

An agent-based model of democratic diffusion

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Abstract

The idea that democracy is contagious, that democracy diffuses across the world map, is now well established among policy makers and political scientists alike. The few theoretical explanations of this phenomenon focus exclusively on the political elites. This article presents a theoretical model and accompanying computer simulation that explains the diffusion of democracy on the basis of the dynamics of public opinion and mass revolutions. On the basis of the literatures on preference falsification, cascading revolutions and the social judgment theory an agent-based simulation is developed and studied. The results demonstrate that the diffusion of attitudes, in combination with a cascading model of revolutions, can indeed theoretically explain the spatial clustering of democracy and the temporal waves of democratization.

1 Introduction

In empirical work, it has been repeatedly established that autocratic countries that are surrounded by democracies have a higher chance of democratizing themselves than coun-

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tries that do not (Gleditsch and Ward 2006). This holds even when there are sufficient controls for common explanations of democratic transitions, such as the levels of economic development or the strength of civil society (Doorenspleet 2001). While this has been observed empirically in various studies, few offer a theoretical explanation beyond the idea that democracy might be seen as a technological innovation (Modelski and Perry 1991, 2002) or that the geographical clustering might be an artifact of cooperation between democracies in a hostile international environment (Cederman and Gleditsch 2004). This paper provides an alternative explanation, based on existing models of opinion formation and the translation of these attitudes into protesting behavior, that explains both the geographical (Gleditsch 2002) and the temporal (Huntington 1991) clustering that we observe. The diffusion of democracy is thus explained using a model of individual, mass level behavior. It should be emphasized that this article is not an attempt to falsify other explanations of democratic diffusion, but rather to demonstrate that a model based on individual attitudes towards democracy *can* explain the observed levels of geographic and temporal clustering. In current explanations of democratic diffusion, an elite based perspective is generally taken by default.¹

With the ousting of Saddam Hussein by the Coalition Forces, an important argument made in public statements was that with the removal of this feared dictator, a beacon of democracy could be established in the Middle East. This beacon would enlighten the Arabs and teach the whole region the joys of democratic life. Arabs would read about the developments in their neighboring country, they would see the images on the news, and they would start to understand how democracy could work in an Arab country. It would make them see that it is possible in their country too, and it would emancipate them and make them oppose their own autocratic regimes. In other words, establishing one democracy in the Middle East would surely lead to a contagious effect, spreading the presence of democracy in the Middle East.

The democracy in Iraq may well be too young to determine whether or not such a contagious effect will take place. While initial developments seem to show as much

¹This is possibly related to the fact that most of the democratic diffusion literature is embedded in the international relations rather than the democratization literature, while the former is generally concerned with states as unitary actors.

resistance to this strengthened Western influence in the Middle East as enthusiasm for more democracy, it is clear that for policy makers this idea of a diffusion of democracy is a very real thing. Especially since the collapse of the Soviet Union and the sudden wave of democratization in Eastern Europe, it has become common wisdom to consider democratization a contagious phenomenon.

Not only policy makers have this vision of a spreading of democracy, also empirical research in political science and international relations shows that the regional context matters in democratization. When controlling for other explanations of democratization, most importantly the level of economic development, the fact that geographically contiguous countries are democratic is still a significant factor in whether or not a country democratizes. Countries surrounded by democracies have a higher chance of democratizing; whole regions follow each other in their democratization in short periods of time (Gleditsch and Ward 2006), most visibly in Eastern Europe and at times in Latin America; and the democratization of the world occurs in temporal waves (Huntington 1991) - all indicators of a process of diffusion or contagion of democracy. Although empirical studies have repeatedly shown that these patterns exist, there is a significant lack of theoretical models explaining the diffusion of democracy, with the notable exceptions of Cederman and Gleditsch (2004) and Gleditsch and Ward (2006).

Geographical patterns of democratization are patterns at a macro-level. It is the democratization of countries as a whole, in their international region, that shows these patterns. Democratization, however, to state the obvious, is in the end a micro-level process. It is individuals that alter constitutions, decide to organize elections, decide to protest against their regime, or decide whether or not to suppress the opposition. A proper understanding of the macro-level patterns of democratization cannot do without a proper understanding of these individual behavioral patterns. This linkage of macro- and micro-level patterns has always been notoriously difficult in the social sciences and by far most studies of social behavior focus on either of the two levels. One attempt to deal with this linkage has been the relatively recent introduction of agent-based modeling in the social sciences. Although early applications exist (see, for example, Schelling (1978)), the real popularity of agent-based modeling has only come about with the recent increase in easily

accessible computing power (Axelrod 1997; Cederman 1997, 2002).

In this article an agent-based model of the diffusion of democracy is presented where the focus is indeed on this linkage between individual behavior and global geographical dynamics. The central actors or agents of the model are thus individual citizens of an imaginary set of countries. On the basis of existing models of public opinion dynamics and the role of private and public opinions in popular protests, a model is developed that, while keeping regime transitions not caused by popular protest exogenous, describes the relation between these transitions, their effect on public opinion in neighboring areas, and subsequent popular regime transitions.

A number of different theoretical models has been used as the foundation of this article. The first is the concept of cascading revolutions as introduced by Granovetter (1973) and further developed in the theories of the spiral of silence (Noelle-Neumann 1993) and preference falsification (Kuran 1995). In these models, the public expression of individual preferences is contingent on the strength of this attitude and the extent to which other individuals express similar attitudes. The stronger the preference, the fewer other public expressions are needed before an individual decides to make his or her own preferences public. Since strengths of attitudes among individuals differ, small changes in this distribution can thus have a cascading effect where more and more individuals publicly express their opinions.

The social judgment theory of persuasion (Sherif and Hovland 1961; Jager and Amblard 2004) suggests that in communication between individuals, the extent to which an argument is persuasive depends on the distance between one's attitude and the received message. When one is communicating with someone who is close in ideological outlook, one is more likely to be convinced and become even closer, while communication with someone very different often confirms those differences and makes one distance oneself even more. Agent-based models of this theory suggest that under certain conditions, this can lead to a persistent diversity of attitudes (Jager and Amblard 2004).

It will be demonstrated that a combination of these two models with democracy promotion by democratic states results in a model of democratic diffusion that can explain the temporal waves and geographical clustering we observe in empirical data (Huntington

1991; Starr 1991). Although the empirical validation of the model is beyond the scope of this article, this clearly suggests that one cannot ignore the dynamics of public opinion when studying the international diffusion of democracy. Some limited policy implications will be presented in the conclusion.

2 Democracy and democratic diffusion

A spirit of democratization seems to have gone around through much of Eastern Europe over the past few years. Several successful and failed attempts at 'stunning elections' (Markoff 1996: 113-4) took place successively in Serbia, Georgia, Ukraine, Belarus, Kyrgyzstan, and Kazakhstan. Albeit with democratic constitutions, these countries had or have leaders solidly in power supported by non-democratic means. Opposition parties of various strengths tried to win the elections by a majority substantial enough to make it impossible for the current leader to stay in power. The successes in some cases became examples for other countries in the region. Representatives from opposition groups in one country became active as mobilizers and advisors to democracy groups in other countries. The various attempts to revert to a democratic order after autocrats tried to control the elections cannot be seen in isolation and are closely connected to each other.

These elections also show the difficulty of properly defining the concept of democracy. Officially, these countries already had democratic constitutions, where political leaders were elected through elections and where citizens were protected from government coercion. In practice, however, these countries showed instances of electoral fraud, coercion, limitations on the formation of opposition parties, harassment of members of the opposition, and so forth. The border between a democratic and a non-democratic state can thus be difficult to determine exactly and a precise definition of the concept of democracy is often crucial (Bell and Staeheli 2001). The remainder of this article will use the concept of democracy in line with Schumpeter (1976) and Dahl (1971). This implies a definition of democracy that is procedural in nature, ignoring for example democratic unfairness due to material inequality among citizens. For a deep analysis of the political system of a particular democratic country this concept might well be too shallow, but for a more global

analysis of patterns of democratization, the concept provides a clear distinction between democratic and non-democratic countries, without getting bogged down in philosophical questions on the quality of democracy.

Dahl's concept of democracy distinguishes two different, orthogonal dimensions of democracy. Only countries that score high on both dimensions are considered full democracies, or, as Dahl prefers, polyarchies. The first dimension is that of participation. For a country to be considered a democracy, a large majority of citizens has to be allowed to participate in the election of leaders. A high level of participation does not guarantee democracy, however. In the Soviet Union, turnout at elections was very high, but the choice on the ballot paper irrelevant. Except for an 'against all' option (Oversloot, van Holsteyn and van der Berg 2002), one could only select members or sympathizers of the communist party. The second dimension of democracy is therefor the level of competition among the elites. Only countries with true competition among the members of the elite, and high levels of participation in elections can be considered democracies in the modern, representative sense of the word.

That brings us to the core concept of this research, the diffusion of democracy. When observing a map of the world, in which countries are colored according to whether they have a democratic regime or not, one can see clear clusters of countries. Large areas where most countries are democratic and large areas where they are not. Furthermore, when one would look at this map over time, observing the changes in regimes, one would again find clear regional patterns. Whole areas democratize at the same time, or neighboring countries experience collapses of democratic regimes one after the other. Latin America forms the most striking example with countries virtually simultaneously democratizing, reverting to dictatorship, and democratizing again during the past century (Markoff 1996).¹ In more statistical terms: "Since 1815, the probability that a randomly chosen country will be a democracy is about 0.75 if the majority of its neighbors are democracies, but only 0.14 if the majority of its neighbors are non-democracies" (Gleditsch and Ward 2006: 916). This observation has been confirmed repeatedly in quantitative empirical research (Starr 1991; Ward et al. 1996; O'Loughlin et al. 1998; Ward and Gleditsch 1998; Gleditsch and Ward 1997, 2000, 2006; Gleditsch 2002; Doorenspleet 2001).

After the publication of *The Third Wave of Democracy* by Huntington (1991), a lot of attention in the literature on democratization has been paid to the waves of democracy he describes. These waves reflect periods during the past two centuries in which processes of democratization were particularly prevalent, followed by periods of democratic breakdown (Huntington 1991; Markoff 1996; Doorenspleet 2001). When plotting the number of democracies over time, or the average levels of participation or competition, these waves are indeed clearly visible.² We could thus make a distinction between spatial (or geographic) clustering, where countries close to each other are likely to have similar political regimes; temporal clustering, where countries in the same time period affect each other globally in their regime transitions; and spatio-temporal clustering, where various countries within a region make transitions in the same direction within a relatively short time period.

Various explanations are possible that could explain some or all of these types of clustering. Among these explanations are the more military-strategic oriented domino theory, which has been applied to the diffusion of communist (*The President's News Conference of April 7, 1954* 1954), Islamic (Staten 1996) and democratic (Starr 1991) regimes alike, or simply the democratization as a result of occupation, like in Germany and Japan after the Second World War. Democracy has been presented as a technological innovation, imitated by more and more countries (Modelski and Perry 1991, 2002; Starr 1991). Conditionality for aid or membership of international organization has been an important factor for democratization and its geographical clustering (Kopstein and Reilly 2000; Levitsky and Way 2005; Gleditsch and Ward 2006). Or the clustering can be explained as a spurious effect, where clustered domestic variables explain the level of democracy. For example, economic development has often been suggested as an explanation of democracy (Lipset 1959, 1960; Cutright 1963; Burkhart and Lewis-Beck 1994), while economic development itself spills over to neighboring countries (Hak 1993).

In the to my knowledge only other existing agent-based model of the diffusion of democracy, Cederman and Gleditsch (2004) model the clustering as an effect of the higher chances of survival for clustered democracies in a hostile environment. Countries that democratize in an area surrounded by non-democracies have a high chance of succumbing

in subsequent wars, while democracies that are contingent to each other help each other militarily and help each other survive. Clustered democracies create zones of peace and do not fight each other, while sharing resources to defend against neighboring regimes. This idea of a democratic peace, of an almost natural law that democracies do not fight each other,³ has been established by Immanuel Kant and has later been described by Karl Deutsch and others (Cederman 1997; Gleditsch 2002).

Without making the claim that only one explanation can be valid, this article will concentrate on the explanation that focuses on the diffusion of ideas. The basic assumption is that popular opinion towards a political regime matters. That regimes where there is a very strong opposition among the population are unlikely to survive. Regimes are likely to try to convince their citizens that their regime is the right approach, and less democratically minded politicians⁴ will try to limit the information supply that undermines their authority, but once the publicly visible level of discontent rises above a certain threshold, the regime will not be able to stay in power. The second underlying assumption of the model is the idea that attitudes towards the regime change as a result of communication among individuals. If the likelihood of communication between citizens of different countries is larger for countries that are adjacent or proximate to each other, one would expect to see the spatial and spatio-temporal clustering of democracy as described above.

Most definitions of diffusion focus on the spread of ideas between individuals or groups or people. Welsh, for example, defines diffusion as “the process by which institutions, practices, behaviors, or norms are transmitted between individuals and/or between social systems” (Welsh 1984: 3). Rogers defines diffusion (of innovation) as “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers 1995: 5). More specifically within the literature on the diffusion of democratic regimes, Kopstein and Reilly state that “[d]iffusion, after all, is a complex process that involves information flows, networks of communication, hierarchies of influence, and receptivity to change.” (Kopstein and Reilly 2000: 12). Although abstracting from some details of Kopstein and Reilly’s definition, the concept of diffusion in this article is similarly concerned with the spread of ideas between individuals, with varying degrees of receptivity and affected by geographical realities.

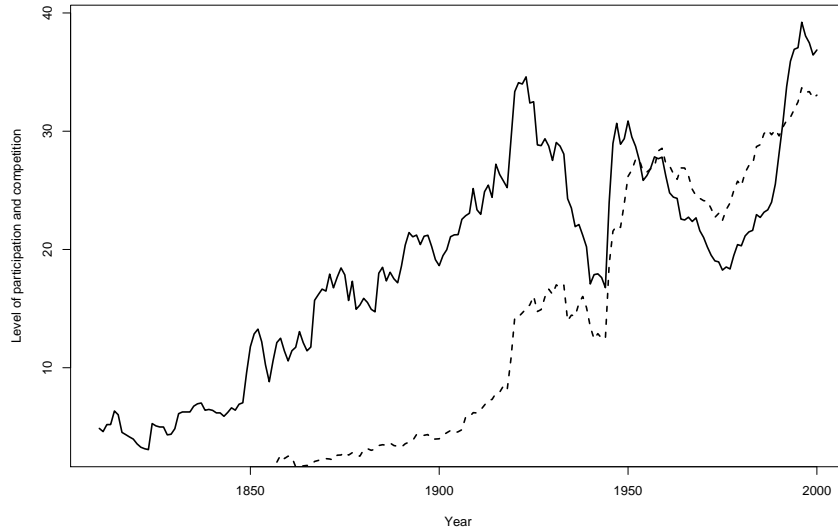


Figure 1: Vanhanen’s Participation and Competition Scores, 1816-2000. The solid line represents the average level of competition for all countries, over time. The dashed line represents the equivalent score for the level of participation.

Vanhanen (1997) developed an extensive dataset measuring the level of democracy in countries worldwide over a period of nearly two centuries. The measures he uses explicitly take into account the two separate dimensions as distinguished by Dahl. Vanhanen measures the dimensions of participation and competition by taking the turnout at national elections and the number of seats allocated to all but the largest party, respectively.⁵ Figure 1 shows the two different measures over the previous two centuries. The temporal clustering as identified by Huntington (1991), is clearly visible.

To demonstrate the spatial clustering one could simply observe maps as described above, were it not that it is difficult to distinguish random clustering from a significantly clustered pattern. To make this possible a statistical measure originally developed in time series analysis, Moran’s I, can be used.⁶ Moran’s I is positive when units are more often adjacent to similar units than one would expect under a random pattern and negative when units tend to be adjacent to dissimilar units. A high level of Moran’s I is thus what we would consider significant spatial clustering. Figure 2 clearly demonstrates the presence of such clustering during most of the previous two centuries.

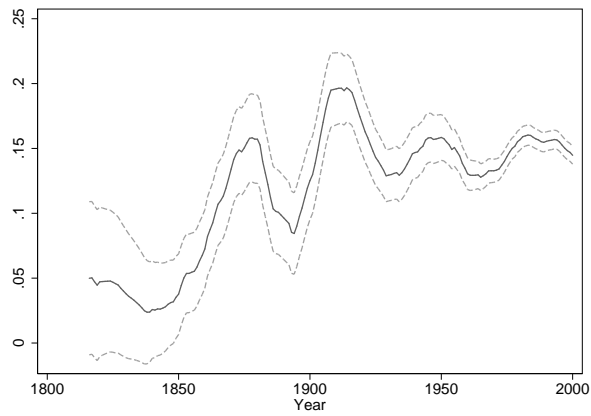


Figure 2: Moran's I on Vanhanen's Participation and Competition Scores, 1816-2000. The solid line is a smoothed representation of the level of clustering. The dashed lines form the 95% confidence interval.

3 Theoretical underpinnings of the model

In *The Spiral of Silence*, Noelle-Neumann develops a theory of the fear of isolation that leads individuals to hide their preferences when they are incongruent with the perceived majority view. During the campaign for the German parliamentary elections of 1965, the two major parties, CDU/CSU and SPD, stayed very close to each other in the opinion polls. Everybody was assuming that the election results would be very tight, but instead, the CDU/CSU won with a clear majority. The opinion polls had thus given a misleading picture of the political climate of the campaign, resulting in a very surprising outcome of the elections. Another question in the same opinion polls was, retrospectively, far more informative. The question ran: "Of course nobody can know, but what do you think: who is going to win the election?" For this question, the parties were very close nine months before the elections, but had gradually moved widely apart, in favor of the CDU/CSU (Noelle-Neumann 1993: 2-3). In other words, the perceived majority was far more revealing than the demonstrated majority in the polls. The theory of the spiral of silence and that of preference falsification by Kuran (1995) are closely related. Kuran (1991) makes a distinction between private and public preferences, whereby the former are relatively stable and whereby the latter are determined by both the private preferences and the perceived cost or risk of expressing these.

Recalling the example of the Orange Revolution in Ukraine, a striking feature is the discrepancy between the reputation of the Ukrainian population of being relatively apathetic and the sudden large protest movement in the streets of Kiev. Given the spiral of silence, two factors are likely to explain this surprising dynamic: the campaign might have affected the attitudes of some citizens and this possibly small change in their attitudes might have triggered a cascade of protest. For some citizens, the little change in attitude as a result of campaigning might have been just that little bit needed to bring people over a threshold from not protesting to protesting. In other words, their attitude was already very close to that of the protesters, but just needed that tiny little push. For other citizens, that had pro-democratic attitudes but were just not passed the threshold to protest, their reluctance to protest will have become significantly lower once they saw larger numbers of people on the street. Suddenly, they had somewhat less to fear from the authorities, as they would not be standing there on their own in the streets, but in a crowd, and suddenly they knew that they were not the odd exception, but that they had the support of many people in their country. Thus more people started to protest, and the more there were, the more those with a slightly higher threshold felt safe enough to take to the streets as well. This is the mechanism of the cascading revolution (Granovetter 1978; Kuran 1991, 1995; Lohmann 1994).

Although the revealed preferences in these models depend on the context, on the preferences revealed by other agents in the same ecology, the 'real' or private preferences are assumed to be fixed. To explain the diffusion of democracy, the international spread of attitudes towards democracy, the cascading model of revolutions is thus insufficient. The theory used in this article to explain the changes in attitudes themselves through communication is the social judgment theory (Sherif and Hovland 1961): "Whereas the quality of arguments may determine the extent to which one is being persuaded by another person, often people respond quite simple by favoring positions close to their own, and rejecting more distant positions" (Jager and Amblard 2004: 295). When confronted with the attitudes of another person, an individual thus adjusts his or her own attitude depending on the difference in opinion. When the advocated position is close to that of the receiving individual it is said to be within the *latitude of acceptance* and the individual is likely to

change attitude somewhat towards the advocated position. On the other hand, when confronted with a position entirely different from ones own, within the *latitude of rejection*, the individual will emphasize the difference and move slightly away from the advocated position. In between there is a *latitude of non-commitment* where the individual is not affected by the advocated position (Jager and Amblard 2004: 295-296).

The face validity of the social judgment theory can be demonstrated with an example close to most readers. Imagine the quantitative political scientist arguing vehemently before a fellow political scientist to defend his or her quantitative approach. If the listener is already inclined to do quantitative analyses, he or she is likely to be easily convinced by the arguments and to strengthen the belief that quantitative methods are indeed the most valid approach to political research. If the listener is an area specialist, however, used to apply more in-depth comparative methods and generally opposed to quantifying human behavior, the arguments will sound unconvincing. Moreover, they are likely to highlight the attitudes that were already objectionable to the listener, who will subsequently become even more opposed to quantitative approaches to social science research. The effect of the arguments are thus likely to be dependent on the initial distance between the advocated position and that of the listener or judging agent. ⁷

4 An agent-based model

An agent-based model is a computer simulation to perform the equivalent of a thought experiment (Holland 1995: 156) where a large number of agents interact on the basis of a few relatively simple rules. Whereas game theory is usually a solid approach to understand the outcome or dynamics of games with few actors, the results of large numbers of actors that interact with each other and where the actions of one actor affect that of all other actors are generally difficult to trace mathematically. Computer simulations can help to understand the dynamics of such models. In an agent-based simulation the rules of behavior are usually simple and there are few types of different actors. While the rules are simple, the resulting patterns in the system as a whole can be highly complex and often surprising given the rules of interaction, hence the term *emergence* (Holland 1998;

Johnson 2001). Agent-based simulations generally need lengthy computations and thus have become popular only after the widespread availability of computing power. Although early examples exist, most notably Schelling (1978), most applications are of more recent date. Examples of such models in political science are the model of democratic survival and geographic clustering by Cederman and Gleditsch (2004), models on cooperation (Axelrod 1997), the model of secessionism in multi-cultural states by Lustick, Miodownik and Eidelson (2004), a model endogenizing the international state system (Cederman 1997), and a model of policy and party competition by Laver (2005).

This model on democratic diffusion revolves around a number of key concepts. This section will discuss these concepts theoretically, while a more detailed and technical description of the model and its parameters is provided in the appendix. A schematic overview of the model is presented in figure 3. The first concept is the political regime of the country. Abstracting from the complexities in the classification of political regimes, regimes are divided in two categories, democracies and non-democracies. Although the different levels of democracy and the wide variety of types of non-democratic regimes is of huge importance for the understanding of particular countries and specific comparisons of countries, for a model studying the worldwide clustering of political regimes, the details of such a classification are of less relevance. The distinction between democracies and non-democracies is also the only distinction we are really interested in here and the level of democracy in a country is thus a simple binary variable.

The second concept that is crucial to the simulation is that of an individual's attitude towards democracy. The idea is that any person has a particular attitude towards the concept of democracy, on a scale from strong support for democracy to strong opposition to democracy. In reality, it is unlikely that such a scale exists within someone's political outlook. Rather, the attitude towards one's own current political regime and that towards the concept of democracy in general is likely to be a complex combination of a multitude of different attitudes, expectations, experiences, and beliefs. The intricacies of such psychological and ideological preferences are assumed to be of little relevance to the overall pattern of democratic diffusion, however, and a relatively simple scale should therefore suffice. The attitude towards democracy scale measures the actual attitude towards the

regime of an individual citizen, rather than the demonstrated preferences.

Through communication, the third concept underlying the model, these individuals change their attitudes. By talking to others about democracy and about their ideological outlook on the world, one can gradually change one's own opinion towards democracy. This communication takes most likely place between citizens of the same country and to a lesser extent between randomly selected citizens of neighboring countries. The underlying assumption is thus that geographical distance matters for the frequency of interpersonal contact.² The direction of this change, according to the social judgment theory, depends on the similarity between the two individuals at the outset. Individuals that have opinions very similar to one another are likely to refine their attitudes through the interaction and to move closer towards each other in terms of their attitudes and beliefs, while individuals with very different attitudes will diverge even more.

Regimes will not helplessly watch how citizens change their attitudes. Instead, they are likely to attempt to influence those attitudes. Especially democratic countries tend to make a serious effort trying to stimulate democratization abroad. Sometimes by using pressure towards foreign political leaders, but often also by stimulating grass-roots organizations in non-democratic countries or by providing alternative news sources to those provided by autocratic governments. A good example would be *Radio Free Europe*, which presented regional news from the Western perspective across Eastern Europe. In the model this element has been labeled broadcasting, for lack of a better term, which encompasses all forms of attempts by democratic governments to stimulate positive attitudes towards democracy in (neighboring) non-democratic countries. Radio broadcasting is a good example, but this also includes supporting local organizations, distributing newspapers or pamphlets, or any other form of 'educating' individuals abroad by democratic governments. The presence of Serbian advisors in the Ukrainian Orange Revolution is a good example.

Autocratic countries are likely to be concerned, to varying degrees, with the restriction of this information flow to their citizens. North Korea and China are prime examples,

²See Mok, Wellman and Basu (2007) for an extensive overview of the literature on this assumption, as well as an empirical analysis of the effect of distance on social networks in a Toronto neighborhood.

where access to the Internet is highly restricted and filtered for political purposes, as was the Soviet restriction on a large number of publications. These policies isolate citizens from foreign influences, including or primarily those that promote democratization. In this model, this enforced isolation of the citizens of non-democratic regimes limits the effects of broadcasting attempts by neighboring countries and lowers the chances of cross-border communication between individuals of the country and foreign individuals. Democratic regimes are assumed not to limit any international communication. One could argue that such limitations on free information would contradict the concept of democracy sufficiently not to consider such a country a democracy. In terms of implementation, the effects of broadcasting and isolation are what distinguish democracies from authoritarian regimes.

The sixth concept of the model is what has been labeled protesting. Similar to broadcasting, protesting should here be seen as an abstraction of a broad spectrum of forms of political action. It includes all those publicly visible manifestations of individual's attitudes towards democracy, or rather, the current political regime. Protests might literally mean protesting on the street, like in the Ukraine or the demonstrations in the DDR before the fall of the Berlin Wall, but they might also include dissenter writings or other forms of protesting art, mobilization for political action, like Solidarity in Poland, or votes for an opposition party in limitedly competitive elections. The protests have to be public, however, to qualify for this protest category, as the mechanism of the spiral of silence or preference falsification, requires the visibility of these protests. Observing fellow individuals having the courage to take to the streets, literally or figuratively speaking, might lower the threshold for opponents of the regime to join the protests. The combination of the attitude towards democracy and the protesting status of an individual thus implements the spiral of silence into the agent-based model.

Finally, regimes can change, democracies can turn authoritarian or vice versa. Such transitions can be largely due to actions by the political elite (Burton and Higley 1987), or due to a public demonstration of a serious lack of support among the general population. The former are not part of this particular model and are considered exogenous to it. More in general, coups in this model encompass all those regime changes that are not explained by the level of protest in a country. The chances for such a regime change that is not

explained by public protest is assumed to be higher directly after a regime change took place. This models the concept of regime consolidation (Linz and Stepan 1996). The second form of regime change, however, is right at the core of the model. Regimes make a transition when all individuals in the capital protest. Due to the cascading nature of this protest mechanism, many countries where a substantial number of inhabitants are protesting have a good chance of falling into a state where all citizens are protesting the regime. It is thus the clustering of these revolutions that the model is trying to illuminate.

After the provinces, country borders, and citizens have been initialized, each simulation will run through 8000 iterations. Each iteration the following steps will take place, in this order: the level of isolation for each non-democracy will change following a random walk; a random set of individual citizens will communicate with randomly selected fellow citizens; each citizen will determine whether or not to join the anti-regime protest; one randomly selected democratic capital will broadcast a pro-democratic message; and for each country it will be determined whether there are sufficient protesters for a revolution, or whether a random, exogenous coup will take place.

5 Simulation results and discussion

An agent-based model is to a considerable extent random: parameters are initialized with random values⁸ within preset ranges (see table 2) and parts of the model that are considered exogenous are implemented as random events. Similar to statistical analysis, the solution to separate random effects from modeled ones lies to a large extent in the size of the 'sample'. Whereas we can get more accurate estimates of model parameters in statistics by taking larger random samples, in agent-based modeling we acquire a similar large N by running the simulation many times. For this article, the model has been run 2481 times.

The large number of simulations and parameter combinations means that many patterns in this simulation could be analyzed. The prime concern here is with the geographical and temporal clustering. Waves have been measured as the variance of the proportion of democracies over time in the simulation output around a moving average of this trend.⁹

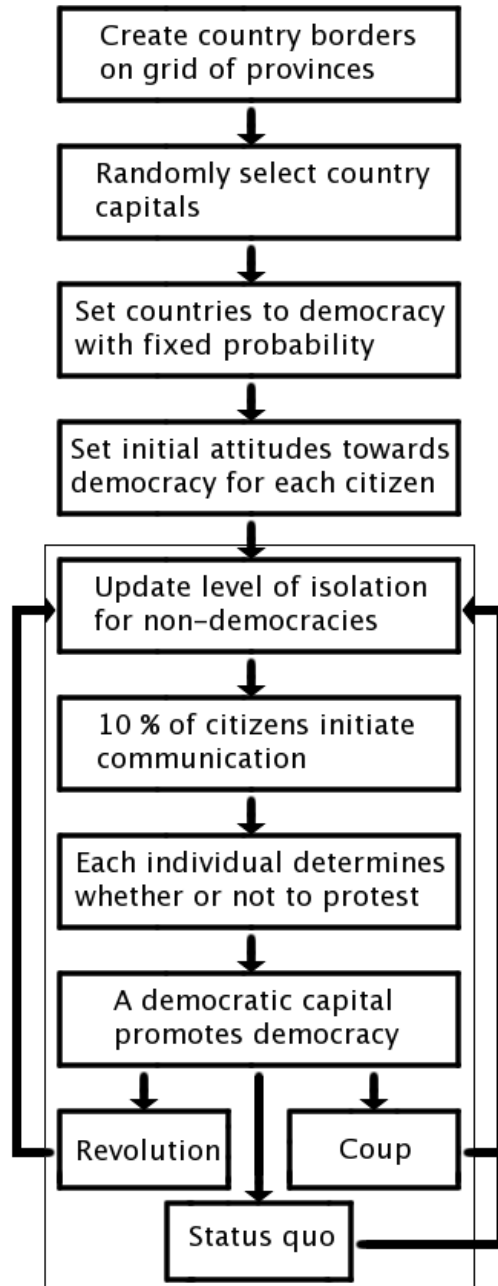


Figure 3: Schematic overview of the agent-based model.

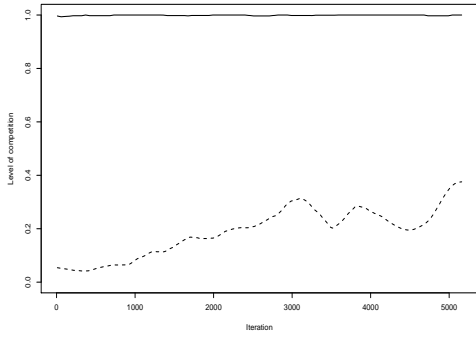


Figure 4: Absence of Waves of Democracy. The dashed line represents the average level of competition in the empirical data. The solid line represents the proportion of citizens in the model living in a democratic regime. See footnote 10 on how iterations are matched on time.

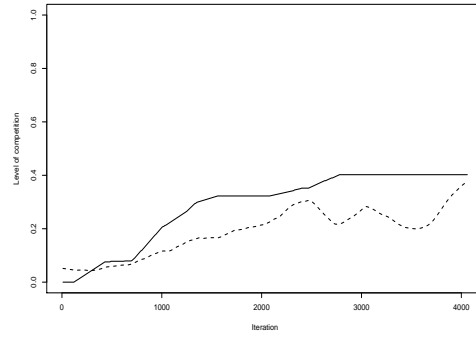


Figure 5: Presence of Waves of Democracy. The dashed line represents the average level of competition in the empirical data. The solid line represents the proportion of citizens in the model living in a democratic regime. See footnote 10 on how iterations are matched on time.

We thus have one number for each simulation run that represents the level of waves. The higher this number, the more the pattern looks like waves. Samples of two extreme values of this parameter are visible in figures 4 and 5.¹⁰ Different methods exist to study the parameter space of an agent-based simulation. Since the way parameters are assigned in these simulations emulates the random sampling of simulations from the imaginary total population of possible parameter combinations, the most appropriate type of analysis is parametric statistics. A regular ordinary least squares regression analysis of the level of waves is presented in the first column of table 1. For the exact definition of the various parameters one has to refer to the appendix.

Of the statistically significant effects the initial proportion of democracies and the border multiplier are of relatively little interest. The former is due to the fact that the simulation has a bias towards a growing level of democracy since only democracies broadcast their regime to citizens in the neighborhood of the capital. Since the level of democracy is more likely to grow during the simulation than to go down, there is less 'space' for waves when it starts already at a high level. A good example of this is the pattern in figure 4. The effect of the border multiplier is somewhat more difficult to interpret. A larger multiplier means larger countries in terms of their area. A possible explanation would be

that larger countries means that the effect of broadcasting is reaching fewer foreigners and thus affecting the attitudes of foreigners less.

Substantively of more interest are the effects of the initial level of isolation and the effect of the number of levels. The number of levels is of itself a technical and artificial element of the model, thus the strength and direction of its effect are of minor interest. The number of levels represents the precision by which attitudes towards democracy are measured for individual agents in the model. The fact that this parameter is of significant importance in explaining the level of waves in the model output, however, implies that the attitude measurement matters, thus that the mechanisms of diffusion matter in the explanation of the waves. The temporal clustering in the model is not explained by the volatile nature of the random coups in the model, but rather by the effect of the diffusion of attitudes. The significance of the initial level of isolation leads to the same conclusion. The higher the initial level of isolation for the non-democratic countries in the model, the less chance for cross-border communication of democratic attitudes, thus the less diffusion of attitudes takes place. This has a significantly negative impact on the presence of waves. Finally, the coefficient for the decay strength parameter γ also suggests that the effect of exogenous coups on the presence of waves is a negative one. The lower this parameter, the faster the fragility of a newly formed regime decays, thus the lower the effect of coups after regime changes.

The second column in table 1 presents a similar regression model, this time concerning the level of clustering in the model. For every hundredth iteration of each simulation run Moran's I (see note 6) was calculated. To acquire an indicator of the overall level of clustering of a particular simulation run, the sum of Moran's I for all iterations was used. A simulation in which there is consistently a high level of clustering will thus score high, while a simulation that only shows brief episodes of clustering or no clustering at all will show a low score. Similar to the presence of waves, the significant effects of the precision of attitude measurement, of the initial average level of isolation and of the size of the effect of broadcasting imply that communication and individual attitudes matter for the level of spatial clustering. The latter two are of the expected sign: the less the cross-border communication is restrained by censorship and the more democratic regimes

try to stimulate positive attitudes towards democracies, the more democracies cluster geographically. The effect of the strength of the decay of fragility after a regime change and the border multiplier have a similar effect, and similar interpretation, as concerning temporal waves. The fact that the model is not driven by its exogenous component is further underlined by the lack of an effect of the chance of random revolutions in both models. Surprisingly, however, the chance of cross-border communication also has no significant effect.

An agent-based model is the equivalent of a sophisticated and advanced thought experiment. The results do not tell us whether the mechanisms of preference falsification, cascading revolutions, social judgment theory, or the 'broadcasting' of democracy are indeed important factors in democratization and democratic diffusion. What the results do tell us, however, is that waves and spatial clusters as empirically observed could indeed, theoretically, be explained by a combination of these factors. In many runs of the simulation, the resulting patterns of clustering and of the global increase in democracy are similar to those we experienced of the past two centuries. This implies that it is insufficient to concentrate on the elite level when studying the international diffusion of democracy, as for example in the analyses of Levitsky and Way (2005), Cederman and Gleditsch (2004), Modelski and Perry (1991), and many others. Not only the attitudes of the elite or the military-strategic position of a country matter, but also the public opinion and its international and domestic dynamics affect the process of democratization in a country.

6 Conclusion

On the basis of this model one can conclude that it is worthwhile to further investigate the mechanisms of preference falsification and the spread of public opinion through the interaction of individuals empirically. Both are difficult to analyze empirically. For preference falsification the obvious complication is the fact that the actual opinions are kept private and cannot be deduced from the behavior of individuals. For the study of the diffusion of ideas, similarly, the actual attitude that is being spread might well be largely invisible due

to the spiral of silence. Furthermore, it is difficult to determine how individuals acquire their attitudes. The results of the simulations presented here, however, suggest that it is certainly useful to continue to try to empirically validate these theories, as they could well lead to the aggregate patterns of waves of democracy and geographical clustering of regimes.

If the diffusion of democracy is indeed driven to a large extent by the broadcasting effect of a democratic regime, and if democratic regimes indeed are likely to invest in policies to promote democracy in the near abroad, this would suggest that it might indeed have a serious positive impact to democratize a country in a non-democratic area. Contrary to the survival model of Cederman and Gleditsch (2004), where an individual country democratizing would have little effect on democratization in neighboring countries, the model presented here promises more positive results from, for example, the establishment of a democracy in Iraq. Of course, one can never see the model in isolation and there are many other factors that affect popular attitudes, including those towards democracy as a concept. Not only the policies of a pro-democratic force in the Middle East matters, also, for example, the popular image of the actors that generated this democracy in the first place. The model does imply, however, that islands of democracy matter for the spread and diffusion of democracy.

Not only does it imply that single countries can have an impact on their region, it also suggests that since the private opinion towards democracy matters, policies that promote democratic ideas abroad matter. Initiatives along the lines of *Radio Free Europe* can have significant positive impacts on the international democratization. While the effects might be difficult to discern initially, the increase in the hidden mass of public support for democracy can suddenly be tipped into a revolution that topples the regime. The dynamics of the cascading revolutions hide part of the positive effects of promoting democracy.

The global waves and clusters of democracy can theoretically be explained by a combination of the spiral of silence, cascading revolutions, and social judgment mechanisms. Democratic regimes should stimulate the establishment of democratic regimes in clusters of autocracies and should promote positive ideas about democracy about the populations of such regimes, in order to stimulate the global spread of democracy. Further empirical

research can validate these theoretical claims.

References

- Axelrod, Robert. 1997. *The complexity of cooperation: agent-based models of competition and collaboration*. Princeton, NJ: Princeton University Press.
- Bell, James E. and Lynn A. Staeheli. 2001. "Discourses of diffusion and democratization." *Political Geography* 20:175–195.
- Burkhart, R.E. and M.S. Lewis-Beck. 1994. "Comparative democracy: the economic development thesis." *American Political Science Review* 88(4):903–910.
- Burton, Michael G. and John Higley. 1987. "Elite settlements." *American Sociological Review* 52:295–307.
- Cederman, Lars-Erik. 1997. *Emergent actors in world politics*. Princeton: Princeton University Press.
- Cederman, Lars-Erik. 2002. "Endogenizing geopolitical boundaries with agent-based modeling." *PNAS* 99(3):7296–7303.
- Cederman, Lars-Erik and Kristian Skrede Gleditsch. 2004. "Conquest and regime change: an evolutionary model of the spread of democracy and peace." *International Studies Quarterly* 48(3):603–629.
- Cliff, Andrew D. and J. Keith Ord. 1973. *Spatial autocorrelation*. London: Pion.
- Cutright, Philip. 1963. "National political development: measurement and analysis." *American Sociological Review* 45:253–264.
- Dahl, Robert A. 1971. *Polyarchy. Participation and opposition*. New Haven: Yale University Press.
- Doorenspleet, Renske. 2000. "Reassessing the three waves of democratization." *World Politics* 52(3):384–406.

- Doorenspleet, Renske. 2001. *The fourth wave of democratization: identification and explanation*. Leiden: Leiden University.
- Gardner, Martin. 1983. *Wheels, Life, and Other Mathematical Amusements*. W.H. Freeman.
- Gleditsch, Kristian and Michael Ward. 1997. “Double take: a reexamination of democracy and autocracy in modern polities.” *Journal of Conflict Resolution* 41:361–83.
- Gleditsch, Kristian and Michael Ward. 2000. “War and peace in time and space: the role of democratization.” *International Studies Quarterly* 36.
- Gleditsch, Kristian S. and Michael D. Ward. 2006. “Diffusion and the International Context of Democratization.” *International Organization* 60(4):911–933.
- Gleditsch, Kristian Skrede. 2002. *All international politics is local: the diffusion of conflict, integration, and democratization*. University of Michigan Press.
- Granovetter, Mark. 1973. “The strength of weak ties.” *American Journal of Sociology* 78:1360–1380.
- Granovetter, Mark. 1978. “Threshold models of collective behavior.” *American Journal of Sociology* 83:1420–1443.
- Hak, Bin Chua. 1993. On spillovers and convergence PhD thesis Department of Economics, Harvard University Cambridge, Massachusetts: .
- Holland, John H. 1995. *Hidden order: how adaptation builds complexity*. Reading, MA: Addison-Wesley.
- Holland, John H. 1998. *Emergence: from chaos to order*. Reading, MA: Addison Wesley.
- Huntington, Samuel. 1991. *The Third Wave: Democratization in the Late Twentieth Century*. Norman, Oklahoma: University of Oklahoma Press.
- Jager, Wander and Frédéric Amblard. 2004. “Uniformity, bipolarization and pluriformity captured as generic stylized behavior with an agent-based simulation model of attitude change.” *Computation & Mathematical Organization Theory* 10:295–303.

- Johnson, Steven. 2001. *Emergence: the connected lives of ants, brains, cities, and software*. New York: Scribner.
- Kopstein, Jeffrey S. and David A. Reilly. 2000. "Geographic diffusion and the transformation of the postcommunist world." *World Politics* 53:1–37.
- Kuran, Timur. 1991. "The East European revolution of 1989: is it surprising that we were surprised?" *The American Economic Review* 81(2):121–125.
- Kuran, Timur. 1995. *Private truths, public lies. The social consequences of preference falsification*. Cambridge, Massachusetts: Harvard University Press.
- Laver, Michael. 2005. "Policy and the dynamics of political competition." *American Political Science Review* 99(2):263–281.
- le Gallo, Julie. 2000. "Econometrie spatiale. 1. Autocorrélation spatiale." Working Paper no. 2000-05, Laboratoire d'Analyse et des Techniques Economiques.
- Levitsky, Steven and Lucan A. Way. 2005. "International linkage and democratization." *Journal of Democracy* 16(3):20–34.
- Linz, Juan J. and Alfred Stepan. 1996. *Problems of democratic transition and consolidation: southern Europe, South America, and post-communist Europe*. Baltimore: Johns Hopkins University Press.
- Lipset, Martin Seymour. 1959. "Some social requisites of democracy: economic development and political legitimacy." *American Political Science Review* 53:69–105.
- Lipset, Martin Seymour. 1960. *Political man: the social bases of politics*. Garden City, NY: Doubleday.
- Lohmann, Susanne. 1994. "The dynamics of informational cascades: the Monday demonstrations in Leipzig, East Germany, 1989-91." *World Politics* 47(1):42–101.
- Lustick, Ian S., Dan Miodownik and Roy J. Eidelson. 2004. "Secessionism in multicultural states: does sharing power prevent or encourage it?" *American Political Science Review* 98(2):209–229.

- Markoff, John. 1996. *Waves of democracy: social movements and political change*. Thousand Oaks, CA: Pine Forge Press.
- Modelski, George and Gardner Perry. 1991. "Democratization in long perspective." *Technological Forecasting and Social Change* 39:23–34.
- Modelski, George and Gardner Perry. 2002. "'Democratization in long perspective' revisited." *Technological Forecasting and Social Change* 69:359–376.
- Mok, Diana, Barry Wellman and Ranu Basu. 2007. "Did distance matter before the Internet? Interpersonal contact and support in the 1970s." *Social Networks* 29:430–461.
- Noelle-Neumann, Elisabeth. 1993. *The spiral of silence*. 2nd ed. Chicago: University of Chicago Press.
- O'Loughlin, J., M.D. Ward, C.L. Lofdahl, J.S. Cohen, D.S. Brown, D. Reilly, K.S. Gleditsch and M. Shin. 1998. "The diffusion of democracy, 1946-1994." *Annals of the Association of American Geographers* 88:545–574.
- Oversloot, Hans, Joop van Holsteyn and Gert van der Berg. 2002. "Against all: exploring the vote 'against all' in the Russian Federation's electoral system." *Journal of Communist Studies and Transition Politics* 18(4):31–50.
- Rogers, Everett M. 1995. *Diffusion of innovations*. Fourth edition ed. New York: The Free Press.
- Schelling, Thomas. 1978. *Micromotives and macrobehavior*. New York: W.W. Norton.
- Schumpeter, Joseph A. 1976. *Capitalism, socialism and democracy*. New York: Harper & Row.
- Sherif, M. and C.I. Hovland. 1961. *Social judgment*. New Haven, CT: Yale University Press.
- Starr, Harvey. 1991. "Democratic dominoes: diffusion approaches to the spread of democracy in the international system." *Journal of Conflict Resolution* 35(2):356–381.

Staten, Clark. 1996. "The Islamic domino theory." EmergencyNet News Service.

<http://www.emergency.com/domino.htm>

The President's News Conference of April 7, 1954. 1954.

<http://coursesa.matrix.msu.edu/hst306/documents/domino.html>

Vanhanen, Tatu. 1997. *Prospects for democracy: a study of 172 countries*. New York: Routledge.

Ward, M.D. and K.S. Gleditsch. 1998. "Democratizing for peace." *American Political Science Review* 92:51–61.

Ward, Michael D., John O'Loughlin, Michael Shin, Corey L. Lofdahl, Kristian S. Gleditsch and Jordin S. Cohen. 1996. "The spatial and temporal diffusion of democracy, 1946-1994." Presented at the 37th Annual Conference of the International Studies Association, San Diego, CA.

Welsh, William A. 1984. "Inter-nation interaction and political diffusion: notes toward a conceptual framework." Paper presented at the annual meeting of the International Studies Association, Atlanta, March 28-31.

Appendix: Model implementation

The setup

In the setup stage three key elements are created and initialized: provinces, countries, and citizens. The citizens form the main agents of the model. Let us first turn to the creation and placement of the provinces. The provinces form the cells of what is commonly known as cellular automata of size W by H .¹¹ Cellular automata are a grid of adjacent square cells which keep changing state using simple rules, on the basis of information from the previous state of the cell and the state of cells in what is called the Neumann neighborhood, the four cells directly adjacent. The most famous example of a cellular automata is the Game of Life, which is a small set of very simple rules which leads to cyclic patterns, *perpetua mobilia*, and patterns far more complex than expected from the

initial rules (Gardner 1983; Johnson 2001). Although cellular automata form the basic foundation and inspiration for this model, in line with a model of democratic diffusion by Cederman and Gleditsch (2004), the model does deviate on several fronts from regular cellular automata models. One aspect that is unusual for cellular automata is that the map of this model wraps around its borders. The cells at the edges of the map are directly adjacent to those on the opposite edge - similar to creating cellular automata on the surface of a torus. This is common in computer games that are based on cells and that try to simulate the fact that the world is round.

Once the provinces have been created country borders are added to the map. Drawing borders grouping together certain provinces is of course a clear deviation from any common cellular automata. The country borders are created by an algorithm where countries “conquer” neighboring provinces which become part of the country of the conquering province, unless this leads to a fragmented country that the province is originally from. $W \times H \times M$ times a random combination of two neighboring provinces, P_1 and P_2 , is selected. M is a configurable parameter, whereby a larger M leads to larger countries. If $C_{P_1} \neq C_{P_2}$, thus if the two provinces are located in different countries, C_{P_1} will conquer P_2 , unless this leads to a disconnected former C_{P_2} .¹² This algorithm results in a somewhat realistic looking map, with varying forms and sizes of countries, and is derived from the model of Cederman and Gleditsch (2004): their model models wars between countries, whereas in this model these wars are only applied to the setup stage to create the borders. Each country C is subsequently assigned a random level of isolation, $\varphi_0 \sim N_{[0,100]}(\phi_{mean}, \phi_{std})$.¹³ With a probability π , the country is set to be a democracy ($\Omega = 1$), otherwise it is set to be an autocracy ($\Omega = 0$). Randomly one of the provinces of the country is assigned as the capital.

For each province a random number of citizens is set, $N_{citizens} \sim N_{[1,\infty)}(C_{mean}, C_{std})$, with an initial attitude towards democracy $\alpha_i \sim N_{[0,\lambda-1]}(A_{mean}, A_{std})$. The threshold values of the social judgment model are assigned as $t_i \sim N_{[0,\infty)}(T_{mean}, T_{std})$ and $u_i \sim N_{[0,t_i]}(U_{mean}, U_{std})$. By default, a citizen is not protesting, $\psi_i = 0$.

The iteration

Once all initial values have been set, country borders have been created, and citizens have been assigned to their provinces, the series of iterations starts. Each iteration five steps are taken:

1) The level of isolation for each country is updated. It is reasonable to assume, perhaps even true by definition, that democracies do not limit the communication of their citizens with foreigners. For this reason, each country that is a democracy in this model resets the level of isolation to zero. For all other countries, the level of isolation is modeled as a straightforward random walk:

$$\varphi_{t+1} = \begin{cases} 0 & \text{if } \Omega = 1 \\ \varphi_t + U, \text{ where } U \in \{-1, 0, 1\} & \text{otherwise,} \end{cases} \quad (1)$$

whereby φ_{t+1} is truncated to $[0, 100]$. U is a random draw from the set $-1, 0, 1$. With a random walk it is implicitly assumed that levels of suppression generally change over time, and that without other predictive variables, the best prediction of the level of isolation at time t is likely to be the level of isolation at time $t - 1$.

2) $N_{citizens}/10$ times a random citizen (S) is selected to initiate communication. The probability for each of the four provinces P in the Neumann neighborhood that a citizen will be targeted from this province is:

$$Pr(P) = \begin{cases} \tau/4 & \text{if } C_P = C_S \\ \frac{\tau \max(\varphi_{C_S}, \varphi_{C_R})}{400} & \text{otherwise.} \end{cases} \quad (2)$$

τ is a model parameter indicating the probability of cross-border communication. The maximum level of isolation between the two countries is taken, as it is assumed that what really matters for communication to occur is whether the more restricted of the two countries can be reached.¹⁴ If a neighboring province is selected, a citizen (R) will be randomly selected from this province, otherwise this will be done from the province of S . Once a sending (S) and a receiving (R) citizen have been selected, given that their

attitudes towards democracy differ, the attitude of R is updated in line with the social judgment model of communication:

$$\alpha_R = \begin{cases} \alpha_R + \text{sign}(\alpha_S - \alpha_R) \times 1 & \text{if } |\alpha_S - \alpha_R| < u_R \\ \alpha_R - \text{sign}(\alpha_S - \alpha_R) \times 1 & \text{if } |\alpha_S - \alpha_R| > t_R \\ \alpha_R & \text{otherwise,} \end{cases} \quad (3)$$

whereby α_R , the attitude towards democracy, is truncated to $[0, \lambda - 1]$.

3) After the order in which citizens are being processed has been randomized, each citizen determines whether or not to start or stop protesting. In line with the cascading model of revolution as described above, a citizen will join the protest if the attitude against the current regime is strong enough relative to the proportion of protesters in the citizen's province to dare to risk the costs of protesting.

$$\psi_i = \begin{cases} 1 & \text{if } \Omega_{C_i} = 0 \quad \& \quad \Upsilon \leq \frac{\alpha_i}{\lambda} \quad \text{or} \\ & \text{if } \Omega_{C_i} = 1 \quad \& \quad \Upsilon \geq \frac{\alpha_i}{\lambda} \\ 0 & \text{otherwise,} \end{cases} \quad (4)$$

where

$$\Upsilon = \frac{\sum_{j \in P_i} \psi_j}{N_{\text{citizens}, P_i}}. \quad (5)$$

ψ_i is a variable that is 1 when citizen i is protesting and 0 otherwise.

4) One randomly selected democratic capital will broadcast its democratic values to citizens in neighboring provinces. In this case not the Neumann neighborhood is taken into account, but all nine provinces that are either in the Neumann neighborhood or diagonally adjacent, including the capital itself. For each of the nine provinces, the probability of receiving the broadcast is one when the province is part of the same country, or one minus the maximum level of isolation of the two countries involved. For a province that receives the broadcast, all citizens update their attitude towards democracy by the size of B .

5) Each country determines whether or not a revolution will take place:

$$\Omega_{t+1} = \begin{cases} 1 - \Omega_t & \text{if } \Upsilon_{capital} = 1 \quad \& \quad D \geq s \quad \text{or} \\ & \text{with probability } \max(K, \beta e^{\gamma s}) \\ \Omega_t & \text{otherwise,} \end{cases} \quad (6)$$

where s is the time since the last revolution or coup, K the base probability of a coup, D a fixed number of iterations that a revolution cannot take place, and β and γ are parameters that determine the decay function of regime instability shortly after a regime change took place.

There are two ways in which a country can make a transition from or towards democracy: a country makes a transition when all citizens in the capital province are protesting¹⁵ or randomly, with a probability which decays with the age of the regime. The latter can be seen as external shocks to the model, the many forms of revolutions in the world that are not caused by the diffusion of attitudes or even by public opinion in the first place. When Gorbachev let the Soviet Union slip and the regime collapsed, this can hardly be seen as an effect of democratic diffusion, but the subsequent collapses of many regimes in Eastern Europe to some extent can. The external shock of Gorbachev thus generated a diffusion effect as it is modeled here. Another way to look at this would be to see K as the built-in error in the model, much like any econometric model will include an error term. The fact that for endogenous revolutions only the capital is taken into account can be defended by a quick glance at most coups and revolutions in the world. Protests are generally more threatening when they take place in the capital, and rarely can a country where all but one region are opposed to the regime sustain its political system. Taking into account all provinces leads to unrealistic assumptions, while taking the capital into account seems in line with general perceptions of revolutions. Finally, for a number of iterations after a revolution, set by D , revolutions are not possible. Regimes are considered fragile in the first iterations after a coup or revolution, however, and coups or exogenous regime changes are more likely directly after a regime change, decaying over time.

Notes

¹See for a dynamics map of democratic diffusion created by the Spatial and Temporal Diffusion of Democracy project at the University of Colorado: <http://www.colorado.edu/IBS/GAD/spacetime.html>.

²Albeit perhaps not as distinctly as Huntington suggests or partly explained by changes in the number of countries that affect the proportion of democratic regimes without any country necessarily undergoing a regime transition (Doorenspleet 2000) (but see Gleditsch and Ward 2006).

³Some conflicts can be considered possible exceptions, however, including the Spanish-American War in 1898, India vs. Pakistan in 1948, Israel vs. Lebanon in 1967, and Peru vs. Ecuador in 1981. Thanks to Alexander Baturo for pointing this out.

⁴Although in this model it is assumed that only authoritarian regimes limit the information supply to their citizens, considering such limitations to be undemocratic by definition, it should be noted that it is not entirely absent in modern, Western democracies either. In various European countries, the distribution of Hitler's *Mein Kampf* is illegal and the pressure to limit the free speech of radical Muslims is increasing.

⁵These indicators are only proxies for what they are intended to measure, but unlike more complex measures like the Polity IV democracy score or the Freedom House classification, the extent to which these measures are deviations from the concepts of participation and competition is transparent and can be easily contemplated.

⁶The formula for Moran's I, as presented by le Gallo (2000), is as follows:

$$I_t = \frac{\sum_i \sum_j \tilde{w}_{ijt} (x_{it} - \bar{x}_t)(x_{jt} - \bar{x}_t)}{\sum_i \sum_j \tilde{w}_{ijt}} \cdot \frac{N_t}{\sum_i (x_{it} - \bar{x}_t)^2} \quad \text{where} \quad \bar{x}_t = \frac{1}{N_t} \sum_i x_{it}$$

With \tilde{w}_{ijt} being the standardized value of the contiguity matrix W_t , x_{it} being the respective score for unit i in year t , and N_t being the number of observations for year t . Under the normality assumption, the standard error of this statistic can be calculated as follows (Gleditsch 2002; Cliff and Ord 1973):

$$E(\sigma_{I_t}^2) = \frac{N_t^2 S_1 - N_t S_2 + 3S_0^2}{S_0^2 (N_t^2 - 1)}$$

where

$$S_0 = \sum_i \sum_j (w_{ijt} + w_{jit}), S_1 = \frac{1}{2} \sum_i \sum_j (w_{ijt} + w_{jit})^2, S_2 = \sum_i \sum_j (\tilde{w}_{ijt} + \tilde{w}_{jit})^2$$

Since in the analysis presented here w_{ijt} can only have the values 1 or 0, and W_t is a symmetric matrix, this can be reduced to

$$S_0 = S_1 = 2 \sum_i \sum_j w_{ijt}, S_2 = \sum_i \sum_j (\tilde{w}_{ijt} + \tilde{w}_{jit})^2$$

⁷The author thanks Scott Page for suggesting this example.

⁸It is in fact more common to do parameter sweeps - iterate over a fixed set of parameter combinations. Such fixed sets of parameters, however, are relatively arbitrary in nature and make it more difficult to

find critical values and see the precise relationship between the parameters and the model output. In this article, the parameter settings are seen as a random sample from the overall parameter space.

⁹The trend itself was smoothened by a moving average with a window of 210 iterations to avoid including very small waves and the variance was then taken around a moving average of 2010 iterations.

¹⁰Matching the iterations in the simulation on the real world time scale is a non-trivial problem. For the figures in this article, the iterations were mapped on time such that the squared deviations of the level of democracy in the simulation from the empirical average level of competition, divided by the number of iterations in the range ($\frac{\sum_t(\pi_t - VC)^2}{N_{iterations}}$, where VC is the worldwide average Vanhanen's competition score and $\pi_t = \frac{1}{N_{countries}} \sum \Omega_t$ is the proportion of democracies in the simulation), is minimized.

¹¹All parameters referred to in the text are assigned random values for each run, drawn from a uniform distribution. The different parameters and the range over which initial values are set can be found in table 2.

¹²The following regression equation gives an impression of the relation between these variables and the resulting number of countries: $N_{countries} = 484.3 + .1933 \times W \times H - 41.98 \times M$, with $R^2 = 0.7560$.

¹³Throughout this article, $N_{[a,b]}(c, d)$ is a draw from a normal distribution, with mean c , standard deviation d and truncated to the interval $[a, b]$.

¹⁴ τ is divided by four because there are four neighbors in the Van Neumann neighborhood. The division by 100 is because φ is scaled from 0 to 100.

¹⁵A requirement of 100% protesters might seem too strong, but given the mechanisms of the cascading model of revolution this is theoretically the most appropriate and also in practice does not hold back many countries where there is a large proportion of protesters smaller than 100%.

	Waves		Clusters	
(Intercept)	-6.0302	**	0.0000	**
	(0.2383)		(0.0173)	
Number of levels (λ)	-0.0018	**	0.1299	**
	(0.0006)		(0.0228)	
Initial proportion democracies (π)	-1.1774	*	-0.0303	
	(0.4990)		(0.0173)	
Initial average attitude (A_{mean})	0.0009		-0.1685	**
	(0.0011)		(0.0174)	
Initial average isolation (ϕ_{mean})	-0.0024	*	-0.0693	**
	(0.0010)		(0.0173)	
Initial average nr of citizens (C_{mean})	-0.0002		-0.0303	
	(0.0012)		(0.0173)	
Regime delay (D)	0.0015		-0.0247	
	(0.0019)		(0.0173)	
Chance of cross-border communication (τ)	-0.0583		-0.0005	
	(0.0927)		(0.0173)	
Random chance of coups (K)	0.5120		-0.0211	
	(0.4905)		(0.0173)	
Average in-group threshold (U_{mean})	-0.0008		-0.0012	
	(0.0013)		(0.0173)	
Average out-group threshold (T_{mean})	0.0011		-0.0217	
	(0.0012)		(0.0173)	
Broadcast effect (B)	0.0013		0.1762	**
	(0.0008)		(0.0228)	
Strength of regime fragility decay (γ)	-0.6250	*	-0.0872	**
	(0.3070)		(0.0173)	
Border multiplier (M)	-0.0456	**	-0.3592	**
	(0.0051)		(0.0173)	
Field size ($W \times H$)	-0.0001		0.1047	**
	(0.0002)		(0.0173)	

Table 1: Explanatory model parameters on the log of the level of waves and the level of clustering, using standardized variables

Parameter	Description	Range
W	Field width	10 - 30
H	Field height	10 - 30
M	Border multiplier	0 - 20
ϕ_{mean}	Isolation mean	0 - 100
ϕ_{std}	Isolation standard deviation	1 - 30
π	Initial proportion of democratic countries	0 - 0.2
C_{mean}	Number of citizens, mean	20 - 100
C_{std}	Number of citizens, standard deviation	1 - 40
λ	Number of levels on attitude scale	3 - 300
τ	Chance of cross-border communication	0 - 1
A_{mean}	Initial attitude mean	0 - 100
A_{std}	Initial attitude standard deviation	1 - 50
U_{mean}	In-group threshold, mean	0 - 80
U_{std}	In-group threshold, standard deviation	1 - 20
T_{mean}	Out-group threshold, mean	20 - 100
T_{std}	Out-group threshold, standard deviation	1 - 20
B	Size of the effect of broadcasts	1 - λ
K	Random chance of coups	0 - 0.0002
D	Regime delay	50 - 100
β	Starting point of decaying regime fragility	0 - 0.2
γ	Strength of regime fragility decay	0 - -0.33

Table 2: Model parameters and value ranges