Political election: ABM perspective

Max Bongers, Ruben Bonneur, Bence Gergely, Laurens Prast, and Amal Salman
University of Amsterdam

Abstract

Voting systems have been an essential tool in democratizing governments around the world. They have been studied extensively to show that differences between them can affect an election's outcome as well as significantly influence voting behavior. Here we develop an agent-based model to study the effects of voting systems on an election's outcome, considering individuals' social networks, identities, and the candidates' campaign strategies. Using different experimental setups while running the simulations, our results indicate that voting systems result in significantly different election outcomes, with better performances depending on the scenario in which they were applied. A sensitivity analysis concluded that many of the model's parameters are sensitive, and their differences are outlined. Future work can add layers of complexities to the agent-based model, for example, by adding more identity parameters to voters or giving agents the option to be strategic voters.

1 Introduction

Political voting systems have been a primary tool in democratizing governments (Ayanleye, 2013). However, many of these systems are vulnerable to manipulation, intentional or accidental, resulting in outcomes that do not represent the preferences of the majority (Faliszewski et al., 2009). That is why extensive research has been conducted in the last centuries to find the best voting system for particular contexts and to identify the pitfalls and benefits of each system. Most of the evidence provided to support claims about a certain system depends on data analysis of previously-held elections and surveys. While this gives much insight into trends and patterns that occur when using a particular system, it does not provide good explanations of the workings of each system nor the reasons why these trends occur. Agent-based modelling can be a very useful tool to offer some of these much-needed explanations, as it is invaluable in studying complex social processes such as elections (Qiu & Phang, 2020; Singh et al., 2011). This is because it models every individual in the society, candidates and voters alike, considers the interactions between them and the influences they have on one another and identifies which parameters result in certain emergent phenomena (Qiu & Phang, 2020; Singh et al., 2011).

This report discusses the model we built to answer the question: What is the effect of different voting systems on an election's outcome? We specifically consider the three voting systems plurality, instant-runoff—also called alternative vote—, and approval voting. We built a social network of candidates and voters and considered certain factors that might influence voting behaviour, such as candidates' political campaigns, voters' identities, and the influences of a person's social connections.

In the following, Section 2 will discuss sociopolitical theories, their relevance to our study, and the details of the three chosen voting systems. Section 3 describes the model we have built, following the ODD+D protocol (Müller et al., 2013). Finally, the simulations' setup and results are discussed, and future work is suggested.

2 Theoretical Background

Social choice theory studies "the aggregation of individual preferences toward a collective choice" (Brandt et al., 2016). Voting rules and the phenomena arising thereof are thus an essential part of these studies. There are many voting systems (also called electoral systems), and while some are more applicable in some contexts than others, it is their effect on the result that makes the choice between them crucial, especially in a political election. A recent study was able to sort the voting systems popularly used in democracies into three main categories: majoritarian, proportional, and mixed systems (Bormann & Golder, 2013).

Majoritarian systems dictate that the candidate who receives the most votes wins. Depending on the system, that can be by reaching the absolute majority of the votes or receiving more votes than any other candidate. Proportional systems are where multiple candidates win (e.g., members of a parliament), usually by reaching a certain "quota" number of votes. Finally, mixed systems carry the elections using partly majoritarian and partly proportional systems, dependently or independently. This report focuses on majoritarian systems where one candidate wins, specifically the following three systems: plurality, instant-runoff, and approval voting.

Plurality voting is where each voter votes for only one candidate and the candidate with the majority of votes (not necessarily absolute majority) wins. In instant-runoff voting, voters rank all candidates in order of their preference, then the voter's first preferences are counted ("Electoral

Systems", n.d.). If a candidate receives the absolute majority of votes they win, otherwise, the candidate with the least votes is eliminated, and the second preferences of the voters who had them as their first preference are now counted for the remaining candidates. This process is repeated until a candidate reaches the absolute majority or only one candidate remains. In approval voting, the voters can vote for any number of candidates, and the candidate with the majority of votes wins (not necessarily absolute majority)—here approving all candidates is discarding your vote since it will not affect any candidate differently than another (Brams & Fishburn, 1978).

Different voting systems can have significant long-term effects on government effectiveness, violence and conflict, and economic growth, among other things (Menocal, 2011; Taagepera & Qvortrup, 2012) which is why it is important to study the differences between them. They also affect voting behaviour, notably voter turnout and whether voters are true to their preferences or use strategies to affect the election outcome. Proportional voting systems are more inclusive to small parties because only a small percentage of votes is needed to guarantee a seat, increasing voters' comfort in being truthful while voting for the candidates they most align with (Taagepera & Qvortrup, 2012). These systems, therefore, invoke little strategic voting, and for the same reasons, generate more turnout (Noseck, 2018). In majoritarian voting systems, on the other hand, it is usually the case that two or a maximum of three candidates have a reasonable chance of winning, making voters feel like they are wasting their votes voting for less popular candidates, invoking strategic voting, decreasing turnout, and overall encouraging a two-party system (Taagepera & Qvortrup, 2012).

3 The Model

3.1 Overview

3.1.1 Purpose

The purpose of the model is to evaluate the effects of the type of election systems on the outcome of the election. The model is used to understand the underlying mechanisms and emergent properties of voting systems from a scientific research perspective.

3.1.2 Entities, state variables and scales

The agents of the model consist of voters and parties. Each voter and party has a political position that is given by coordinates on a 2-dimensional political spectrum representing the left/right and the authoritarianism/liberalism ideologies. The political position of voters can be influenced, the first method is by other voters. Voters have connections to other voters in a Barabási–Albert type network. Voters can then move towards the political position of voters that are connected to them. These connections are formed based on the difference of political position between two voters and the number of connections of the voters. Physical distance is not considered in this model. This is influenced by the adaption rate parameter of the voters and the strength of the connection to the other voter. The strength of a new connection is based on the political distance between the two agents. Lower adaption rates and strength of connections will result in a lower influence on the other voter. Voters also have an age parameter, this parameter increases over time and this, in turn, decreases the adaption rate of voters. Voters after a certain age are removed from the population and replaced by a new voter. Parties are also assigned a fixed campaigning strategy. These strategies consist of targeting closely aligned voters, targeting voters on the edges of party influence and randomly targeting voters. The model runs for 200 iterations, after the last iteration, the winner of the election is decided.

3.1.3 Process overview and scheduling

For the model first, the agents and parties are initialised. Then during each cycle, the political position of each agent is updated dependent on the influence of parties and connected voters. Every agent is pulled towards other agents it is connected to in the network, how much it's pulled towards each of them depends on the strength of the connections. Furthermore, the connections of the agents are updated by removing connections and updating connections. Connections are removed randomly but are added partly randomly and partly based on a logistic function with the political distance between the voters as input. Voters with more connections have an increased chance of forming additional connections. The age of all voters is increased every iterations, and voters at the maximum age are removed from the model and replaced by new voters with the minimum age. Additionally, all voters adaption rate linearly decreases over time with added noise. Every 4 years elections are held. During each election, each voter will only vote for the party that is closed to its political position or in the case of the approval voting system, not at all. Different types of elections are held using the same initial conditions using various initial party setups. All elections are held during a single cycle of the model.

3.2 Design Concepts

3.2.1 Theoretical and Empirical Background

Since our research aims to answer the question of how different voting systems affect the outcome of an election, we need to consider what other factors affect voting behaviour. A person's social network has a big influence on their political preferences, and the closer the connection between two people the higher the influence, e.g. members sharing a household, especially married couples, have a high tendency of sharing political views (Huckfeldt & Sprague, 1991; Nickerson, 2008; Richey, 2008). We modelled the social network after the Barabási–Albert network, which is a scale-free network (a network with a degree distribution that follows a power law), with preferential attachment, where a node/agent has a higher chance of forming a new connection the higher the number of connections they already have (Fronczak, 2018). This results in a network with a small number of hubs, commonly used to represent social networks, more prevalent on web and social media platforms (Barabási & Albert, 1999; Fronczak, 2018). Although it is not the most accurate representation of a real, physical social network, it is sufficient for our purposes (Broido & Clauset, 2019). The agents' decision model is based on the assumption that voters value both political dimensions evenly and that only the political position of the party in relation to their own influences their voting decision. The decision model also assumes that the voters have bounded rationality and are therefore unable to vote strategically. Voters are also assumed to be perfectly rational and thus be able to perfectly assess their own political position and the political position of all parties. Another very influential factor on voters' choice is the voter's identity. Gender, race, age, religion, etc. all have strong effects on one's political ideology (Bassi et al., 2011; Taagepera & Qvortrup, 2012). To keep the model simple and not impose biases we included only age as an identity factor affecting voters' choice. We model the voter's adaptability to change as one that decreases with age, which is a hypothesis supported by previous political studies (Alwin & Krosnick, 1991) and also by studies about general changes in attitude with increasing age (Krosnick & Alwin, 1989).

Finally, political campaigns also have big effects on voting behaviour, each trying to gravitate as many voters as possible towards them. Targeted campaigns as usually more successful in that, but more randomly spread campaigns, for example through media, also have a big effect (Johann et al., 2018). To keep the model simple we only consider campaign that target agents close to the party. The voting methods are based on real-world-tested voting methods. Data for some of these voting methods was limited thus no heuristics are used to implement the voting systems. A social model was used to test the effect of different voting systems as the model in relatively easy to implement but is able to give relatively realistic results.

3.2.2 Individual Decision-Making

Voters can make 2 decisions: changing their political position and deciding to vote for a party. Voters can change their political position based on the adaption rate and the strength of their connections. The connection strength is multiplied by the difference vector between the political positions of the voters. Then a check is performed if the voter will update its political position. If the adaption rate is above a uniformly randomly generated number an agent will change its political position based on the combination vector of all its connected agents. This change in political opinion can be explained by individuals changing their ideas based on the ideas of the people they communicate with. This can be in 2 ways: Adapting into the voter's social environment and by being convinced by members of the social network of their political positions. The strength of the connections, in this case, is how close the voter is to the connected voter. And the increased influence can be explained by the fact that individuals you are closer to are able to affect you more strongly. The adaption rate can be seen as a metric describing how respective the voter is to outside influence. This is calculated randomly in order to take into account the importance of certain political arguments to the voter or the importance of politics in social connections. Agent voting decisions are dependent on the voting system. In the first part, the post and the run-off system agents will vote based on the party that has the closest proximity in political position. In the approval voting system, agents will vote on all parties within the specified voting range. Voters outside all parties voting ranges will not vote in the election. The basic reasoning for this decision making is that the parties with the closer political distance appeal to the voter mostly.

3.2.3 Learning

There is no learning mechanism in the model based on the outcome of elections. The adaption rate of voters will however decrease over time. This results in a lower chance for the voter to update its political position. Thus resulting in a more rigid political position as the voter ages.

3.2.4 Interaction

Voters in the model are directly influenced by parties and voters. Voters are also indirectly influenced by other voters. Voters are only directly influenced by connected voters and if they are part of the strategy of a party. All voters are also influenced indirectly by other voters in the network as these are able to influence the political position of their connected voters. From these constraints, an emergent property of the model will emerge. Firstly the parties influencing the voters will cause voters to cluster around the political position of parties. Then if parties are far enough apart the separate social clusters of voters will appear. These social clusters effectively prevent agents from significantly changing their political position as most of their influence will point them towards the same position.

3.2.5 Heterogeneity

The agents are heterogeneous in several ways. The adaption rate of all agents is a uniformly distributed random value. The age of the voters can also vary thus a proportion of the population is replaced each year. The change in adaption rate also is different between voters. Lastly, the connections of the agents are heterogeneous, some will have a lot more than others.

3.2.6 Stochasticity

The randomness is used in various instances of the model. During initiation, the political coordinates of each voter and political party are randomly generated from a uniform distribution. The age and adoption rate of each voter is also uniformly randomly generated. After this, the connections between the voters is generated randomly. Which connections are formed is partly random and the strength of the connections is also partially random. During each cycle, connections are removed at random. Updating the political position of each voter is also random.

3.2.7 Observation

The effectiveness of the election type is tested by comparing the overall satisfaction level of the chosen party. For this, the metric of the average political distance of the voter to the winning party is used. Multiple emergent properties arise from the model. The network formed different types of clustering: Single large clusters and multiple sparsely connected clusters. The model also showed emergent properties of elections such as the spoiler effect and the center squeeze effect.

3.3 Details

3.3.1 Implementation Details

The Model is made in python using the MESA and the networkX package. (code can be found on our GitHub page)[1]

3.3.2 Initialisation

The model is initialised with 3 or political parties with different political positions and differing ing strategies. Different fixed political poisons of the party are tested. The 100 voters are initialised with different political positions, adaption rates, age and connections to other voters. The model is run for 200 iterations.

3.3.3 Submodels

The political spectrum consisted of a continuous grid of 200 by 200. Voters political position was randomly generated from a uniform distribution. The ages of the participants was a uniformly randomly generated number from 18 to 79. The adaption rate, which ranged from 0 to 1, was generated semi-randomly, based on the agent's age, Each year noise was added to the increase in adaption rate. The social network was built using multiple decisions. All Voters have their connections updated during each time step. The social network was initialised as a Barabási–Albert graph, with each connection having strength m of 0.05. Then a random voter is picked which is a

[1] https://github.com/mrpogge/ABM_political_election

possible candidate for a new connection. The Fermi-Dirac distribution is used to form a new connection, and is given by the formula below, where D is the political distance with and alpha and beta are parameters that determine how fast the function changes. (Talaga & Nowak, 2019)

$$\frac{1}{1 + \exp(\alpha(D_p - \beta))} + c$$

Where c is a parameter that scales with the number of current connections an agent has. The new connection is then formed problematically based on the outcome of the distribution. During each iteration a connection is removed with a probability of 40%. The political position of each agent is updated through connections by moving towards each connected voter with a probability of their adaption rate times 100. The voters then move towards each of their neighbours based on the strength of the connections. Political parties will randomly pick 10 agents within a radius of 35 and move them 10% closer to the party. In the Plurality voting system, voters vote for the party that has the smallest political distance. In instant runoff voting, agents vote in increasing order of political distance. In the approval voting system, agents vote for all parties within a radius of 80 of their political position.

4 Results

4.1 Sensitivity Analysis

For the Sensitivity Analysis (SA) we performed a Sobol analysis for 5 variables that govern the behaviour of the agents in the system. Namely, α and b values of the Fermi-Dirac distribution, pull of the connections (the influence of social connections), pull of parties (the influence of political parties) and the reach radius of the parties, where they can influence voters. We fixed every other parameter of the model, moreover, we fixed the parties to be equidistant from each other. We created 64 samples for the variables with 30 replication each, and we ran the models for 100 iterations.

The results showed that the reach radius had the highest first-order sensitivity, whereas the total order sensitivity was higher than zero for every variable (see. Appendix). This result suggests that the selected variables are sensitive and in complex higher-order interactions with each other. And the reach radius has the highest sensitivity which means, that the bigger the population a party can target, the more influence they have on the results of the election.

4.2 Voting systems in different scenarios

The model was run for multiple different party scenario and in each scenario the winner was determined for every voting system. In Figures 1,2 and 3 the results of 1 election of the even spacing, spoiler effect and center-squeeze scenario's are shown. In these figures, the plurality voting system is shown by the coloured smaller dots which represent the voters that belong to a certain party. The approval voting system is shown by the ovals. All the voters that are in an oval vote on that party. The instant runoff voting system works like the plurality voting system, but until one party gets half of all the votes a party is removed.

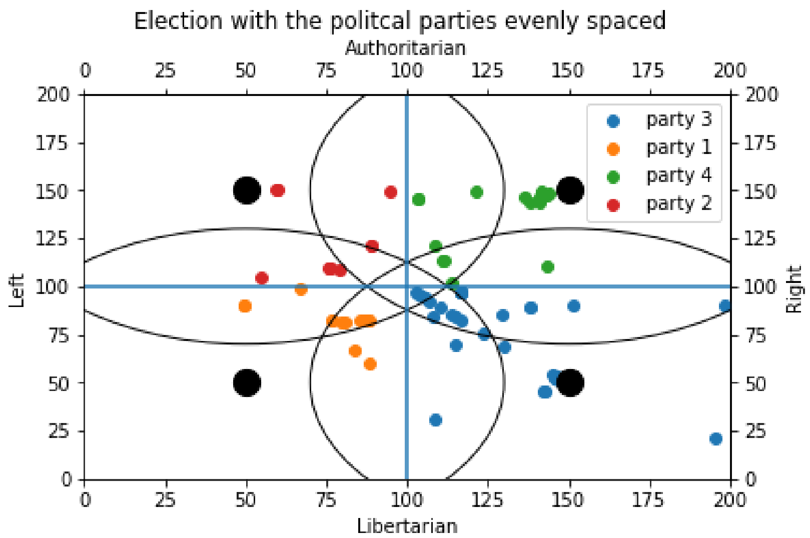

Figure 1

In even spacing, all parties have equally large distances to each other and an equally large distance to the center.

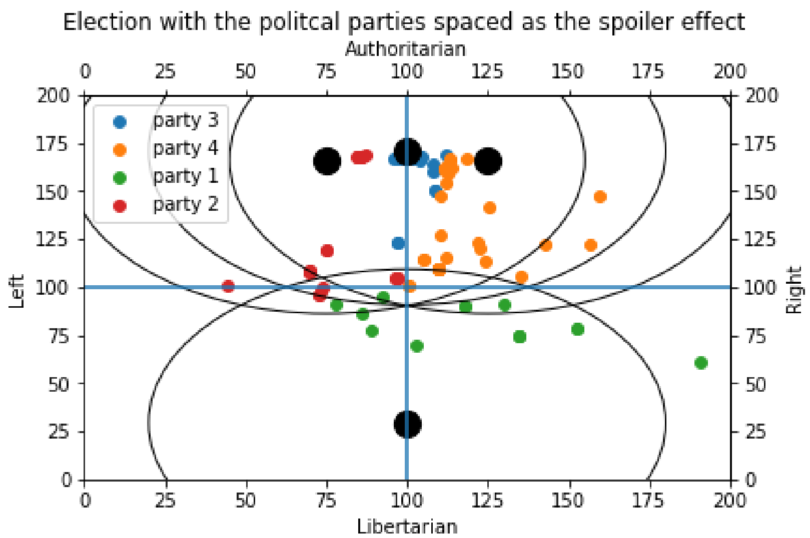

Figure 2

In this scenario, 3 parties are placed on one side of the spectrum and one party is placed on the opposite side of the spectrum. It is called the spoiler effect because in theory most of the time one of the three parties should be most likely to win, but under the plurality voting system, their votes get divided and therefore the election is spoiled for all three parties. The solution for this problem is supposed to be the instant runoff voting system in theory.

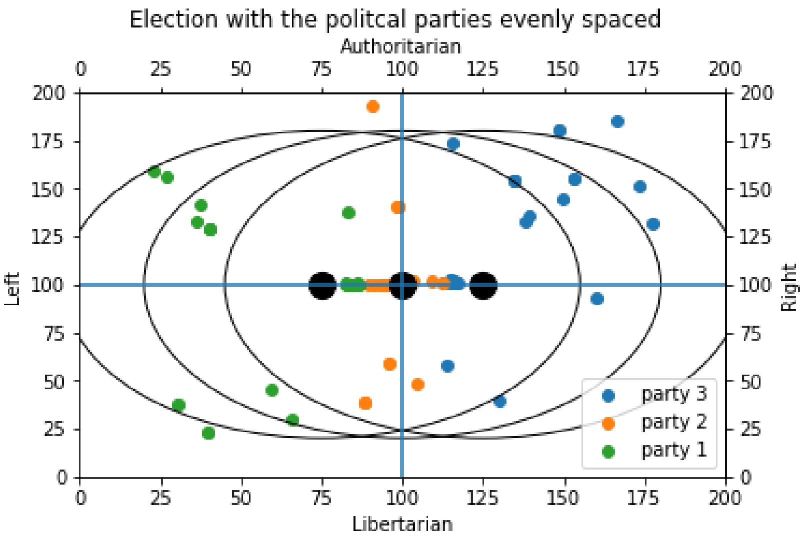

Figure 3

Two parties are on the opposite sides of the spectrum with one party in the middle. In this scenario, it can happen that the middle party loses in the instant runoff election while it is more appealing to more voters than one of the parties on the opposite side of the spectrum. The solution for this problem is supposed to be the approval voting system in theory.

The total distance of all the voters from the winning party was measured. This is to measure how content all the voters were with the winning party. In the ideal situation, the winning party has the least amount of distance from all voters. In addition, random placement of the parties was added, the placements were different in every simulation. The results for the four different spacing's of the political parties are shown in table 1.

Voting System	Even spacing	Spoiler effect	Center-squeeze	Random
Plurality	6860	7278	3406	6152
Instant runoff	6881	6944	3262	6142
Approval	6819	6929	3365	6144

Table 1

The parameters that where used during this simulations can be seen in appendix 6.2. For all four different spacings of the politcal parties 1000 simulations were done.

The data was not normally distributed, for this reason, a Kolmogorov-Smirnov test was done on the data, to test for significance. For the random party placement, no difference was found, which can also be seen in table 1, there are only very marginal differences in the mean distances. For the even spacing, there was also no significant difference found between any of the voting systems. In the spoiler effect the instant run off and approval voting system was found to be significantly different ($p < 0.05$) from the plurality voting system and in the center-squeeze placement all the voting systems were found to be significantly different from each other ($p < 0.05$). All of the specific significance values can be found in appendix 3.

4.3 Network

After the 200 iterations the resulting network was also analysed, mainly for their clustering; which is done by measuring the network's modularity (Clauset et al., 2004). An example of a resulting network can be seen in figure 4.

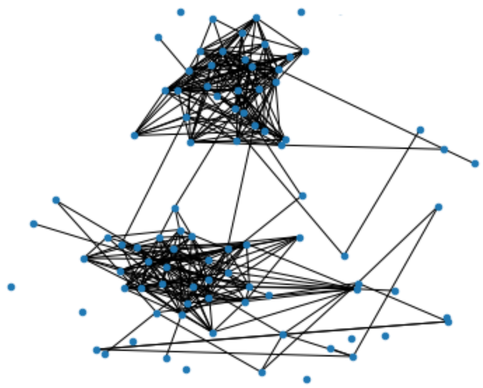

Figure 4

Example of resulting network after 200 iterations. Modularity = 0.59, center squeeze party placement

As can be seen there are two very distinct clusters that have formed, these can be seen as analogous to 'echo chambers' in the real world, where agents receive little information from outside sources, and receive most of it from agents in their group. This is a self-reinforcing phenomena, at least in our model, agents who are closer together form connections, which in turn pulls them closer together, which in turn makes them form connections etc. It needs to be noted that such a clean two-cluster network is definitely not always the case, sometimes it's more akin to a random network. However when measuring the modularity of every resulting network and averaging them it can be seen that for most party placements, the modularity is considerably higher than what the network was initialised with (a Barabasi-Albert network):

	Baseline	Even spacing	Spoiler effect	Center-squeeze	Random
Modularities	0.281	0.428	0.4395	0.217	0.541

Table 2

Average modularities of the networks and party placements. The baseline is the average modularity of the networks the model was initialised with.

As can be seen the only modularity that is lower than the baseline is the center-squeeze placement, this makes sense since these are all placed very close together, meaning the agents will cluster together in the middle, resulting in one big cluster in the network, which means a lower modularity. Every other party placement has a considerably higher modularity than the baseline meaning that there are more subclusters than the model started out with.

5 Discussion & Conclusion

With the Kolmogorov-Smirnov test, it was shown that for the even spacing scenario all the results are not statistically significantly different, so for this scenario, the voters would be equally content with the election result of all the voting systems. With the Kolmogorov-Smirnov test, it was tested that the plurality voting system is significantly different compared to the instant runoff voting system and the approval voting system, while the other two voting systems are not significantly different from each other. The result of this test means that for the spoiler effect scenario the plurality voting system has the largest distance to all voters as seen in table 1, which means that the plurality voting system would be the worst voting system for this scenario. The difference between the instant runoff voting system and the approval voting system are not statistically significant therefore for this scenario it would not matter which one would be chosen. The results for the three voting systems in the center-squeeze scenario are all significantly different. This was again tested with the Kolmogorov-Smirnov test. Therefore for this scenario, the instant runoff voting system would give the minimal distance to all voters in this model as seen in table 1.

To conclude, voters could benefit from different voting systems when the political parties are spaced in different ways over the political spectrum. For these three scenarios, it is seen that the plurality voting system performs the worst when the difference in distance to all voters between the voting systems in the different scenarios is significantly different.

The model produced 'echo-chambers' in the social network, although not directly related to our results, it is still interesting to see such a phenomena emerge with the relatively simple rules that are implemented in the model. The emergence of these clustering are somewhat akin to real political views, which are getting increasingly polarising (Prior, 2013), although perhaps not to such an extent as seen here in the resulting networks.

Future work that can be done to expand this model is by implementing a voting system where parties need to form coalitions to get the majority. Also, more identity parameters can be added to agents such as gender and race. To simulate strategic voting a form of inductive reasoning of the agents can be added.

Appendix

Appendix 1: First order and Total order Sensitvity results

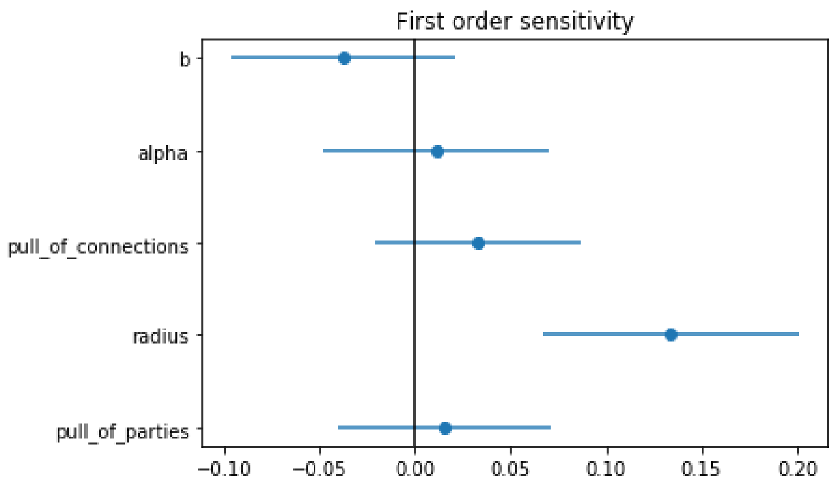

Figure 5

First-order results of the Sobol Sensitivity analysis

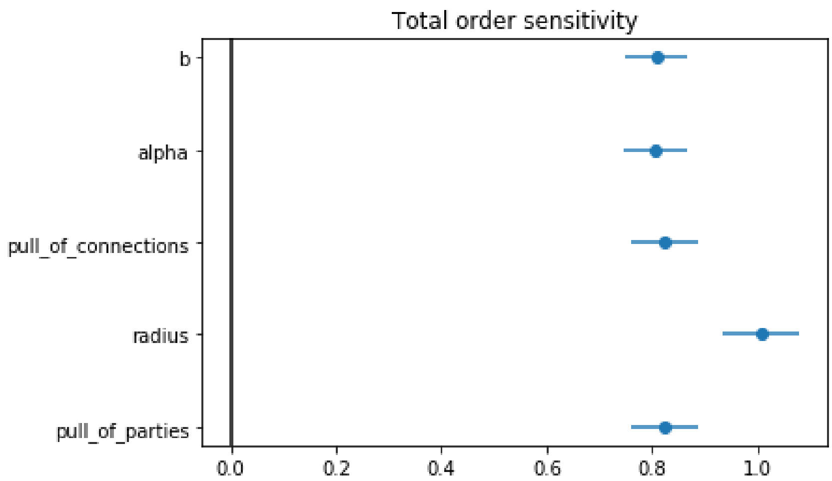

Figure 6

Total order results of the Sobol Sensitivity analysis

Appendix 2: Parameter used during the simulations

The exact parameters that were used for our simulations were as following:
initial parties: 3 or 4, depending on the scenario
height width: 200
num steps: 200

num voter: 100
min age: 18
max age: 79
campaign years: 4
campaign type: ’close’
campaign resources: 0.1
pull of parties: 0.1
radius: 35
barabasi: 0.04
pull of connections: 0.1
p remove connection: 0.4
random chance add: 0
alpha: 0.5
b: 0.1
approval radius: 80

Coordinates of the party positions for the different scenarios:
Equal spacing square: [(50, 50),(50, 150),(150, 50),(150,150)]
Center squeeze spacing: [(75,100),(100,100),(125,100)]
Spoiler effect spacing: [(100, 29.29),(75, 166.14),(100, 170.71),(125,166.14)]
Random spacing: generate random numbers for all the coordinates of all the parties

Appendix 3

	Plural	Run off	Approval
Plural	x	7.7e-10	0.0017
Run off	7.7e-10	x	7.3e-5
Approval	0.0017	7.3e-5	x

Table 3

Significances of center-squeeze party placement

	Plural	Run off	Approval
Plural	x	0.999	0.999
Run off	0.999	x	0.999
Approval	0.999	0.999	x

Table 4

Significances of random party placement

	Plural	Run off	Approval
Plural	x	8.5e-19	3.3e-24
Run off	8.5e-19	x	0.76
Approval	3.3e-24	0.76	x

Table 5

Significances of spoiler effect party placement

	Plural	Run off	Approval
Plural	x	0.722	0.313
Run off	0.722	x	0.054
Approval	0.313	0.054	x

Table 6

Significances of spoiler equal spacing party placement

References

Alwin, D. F., & Krosnick, J. A. (1991). Aging, Cohorts, and the Stability of Sociopolitical Orientations Over the Life Span [Publisher: The University of Chicago Press]. *American Journal of Sociology*, *97*(1), 169–195. https://doi.org/10.1086/229744

Ayanleye, O. (2013). Elections as a tool of democratization in africa. *Oida international journal of sustainable development*, *6*(06), 143–156.

Barabási, A.-L., & Albert, R. (1999). Emergence of scaling in random networks. *science*, *286*(5439), 509–512.

Bassi, A., Morton, R. B., & Williams, K. C. (2011). The Effects of Identities, Incentives, and Information on Voting [Publisher: [The University of Chicago Press, Southern Political Science Association]]. *The Journal of Politics*, *73*(2), 558–571. https://doi.org/10.1017/s0022381611000284

Bormann, N.-C., & Golder, M. (2013). Democratic Electoral Systems around the world, 1946–2011 [Publisher: Pergamon]. *Electoral Studies*, *32*(2), 360–369. https://doi.org/10.1016/j.electstud.2013.01.005

Brams, S. J., & Fishburn, P. C. (1978). Approval Voting [Publisher: Cambridge University Press]. *American Political Science Review*, *72*(3), 831–847. https://doi.org/10.2307/1955105

Brandt, F., Conitzer, V., Endriss, U., Lang, J., & Procaccia, A. D. (2016). Introduction to Computational Social Choice. In A. D. Procaccia, F. Brandt, J. Lang, U. Endriss, & V. Conitzer (Eds.), *Handbook of Computational Social Choice* (pp. 1–20). Cambridge University Press. https://doi.org/10.1017/CBO9781107446984.002

Broido, A. D., & Clauset, A. (2019). Scale-free networks are rare. *Nature communications*, *10*(1), 1–10.

Clauset, A., Newman, M. E., & Moore, C. (2004). Finding community structure in very large networks. *Physical review E*, *70*(6), 066111.

Electoral Systems. (n.d.). Retrieved January 27, 2022, from https://aceproject.org/ace-en/topics/es/esd/esd01/esd01d/default

Faliszewski, P., Hemaspaandra, E., Hemaspaandra, L. A., & Rothe, J. (2009). A richer understanding of the complexity of election systems. *Fundamental problems in computing* (pp. 375–406). Springer.

Fronczak, P. (2018). Scale-free nature of social networks. In R. Alhajj & J. Rokne (Eds.), *Encyclopedia of social network analysis and mining* (pp. 2300–2309). Springer New York. https://doi.org/10.1007/978-1-4939-7131-2_248

Huckfeldt, R., & Sprague, J. (1991). Discussant effects on vote choice: Intimacy, structure, and interdependence. *The journal of politics*, *53*(1), 122–158.

Johann, D., Königslöw, K. K.-v., Kritzinger, S., & Thomas, K. (2018). Intra-campaign changes in voting preferences: The impact of media and party communication. *Political communication*, *35*(2), 261–286.

Krosnick, J. A., & Alwin, D. F. (1989). Aging and susceptibility to attitude change. *Journal of Personality and Social Psychology*, *57*(3), 416–425. https://doi.org/10.1037//0022-3514.57.3.416

Menocal, A. R. (2011). *Why electoral systems matter: An analysis of their incentives and effects on key areas of governance* (tech. rep.). Overseas Development Institute (ODI). London. Retrieved January 18, 2022, from https://odi.org/en/publications/why-electoral-systems-matter-an-analysis-of-their-incentives-and-effects-on-key-areas-of-governance/

Müller, B., Bohn, F., Dreßler, G., Groeneveld, J., Klassert, C., Martin, R., Schlüter, M., Schulze, J., Weise, H., & Schwarz, N. (2013). Describing human decisions in agent-based models–odd+ d, an extension of the odd protocol. *Environmental Modelling & Software*, *48*, 37–48. https://doi.org/10.1016/j.envsoft.2013.06.003

Nickerson, D. W. (2008). Is voting contagious? evidence from two field experiments. *American political Science review*, *102*(1), 49–57.

Noseck, J. (2018). The Consequences of Electoral System Change for Voter Turnout in Established Democracies. Retrieved January 18, 2022, from https://ecpr.eu/Events/Event/PaperDetails/42114

Prior, M. (2013). Media and political polarization. *Annual Review of Political Science*, *16*, 101–127.

Qiu, L., & Phang, R. (2020). Agent-based modeling in political decision making. *Oxford research encyclopedia of politics*. http://dx.doi.org/10.1093/acrefore/9780190228637.013.913

Richey, S. (2008). The autoregressive influence of social network political knowledge on voting behaviour. *British Journal of Political Science*, *38*(3), 527–542.

Singh, V. K., Basak, S., & Modanwal, N. (2011). Agent based modeling of individual voting preferences with social influence. *International Conference on Computational Science, Engineering and Information Technology*, 542–552.

Taagepera, R., & Qvortrup, M. (2012). Who Gets What, When, How – Through Which Electoral System? *European Political Science*, *11*(2), 244–258. https://doi.org/10.1057/eps.2011.35

Talaga, S., & Nowak, A. (2019). Homophily as a process generating social networks: Insights from social distance attachment model. *arXiv preprint arXiv:1907.07055*.