The Utility of Agent Based Modelling in Identifying Neighborhoods Effects of Democratization in Heavily Autocratic and Mixed Regime Regions

Devanshi Shah, Second-year Undergraduate Political Science Student

Introduction and Background*

*Important Note: This model is a work in progress. The original purpose of this project was to explore the framework of building an agent-based model, and simply do so through a topic of interest (in this case, neighborhood effects and democratization). As such, much of the proposed explanations of the model results rest on reasoned assumptions. There is full intention to return to the model and incorporate supporting literature to solidify the content of this paper and refine the rules of the ABM to reflect what scholars believe about this topic.

The concept of the "neighborhood effect" in international politics is relatively new, though a promising framework for scholars to utilize in studying democratization through the lens of what is known as a political neighborhood (Gartzke 2003; pg. 371). Neighborhood effects rely on the assumption that states' actions can be contextualized by their socio-political coexistence with contiguous states (Gartzke 2003; pg. 371). In simpler terms, the dynamics occurring within and among states of geographic proximity to one another appear to be of considerable influence on each state in that political neighborhood (Gartzke 2003; pg. 371).

With this, ideas about whether the characteristics of state regimes in a reasonably defined neighborhood can impact one another; if a historically autocratic state was surrounded by democratizing neighborhoods, how would the autocratic state respond, and vice versa? Would an autocrat tighten its repressive hold over its borders, or would it fear revolution and concede the introduction of democratic institutions such as elections at the local level? Perhaps a democracy would retaliate by democratizing even further. The central questions proposed here revolves around these curiosities:

> ***Central Question 1:*** *Given certain assumptions about the preferences for regime type of autocratic states as a function of neighborhood regime activity, is it possible for trends toward democratization to embed themselves into heavily autocratic neighborhoods?*
>
> ***Central Question 2:*** *Given certain assumptions about the preferences for regime type of autocratic, anocratic, and democratic states as a function of neighborhood regime activity, what is the nature of the regime authority dynamics within neighborhoods of more diverse regime types?*

As a response to the first questions, an agent-based model (hereafter ABM) was generated to gauge what the ideal conditions may entail for a heavily autocratic neighborhood of states must be in order for a significant proportion (or even an insignificant proportion) of those regimes to become amenable (whether out of coercion or not) to introducing measures of democracy

within their borders. To answer the second question, another version of the aforementioned ABM was developed to gauge whether the beliefs about state preferences accounting for regime type would result in a shift toward democratization given an environment of mixed regime types. To be clear, this ABM does not attempt to pose or answer the question of whether neighborhood effects exist; rather, that they do exist is an integral assumption of the model. Instead, the ABM attempts to determine whether there exist specific preferences for an individual state's regime type in reaction to the regime type of its neighbors. Naturally, this objective raises several sub-questions:

Sub-question 1 (Model Version 1): *Are there certain behavioral rules that can significantly shape the landscape to increase an autocratic state's inclination to introduce democratic institutions, thus resulting in a general trend away from authoritarianism in a neighborhood?*

Sub-question 2 (Model Version 2): *Given a region (grid) with mostly diverse regime types, do there exist certain behavioral rules that will result in a general shift towards democratization, or away from autocracy?*

Sub-question 3**: *If it is found that such behavioral rules exist, then what efforts are necessary to create the conditions necessary for those rules to manifest in neighborhoods?*

Sub-question 4 (Model Version 1 & 2): *When running the ABM, will there emerge patterns of "blocks" of the same regime type (ex. a block of anocracies or democracies), and what does this indicate about the neighborhood dynamics between states?*

**Will be addressed in the Implications section.

To uniformly account for the level of autocracy and/or democracy among states in a neighborhood on a discrete spectrum, the Polity scale is employed in the ABMl as the indicator of regime authority. The Polity scale consists of 4 classifications: autocracy, closed anocracy, open anocracy, democracy, and full democracy. These five regime types are mapped to a discrete scale ranging from -10 to 10. The score and corresponding classification breakdown is as follows:

Score Range	Regime Classification
[-10, -6]	*Autocracy*
[-5, 0]	*Closed Anocracy*
[1, 5]	*Open Anocracy*
[6, 9]	*Democracy*
10	*Full Democracy*

Note that because the neighborhood of interest is heavily autocratic, the initial stage of the ABM consists of a neighborhood in which states' Polity scores lie between -10 and -0, indicative of an autocratic or closed anocratic regime.

The specific rules employed in both versions of the ABM were formulated on the basis of several theoretical claims. The first concerns open anocracies, who lie on the threshold between autocracy and democracy, and would thus likely have a preference to match neighborhood regime activity for better stability. For example, if an open anocracy's neighbors are tending towards authoritarianism, it would likely do the same, resulting in a drop in its Polity score. The second claim used to create the rules is in regard to democracies, who would likely see a relatively more autocratic neighborhood as a threat to its democracy, and thus "ramp up" its institutions to preserve that democracy (this behavior can be conceived as the opposite of reactionary backsliding). If it notices its neighbors are more democratic than itself, it would likely want to match this– in any case, a democracy would not look to backslide in a given circumstance. The final assumption used to create the rules has to do with the preservation of the status quo and the phenomenon of backsliding by autocratic (including closed) regimes as a reactionary response to spatial proximity to democratization. On a general level, it is assumed that autocratic regimes want to maintain the highest level of political control possible, and do not want to make concessions that would reduce their authority and converge from the status quo. For this reason, if an autocrat observes that its neighbors are adopting democratic measures, it may "double down" (i.e. the backsliding effect) on its own authoritarianism to ensure that these trends don't seep into its borders and threaten the status quo. The mathematical dimensions of the model's rules will be explained in the following section.

Methods and Model Mechanics

Explanation of Model Rules

The basic theoretical framework outlined in the previous section lays the foundation for the mathematical updating rules created for the ABM. Please note that:

1. The model environment is visualized as a 10x10 grid, in which each state occupies one of the 100 cells, representing its spatial position.
2. For an agent (state) on the grid, its neighboring agents (states) are the 8 cells surrounding it- thus, the typical neighborhood of a state comprises its 8 bordering neighbors and itself situated in the center, with the exception of states situated in cells near the edges of the grid.
   a. Illustration of a neighborhood:

Nbr. 1	Nbr. 2	Nbr. 3

Nbr. 8	*State*	Nbr. 4
Nbr. 7	Nbr. 6	Nbr. 5

3. For simplicity, at each time interval, if a state undergoes a change in its Polity score, this change will be either a one unit increase or a one unit decrease
4. The probabilities assigned to the Polity score changes are educated estimates given the general the assumptions explained in the previous section.
5. To measure the collective regime authority of the state's neighbors, the model will utilize the average of the neighbors' Polity scale scores as the input parameter and evaluate it against the state's preference rules to determine its Polity score at the next interval.
6. The preference rules for a state are formulated based on theory about maintenance of the status quo and reactionary backsliding.
7. It is assumed that all states of the same regime type have identical preferences for model simplicity.

Accounting for what is above, the first set of rules for Version 1 are as follows:

Model Version 1: Initial Neighborhoods of Heavily Autocratic/Closed Anocratic Regimes

Preference Rule 1:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is greater than 2*** points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.7, x will decrease ($x_t > x_{t+1}$)*
2. *with p = 0.2, x will not change ($x_t = x_{t+1}$)*
3. *with p = 0.1, x will increase ($x_t < x_{t+1}$)*

Preference Rule 2:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is less than 2* points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.1, x will increase ($x_t < x_{t+1}$)*
2. *with p = 0.6, x will not change ($x_t = x_{t+1}$)*
3. *with p = 0.3, x will decrease ($x_t > x_{t+1}$)*

> ***A bound of 2 was chosen in an attempt to ensure that a state's motivations to backslide are grounded in reasonable belief that neighboring regimes are markedly more or less democratic than the state.*

The first version of the ABM runs on the assumption that the states are generally autocratic, with Polity scores between -10 and 0.

The first rule captures the essence of reactionary backsliding– seven out of 10 times, if an autocrat observes that on average, neighboring states have recently become more democratic, its "knee-jerk" response is to further regress and become more autocratic in an attempt to stave off any potential for democratization that may spread from the neighborhood. The goal is to preserve the status quo that allows the autocrat to retain its authority. 3 out of 10 times, the autocratic state will maintain the same level of regime authority; ergo, little to no reactionary backsliding occurs, which should be less likely according to the assumptions. Finally, to account for an element of randomness or unique cases, 1 out of 10 times, the autocratic regime will actually see an increase in democracy within its borders.

The second rule is designed to express a state's preferences in the case that the average of its neighbors Polity scale scores are noticeably less democratic (or more autocratic) that itself. In that case, the assumption is that the state does not feel threatened by its neighbors' backsliding since it wants to preserve its autocratic regime. Therefore, 6 out of 10 times, the state will retain its score at the previous interval. However, states may also see the backsliding in their neighborhood as a signal that it is acceptable for them to further backslide as well to consolidate its authority, if the state determines that the cost of efforts to backslide are worth it. For that reason, 3 out of 10 times, the state will become more autocratic the following interval. Again, to account for randomness or unique cases that break the assumptions, the autocratic regime will see an increase in democracy within its borders in 1 out of 10 occurrences.

The second set of rules for Version 2 is as follows. Note that these rules are score-dependent, or dependent upon the regime type of the state, as scores reflect regime types:

> ## *Model Version 2: Initial Neighborhoods of Mixed Regimes*
>
> ### *For Autocracies and Closed Anocracies:*
>
> ### *Preference Rule 1:*
>
> *The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is greater than 2 points of the cell's Polity score x, then at the next time step (t+1):*
>
> 1. *with p = 0.7, x will decrease ($x_t > x_{t+1}$)*
> 2. *with p = 0.2, x will not change ($x_t = x_{t+1}$)*
> 3. *with p = 0.1, x will increase ($x_t < x_{t+1}$)*

Preference Rule 2:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is less than 2 points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.1, x will increase ($x_t < x_{t+1}$)*
2. *with p = 0.6, x will not change ($x_t = x_{t+1}$)*
3. *with p = 0.3, x will decrease ($x_t > x_{t+1}$)*

For Open Anocracies:

Preference Rule 1:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is greater than 2 points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.1, x will decrease ($x_t > x_{t+1}$)*
2. *with p = 0.3, x will not change ($x_t = x_{t+1}$)*
3. *with p = 0.6, x will increase ($x_t < x_{t+1}$)*

Preference Rule 2:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is less than 2 points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.1, x will increase ($x_t < x_{t+1}$)*
2. *with p = 0.3, x will not change ($x_t = x_{t+1}$)*
3. *with p = 0.6, x will decrease ($x_t > x_{t+1}$)*

For Democracies and Full Democracies:

Preference Rule 1:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is greater than 2 points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.1, x will not change ($x_t = x_{t+1}$)*
2. *with p = 0.9, x will increase ($x_t < x_{t+1}$)*

Preference Rule 2:

The average Polity score of a cell's 8 neighbors (or maximum set of neighbors) is less than 2 points of the cell's Polity score x, then at the next time step (t+1):

1. *with p = 0.95, x will increase ($x_t < x_{t+1}$)*
2. *with p = 0.05, x will not change ($x_t = x_{t+1}$)*

The first version of the ABM runs on the assumption that the states can potentially be of any regime type, with Polity scores between -10 and 10.

The preference rules for autocratic states remain the same as the first model, and closed anocracies have been grouped in with these rules for simplicity and the judgment that both regimes have mostly similar preferences.

For open anocracies, as explained above, the rules reflect their preference to generally match their neighbors due to their "in-between" position on the Polity scale. Therefore, if on average, an open anocracy's neighbors are more autocratic than itself, then 6 out of 10 times, it will see a 1 point decrease in its Polity score to match that of its neighbors, and vice versa for if its neighbors were more democratic than itself. Otherwise, in either case, there is a 30 percent chance that its score will not change, perhaps because the cost of increasing authoritarianism or increasing democracy is not worth the payoff of matching its neighbors. To account for randomness or cases that may break the assumptions, one out of 10 times, the open anocracy will move in the opposite direction of its neighbors.

The preference rules for democracies reflect their desire to promote this form of government for others and maintain it for themselves (especially in cases of autocratic threats), which can be described as reactionary "reverse backsliding." If a democracy's neighbors are generally more democratic than itself, then the democracy does not feel threatened, and instead will likely be inclined to match the scores of its neighbors 9 out 10 times, or simply retain its score ten percent of the time. Conversely, if a democracy's neighbors are, on average, less democratic/more autocratic, then the democracy will likely feel threatened by the impending possibility of autocratic ideals entering its borders, and thus retaliate by increasing its level of democracy 95 out of 100 times, rarely keeping the same previous score (five percent of the time).

Core Model Code

The ABM itself was created via the Mesa Library in Python, and both versions of the model were constructed identically, save for the difference in the model rules. The basic skeleton of the ABM involves first creating 2 classes: the agent and the model, which outline all of the objects created from them.

In coding the agent class, the __init__ method was used to initialize the objects' attributes that belong to the agent. This includes the unique identification of the model and the "self" parameter, which allows for accessing the attributes and methods of the agent class. After initialization, the step method was employed to code the actions that the agent takes at each

step of the model. This is where the rules for the agent for each ABM version were written using the "self" parameter.

In coding the model class, the same technique as above was used. The attributes initialized under the __init__ method included N (the total population of agents), the grid width and height, and self. The code assigning the agents to a cell in the grid was also compiled here. The step method simply employed the schedule.step() function, which allows the model to progress by the specific number of intervals when running.

Visualization Generation

Once the core code of the ABM was written, the next step was to generate the code that will project the model's results into visualizations for convenient interpretation. The first visualizations created were histograms (created via the matplotlib library in Python) to gauge the distribution of states across the score spectrum after several iterations of the model. The next visualization was a color barchart that was graphed using the same library, which displayed the 10x10 grid (in which each cell is a state agent) after 10 steps of the model. Each cell was colored based on its score for expedient observation of how certain neighborhoods were shaped by the 10th step of the model (the more autocratic a state, the darker its cell color is). Finally, the code to launch the simulation of the ABM was written. Each grid cell was coded to contain a circle (representing the state agent), and the circle is colored based on the Polity score of the state (shown below and on pg. 2):

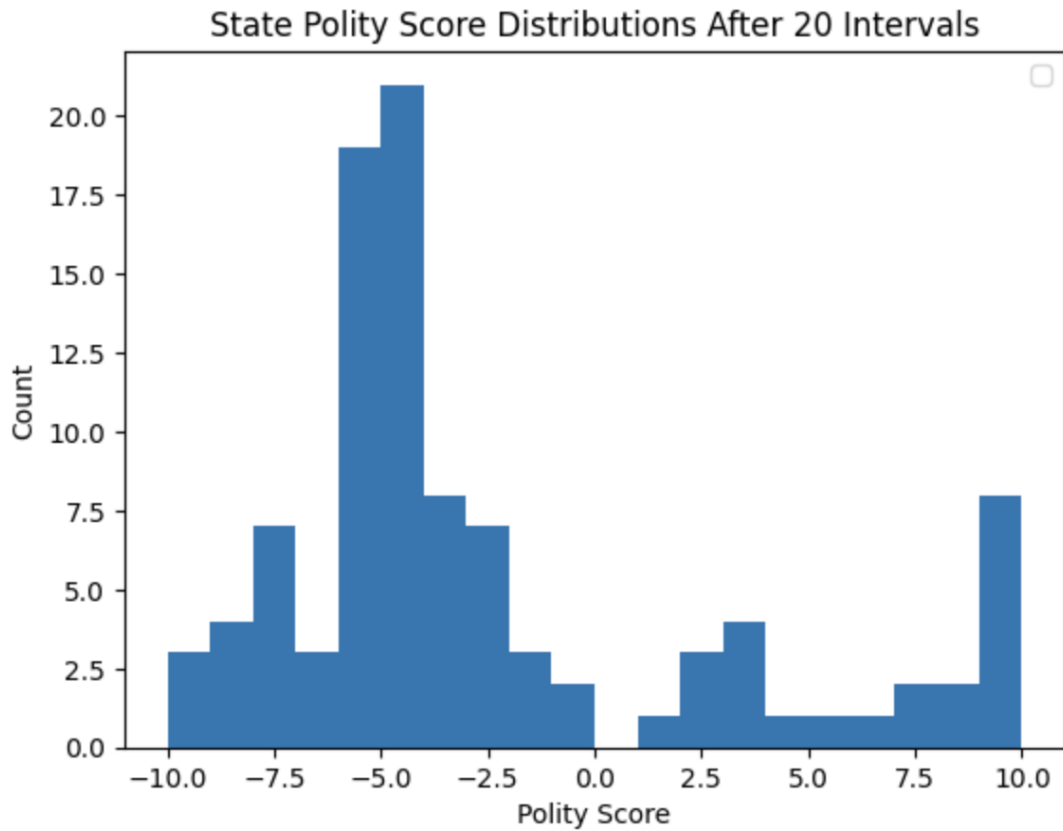| Score Range	Regime Classification
[-10, -6]	Autocracy, Red
[-5, 0]	Closed Anocracy, Orange
[1, 5]	Open Anocracy, Yellow
[6, 9]	Democracy, Green
10	Full Democracy, Blue

The simulation consists of 4 features: the grid itself (via the CanvasGrid() function from mesa.visualization) that changes according to the rules in real time; a set of start, stop, and reset buttons to run the model over the desired number of iterations; an adjustable bar to manipulate the speed at which the iterations take place; a graph of the distribution of Polity scores of the agents in the model (via the ChartModule() function from mesa.visualization). The simulation was launched using the ModularServer() function from mesa.visualization, followed by assigning a port number and calling the launch() function.
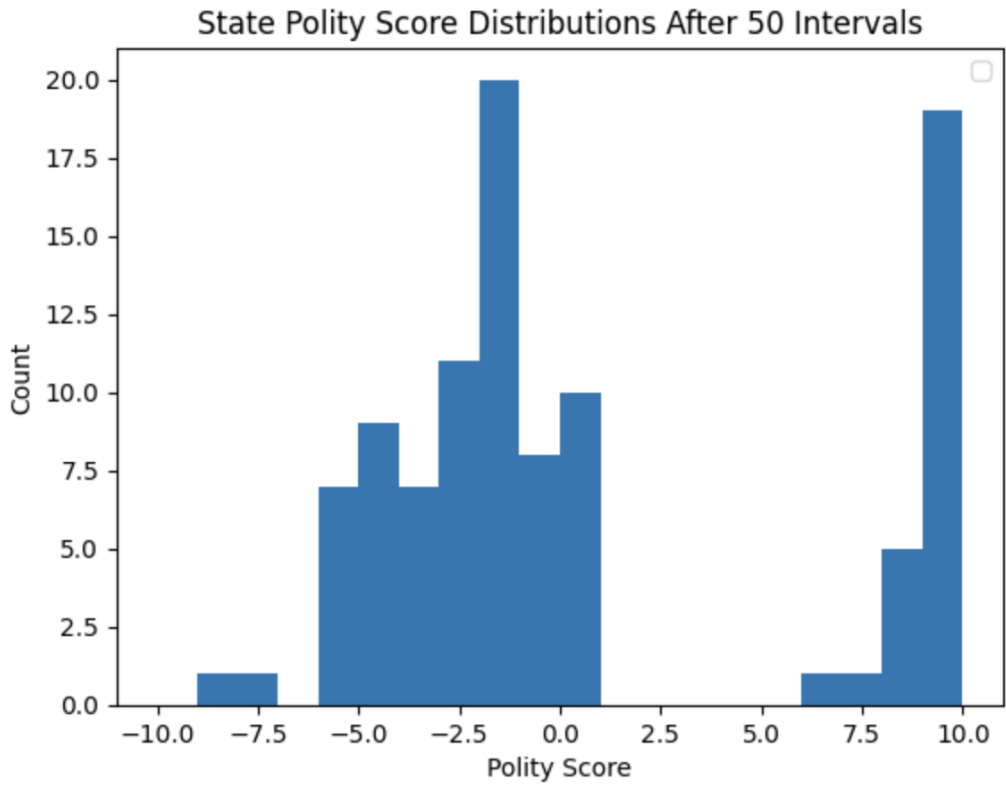

Preliminary Findings

Model Version 1

After running the ABM for several variations of time steps (ex. 10, 50, 100, 200, 250, 500), several visualizations were generated. The first of the visualizations were histograms that depict the score distribution of each state at the last time step. Below are histograms generated for 20, 50, 100, and 250 intervals. Note that each map is not a chronological progression from the last, but rather a randomized/new depiction of the ABM at different time step values.
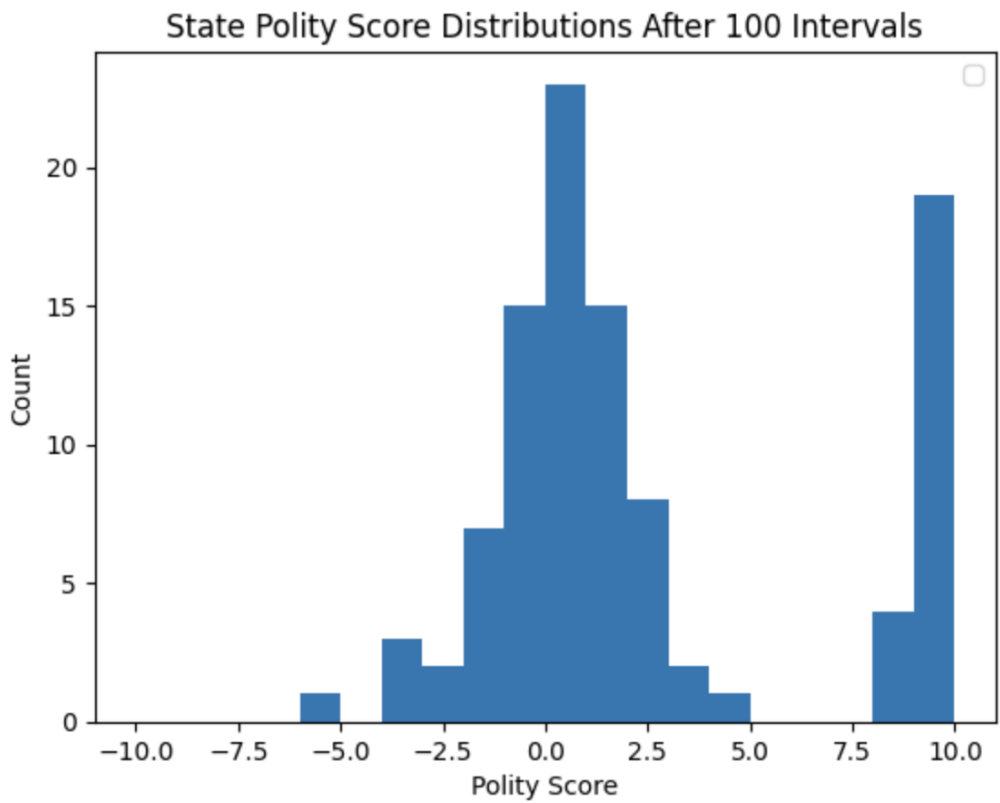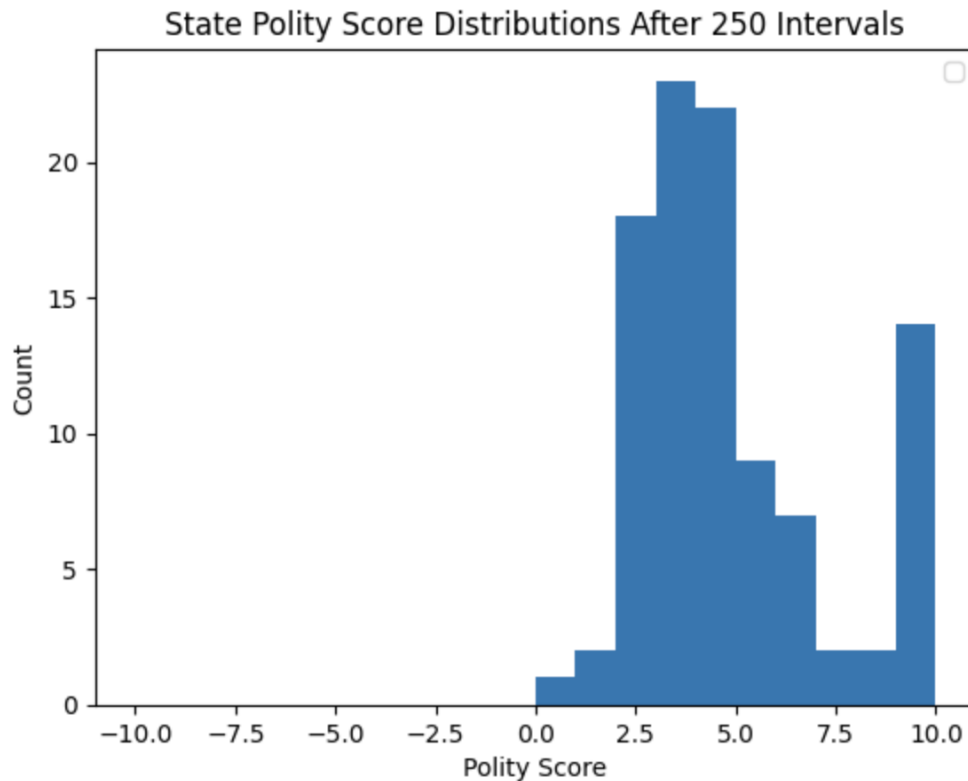
20 Time Steps:

50 Time Steps:

State Polity Score Distributions After 50 Intervals

100 Time Steps:

State Polity Score Distributions After 100 Intervals

250 Time Steps:

State Polity Score Distributions After 250 Intervals

Analysis: After 20 intervals, it appears that most of the Polity scores are at or around -5, though there is another smaller peak around 10. This indicates that most of the states at this point are largely still authoritarian (either autocracies or closed anocracies), which makes sense given their resistance to democracy and the relatively short duration the model has been run for. Running the model for 50 time steps, it is evident that the distribution around the lower scores has become more condensed and centered around 0 to -2, while the peak at 10 has become more pronounced. When run for 100 time steps, there appears to be, in a way, two distributions on the histogram– the first one looks quite normally distributed around 0, indicating that the average of the Polity scores are increasing with time; the "second" distribution of a peak at 10 appears to mirror very closely how it manifested in the previous histogram, indicating that higher scored democracies are stable interval to interval. In the version of the histogram in which the model has been run 250 times, we can see that the overall distribution of scores has moved noticeably right towards positive scores, however the number of high-scoring democracies decreased in "exchange" for that overall shift towards the right. The results here deviate from what was expected: the rules for authoritarian states (scores from -10 to 0) indicate that there is a significant resistance to introducing democratic institutions within their borders, yet after 250 time steps, there appears to generally be a complete eradication of autocratic and closed anocratic regimes in favor of mostly open anocratic regimes, which seems like a phenomenon of compromise– autocrats don't want to adopt democracy (6-10), but will settle for open anocracy. Could this settlement attitude be due to the threat of revolution and monumental

adjustment of the status quo (more so than simply decreasing autocracy as a concession)? The model communicates that overall, the rules seem somewhat capable of diminishing the presence of authoritarian regimes, to an extent.

To better grasp the spatial distribution of Polity scores by the last time step of the model, a heatmap was created for intervals of 20, 50, 100, and 250 steps. These visualizations can help answer the fourth sub-question of whether "blocks" of similar regime types form across the grid. The heatmaps for each variation of time steps are depicted below. Note that each map is not a chronological progression from the last, but rather a randomized/new depiction of the ABM at different time step values.
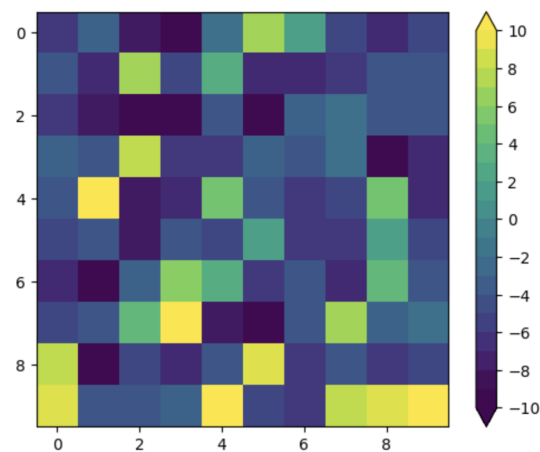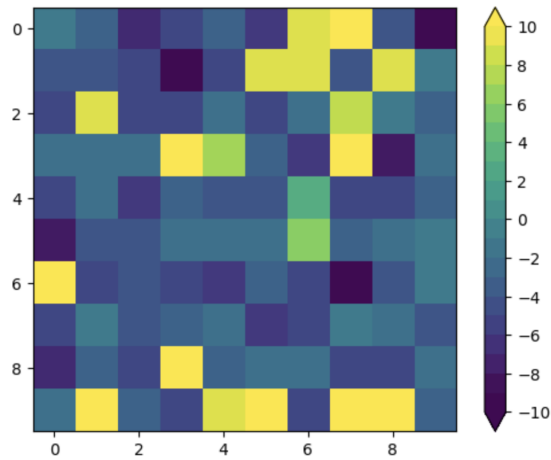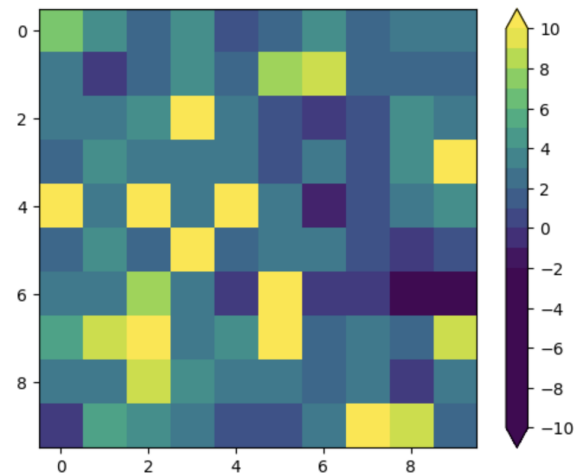
20 Time Steps:
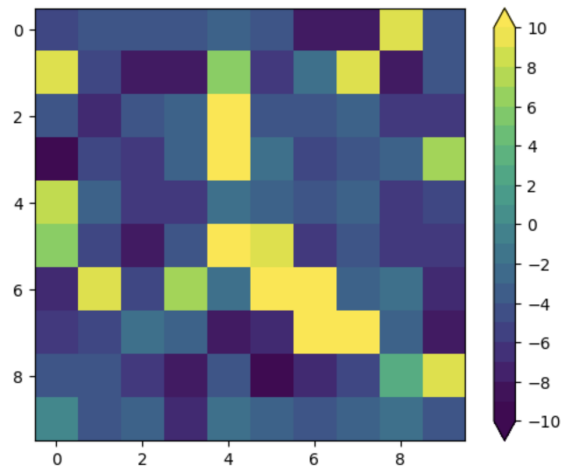
50 Time Steps:

*100 Time Steps:*

250 Time Steps:

Analysis: As the magnitude of the time steps increase, there is a clear lightening effect taking place across the grid, where at 250 time steps, most of the cells (states) appear to have scores that hover near the range from 0 to 2, again indicating that most of the states are now open anocracies, which was also visible in the histogram visualization. At every time step variation of the model, the high-scoring democracies (of a yellow or light green color) seemed to have formed small coalitions or blocks, which raises a question of whether this self-organization could be a response to being surrounded by a swarm of less democratic regimes- however, each regime is behaving according to the same set of rules, which are written from the perspective of the autocrat. Thus, wouldn't states that turned democratic over time only have done so out of necessity to avoid a major breakdown of the status quo? Though, once a state becomes democratic, then its urge to backslide reduces significantly as there are few states that are more democratic than itself. This could be a model limitation or error— it may pay to write another conditional rule that incentivizes democracies that were former autocratic regimes to backslide

once it is among the most democratic. On the other hand, maybe there is an incentive to remain democratic, perhaps for the allyship that country may receive from global democracies, such as NATO states. Finally, though the heatmap shows that scores largely have shifted to positive values after hundreds of iterations, there still appears to be a consistent number of states that, although are no longer autocracies, remain closed anocracies (i.e. have negative scores). This collective seems to represent the highly resistant authoritarian states.

To understand similar spatial dynamics of the heatmap classified by the 4 regime types, the ABM simulation can be run. The following figures depict the initial state of neighborhoods of mixed regime types, and the grid after 500 time steps in an attempt to find an equilibrium point.
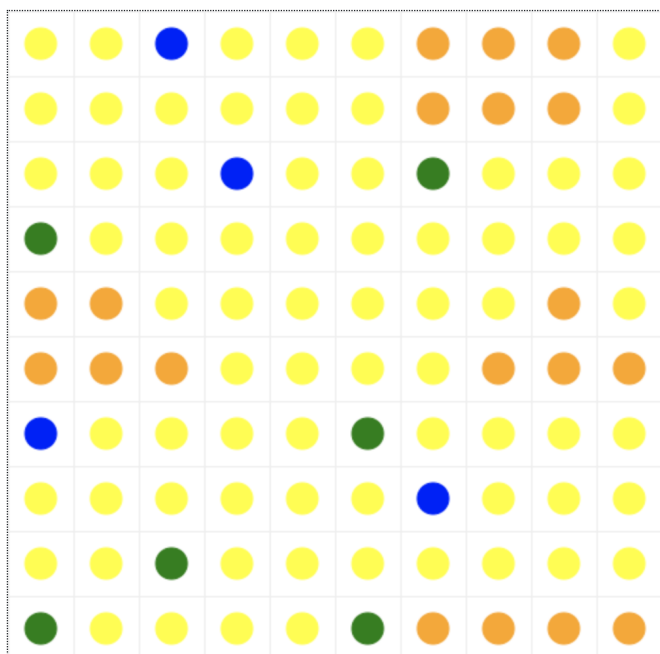
Time Step = 0:
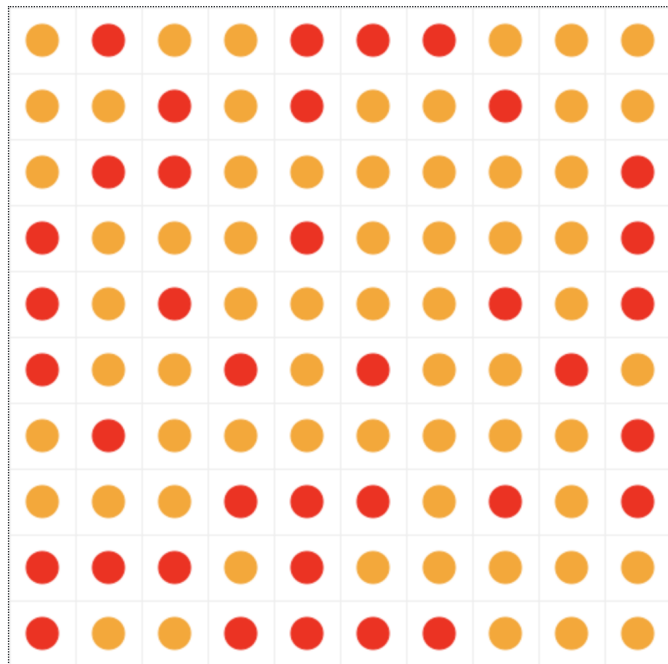
Current Step: 0

Time Step = 500:

Current Step: 501

Analysis: This model also allows for the determination of the regime progression of each state by the end of the 500th time step. For example, the closed anocracy at the [3, 1] coordinate position ultimately became a full democracy, which can be extrapolated by looking at the same coordinate position on the second grid. Interestingly, it is not only clear that a vast majority of the regimes transitioned to open anocracies at the conclusion of the 500th time step, but also that the states that did remain or become closed anocracies seemed to form small coalitions– no closed anocracy is isolated from its peer regimes dispute there being far fewer of this type compared to open anocracies. Conversely, all democracies appear to be isolated, which re-opens the previous question proposed about the accuracy of the rules in reflecting authoritarian preferences. Looking at cell [3, 1], now that all of its neighbors are open anocracies, and definitely more than 2 points below that state's scores, would it not want to at least match its neighborhood, assuming it has the same tendencies as an authoritarian regime? Again, this suggests that either the model rules should be re-evaluated, or that the rules reflect an autocracy/closed anocracy-turned-democracy's new strong preference to remain a democracy. This pattern could also reflect the 10% randomness measure in which the state acts the opposite manner of what is expected; this could signal that autocracies/closed anocracies will actually concede and settle for open anocracy if they feel compelled or threatened into doing so (proposed in the analysis of the histograms as well). Or perhaps, that magnitude should be reduced to reflect just how rare this phenomenon is.

Analysis of Questions, Model Version 1

Central Question 1: *Given certain assumptions about the preferences for regime type of autocratic states as a function of neighborhood regime activity, is it possible for trends toward democratization to embed themselves into heavily autocratic neighborhoods?*

Yes and no. While there was an overall shift from negative Polity scores to a vast majority of positive Polity scores, that does not necessarily indicate that democracy has taken or will take hold across neighborhoods. In fact, after running the simulation for 500 intervals, it is very clear that most states are "stuck" as open anocracies, on the threshold between democracy and closed anocracy. So while there was a general shift towards less authoritarian regimes, that progress seems to stagnate at largely open anocratic neighborhoods. The few states that did actually become democracies, however, remained stable as democracies, which is promising. But, as was brought up in this section, it is not clear if that accurately reflects the preferences of those states, since it is still assumed that they maintain the same autocratic perspective as their neighbors; further investigation must be conducted into this, and supporting literature should be brought in as well. Therefore, it was observed that trends *toward* democratization can embed themselves in heavily autocratic regimes, but those trends appear to stagnate around Polity scores between 0 and 5, with very few exceeding that bound to become democratic. There must be further manipulation of the rules to change the current equilibrium so that the model can overcome the stagnation of scores around the open anocracy regime type.

Sub-question 1 (Model Version 1): *Are there certain behavioral rules that can significantly shape the landscape to increase an autocratic state's inclination to introduce democratic institutions, thus resulting in a general trend away from authoritarianism in a neighborhood?*

Though the model was not able to provide a definitive answer to this question, it showed some promise of the potential to alter the original rules to increase individual preferences to democratize. To map this to theoretical explanations, perhaps those Polity score increases can be a result of concessions by the authoritarian regime. For example, if an autocrat observed that 75 percent of its neighbors were democracies, then perhaps instead of reactionary backsliding, it would introduce a toned-down measure of democratization into its regime for fear of a revolution by its constituency that might do more damage to the status quo than simply conceding a number of freedoms to the population.

Sub-question 4 (Model Version 1 & 2): *When running the ABM, will there emerge patterns of "blocks" of the same regime type (ex. a block of anocracies or democracies), and what does this indicate about the neighborhood dynamics between states?*
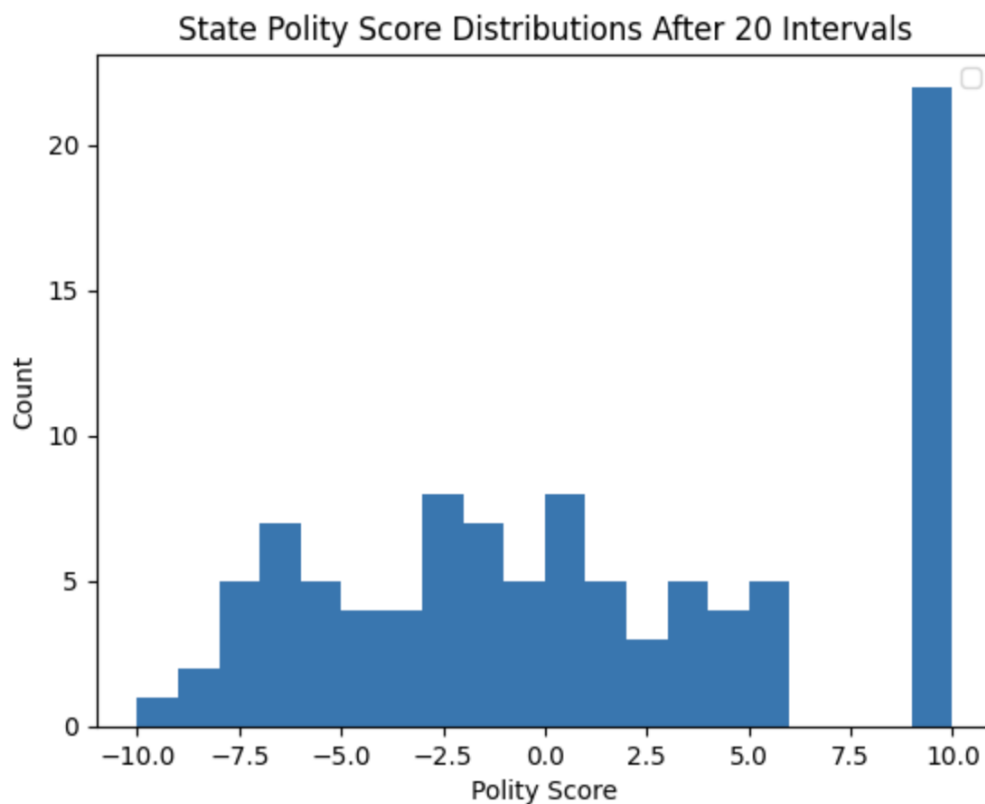
Analyzing the breakdown by score, it is clear that states with scores on the higher end of the spectrum formed small "coalitions" so that nearly every democracy had democratic allies on at least one of its borders. The heatmap for 250 time steps also depicts a fair amount of "color blocking" for states whose scores are low-positive, further reflecting some desire to match a proportion of one's neighborhood. This matching phenomenon may be due to the security assurance it provides– states with similar regime types have further aligned preferences, which means there may be some unspoken allyship between them. Having these similar states close

by could serve as a deterrence mechanism to states of competing regime types who may threaten to unfavorably affect the status quo for another state.

Model Version 2

After running the ABM for several variations of time steps (ex. 10, 50, 100, 200, 250, 500), several visualizations were generated. The first of the visualizations were histograms that depict the score distribution of each state at the last time step. Below are histograms generated for 20, 50, 100, and 250 intervals. Note that each map is not a chronological progression from the last, but rather a randomized/new depiction of the ABM at different time step values.
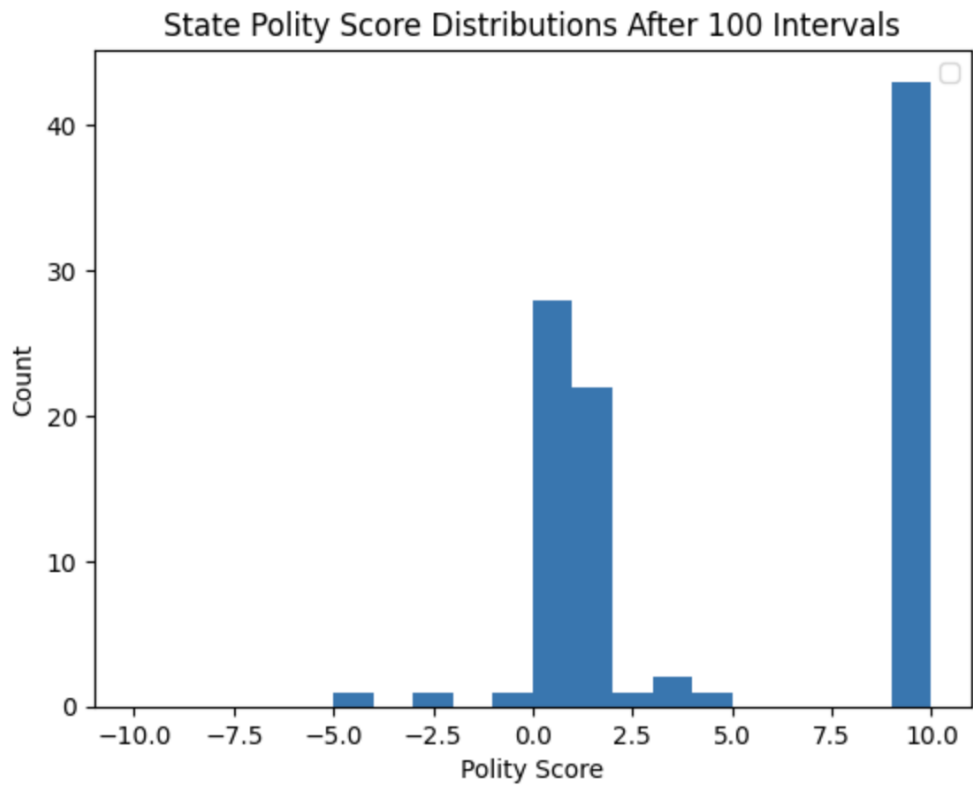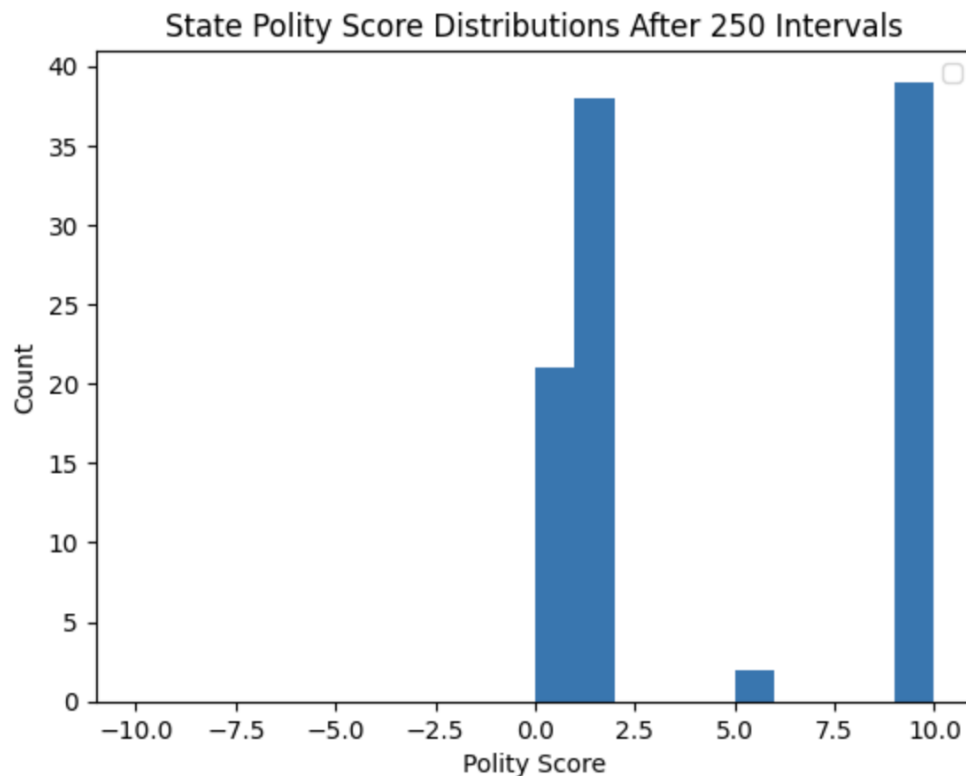
20 Time Steps:

50 Time Steps:

State Polity Score Distributions After 50 Intervals

100 Time Steps

State Polity Score Distributions After 100 Intervals
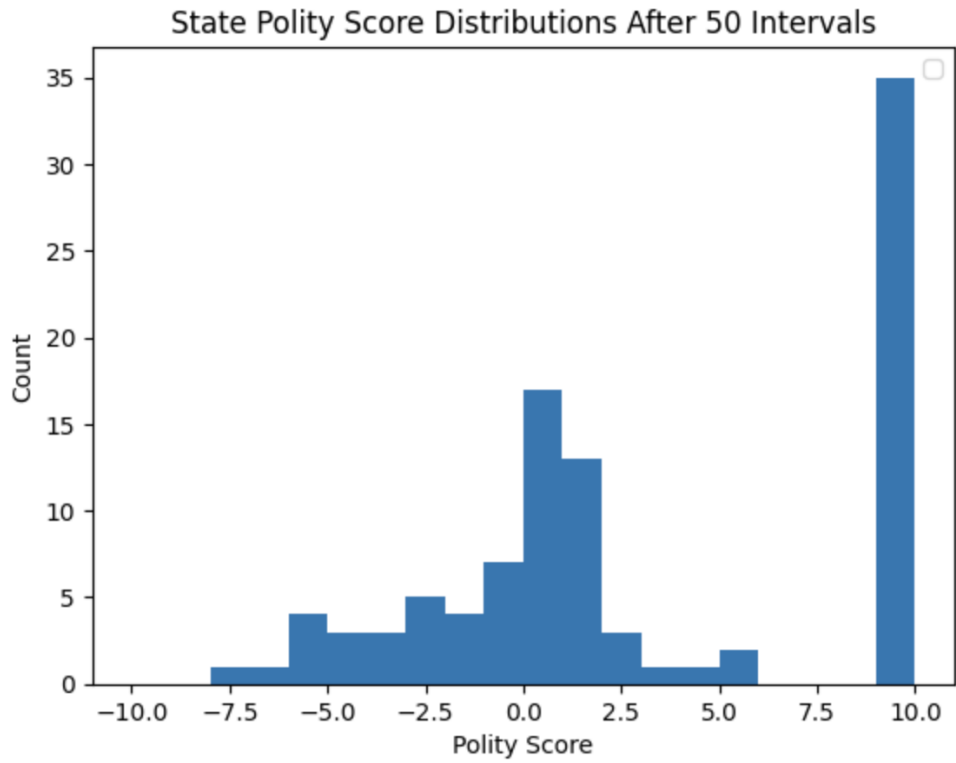
State Polity Score Distributions After 250 Intervals

Analysis: The histogram modeling the duration of 10 time steps shows a pretty evenly spread distribution of scores around -10 and 6, but a peak of outliers comprising about ¼ of the population with scores around 10. Very few states are on the extreme left of the spectrum, at autocracy. Over the next 3 graphs, as time steps are increased, the number of highest-scoring states appears to stabilize around 40. The previously somewhat even spread of states around the range of scores from -10 to 6 has somewhat converged around a score of 0, and this is further solidified in the final version of the histogram modeling 250 time steps. Overall, there appear to be large proportions of highly-scoring states (democracies), but they are outnumbered approximately 1.5 times by states with scores between 0 and 2 (open anocracies). The final histogram indicates that regime preferences converge to mainly 2 categories: democracy (likely full democracy, which will be confirmed by the simulation imagery), and open anocracy. It is unclear at the moment what this might mean in terms of system-level dynamics, but a potential explanation might be one of balance of compromise. The system converged to a grid in which about 35 to 40 percent of countries are either highly democratic, while 60 to 65 percent are generally open anocracies. Perhaps this increased presence of open anocracies or low-positive scores is to account for what is essentially a complete loss of autocracies.

To better grasp the spatial distribution of Polity scores by the last time step of the model, a heatmap was created for intervals of 20, 50, 100, and 250 steps. These visualizations can help answer the fourth sub-question of whether "blocks" of similar regime types form across the grid. The heatmaps for each variation of time steps are depicted below. Note that each map is not a

chronological progression from the last, but rather a randomized/new depiction of the ABM at different time step values.
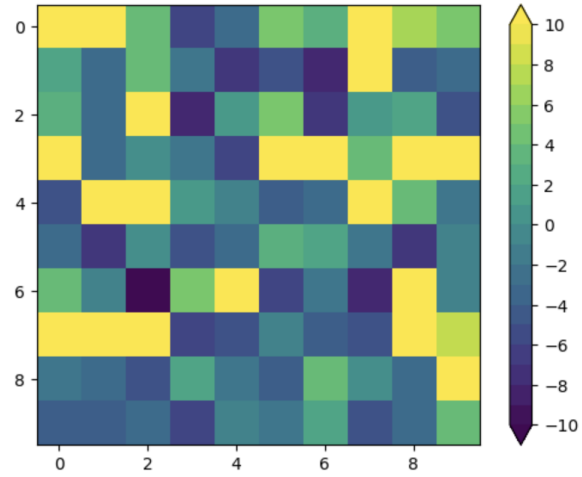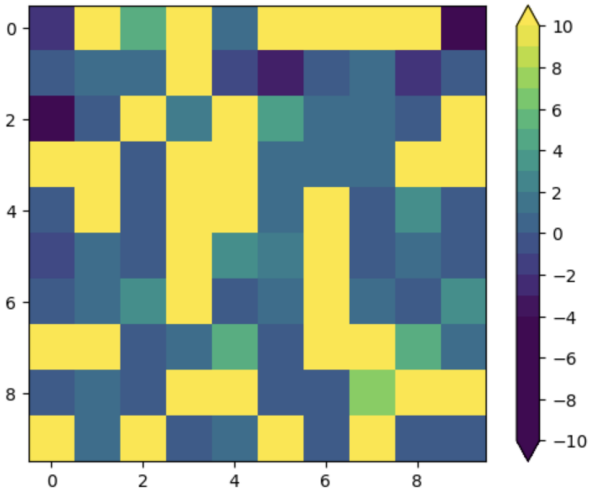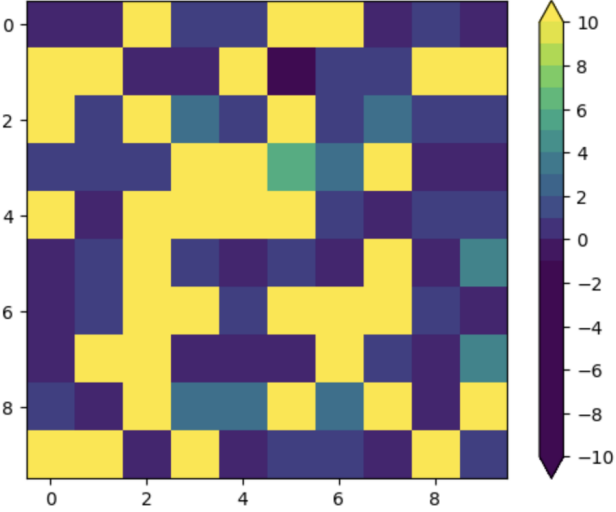
20 Time Steps:
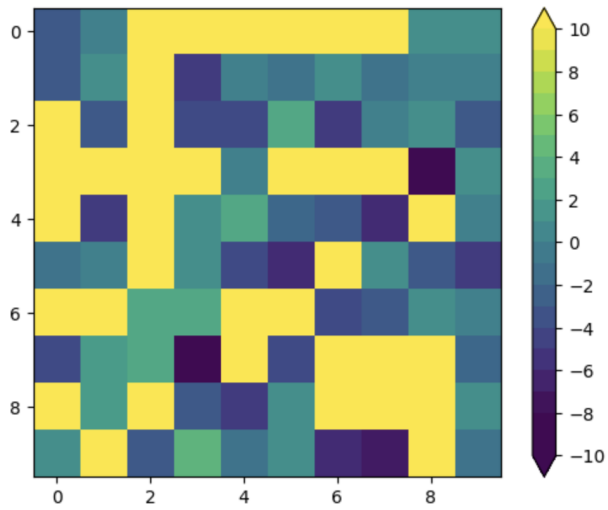
50 Time Steps:
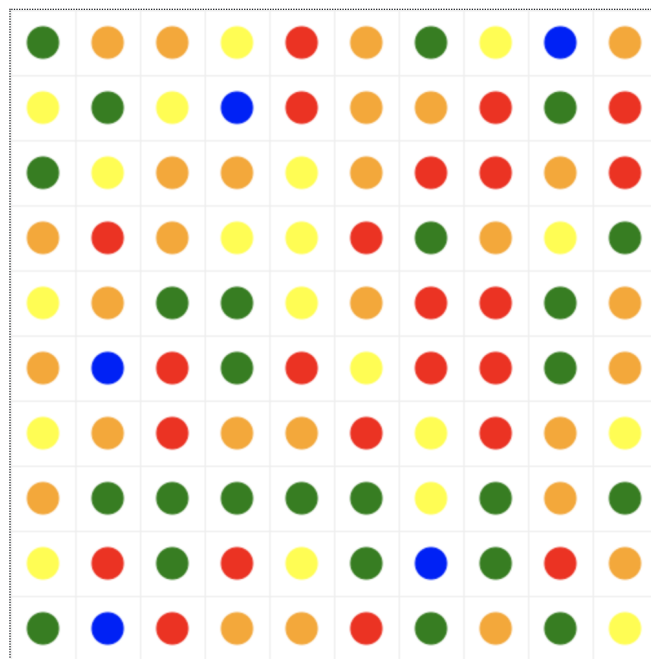
100 Time Steps:

250 Time Steps:

Analysis: In the first heatmap, it is visible that most states with similar colors (i.e scores) share borders with one another, and this pattern is extremely pronounced for highest-scoring countries, or full democracies. That block of yellow grows significantly as the time steps are increased, and the graph appears to depict the yellow cells almost "snaking" around the grid to form some sort of lengthy network across space. There is also an increase in scores hovering near 0, plus or minus a marginal magnitude of points. As the time steps approach 100 and 250, there are more obvious coalitions that form among the "blue" and "purple" states, and again, the assurance of security and/or deterrence signaling objective which was explained for the first version of the model may be applicable here. It is almost as if de facto or makeshift neighborhoods of similar scores (and thus regimes) have self-organized so that nearly each type shares a border with at least one other that is of an identical or similar type. In the 250

time-step version of the heatmap visualization, there also appears to be a trend in which states with scores in the range from 0 to 2 (the lighter purple cells) are sandwiching states with scores less than 0 (the darkest purple cells). One proposed explanation could be that the lighter purple cells are more comfortable with bordering both the dark purple and yellow states, because they lie closer to a half-way point between both. However, the dark purple and yellow cells have a greater difference in scores, meaning they have very different preferences, and thus are not as amenable to bordering states at the opposite end of the spectrum. In a sense, the low-positively scored states act as a buffer or mediator state between the high-negatively scored and high-positively scored states.

To understand similar dynamics of the heatmap classified by the 4 regime types, the ABM simulation can be run. The following figures depict the initial state of the neighborhoods, which are of mixed regime types, and the grid after 500 time steps in an attempt to find an equilibrium point.
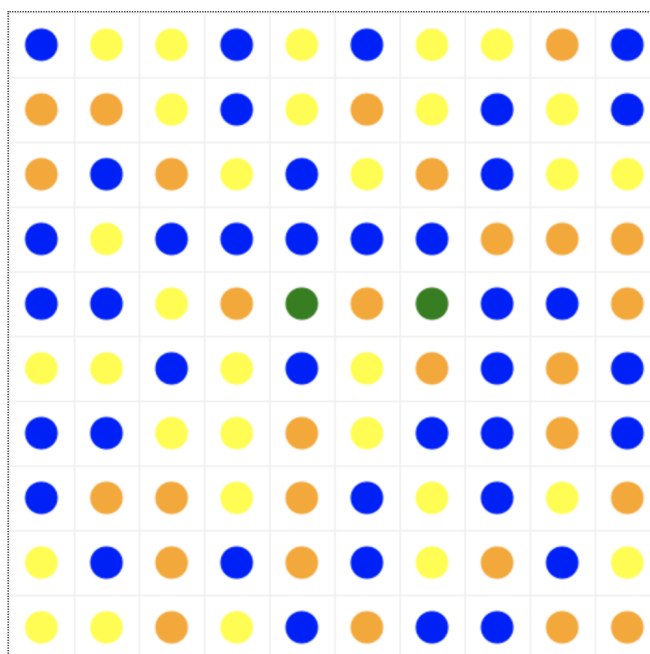
Time Step = 0:

Current Step: 0

Time Step = 500:

Analysis: The grid after 500 time steps has very similar patterns to what was observed in the heatmap, and this simplified version by regime type rather than score is easier to interpret. First, we see an essentially full eradication of autocracies after 500 iterations. For any regime type, it is clear that there are few isolated regimes– most from these "coalitions" referenced earlier, but there are stark size differences between each regime type present. Blue cells (full democracies) have a vast, sprawling network across the grid, and this network survives as the model approaches infinitely many iterations, indicating that inducing an environment with many stable full democracies is entirely viable with the current assumptions and model rules. On the other hand, yellow and orange cells (open and closed anocracies, respectively) have a much larger volume of significantly smaller blocks of 3 to 4 states scattered throughout the grid. Why did they not form sprawling networks like full democracies? Perhaps this could be because there is an implied allyship between orange and yellow cells. Though open anocracies lie in some "in-between" point between autocracy and democracy, they are always closer in score to closed anocracies than full democracies, indicating that this regime type has preferences that more align with closed anocracies. For that reason, they appear on the grid as small blocks, but can really be considered as closer to a full unit, making them just as sprawling, if not more, than full democracies on this grid. The model when running also depicts a fair amount of oscillation between yellow and orange cells, further suggesting that anocracies of both types much rather prefer to remain similar to one another than match their fully democratic neighbors. Interestingly, we also see that a fair amount of green cells (democracies) transition to open anocracies (keep in mind that both grids are spatially identical, and states don't move cells, they only change scores over iterations), and a fair amount of autocracies become full democracies (this is very noticeable in column 9). There are even full democracies that backslide to anocracy. It is again very counterintuitive to see these dynamics– wouldn't green cells want to remain green or would

even rather become blue than yellow? And, wouldn't autocracies prefer to backslide and remain "as red" or as autocratic as possible given a higher neighborhood score average? At least, that is what the rules seem to reflect, yet the actual simulation seems to defy those assumptions, and a similar dilemma was uncovered when analyzing the first version of the model. As was explained previously, this system-level behavior could indicate some unaccounted for incentive for democracies to backslide, and autocracies to do the opposite, or the model rules simply need to be better refined. The 10% randomness factor in which states act unexpectedly may be of an excessive quantity, and reducing it to 5 or 2.5 percent may produce the expected results. Regardless, further model manipulation is necessary to understand why these phenomena are occurring.

Analysis of Questions, Model Version 2

Central Question 2: *Given certain assumptions about the preferences for regime type of autocratic, anocratic, and democratic states as a function of neighborhood regime activity, what is the nature of the regime authority dynamics within neighborhoods of more diverse regime types?*

Over many time steps, there seems to be a strong regime preference for states of either anocracy or full democracy, and few and far in between. In a mixed regime neighborhood, as the iterations of the model approach infinity, given the assumptions and mode rules, this pattern is almost certain to manifest on the grid. However, these assumptions come into question when accounting for the history of individual states' transitions from the first iteration to the final iteration of the simulation. For example, there was an expectation that democracies and states with positive scores in the initial stages would retain and strengthen/increase their scores towards further democratization, yet there were also a volume of such states that actually ended up anocratic by the end of the simulation, a volume not extremely large, but nonetheless still too significant to ignore. Conversely, it was expected that regimes starting out autocratic or closed anocratic would be resistant to democratization and therefore end up strengthening/decreasing their scores towards authoritarianism, yet similar to democracies, actually ended the last iteration with more democratic regimes than previously. These patterns may reflect a shortcoming in the theoretical assumptions and rules that the model was built on, but could also imply the underlying presence of a factor that causes this behavior– perhaps there is an incentive for democracies to become anocratic, and vice versa for autocracies/closed anocracies. This incentive could be the result of a "pushing" factor, where an autocracy only democratizes because it deems that it is more worth bearing the cost of this than a potential uprising that could strip an autocrat of most power. "Pulling" factors can also be at play here, in which perhaps a democracy (not a full democracy) decides that changing the status quo and becoming anocratic is in the regime's (or leaders') best interest, which is not a decision made out of compulsion. Either way, on the system-level, there is some phenomenon of compromise playing out- there are many full democracies, with the highest scores, and they are outnumbered by anocracies, which have low-negative and low-positive scores, but are not pulling down the level of democracy like autocracies would with scores of up to -10. Thus, overall, it seems that what was thought of as an outlying score of 10 becomes quite common

after 500 iterations, and to counterbalance that, there is a larger volume of non-autocratic and non-democratic states.

Sub-question 2 (Model Version 2): *Given a region (grid) with mostly diverse regime types, do there exist certain behavioral rules that will result in a general shift towards democratization, or away from autocracy?*

Unlike the first version of the model, there are significantly more full democracies, indicating that in mixed-regime environments, democracy can prevail in the presence of anocracy. Thus, the current model rules do indicate that at equilibrium or near-equilibrium, there is a significant shift to full democratization in general. Though, the question now would be whether these rules can be further altered to allow the anocracies at the current equilibrium to actually transition to democracy. There could be a tradeoff here: Perhaps the number of full democracies would have to reduce in order for this to happen. Would it be more beneficial to have a majority of cells be green (so, non-full democracies) with a small proportion of open anocracies, or is it optimal to keep something similar to the current equilibrium, where there are a significant number of full democracies, but as an apparent result a greater number of anocracies to counterbalance the scores of 10? The answer to this could depend on the objective, and whether the cost of reducing full democracies to democracies in order to increase the number of democracies and reduce the number of anocracies would be worth it. And if it is worth it, how can the rules be manipulated or altered to reach that image of an equilibrium? Can that equilibrium ever be reached at all? These are important questions worth exploring.

Sub-Question 4 (Model Version 1 & 2): *When running the ABM, will there emerge patterns of "blocks" of the same regime type (ex. a block of anocracies or democracies), and what does this indicate about the neighborhood dynamics between states?*

The emergence of these coalitions or blocks of similar or same regime types is an important and expected pattern present in the model. As explained in the first version analysis of the model, these blocks can perhaps be interpreted as "teams" of states that serve the purpose of deterring other states of competing regimes from threatening a state on the team, because they have very obvious and nearby support from their teammates. A state would also likely be more comfortable retaining its regime type if it finds itself in a coalition, which mathematically would mean that the neighbor score average would be similar and indicative of a consistent score for that state over iterations of the model. Mapping this to real-world applications, the Polity scale scores for African countries in 2017 appears to reflect this pattern of "blocking" by regime type. The states of the most dominant regime types of that year– closed anocracy, open anocracy, and democracy are not evenly scattered across the continent. Instead, they largely border one another. In the southern region of the continent, there is a team of democracies, while in the north and central regions, there is a block of closed anocracies. In the west lies a coalition of open anocracies. It seems that this phenomenon of "blocks" is already projected across many parts of the globe.

Limitations, Implications and Areas for Future Investigation

Because the model is not fully developed, and much of the ABM's rules were created using reasoned assumptions, one major limitation is that the results are certainly not entirely reflective of observable patterns within the dynamics of inter-state regime activity. To solidify or critique the proposed explanations of the model results and the justifications of the assumptions, more work needs to be done to incorporate ideas from the supporting literature into the formulation of the ABMs preference rules across regime types. For example, this model operates under the assumption that a democracy, if surrounded by heavily authoritarian neighbors, would be resistant to such neighbors and "double down" on its democratic institutions (e.g. increase the freedom of press and the movement of information). Though this may be true in some cases, another reasoned assumption may point to the opposite reaction by a democracy– namely, it may escalate measures that may be considered anti-democratic, such as increasing surveillance within and around its borders to ensure that any autocratic threats to its regime are monitored and addressed before they can pose a significant risk to the security of its democracy. The ramping up of such measures may signal a decrease in that democracy's Polity scores, rather than an increase. To draw a parallel, the United States greatly increased its surveillance measures (of which a consequence was increased discrimination against its Arab and Muslim populations) following the September 11th attacks, even though that behavior can be classified as generally authoritarian. The current model can be re-evaluated to account for such behavior, especially if there is evidence of this in the existing literature. Furthermore, the results of the model did not fully align with the expectations of what would transpire in the simulation, which may point to some unaccounted or confounding variable that is causing such results.

The model can also be expanded to account for different variations of initial neighborhoods. In other words, what can be expected if the initial Polity score ranges are altered given the current rules? It might be worth exploring this idea to determine if there are certain initial conditions necessary for democracy to take root in regions. The question then may be of whether or how these conditions can be brought about. Or, this information can be utilized to identify specific existing political neighborhoods to which the rules of the model may apply.

It is also certainly worth manipulating the current rules to determine if there exist any optimal sets of rules under which democracy can flourish, or under which autocracy can vanish, at the very least. One rule change that may yield interesting results is one discussed in the previous section about whether conditions exist so that autocracies feel more inclined to make concessions for democracy rather than backslide. This is sort of a question around whether autocracies draw distinctions between their preferences for regime type as a function of *how much* more democratic or autocratic their neighbors are in relation to themselves. Perhaps an autocratic regime is far more likely to backslide by a greater magnitude if its neighbors are markedly more autocratic (e.g. more than 4 points below) than itself, because it feels that backsliding is far more acceptable in that neighborhood. Or, taking a closed anocracy with a Polity score of -2 and a neighbor average score of 3, it might be expected that the anocracy backslides to offset the possibility of anti-autocratic ideals seeping into its borders. However, if

the average score of its neighbors was suddenly in an interval much farther from its own position, such as a 5 or 6, would it react in the same way? Or, instead, would it concede certain democratic measures to its people as a compromise? This compromise may not necessarily be because the anocratic state generally prefers democratization, but rather because the threat of revolution by its people is too great due to the state's spatial proximity to relatively much more democratic states. Even if it tried to keep democratic ideals out of its border, it would be impossible because of the circumstances. Therefore, the potential destruction of the status quo by revolution due to backsliding is not worth the guaranteed adjustment to the status quo of moving "up" marginally on the Polity scale. So, the anocracy may decide to concede a certain level of democratic features, such as granting greater access to external news sources. Nuanced behavior stemming from such assumptions are important to follow up on with supporting literature, so that the model may be revised to account for these details.

Another key manner in which to strengthen the model is to adopt the "many model" approach, or try to combine the ABM with other types of formal models to introduce novel perspectives or confounding variables that were not previously accounted for. For example, one potential area of expansion for the model would be accounting for history. Right now, the agents simply act on information that they are being fed at a specific time interval. Their histories or memories are not a feature of the model rules, though a state's history, whether that be of its own regime changes or its interactions with other regimes in its neighborhood, may be a critical factor in a state's preferences or behavior. To remedy this, perhaps the current model can be combined or used with a model that does account for history, such as Polya's Urn model. For example, if a state has a well-established legacy of autocracy spanning centuries into the past, that history may affect its behavior, and the current rules of the model may not fit its actual preferences for regime type– maybe the probability that it backslides is much greater, or the magnitude of its backsliding is much greater. Some "urn" that represents a state's previous history can be considered, and it may contain elements that model the regime type or Polity scores throughout the history of that state. When an element is drawn at random, then it must be returned to the urn along with another element of the same variety, indicating that a state's previous history is predictive of its future. To provide further context, if a state that had a history of being an autocracy 90 percent of the time, while it was a closed anocracy 10 percent of the time, then its "urn" would contain elements of which 90 percent represent autocracy, and 10 percent represent closed anocracy. Then, when an element is drawn at random, it is far more likely to be an element representing autocracy; thus, that chosen element along with another element of autocracy would be returned to the urn, indicating a strong autocratic disposition because of its record. There must be a way to aggregate Polya's Urn with the ABM to refine the predictability of the model, as history likely plays an important role.

It is also entirely possible that states that are on the threshold between autocracy and democracy might be more vulnerable to frequent score oscillations because of their desire to match their neighbors– not being strongly authoritarian or democratic may make a state vulnerable to external influence and pose a threat to the status quo. To account for this or better observe this hunch, it would be extremely useful to generate a visualization that tracks the regime or Polity score evolution of individual states, and to compare those evolutions both

between groups and across groups to gauge and possible patterns. Moreover, there was an attempt to create a graph of the distribution of regimes over the iterations of the model to determine if there was any equilibrium reached after a certain period of time. However, the mechanics of the code were unsuccessful and more effort is needed to overcome those issues to produce an accurate graph of this dynamic. However, after running the model for 500 time steps, there does appear to be some level of a stationary distribution achieved, though some oscillations between closed and open anocracies persist. Plotting those anomalies on a graph would provide further clarity over questions of an equilibrium state for this ABM, and would also be useful when several other versions of the model based on solid theory about state preferences from the literature are developed.

Though the current draft of this ABM is still in its initial stages, and much more work will be done to improve the predictability of the model, it can still be considered a promising approach for advancing the knowledge around political neighborhoods and the inter-state dynamics of regime authority, especially considering that this is a relatively unpopular topic of international politics.

(Reference listed below)

References

Gartzke, Erik. Review of The "Neighborhood Effect" in International Politics, by Kristian Skrede Gleditsch. International Studies Review 5, no. 3 (2003): 371–73. http://www.jstor.org/stable/3186579.