced by it (Brader and Tucker, 2012). This mechanism is modeled by Jackson (2003), who assumes that voters can, over time, develop (and strengthen) a party identity or become alienated from the party depending on the ideological congruence between voter and party. Depending on the level of party identification, voters are then influenced towards the party's direction (i.e., party attraction). An extension of our model could implement a similar mechanism by implementing a "running tally" (Fiorina, 1977). However, such an analysis would be computationally highly expensive as our analysis is not confined to two parties, but at maximum 16 different parties, which would all have to be tracked by each individual voter at the same time. We believe that doing so would particularly make the hunter less successful (as the hunter would receive a delayed feedback about its actions).

Our analysis currently only focuses on the four types of parties introduced by Laver (2005). However, in the subsequently published book (Laver and Sergenti, 2012), they also introduce a hill-climbing type of party, the so-called "explorer". This party type searches for alternative positions in its neighborhood that could improve its vote share. It is highly successful and perhaps closest to the party that Downs (1957a) envisions. Furthermore, Laver and Sergenti (2012) introduce different target functions beyond vote-maximization, namely policy orientation by party leaders. Both changes would be rather straightforward to implement and are interesting avenues to pursue in future research.

Currently, voters can only be attracted towards parties (if they vote for them) or other voters (if they are sufficiently close). However, there is also empirical evidence for negative social influence, i.e. people are repulsed by the views of others if their views are already highly dissimilar (Hovland et al., 1957; Bail et al., 2018). Introducing negative social influence would likely increase the polarization of voters (see, e.g., Flache and Macy, 2011) and could make the strategic positioning of parties more intricate.

Future research can build on our open source model to address those limitations and build an even more general or "realistic" model.

6 Conclusion

How should parties place themselves in the policy space to be successful? Spatial models have a long tradition in providing answers to this question, but most of these models focus on a world where voter preferences are static, hence drastically simplifying the problem. In the current paper, we modeled endogenous voter preferences by allowing voters to be persuaded by i) parties and, simultaneously, ii) other voters (who are sufficiently similar, i.e. within the confidence bound, see Hegselmann and Krause, 2002). So far, these two mechanisms have only been studied separately in a few papers.

We use Laver's 2005 model of party competition as a benchmark for our analysis, as the political parties in this model follow boundedly rational strategies, as such strategies have proven in other disciplines to be a successful way for agents to navigate complex systems (see, e.g., Dosi et al., 2020). We hence adopted the four party strategies (hunters, stickers, aggregators and predators) introduced by Laver (2005) and first studied how successful each strategy is for varying levels of social influence, party attraction and confidence bounds.

Hunters randomly shift positions. They continue to move in the same direction if they gain more voters, otherwise, they switch their direction. As such, they are akin to a very simple hill-climbing mechanism for a fitness landscape known from the biological sciences. As long as the hunter climbs up the fitness landscape, so to speak, it continues to do so. As soon as the move does not pay, however, it tries to move in a different way. Naturally, hill-climbing mechanisms work best if the shape of the fitness landscape indeed offers some hills to climb. We showed in our paper that hunters are most successful in a static voter distribution (as studied by Laver, 2005), but that their performance drastically decreases with social influence and party attraction. This is because social influence and party attraction tends to make the voter landscape completely flat for the most part (which results in zero votes). Invoking a potential real-world example, a center party that was caught between two modes of a highly polarized voter distribution could perhaps not find the mode by testing small changes in this or that direction, as such small changes could not convince a highly polarized electorate. In an extension of our model, we showed that hunters perform much better if we introduce a noise term to opinion dynamics. The performance of hunters then crucially depends on the confidence bound. When we activated social influence for a very low confidence bound of $\epsilon = 0.05$, hunters were the best-performing party. However, their performance decreased with the confidence bound.

Aggregators adjust their ideology to match the average position of their supporters. Changes in the position of an aggregator are hence triggered by changes *of* their electorate or *within* their electorate. Their success increases with social influence, but decreases with party attraction (although the latter only holds if social influence is larger than zero). The former effect is due to the fact that aggregators are the only party type that are directly receptive to ideological changes in their electorate. The decrease with party attraction, on the other hand, comes from the strengthening of other party types – namely stickers and predators. Aggregators are the most successful parties over a wide range of the parameter space. Thus, for parties to directly respond to changes within "their" electorate generally seems to be a viable strategy.

Stickers do not adapt their ideology, hence possibly representing an extreme case of policy-motivated parties. The performance of stickers increases with party attraction and decreases with social influence. This is because party attraction pulls the (initial) voters of the party towards it, thus consolidating its voter base. In contrast, social influence potentially pulls voters away from the party, a tendency to which the party cannot react. Hence, "idealism" (only) pays off, if the party's ability to convince voters of their ideology is very high.

Finally, predators always chase the strongest party by incrementally adapting their ideology towards it. If they are already the largest party, they do not move. In the context of the surge of right-wing parties in Europe, this could represent a mainstream party that would increasingly move to the right not because of its own voters demand such a move, but rather in order to win over voters from the right-wing parties. There are two ways in which this strategy can become the most successful one: First, it can tie for the first place with the aggregator, if the voter distribution is characterized by a consensus. Second, it can even outperform the aggregator if party attraction is very high compared to social influence. In this case, the sticker strategy is also relatively successful and the predator – who can basically copy any other party – is now left with the choice to copy the most successful aggregator "or" sticker, hence outmaneuvering the aggregators. Furthermore, strong party attraction allows the predator to carry its initial following towards its new location, making it highly agile. The performance of predators drastically decreased when we introduced a noise term to opinion dynamics.

The non-trivial results regarding the predator are driven by the fact that, for a predator to win, typically there must exist an objectively "best" location that supports multiple parties. This is incidentally why this strategy is the worst-performing one in the baseline scenario where opinions of voters are constant and their positions are drawn from a uniform distribution. Whenever a predator approaches another party, this location instantly becomes less attractive, because two parties must share the voter base. This makes the predator a non-viable strategy in relatively flat voter landscapes. The predator is furthermore a bad strategy if it is confronted with two or more poles that are of approximately equal size. This is because as soon as the predator (or swarm of predators, if the number of predators is larger than one) moves to pole A, pole B will win, triggering a move towards pole B et cetera. The predator is successful, if it is able to adapt towards pole which is much stronger the others, in particular if party attraction is so high that it can carry its original voter base towards the new location, thus further strengthening it.

We have also studied how strategic party competition and opinion dynamics shape the resulting ideological landscape in terms of fragmentation and polarization. Generally, we find that social influence reduces voter and party fragmentation as well as polarization for large values of the confidence bound. Consistent with Hegselmann and Krause (2002), a confidence bound of $\epsilon = 0.15$ increases polarization in contrast. Party attraction, on the other hand, generally raises polarization and fragmentation.

Finally, party attraction makes voters feel more represented by their party (thus decreasing "voter misery"), but increases party system extremism, as measured by "weighted eccentricity". Social influence with large confidence bounds reduces both voter misery and party system extremism.

This paper is the first to systematically study strategic party competition with voters whose views are endogenously shaped by both to i) party policy and ii) views of other voters, thus filling a gap in the literature that was already recognized by its founding fathers (see Downs, 1957a, p. 140) and called "one of the largest substantive prizes for a dynamic model of party competition" by Laver (2005). However, it has left many promising avenues for future research using the basic framework that we provide as an open source code for all researchers to use. Beyond our particular findings, we hence believe that our model represents a qualitative change in the field of spatial party competition that could be applied to qualify and generalize many existing models, thus elevating their analysis to the next level.

Acknowledgements

We thank Joachim Behnke, David Garcia and Teresa Lackner, as well as participants of seminars at the Zeppelin University of Friedrichshafen and the University of Graz for comments on a previous version of this manuscript. Any errors are ours.

References

Adams, J. F., Merrill III, S., and Grofman, B. (2005). *A unified theory of party competition: A cross-national analysis integrating spatial and behavioral factors.* Cambridge University Press.

Bail, C. A., Argyle, L. P., Brown, T. W., Bumpus, J. P., Chen, H., Hunzaker, M. F., Lee, J., Mann, M., Merhout, F., and Volfovsky, A. (2018). Exposure to opposing views on social media can increase political polarization. *Proceedings of the National Academy of Sciences*, 115(37):9216–9221.

Bechtel, M. M., Hainmueller, J., Hangartner, D., and Helbling, M. (2015). Reality Bites: The Limits of Framing Effects for Salient and Contested Policy Issues. *Political Science Research and Methods*, 3(3):683–695.

Bergé, L. (2018). Efficient estimation of maximum likelihood models with multiple fixed-effects: the R package FENmlm. *CREA Discussion Papers*, (13).

Bond, R. M., Fariss, C. J., Jones, J. J., Kramer, A. D., Marlow, C., Settle, J. E., and Fowler, J. H. (2012). A 61-million-person experiment in social influence and political mobilization. *Nature*, 489(7415):295–298.

Brader, T. and Tucker, J. A. (2012). Following the party's lead: Party cues, policy opinion, and the power of partisanship in three multiparty systems. *Comparative Politics*, 44(4):403–403.

Brandts, J., Giritligil, A. E., and Weber, R. A. (2015). An experimental study of persuasion bias and social influence in networks. *European Economic Review*, 80:214–229.

Cox, G. W. (1987). Electoral equilibrium under alternative voting institutions. *American Journal of Political Science*, 31(1):82–108.

Deffuant, G., Amblard, F., Weisbuch, G., and Faure, T. (2002). How can extremism prevail? A study based on the relative agreement interaction model. *Journal of artificial societies and social simulation*, 5(4).

Deffuant, G., Neau, D., Amblard, F., and Weisbuch, G. (2000). Mixing beliefs among interacting agents. *Advances in Complex Systems*, 3(01n04):87–98.

Delli Gatti, D., Guilmi, C. D., Gaffeo, E., Giulioni, G., Gallegati, M., and Palestrini, A. (2005). A new approach to business fluctuations: Heterogeneous interacting agents, scaling laws and financial fragility. *Journal of Economic Behavior & Organization*, 56(4):489–512.

Dosi, G., Fagiolo, G., and Roventini, A. (2010). Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles. *Journal of Economic Dynamics and Control*, 34(9):1748–1767.

Dosi, G., Napoletano, M., Roventini, A., Stiglitz, J. E., and Treibich, T. (2020). Rational heuristics? expectations and behaviors in evolving economies with heterogeneous interacting agents. *Economic Inquiry*, 58(3):1487–1516.

Downs, A. (1957a). An economic theory of democracy. *Harper & Row.*

Downs, A. (1957b). An Economic Theory of Political Action in a Democracy. *Journal of Political Economy*, 65(2):135–150.

Druckman, J. N., Levendusky, M. S., and McLain, A. (2018). No need to watch: How the effects of partisan media can spread via interpersonal discussions. *American Journal of Political Science*, 62(1):99–112.

Druckman, J. N., Peterson, E., and Slothuus, R. (2013). How Elite Partisan Polarization Affects Public Opinion Formation. *American Political Science Review*, 107(1):57–79.

Duggan, J. and Fey, M. (2005). Electoral competition with policy-motivated candidates. *Games and Economic Behavior*, 51(2):490–522.

Enders, A. M. (2021). Issues versus affect: How do elite and mass polarization compare? *The Journal of Politics*, 83(4):1872–1877.

Esteban, J.-M. and Ray, D. (1994). On the Measurement of Polarization. *Econometrica*, 62(4):819.

Feddersen, T. J., Sened, I., and Wright, S. G. (1990). Rational voting and candidate entry under plurality rule. *American Journal of Political Science*, pages 1005–1016.

Fiorina, M. P. (1977). An outline for a model of party choice. *American Journal of Political Science*, 21(3):601–625.

Fiorina, M. P. and Abrams, S. J. (2008). Political polarization in the american public. *Annu. Rev. Polit. Sci.*, 11(1):563–588.

Flache, A. and Macy, M. W. (2011). Small worlds and cultural polarization. *The Journal of Mathematical Sociology*, 35(1-3):146–176.

Fowler, J. H. and Laver, M. (2008). A Tournament of Party Decision Rules. *Journal of Conflict Resolution*, 52(1):68–92.

Francia, P. L. (2018). Free media and twitter in the 2016 presidential election: The unconventional campaign of donald trump. *Social Science Computer Review*, 36(4):440–455.

French Jr., J. R. P. (1956). A formal theory of social power. *Psychological Review*, 63(3):181–194. Place: US Publisher: American Psychological Association.

Gerber, E. R. and Jackson, J. E. (1993). Endogenous preferences and the study of institutions. *American Political Science Review*, 87(3):639–656.

Gestefeld, M. and Lorenz, J. (2023). Calibrating an opinion dynamics model to empirical opinion distributions and transitions. *Journal of Artificial Societies and Social Simulation*, 26(4).

Glaeser, E. L., Sacerdote, B. I., and Scheinkman, J. A. (2003). The social multiplier. *Journal of the European Economic Association*, 1(2-3):345–353.

Grewenig, E., Lergetporer, P., Werner, K., and Woessmann, L. (2020). Do party positions affect the public's policy preferences? Experimental evidence on support for family policies. *Journal of Economic Behavior & Organization*, 179:523–543.

Hegselmann, R. and Krause, U. (2002). Opinion Dynamics and Bounded Confidence Models, Analysis and Simulation. *Journal of Artifical Societies and Social Simulation*, 5(3).

Hegselmann, R. and Krause, U. (2015). Opinion dynamics under the influence of radical groups, charismatic leaders, and other constant signals: A simple unifying model. *Networks & Heterogeneous Media*, 10(3):477–509.

Hinich, M. J. and Ordeshook, P. C. (1970). Plurality maximization vs vote maximization: A spatial analysis with variable participation. *American Political Science Review*, 64(3):772–791.

Hotelling, H. (1929). Stability in Competition. *The Economic Journal*, 39(153):41.

Hovland, C. I., Harvey, O., and Sherif, M. (1957). Assimilation and contrast effects in reactions to communication and attitude change. *The Journal of Abnormal and Social Psychology*, 55(2):244.

Jackson, J. E. (2003). A computational theory of electoral competition. *Computational Models in Political Economy*, pages 109–142.

Kollman, K., Miller, J. H., and Page, S. E. (1992). Adaptive Parties in Spatial Elections. *American Political Science Review*, 86(4):929–937.

Kollman, K., Miller, J. H., and Page, S. E. (1998). Political parties and electoral landscapes. *British Journal of Political Science*, 28(1):139–158.

Lackner, T., Fierro, L. E., and Mellacher, P. (2024). Opinion dynamics meet agent-based climate economics: An integrated analysis of carbon taxation. *LEM Working Paper Series*, 2024/11.

Laver, M. (2005). Policy and the Dynamics of Political Competition. *American Political Science Review*, 99(2):263–281.

Laver, M. (2011). Why Vote-seeking Parties May Make Voters Miserable. *Irish Political Studies*, 26(4):489–500.

Laver, M. and Schilperoord, M. (2007). Spatial models of political competition with endogenous political parties. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 362(1485):1711–1721.

Laver, M. and Sergenti, E. (2012). *Party competition: An agent-based model.* Princeton studies in complexity. Princeton Univ. Press, Princeton, NJ.

Lehrer, R. and Schumacher, G. (2018). Governator vs. Hunter and Aggregator: A simulation of party competition with vote-seeking and office-seeking rules. *PLoS ONE*, 13(2):e0191649.

Ma, L., Krishnan, R., and Montgomery, A. L. (2015). Latent homophily or social influence? an empirical analysis of purchase within a social network. *Management Science*, 61(2):454–473.

Marchi, S. D. (1999). Adaptive models and electoral instability. *Journal of Theoretical Politics*, 11(3):393–419.

Markus, G. B. and Converse, P. E. (1979). A dynamic simultaneous equation model of electoral choice. *American Political Science Review*, 73(4):1055–1070.

Mäs, M., Flache, A., and Helbing, D. (2010). Individualization as driving force of clustering phenomena in humans. *PLoS computational biology*, 6(10):e1000959.

Maurin, E. and Moschion, J. (2009). The social multiplier and labor market participation of mothers. *American Economic Journal: Applied Economics*, 1(1):251–272.

Mellacher, P. (2023). The impact of corona populism: Empirical evidence from Austria and theory. *Journal of Economic Behavior & Organization*, 209:113–140.

Muchnik, L., Aral, S., and Taylor, S. J. (2013). Social influence bias: A randomized experiment. *Science*, 341(6146):647–651.

Osborne, M. J. (1993). Candidate positioning and entry in a political competition. *Games and Economic Behavior*, 5(1):133–151.

Osborne, M. J. (1995). Spatial models of political competition under plurality rule: A survey of some explanations of the number of candidates and the positions they take. *Canadian Journal of Economics*, pages 261–301.

Osborne, M. J. and Slivinski, A. (1996). A model of political competition with citizen-candidates. *The Quarterly Journal of Economics*, 111(1):65–96.

Sadiraj, V., Tuinstra, J., and Winden, F. v. (2006). A computational electoral competition model with social clustering and endogenous interest groups as information brokers. *Public Choice*, 129(1):169–187.

Sanders, D., Clarke, H. D., Stewart, M. C., and Whiteley, P. (2008). The endogeneity of preferences in spatial models: Evidence from the 2005 british election study. *Journal of Elections, Public Opinion and Parties*, 18(4):413–431.

Scheller, S. (2019). The Strategic Use of Fear Appeals in Political Communication. *Political Communication*, 36(4):586–608.

Slothuus, R. (2010). When Can Political Parties Lead Public Opinion? Evidence from a Natural Experiment. *Political Communication*, 27(2):158–177.

Ward, H. (2006). Preference shaping and party competition: Some empirical and theoretical arguments. In *Democratic politics and party competition*, pages 267–292. Routledge.

A Fragmentation in y

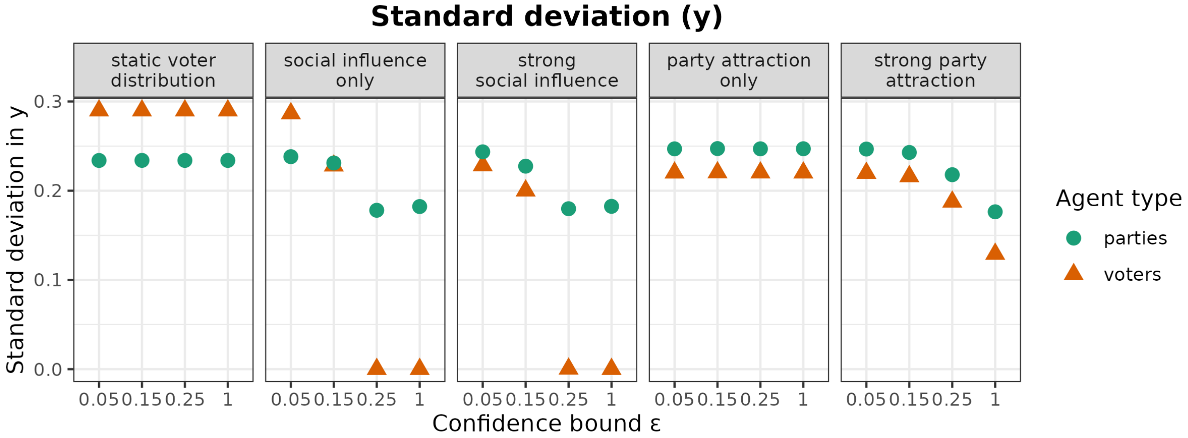

Figure 9: Fragmentation of parties and voters as measured in the standard deviation of their ideological positions in the y-dimension.

B Data tables

		Aggregator			Hunter		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.3897	(0.3867 - 0.3927)	0.3870	0.4005	(0.3974 - 0.4035)	0.3920
	0.15	0.3901	(0.3871 - 0.3932)	0.3876	0.3991	(0.396 - 0.4021)	0.3920
	0.25	0.3893	(0.3863 - 0.3923)	0.3874	0.4005	(0.3974 - 0.4036)	0.3928
	1	0.3893	(0.3863 - 0.3924)	0.3874	0.4000	(0.3969 - 0.4031)	0.3924
social influence only	0.05	0.3742	(0.371 - 0.3773)	0.3961	0.3453	(0.3423 - 0.3483)	0.3851
	0.15	0.4308	(0.4275 - 0.4341)	0.4197	0.2818	(0.2789 - 0.2848)	0.3756
	0.25	0.4797	(0.477 - 0.4825)	0.3477	0.0281	(0.0268 - 0.0294)	0.1644
	1	0.4797	(0.477 - 0.4824)	0.3479	0.0262	(0.0249 - 0.0274)	0.1588
strong social influence	0.05	0.2948	(0.2918 - 0.2978)	0.3838	0.2770	(0.2741 - 0.2799)	0.3721
	0.15	0.4453	(0.442 - 0.4485)	0.4187	0.2166	(0.2139 - 0.2193)	0.3405
	0.25	0.4989	(0.496 - 0.5017)	0.3618	0.0254	(0.0242 - 0.0266)	0.1571
	1	0.5038	(0.5009 - 0.5066)	0.3651	0.0240	(0.0228 - 0.0252)	0.1528
party attraction only	0.05	0.2338	(0.231 - 0.2365)	0.3514	0.1494	(0.147 - 0.1517)	0.2994
	0.15	0.2349	(0.2322 - 0.2377)	0.3521	0.1507	(0.1483 - 0.153)	0.3006
	0.25	0.2338	(0.2311 - 0.2366)	0.3513	0.1508	(0.1485 - 0.1532)	0.3010
	1	0.2340	(0.2312 - 0.2367)	0.3515	0.1504	(0.1481 - 0.1528)	0.3007
strong party attraction	0.05	0.2356	(0.2329 - 0.2384)	0.3523	0.1449	(0.1426 - 0.1472)	0.2977
	0.15	0.2801	(0.2772 - 0.2831)	0.3777	0.1215	(0.1194 - 0.1237)	0.2766
	0.25	0.3186	(0.3155 - 0.3218)	0.3992	0.0999	(0.0979 - 0.1019)	0.2562
	1	0.3325	(0.3294 - 0.3357)	0.4002	0.1105	(0.1084 - 0.1126)	0.2688

Table 7: Winning probability (aggregators and hunters)

		Predator			Sticker		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.0733	(0.0713 - 0.0753)	0.2541	0.1349	(0.1328 - 0.137)	0.2689
	0.15	0.0737	(0.0717 - 0.0757)	0.2550	0.1355	(0.1334 - 0.1376)	0.2703
	0.25	0.0731	(0.0712 - 0.0751)	0.2540	0.1354	(0.1333 - 0.1376)	0.2696
	1	0.0736	(0.0716 - 0.0756)	0.2548	0.1354	(0.1333 - 0.1376)	0.2698
social influence only	0.05	0.1094	(0.107 - 0.1118)	0.3050	0.1695	(0.1672 - 0.1718)	0.2951
	0.15	0.1466	(0.1439 - 0.1493)	0.3445	0.1391	(0.1369 - 0.1413)	0.2762
	0.25	0.4784	(0.4757 - 0.4811)	0.3461	0.0121	(0.0113 - 0.013)	0.1046
	1	0.4783	(0.4756 - 0.4811)	0.3463	0.0142	(0.0133 - 0.0151)	0.1138
strong social influence	0.05	0.2308	(0.2276 - 0.234)	0.4092	0.1959	(0.1933 - 0.1984)	0.3213
	0.15	0.1860	(0.1831 - 0.189)	0.3758	0.1505	(0.1483 - 0.1528)	0.2879
	0.25	0.4594	(0.4566 - 0.4622)	0.3583	0.0148	(0.0138 - 0.0157)	0.1168
	1	0.4543	(0.4515 - 0.4571)	0.3609	0.0164	(0.0154 - 0.0173)	0.1228
party attraction only	0.05	0.3867	(0.3831 - 0.3902)	0.4554	0.2285	(0.2258 - 0.2312)	0.3438
	0.15	0.3845	(0.3809 - 0.388)	0.4551	0.2283	(0.2256 - 0.231)	0.3436
	0.25	0.3858	(0.3822 - 0.3894)	0.4554	0.2280	(0.2253 - 0.2307)	0.3434
	1	0.3858	(0.3823 - 0.3894)	0.4552	0.2282	(0.2255 - 0.2309)	0.3435
strong party attraction	0.05	0.3944	(0.3909 - 0.398)	0.4566	0.2234	(0.2207 - 0.2261)	0.3429
	0.15	0.3912	(0.3876 - 0.3948)	0.4600	0.2055	(0.2029 - 0.2081)	0.3354
	0.25	0.4098	(0.4062 - 0.4135)	0.4649	0.1700	(0.1675 - 0.1725)	0.3156
	1	0.4367	(0.4331 - 0.4404)	0.4686	0.1187	(0.1165 - 0.1208)	0.2747

Table 8: Winning probability (predators and stickers)

		Aggregator			Hunter		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.1397	(0.1389 - 0.1404)	0.0991	0.1433	(0.1424 - 0.1441)	0.1117
	0.15	0.1396	(0.1388 - 0.1404)	0.0989	0.1432	(0.1423 - 0.1441)	0.1117
	0.25	0.1395	(0.1387 - 0.1403)	0.0988	0.1432	(0.1423 - 0.1441)	0.1117
	1	0.1395	(0.1388 - 0.1403)	0.0989	0.1433	(0.1424 - 0.1441)	0.1118
social influence only	0.05	0.1405	(0.1398 - 0.1413)	0.1010	0.1356	(0.1347 - 0.1365)	0.1102
	0.15	0.1855	(0.1846 - 0.1864)	0.1199	0.1114	(0.1104 - 0.1124)	0.1270
	0.25	0.2282	(0.2266 - 0.2299)	0.2078	0.0141	(0.0134 - 0.0149)	0.0951
	1	0.2282	(0.2266 - 0.2299)	0.2078	0.0129	(0.0122 - 0.0136)	0.0898
strong social influence	0.05	0.1341	(0.1333 - 0.1349)	0.1014	0.1074	(0.1067 - 0.1082)	0.0963
	0.15	0.1912	(0.1902 - 0.1922)	0.1238	0.0843	(0.0834 - 0.0851)	0.1101
	0.25	0.2306	(0.229 - 0.2322)	0.2077	0.0126	(0.0119 - 0.0133)	0.0893
	1	0.2313	(0.2297 - 0.2329)	0.2078	0.0117	(0.011 - 0.0124)	0.0858
party attraction only	0.05	0.1196	(0.1188 - 0.1204)	0.0971	0.0852	(0.0846 - 0.0859)	0.0879
	0.15	0.1198	(0.119 - 0.1205)	0.0973	0.0854	(0.0847 - 0.086)	0.0881
	0.25	0.1196	(0.1188 - 0.1203)	0.0970	0.0852	(0.0845 - 0.0859)	0.0880
	1	0.1197	(0.1189 - 0.1205)	0.0972	0.0851	(0.0844 - 0.0858)	0.0880
strong party attraction	0.05	0.1197	(0.1189 - 0.1204)	0.0969	0.0840	(0.0834 - 0.0847)	0.0881
	0.15	0.1290	(0.1282 - 0.1298)	0.1005	0.0763	(0.0756 - 0.077)	0.0876
	0.25	0.1376	(0.1367 - 0.1385)	0.1094	0.0727	(0.072 - 0.0733)	0.0854
	1	0.1414	(0.1405 - 0.1423)	0.1147	0.0789	(0.0782 - 0.0796)	0.0863

Table 9: Average vote shares (aggregators and hunters)

		Predator			Sticker		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.0666	(0.0659 - 0.0673)	0.0886	0.0994	(0.0987 - 0.1001)	0.0862
	0.15	0.0665	(0.0658 - 0.0672)	0.0884	0.0995	(0.0989 - 0.1002)	0.0863
	0.25	0.0665	(0.0658 - 0.0672)	0.0884	0.0996	(0.0989 - 0.1003)	0.0863
	1	0.0665	(0.0659 - 0.0672)	0.0885	0.0996	(0.0989 - 0.1002)	0.0863
social influence only	0.05	0.0713	(0.0705 - 0.072)	0.0955	0.1034	(0.1027 - 0.104)	0.0874
	0.15	0.0931	(0.092 - 0.0941)	0.1303	0.0666	(0.0658 - 0.0674)	0.0979
	0.25	0.2272	(0.2256 - 0.2288)	0.2050	0.0058	(0.0053 - 0.0062)	0.0573
	1	0.2269	(0.2253 - 0.2285)	0.2041	0.0067	(0.0062 - 0.0072)	0.0617
strong social influence	0.05	0.0999	(0.099 - 0.1009)	0.1219	0.1103	(0.1096 - 0.111)	0.0914
	0.15	0.1089	(0.1078 - 0.1101)	0.1510	0.0711	(0.0703 - 0.0719)	0.1010
	0.25	0.2240	(0.2224 - 0.2256)	0.2037	0.0074	(0.0069 - 0.0079)	0.0642
	1	0.2227	(0.2212 - 0.2243)	0.2022	0.0083	(0.0078 - 0.0089)	0.0685
party attraction only	0.05	0.1254	(0.1243 - 0.1264)	0.1331	0.1142	(0.1134 - 0.1149)	0.0946
	0.15	0.1249	(0.1239 - 0.126)	0.1328	0.1141	(0.1134 - 0.1149)	0.0943
	0.25	0.1252	(0.1242 - 0.1263)	0.1329	0.1142	(0.1134 - 0.1149)	0.0944
	1	0.1254	(0.1243 - 0.1264)	0.1334	0.1141	(0.1134 - 0.1149)	0.0943
strong party attraction	0.05	0.1278	(0.1268 - 0.1289)	0.1343	0.1126	(0.1119 - 0.1134)	0.0941
	0.15	0.1291	(0.1281 - 0.1302)	0.1373	0.1096	(0.1089 - 0.1103)	0.0941
	0.25	0.1326	(0.1315 - 0.1337)	0.1398	0.1034	(0.1026 - 0.1041)	0.0924
	1	0.1399	(0.1387 - 0.141)	0.1445	0.0917	(0.091 - 0.0924)	0.0898

Table 10: Average vote shares (predators and stickers)

		Voters			Parties		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.2892	(0.2892 - 0.2893)	0.0084	0.2345	(0.2339 - 0.235)	0.0677
	0.15	0.2892	(0.2892 - 0.2893)	0.0084	0.2345	(0.234 - 0.2351)	0.0677
	0.25	0.2892	(0.2892 - 0.2893)	0.0084	0.2346	(0.234 - 0.2351)	0.0676
	1	0.2892	(0.2892 - 0.2893)	0.0084	0.2347	(0.2341 - 0.2352)	0.0676
social influence only	0.05	0.2860	(0.286 - 0.2861)	0.0086	0.2388	(0.2383 - 0.2394)	0.0675
	0.15	0.2247	(0.2245 - 0.2249)	0.0243	0.2299	(0.2294 - 0.2305)	0.0676
	0.25	0.0000	(0 - 0)	0.0000	0.1794	(0.1788 - 0.18)	0.0766
	1	0.0000	(0 - 0)	0.0000	0.1839	(0.1833 - 0.1845)	0.0782
strong social influence	0.05	0.2285	(0.228 - 0.229)	0.0618	0.2443	(0.2437 - 0.2448)	0.0695
	0.15	0.2003	(0.1998 - 0.2009)	0.0659	0.2283	(0.2277 - 0.2288)	0.0701
	0.25	0.0003	(0.0002 - 0.0003)	0.0080	0.1816	(0.181 - 0.1822)	0.0779
	1	0.0000	(0 - 0.0001)	0.0010	0.1842	(0.1836 - 0.1848)	0.0785
party attraction only	0.05	0.2208	(0.2202 - 0.2213)	0.0697	0.2480	(0.2474 - 0.2485)	0.0747
	0.15	0.2208	(0.2203 - 0.2214)	0.0697	0.2481	(0.2475 - 0.2486)	0.0746
	0.25	0.2208	(0.2203 - 0.2214)	0.0697	0.2479	(0.2474 - 0.2485)	0.0748
	1	0.2207	(0.2202 - 0.2213)	0.0697	0.2479	(0.2473 - 0.2485)	0.0746
strong party attraction	0.05	0.2204	(0.2198 - 0.2209)	0.0698	0.2477	(0.2471 - 0.2483)	0.0748
	0.15	0.2166	(0.2161 - 0.2172)	0.0704	0.2439	(0.2433 - 0.2445)	0.0754
	0.25	0.1895	(0.1889 - 0.1902)	0.0811	0.2199	(0.2192 - 0.2205)	0.0858
	1	0.1301	(0.1296 - 0.1307)	0.0713	0.1774	(0.1767 - 0.1781)	0.0878

Table 11: Standard deviation in x

		Voters			Parties		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.2898	(0.2897 - 0.2899)	0.0097	0.2339	(0.2334 - 0.2345)	0.0676
	0.15	0.2898	(0.2897 - 0.2899)	0.0097	0.2340	(0.2335 - 0.2345)	0.0677
	0.25	0.2898	(0.2897 - 0.2899)	0.0097	0.2340	(0.2334 - 0.2345)	0.0678
	1	0.2898	(0.2897 - 0.2899)	0.0097	0.2340	(0.2334 - 0.2345)	0.0678
social influence only	0.05	0.2866	(0.2865 - 0.2867)	0.0100	0.2382	(0.2376 - 0.2387)	0.0677
	0.15	0.2281	(0.2279 - 0.2282)	0.0236	0.2311	(0.2306 - 0.2316)	0.0676
	0.25	0.0000	(0 - 0)	0.0000	0.1781	(0.1775 - 0.1787)	0.0770
	1	0.0000	(0 - 0)	0.0000	0.1823	(0.1817 - 0.1829)	0.0783
strong social influence	0.05	0.2283	(0.2278 - 0.2288)	0.0629	0.2436	(0.243 - 0.2441)	0.0702
	0.15	0.2000	(0.1995 - 0.2006)	0.0676	0.2275	(0.227 - 0.2281)	0.0707
	0.25	0.0004	(0.0003 - 0.0004)	0.0094	0.1798	(0.1792 - 0.1804)	0.0781
	1	0.0000	(0 - 0)	0.0009	0.1825	(0.1819 - 0.1831)	0.0789
party attraction only	0.05	0.2202	(0.2196 - 0.2207)	0.0702	0.2469	(0.2464 - 0.2475)	0.0748
	0.15	0.2204	(0.2199 - 0.221)	0.0703	0.2472	(0.2466 - 0.2478)	0.0749
	0.25	0.2203	(0.2197 - 0.2208)	0.0702	0.2470	(0.2464 - 0.2476)	0.0748
	1	0.2202	(0.2197 - 0.2208)	0.0702	0.2471	(0.2465 - 0.2476)	0.0747
strong party attraction	0.05	0.2198	(0.2192 - 0.2203)	0.0702	0.2467	(0.2461 - 0.2473)	0.0747
	0.15	0.2161	(0.2155 - 0.2166)	0.0709	0.2429	(0.2423 - 0.2435)	0.0755
	0.25	0.1876	(0.187 - 0.1882)	0.0812	0.2180	(0.2173 - 0.2186)	0.0856
	1	0.1291	(0.1285 - 0.1297)	0.0713	0.1764	(0.1757 - 0.1771)	0.0878

Table 12: Standard deviation in y

		Voters			Parties		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.0001	(0.0001 - 0.0001)	0.0000	0.0238	(0.0237 - 0.0239)	0.0122
	0.15	0.0001	(0.0001 - 0.0001)	0.0000	0.0238	(0.0237 - 0.0239)	0.0122
	0.25	0.0001	(0.0001 - 0.0001)	0.0000	0.0238	(0.0237 - 0.0239)	0.0122
	1	0.0001	(0.0001 - 0.0001)	0.0000	0.0238	(0.0237 - 0.0239)	0.0122
social influence only	0.05	0.0030	(0.0029 - 0.003)	0.0005	0.0252	(0.0251 - 0.0253)	0.0126
	0.15	0.0497	(0.0496 - 0.0498)	0.0082	0.0401	(0.04 - 0.0403)	0.0177
	0.25	0.0000	(0 - 0)	0.0000	0.0000	(0 - 0)	0.0000
	1	0.0000	(0 - 0)	0.0000	0.0000	(0 - 0)	0.0000
strong social influence	0.05	0.0329	(0.0328 - 0.033)	0.0174	0.0283	(0.0282 - 0.0285)	0.0167
	0.15	0.0527	(0.0526 - 0.0528)	0.0171	0.0405	(0.0404 - 0.0407)	0.0203
	0.25	0.0002	(0.0001 - 0.0002)	0.0039	0.0003	(0.0003 - 0.0004)	0.0058
	1	0.0000	(0 - 0)	0.0004	0.0002	(0.0002 - 0.0003)	0.0047
party attraction only	0.05	0.0402	(0.04 - 0.0404)	0.0205	0.0263	(0.0262 - 0.0264)	0.0183
	0.15	0.0403	(0.0401 - 0.0404)	0.0206	0.0264	(0.0262 - 0.0265)	0.0183
	0.25	0.0402	(0.04 - 0.0403)	0.0205	0.0263	(0.0261 - 0.0264)	0.0182
	1	0.0402	(0.0401 - 0.0404)	0.0206	0.0263	(0.0262 - 0.0264)	0.0182
strong party attraction	0.05	0.0405	(0.0403 - 0.0406)	0.0208	0.0262	(0.0261 - 0.0264)	0.0182
	0.15	0.0406	(0.0404 - 0.0408)	0.0207	0.0268	(0.0267 - 0.027)	0.0183
	0.25	0.0354	(0.0353 - 0.0356)	0.0220	0.0242	(0.0241 - 0.0244)	0.0190
	1	0.0229	(0.0228 - 0.0231)	0.0177	0.0169	(0.0168 - 0.0171)	0.0160

Table 13: Polarization

		Weighted eccentricity			Mean eccentricity		
Scenario	ϵ	Mean	95% CI	SD	Mean	95% CI	SD
static voter distribution	0.05	0.0313	(0.0312 - 0.0313)	0.0063	0.0298	(0.0297 - 0.0298)	0.0071
	0.15	0.0313	(0.0312 - 0.0313)	0.0063	0.0298	(0.0297 - 0.0298)	0.0071
	0.25	0.0313	(0.0312 - 0.0313)	0.0063	0.0298	(0.0297 - 0.0298)	0.0071
	1	0.0313	(0.0312 - 0.0313)	0.0063	0.0298	(0.0297 - 0.0298)	0.0071
social influence only	0.05	0.0317	(0.0317 - 0.0318)	0.0061	0.0305	(0.0304 - 0.0305)	0.0071
	0.15	0.0295	(0.0295 - 0.0296)	0.0060	0.0311	(0.031 - 0.0311)	0.0062
	0.25	0.0016	(0.0015 - 0.0016)	0.0056	0.0185	(0.0185 - 0.0186)	0.0087
	1	0.0017	(0.0017 - 0.0018)	0.0060	0.0190	(0.019 - 0.0191)	0.0090
strong social influence	0.05	0.0306	(0.0305 - 0.0306)	0.0075	0.0307	(0.0306 - 0.0307)	0.0079
	0.15	0.0274	(0.0274 - 0.0275)	0.0080	0.0294	(0.0293 - 0.0294)	0.0078
	0.25	0.0002	(0.0002 - 0.0003)	0.0020	0.0181	(0.018 - 0.0182)	0.0086
	1	0.0002	(0.0002 - 0.0002)	0.0017	0.0184	(0.0183 - 0.0185)	0.0088
party attraction only	0.05	0.0288	(0.0287 - 0.0289)	0.0086	0.0307	(0.0307 - 0.0308)	0.0084
	0.15	0.0288	(0.0288 - 0.0289)	0.0086	0.0308	(0.0307 - 0.0308)	0.0084
	0.25	0.0288	(0.0287 - 0.0289)	0.0086	0.0307	(0.0307 - 0.0308)	0.0084
	1	0.0288	(0.0287 - 0.0289)	0.0086	0.0307	(0.0307 - 0.0308)	0.0084
strong party attraction	0.05	0.0287	(0.0287 - 0.0288)	0.0086	0.0307	(0.0306 - 0.0308)	0.0084
	0.15	0.0283	(0.0282 - 0.0284)	0.0086	0.0302	(0.0302 - 0.0303)	0.0085
	0.25	0.0246	(0.0245 - 0.0246)	0.0098	0.0267	(0.0266 - 0.0267)	0.0096
	1	0.0157	(0.0156 - 0.0158)	0.0089	0.0188	(0.0187 - 0.0188)	0.0093

Table 14: Eccentricity

Scenario	ϵ	Mean	95% CI	SD
static voter distribution	0.05	0.0509	(0.0506 - 0.0512)	0.0421
	0.15	0.0509	(0.0506 - 0.0512)	0.0423
	0.25	0.0509	(0.0506 - 0.0512)	0.0423
	1	0.0509	(0.0506 - 0.0512)	0.0422
social influence only	0.05	0.0494	(0.0491 - 0.0497)	0.0409
	0.15	0.0272	(0.0269 - 0.0275)	0.0370
	0.25	0.0034	(0.0032 - 0.0035)	0.0201
	1	0.0039	(0.0037 - 0.0041)	0.0213
strong social influence	0.05	0.0013	(0.0013 - 0.0013)	0.0018
	0.15	0.0010	(0.001 - 0.001)	0.0023
	0.25	0.0002	(0.0002 - 0.0003)	0.0035
	1	0.0003	(0.0002 - 0.0003)	0.0042
party attraction only	0.05	0.0002	(0.0002 - 0.0002)	0.0003
	0.15	0.0002	(0.0002 - 0.0002)	0.0003
	0.25	0.0002	(0.0002 - 0.0002)	0.0003
	1	0.0002	(0.0002 - 0.0002)	0.0003
strong party attraction	0.05	0.0002	(0.0001 - 0.0002)	0.0003
	0.15	0.0001	(0.0001 - 0.0001)	0.0003
	0.25	0.0002	(0.0002 - 0.0002)	0.0003
	1	0.0005	(0.0005 - 0.0006)	0.0005

Table 15: Voter misery