A System Dynamics and Agent-Based Simulation Approach to Test Group-Level Theories of Political Violence

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Abstract

In the political violence scholarship, there is a gap in explaining how group-level dynamics cause mass political violence. There are several theories of why political groups become violent. Because of the qualitative nature of these theories and the feedback complexity of political violence, it is hard to test these theories against each other and against data. This paper describes an attempt to use a combination of system dynamics and agent-based modeling to create a simulation pitting rival theories of political violence against each other and against empirical data. The purpose of the research is theory testing: to see what theory or combination of theories best explains political violence. The paper provides an overview of the relevant theory and data. The paper then develops a dynamic hypothesis and a prototype hybrid NetLogo simulation of two theories, political opportunity and collective action.

Keywords

Political Opportunity, Collective Action, Agent-Based, NetLogo, Simulation

"I was angry with my friend: / I told my wrath, my wrath did end. / I was angry with my foe: / I told it not, my wrath did grow."
– William Blake, A Poison Tree

Problem

Understanding the Dynamics of Political Violence

In the political violence scholarship, there is a gap in explaining how group-level dynamics cause mass political violence. There are several main theories about why political groups become violent. Because of the qualitative nature of these theories, and the feedback complexity of political violence, it is difficult to test these theories against each other and against data.

Regression has been the main method of quantitative investigation by most branches of social science. Regression makes it relatively easy to transform mostly qualitative theories into mathematical models. Regression is also well suited to test these models on many types of quantitative data.

Unfortunately, regression is designed to find correlations of stable stochastic processes that adhere to the Gauss-Markov conditions. As the data gets less "nice", regression requires more "tricks" (interactive variables, lagged variables, WLS, etc.) and produces results that are less accurate and precise.

System dynamics (SD) allows more accurate simulation of systems due to its ability to represent feedback, nonlinearities, and stock/flow dynamics. The weakness of system dynamics for the problem of political violence is that the units of analysis (people, groups, states) are highly heterogeneous in their mental models and interactions with each other. This makes it difficult to safely produce aggregate models of political violence. Workarounds like coflows and arrays are awkward and overly complex.

Agent-based modeling (ABM) is designed to deal with heterogeneous decision maker mental models and interactions. One problem with ABM is that ABM models generally use discrete logic to represent feedback. This detracts from the ability to understand agent behavior, since complex agent behavior ends up being a complex, nested set of discrete logical gates. Similarly, most agent-based models are not built with the rigorous development and testing required by the system dynamics methodology (the stages of the modeling process, the many equation and simulation tests).

Empirically, there are many agent-based models of political violence. Few, if any, of these models are interested in theory testing. Most models are exploratory academic models with titles like "towards a better understanding of XYZ" or "an example of how agent based modeling can be used to represent XYZ" or "a new perspective on XYZ". They usually fail to acknowledge existing theory or test against data. Theory and data are not *necessary* to create good simulations, but they are *useful*.

Other ABM models are more specific, like looking at one case study in particular (data), or one type of interesting causal dynamic (theory). The most specific models are the ones that show the greatest insights. More generally, more specific hypotheses lead to more focused models.

Summary of Approach

I propose to use a combination of system dynamics and agent-based modeling approaches to create a comparison of two rival theories of political violence to see how well these theories explain political violence as seen in the empirical data.

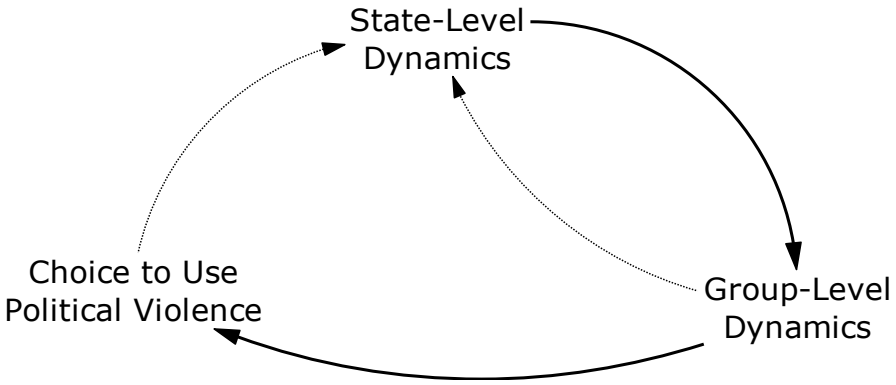

Figure 1. Simulation scope.

The simulation scope will be that shown in Figure 1. The research will focus on how state-level dynamics cause group-level dynamics to change and how those group-level dynamics cause outbreaks of political violence. There are likely to be feedbacks in the opposite direction (dotted lines in Figure 1), but these are secondary in importance. Where theory describes these dotted links, they need to be represented.

Proposed Method:

- Create a **reference mode** by comparing important variables in group-level theories of political violence to group-level data (The Minorities at Risk Project, 2011) and state-level data (The Quality of Government Institute, 2011).
- Take descriptions and diagrams from the theories and use them to make **dynamic hypotheses**.
- Elaborate these causal hypotheses into **system dynamics / agent-based** simulations in NetLogo (Wilensky, NetLogo, 1999).
- **Test the simulations** of theories against the data and against other typical system dynamics tests. See what theory or combination of theories best matches the group and state data over some time frame (a good time frame in terms of data quantity is 1984 to 2004).

As researchers in the complexity sciences have found, models that are able to point-predict future states of complex (social) systems are some combination of impossible, unreliable, and extremely expensive. Fitting theory to data is insufficient to pronounce a theoretical model "good".

The broad question for success will be, "Does the structure generate plausible behavior?" Since this will be an agent-based simulation, it will be important to understand how well the actions and interactions of micro agents show the ability to "generate" the system's macro properties (Epstein, 1999).

Theory

Below is a summary of some of the main group-level theories of political violence. Further in the paper, Political Opportunity Theory (PO) and Collective Action Theory (CA) are simulated in NetLogo.

Relative Deprivation

The Relative Deprivation Theory of political violence is Ted Gurr's (1970) adaptation of the psychological theory of frustration-aggression. Gurr argues that the primary source of the human capacity for political violence is *frustration*. Frustration, when experienced with a certain intensity, scope, and duration, acts to move a group towards anger, political expression, and ultimately violence. In Gurr's theory, frustration comes from *relative deprivation*. Relative deprivation is the sense of a group's members that there is a gap between what they have and what they feel they deserve.

Resource Mobilization

Resource Mobilization Theory (Tilly, 1978; Wikipedia, 2011) emphasizes the importance of resources in social movement development and success. Resource Mobilization Theory assumes that groups are comprised of rational actors who pursue economic goals (money, power, social goods), while being bounded by resources and organizational limitations (like the free rider problem). Resources include: knowledge, money, media, labor, solidarity, legitimacy, and internal and external support from power elite. Social movements develop when individuals with grievances (which are assumed to be largely present in all groups) are able to mobilize sufficient resources to take action.

Political Opportunity

Political Opportunity Theory, also known as Political Process Theory, is an integration and extension of the Relative Deprivation and Resource Mobilization Theories that adds an emphasis on political opportunity. Political Opportunity Theory argues that there are three vital components for movement formation: group consciousness, organizational strength, and political opportunity. This means the group has grievances, the group has the resources to address those grievances through collective (possibly violent) action, and the opposing side (state, other groups) is weak in some way. The emergence of political violence is occurs when these three factors line up.

Collective Action

This theory (Lichbach, 1995) is the extension of the Rational Choice School of Economics, particularly the work of Mancur Olson, to political action/violence. In the Collective Action Theory, the focus is on the actions of rational agents limited largely by organizational dynamics. Instead of focusing on resources per se, Collective Action Theory looks at decisions related to the supply and demand of public goods. Grievances are neither a necessary nor a sufficient condition for political violence. Selective incentives are a major motivation for participation in political violence. The agents look for tactics to achieve more of the goods that they want, but need the support of relatively unmotivated compatriots and potential free riders.

Empirical Data Possibilities

There are several attempts underway to gather and aggregate reference data for group-level and state-level causes/indicators relevant to political violence. Two of the best and most comprehensive sources of panel data (different years, different groups, different states) are the MAROB dataset (The Minorities at Risk Project, 2011) on the organizational dynamics of several groups in the Middle East and North Africa and the Quality of Government dataset (The Quality of Government Institute, 2011) which is a large compilation of academic and NGO statistics on a variety of state-level statistics.

Even though these are some of the best open-source datasets on political violence, the MAROB and QoG both suffer from data sparseness and data quality issues. The MAROB dataset is the fullest and cleanest, with many of its variables full of data for all groups and years. However, some variables contain many blanks and NULLs (value 0 or -99 indicating the information is missing).

The QoG data is a grab bag of reliable and well-populated statistics (UN demographic/economic data), advanced statistics with a very short time frame (Heritage Institute Index of Economic Freedom data), overly detailed data on the formal minutia of government structure and various academicians' statistics from their own research programs.

When choosing data to support a simulation, one must choose between a large number of questionable variables and a small number of relatively reliable variables. For my work, I am using the latter approach and have eliminated many variables from both data sets. Due to the size and format of this data, it is impractical to discuss or display in detail in this paper. Even with a reduced list of variables, there is no obvious reference mode or set of reference modes yet that summarizes all the data well.

For the reader interested in using these data sources, a summary of the more useful variables in both data sets is provided in Appendix A. Access to MAROB and QoG data can be received from their respective websites.

Initial Simulation Approach

To begin, I am trying to simulate the very basic hypotheses of two of the most mature current group theories of political violence, Political Opportunity Theory (henceforth shortened to Political Opportunity / PO) and Collective Action (henceforth shortened to Collective Action / CA). The sections below describe the dynamic hypotheses of these theories, followed by overviews of initial NetLogo simulations of these theories' feedback behavior. For a discussion of Political Opportunity, see Meyer (2004). For a discussion of Collective Action and a suggestion to compare/integrate PO and CA, see Lichbach (1998).

Dynamic Hypothesis

Systems Dynamics Generic Causal Structure

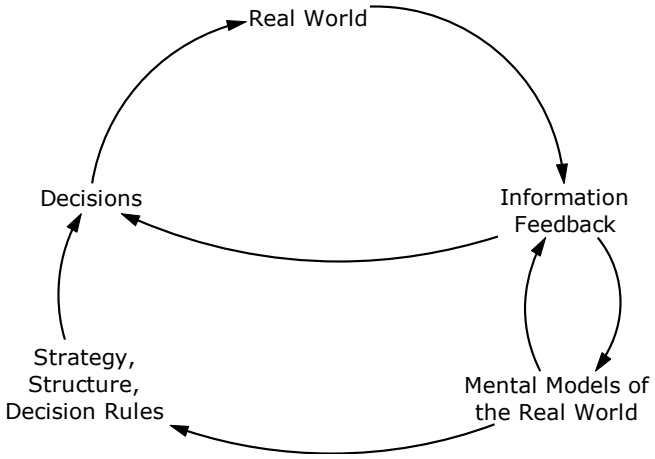

Figure 2. Double loop learning.

It is difficult to quantify different, largely qualitative theories in a standard way without anchoring them to some framework. The broadest structure is the generic structure of decision-making called Double Loop Learning (Sterman, 2000) shown in Figure 2. All these theories of political violence are mainly theories of decision making and learning. In all these theories, people get information about the state of the world and decide to act on that information to change the state. On another level, people use information to change their mental models and then change how they make decisions.

Political Opportunity

PO claims that group action occurs most where a society is somewhere between very pluralistic and completely totalitarian. In an open society, there are many legitimate avenues for political expression. In a closed society, repression (usually) prevents any sort of action disagreeable to the government. In between is a "sweet spot" where the government does not allow groups to get what they want the "legal" way, but is too weak to stop them from using protests, strikes, riots, insurgency, etc. Figure 3 shows this idealized "U-Shape" relationship.

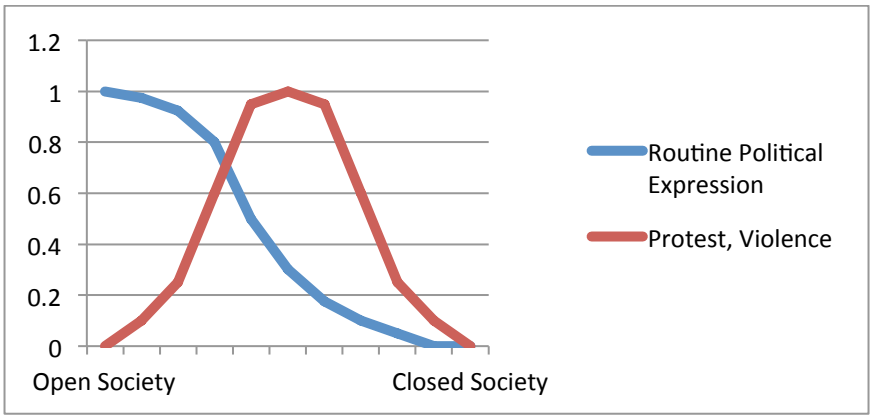

Figure 3. Political actions vs. openness of society.

The dynamic hypothesis responsible for this empirical statement/observation is shown in Figure 4.

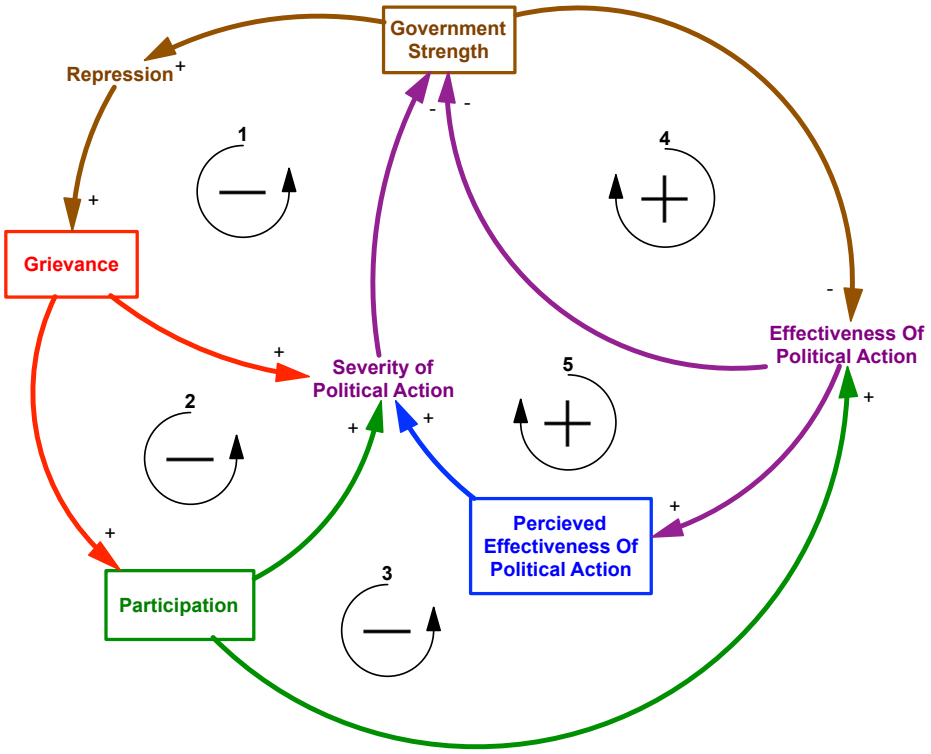

Figure 4. Causal structure of Political Opportunity.

In PO, the main factors behind collective action/violence (*Severity of Political Action*) include a sense of *Grievance* by some group of people, a set of resources such as the *Participation* in a collective movement, and the *Perceived Effectiveness of Political Action.*

The default behavior of PO is a "tipping point" kind of behavior, where strong forces build up and overwhelm a seemingly strong system. The forces that build up the impetus for political action are those of Loops 1, 2, and 3.

In Loop 1, *Government Strength* leads to *Repression*, which leads to *Grievance* and political action. In Loop 2, *Grievance* leads to *Participation* and political action. In Loop 3, *Participation* leads to more effective political action since the *Effectiveness of Political Action* is based on a comparison of the strength of the government to the strength of the movement.

The forces of Loop 4 and 5 initially keep the government strong and the rebels frustrated. As long as the movement is weak, it is unlikely to succeed and therefore stays week. The government continues to be strong and therefore discourages political action. As the movement gets stronger and does more severe political action, the government gets relatively weaker, political action looks more effective, and there is more political action. This "tipping point" behavior happens as the reinforcing Loops 4 and 5 stop working for the government and start working for the rebels. In summary, the status quo of government dominance and political movement inaction is strong, but brittle, allowing the rebels to win if they try.

One main problem for PO is explaining how political action movements get started given the seemingly overwhelming forces of the government and the meager likelihood of successful political action. CA focuses on this question in great detail, but PO suggests several reasons for political action.

One explanation is that some event or process (a war, a natural disaster, democratization, a scandal, etc.) causes the real or perceived balance of power between movement and government to change. Another explanation is that there are always social entrepreneurs on the rebel side who have various degrees of "irrational optimism" about the potential success of the movement. If effective at rabble-rousing, these entrepreneurs can cause large numbers of people to participate/mobilize, thus effecting a "fake it 'till you make it" strategy. The level of optimism in a society has something like a power law distribution, like that shown in Figure 5.

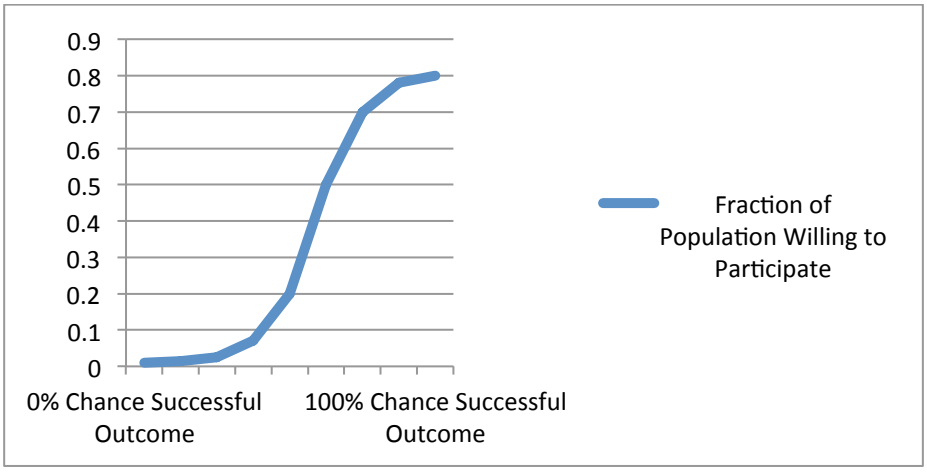

Figure 5. Distribution of optimism in Political Opportunity.

Collective Action

The claim of Collective Action is the "five percent rule". This rule states that the overwhelming majority (approximately 95%) of the sympathizers of a movement do not actually act in the movement. This rule applies roughly 95% of the time. So, most of the time, most "members" of a movement don't do anything important to advance the movement. Mass movements occur, but are infrequent and brief, in general.

The reason behind this behavior is the strong disincentive for a rational actor to engage in collective action (variations of coordination/oversight games like the Prisoner's Dilemma). The proposed taxonomy of solutions to the problems of Collective Action is shown in Figure 6. By default, a bunch of individuals living their lives as such is the "Market". In this scenario, outbreaks of political action and violence are likely to be disordered, perhaps the result of "anomie" or other irrational factors.

The other three scenarios in Figure 6 involve rational actors somehow exploiting societal structures to get other rational actors to commit to risking private costs in pursuit of collective goods. These structures include things like traditions and ethnic ties (Community); logical arguments, covenants, and contracts (Contract); and organizations, secret societies, and vanguards (Hierarchy). In the real world, these tactics can be combined.

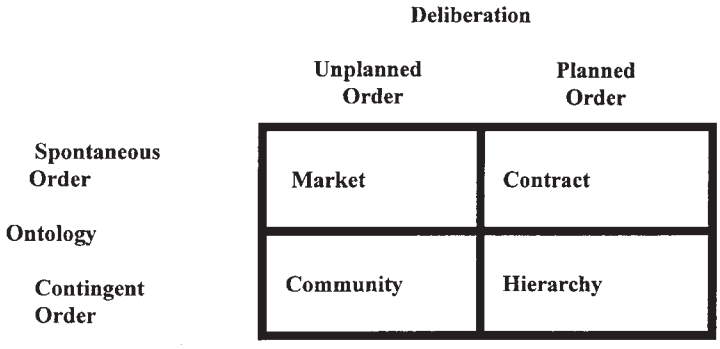

Figure 6. Solutions to the CA problem (Lichbach, 1998).

Finding a dynamic feedback structure to CA is difficult, since CA is a typical Neoclassical economic theory with initial parameters leading directly to rival equilibria. Furthermore, CA is largely a catalogue of potential solutions to the collective action game theory problems of both the rebels and the state, with 10 or more types of strategies discussed for each of the possible scenarios (the full list is in Lichbach (1995)). The closest thing to a general feedback structure for CA is shown in Figure 7.

Whereas PO focuses on the top loop of double-loop learning shown in Figure 2, CA focuses on the bottom loops (changing mental models and strategies). PO looks at political conflict largely in the aggregate, with both the rebel movement and the government acting out of competing pressures (grievances, resources, mobilization/participation). CA focuses on the variables in Figure 4 related to participation and likelihood of success in the framework of a strategic adversarial game between individual rebel leaders/entrepreneurs and government leaders/entrepreneurs shown in Figure 7.

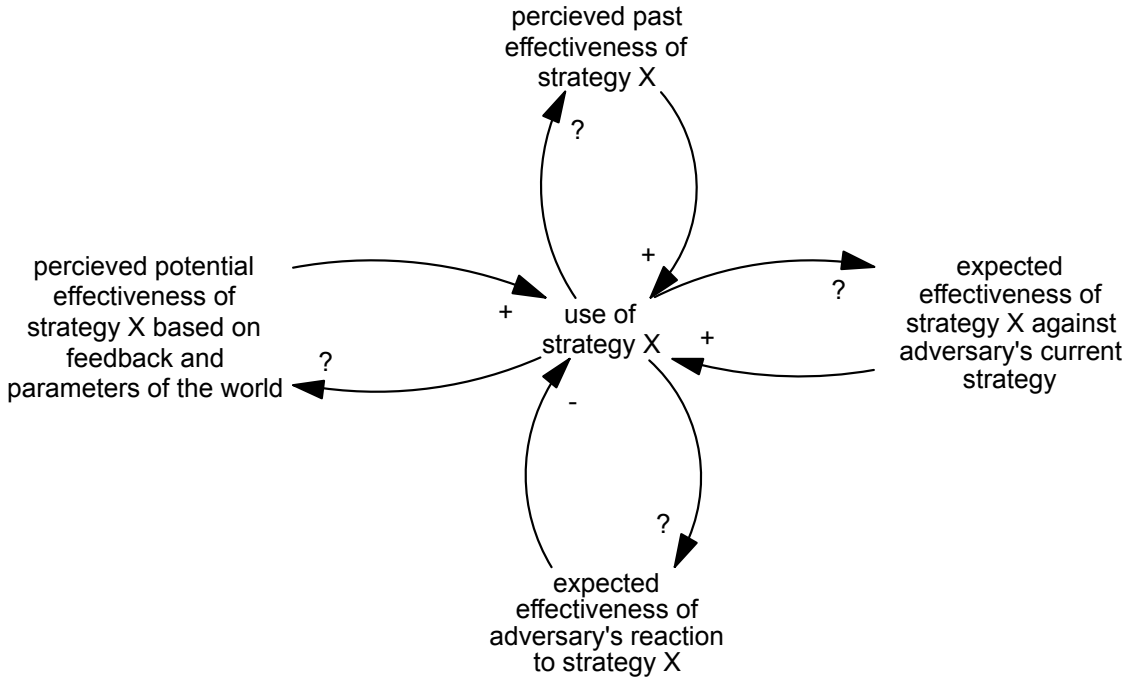

Figure 7. Causal structure of Collective Action.

Although, CA is framed in terms of game theory, it is actually described as a Darwinian evolutionary process. On both the rebel and government side, there are always leaders or social entrepreneurs for whom the struggle over collective goods is salient and important. The motivations of these actors (like all actors in CA) are those of rational self interest: the hope of gain from the pursuit and/or attainment of collective goods. Grievances, resources, or the perceived effectiveness of collective action (the factors of PO) are entirely unnecessary for the dynamics of CA.

The entrepreneurs on the rebel and government side are well aware of the difficulty of collective action. They each monitor the situation of the world and each other's strategies. With this historical data, entrepreneurs try to implement strategies to improve their side's CA situation (increase perceived/real benefits, decrease perceived/real costs, etc.) while hampering the adversary's CA situation. While deciding strategies, the entrepreneurs also keep in mind their adversaries' likely reactions. Finally, seemingly winning strategies are copied and deepened, while losing strategies are avoided and abandoned. In principle, the decision making process could go many iterations deep.

Simulation

Vensim Simulation

Due to the complexities of CA theory, the modeling effort has so far focused on PO, with exogenous variables available to simulate some of the tactics possible in CA. The model documentation for the Vensim model can be found in Appendix B. This model tries to quantify the dynamic hypothesis explained in Figure 4. The default behavior of the model is shown in Figure 8.

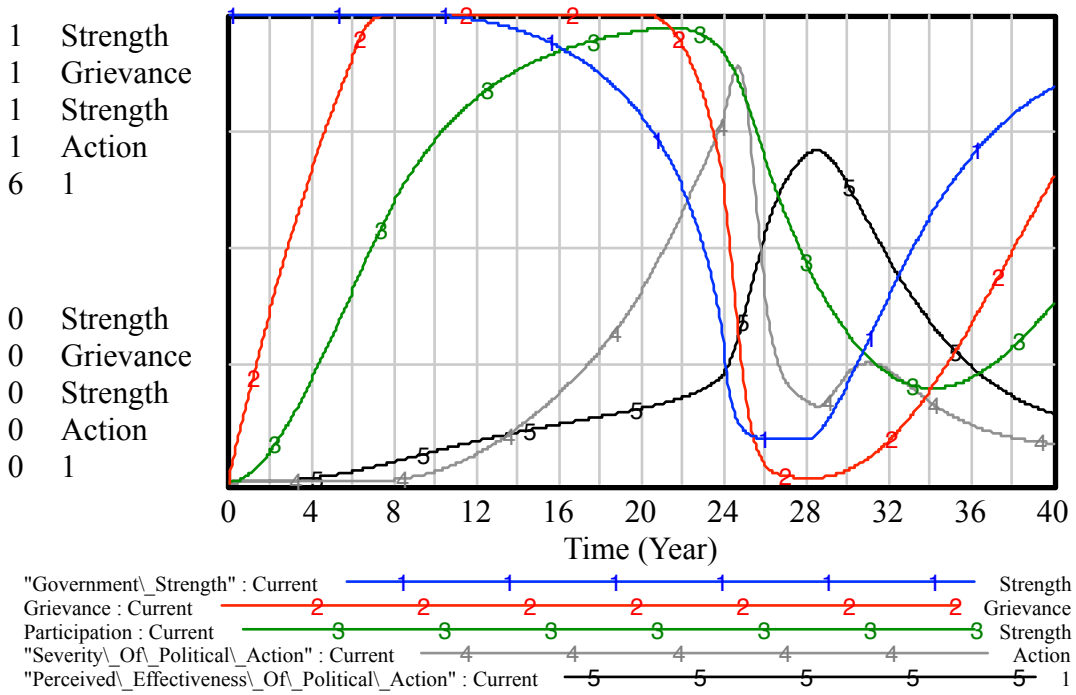

Figure 8. Default behavior of Vensim Model.

Below is an explanation of this behavior, color-coded by variable.

- Government Strength:
  - Too strong at first. Suppresses effectiveness and severity of political action.
  - Critical mass of action degrades government strength beyond strength regeneration ability.
  - Government caves, protests, reduce, strength rebuilds.
- Grievance:
  - Rises quickly from Government Repression (a direct function of Government Strength in the model).
  - Drops when Government Repression eases.
- Participation:
  - Rises and falls more slowly, based on Grievance.
- Severity of Political Action (the only non-stock variable in the graph):
  - Rises later, but very steeply as Grievance, Participation, and Perceived Effectiveness of Political Action all become high.
- Perceived Effectiveness of Political Action:
  - Rises slowly, then quickly after the main revolt has picked up its pace.
  - People think rebellion is ineffective, until eventually they all find themselves in the city square together.
  - People fully realize the effectiveness once the government has already been defeated.

NetLogo

Since ABM is all about learning how disaggregate agents work to generate their societal behavior, each agent should represent a person. This way, the agents can eventually be populated and/or made more heterogeneous in terms of their biology, demographics, mental models, resources, and social networks.

NetLogo (Wilensky, NetLogo, 1999) is a good way to instantiate such an ABM. NetLogo has incredibly simple syntax (no real programming required as compared to RePAST, MASON, and AnyLogic), is open source (LGPL), can be distributed as a Java Applet, and has a large library of existing models to use as building blocks. The best reference model for political violence is the NetLogo Rebellion Model (Wilensky, NetLogo Models Library: Rebellion, 2004) shown in Figure 9.

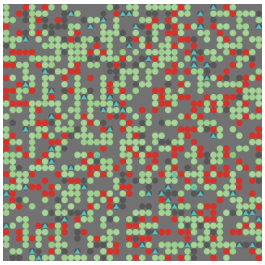

Figure 9. The Rebellion model in NetLogo.

The dynamics of the Rebellion model can be found on the model's webpage or within the internal documentation in its applet. The model has agents who get upset at their government's quality, rebel, are sometimes arrested by roving government police, and spend some time in jail. The model's behavior features waves of violence interrupted by periods of uneasy calm while dissidents cool off in jail.

NetLogo Simulation

The NetLogo simulation (documented in Appendix C) takes the Vensim simulation of PO/CA and changes it, equation by equation into NetLogo syntax. The process of giving individual agents mostly continuous "stock and flow" logic versus the usual discrete logic found in ABM is somewhat complicated, but, basically involves calculating all flows from initials and constants, then doing the Euler method for all stocks.

The result is an agent-based simulation whose agents are all the same (no random behavior added other than contact networks) and whose aggregate and disaggregate behavior perfectly matches that of the Vensim simulation, as shown in Figure 10.

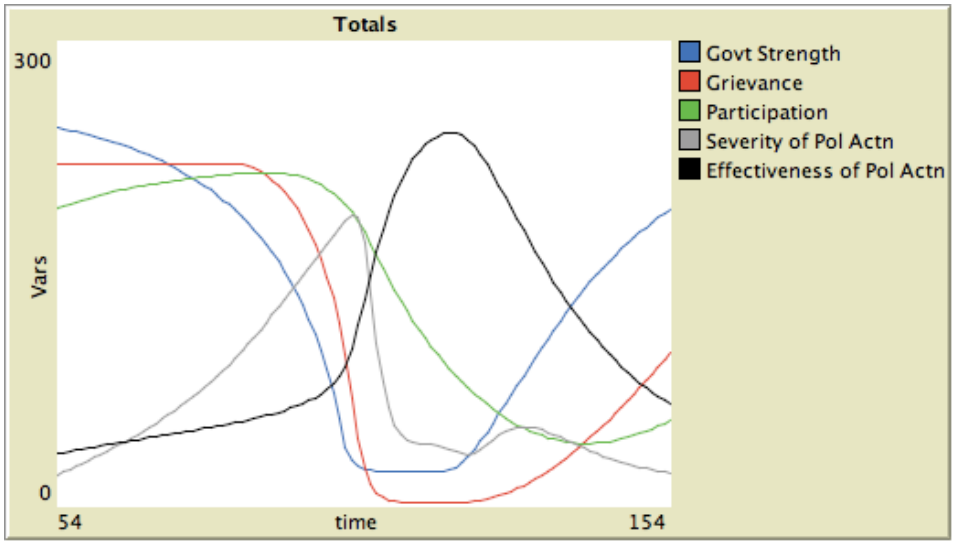

Figure 10. Default Behavior of NetLogo Simulation.

The NetLogo simulation adds some experimental functionality to try to take advantage of the fact that it can have heterogeneous agent properties and networks.

First, the agents can have a random component to their initial *Grievance*, *Participation*, and *Perceived Effectiveness of Political Action* as well as the time constants related to the changes to those stocks. This allows for a heterogeneous population that may not all rebel at the same time.

Second, the agents are connected via a communication network by which they automatically diffuse their grievances. This allows heterogeneous levels of *Grievance*, *Participation*, and *Perceived Effectiveness of Political Action* to average out over time, ceteris paribus.

Third, three CA tactics can be represented by the creation of "zealots". In CA, three of the "market" solutions to the collective action problem of the rebels are social entrepreneurs that convince other people that:

(1) Benefits of political action are high.
(2) Costs of political action are low.
(3) Effectiveness of political action is high.

These policies are simulated exogenously in the NetLogo simulation by having a button and sliders to create an agent with some combination of permanently high or low *Grievance*, *Participation*, and *Perceived Effectiveness of Political Action*. Zealots can be used to continuously spread high grievance and always be ready to join a revolt. Endogenous representation of the full range of CA tactics is for future work beyond this paper.

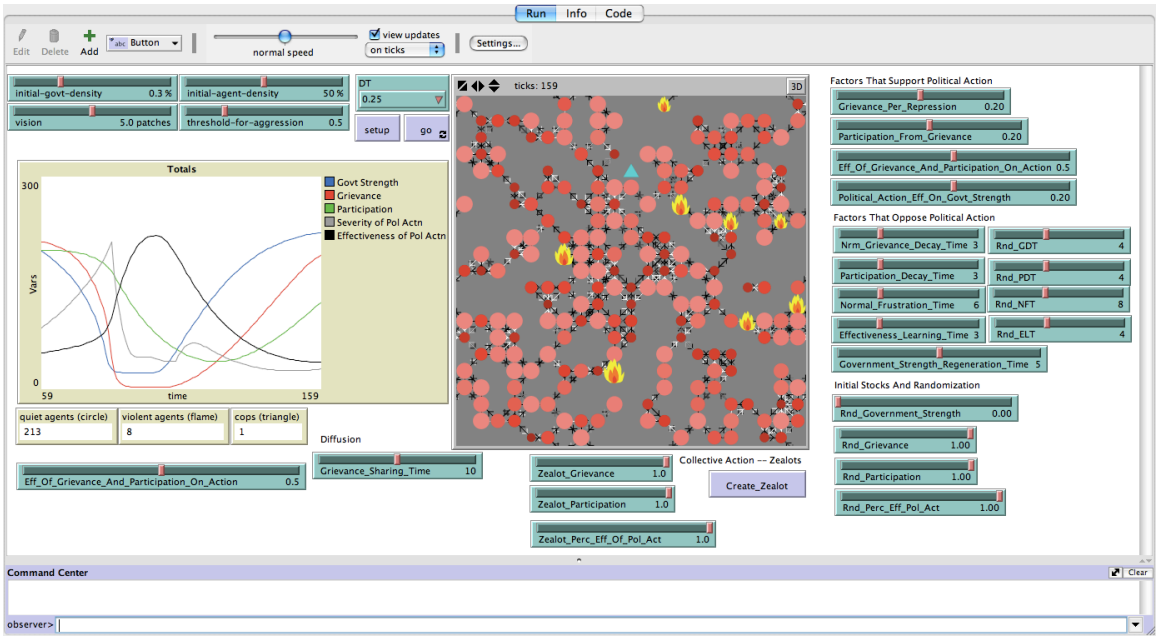

Figure 11. NetLogo Model Interface.

Figure 11 shows a snapshot of a simulation run with randomized agent properties and a few zealot agents. The dynamics of the model are similar to that of the base run, but the agents have different internal states at any given time. The NetLogo visualization helps to track the internal states and networks of many agents. For example:

- The agent size is *Grievance* (bigger is higher).
- The agent color is *Participation* (brighter is higher).
- The presence of a flame icon indicates a high *Severity of Political Action*.
- The color of the arrow between two agents indicates the net amount/direction of *Grievance* being diffused between the two agents (brighter is higher).

NetLogo has additional options for visualization, testing, and analysis, even if these functions are not nearly as advanced as those in Vensim. In the ideal case, the research can develop and test a model as much as possible in Vensim, then port it to NetLogo and keep testing in NetLogo, iteratively developing the model in both software packages.

Discussion

This paper shows the initial stages of an effort to test group-level theories of political violence with system dynamics and agent-based modeling as well as empirical group-level and state-level data. The Vensim and NetLogo simulations allow the representation of the basic behaviors of Political Opportunity Theory and some of the tactics in Collective Action Theory.

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Appendices

Appendix A: Overview of MAROB and QoG Data

The following groups of variables comprise relatively dense panel data for most MAROB groups and their QoG states from 1984 to 2004.

MAROB: Group-Level Data

MAROB offers a wide variety of "dense" panel data on many groups that are considered to be "minorities at risk" of turning to political action / violence to attain their goals. The data set tries to include many alternative causes and descriptions of group action.

1. Name, age, location, founding date
2. Legality, militancy, popularity, …
3. List of grievances
4. Ideological goals
5. State attitude and actions towards group (repression, etc.)
6. Past successes in influencing state
7. Help from outsiders: diaspora, foreign states, international orgs, NGOs
8. Social influence activities of the group (both violent and non-violent)
9. Intra/inter-organizational conflicts
10. Choice of targets and attack types
11. Criminal (financing) activities
12. Collusion with corrupt officials
13. Demographics (cultural, ethnic, religious, linguistic)

QoG: State-Level Data

The following kinds of state-level data are very "dense" panel data (referenced by variable prefix). They are available for most countries for most years, going back a few decades. Sadly, there are many interesting and reliable variables not listed here because they comprise too few years and countries.

1. Fractionalization (cultural, ethnic, religious, linguistic) [example: al, fe, lp, r variables]
2. Government structure [example: ht]
3. Civil and political freedoms / government repression [example: fh]
4. Conflicts [example: ucdp]
5. Basic economic statistics [example: gle, pwt, unna]

Appendix B: Vensim Model of Political Opportunity and Collective Action

Diagrams

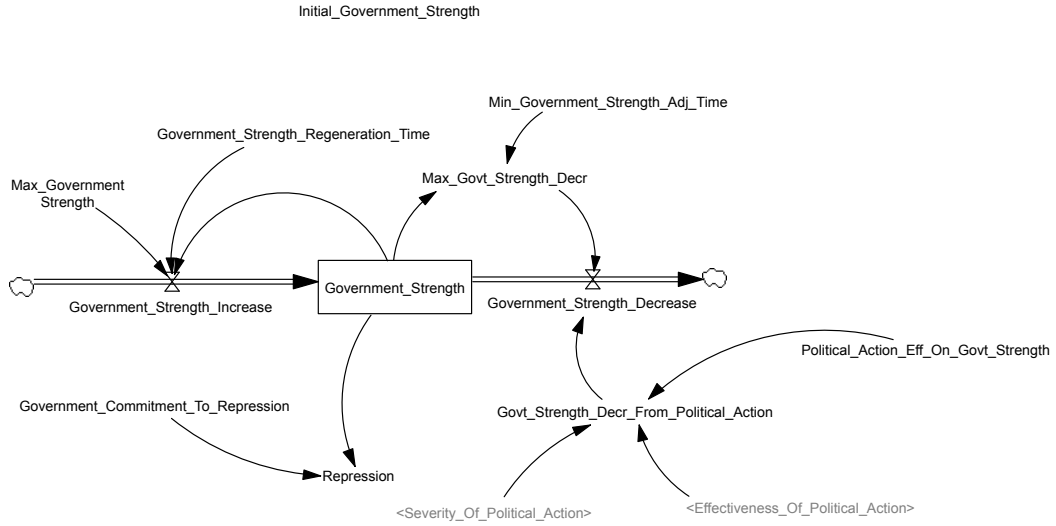

Figure 12. Government Strength.

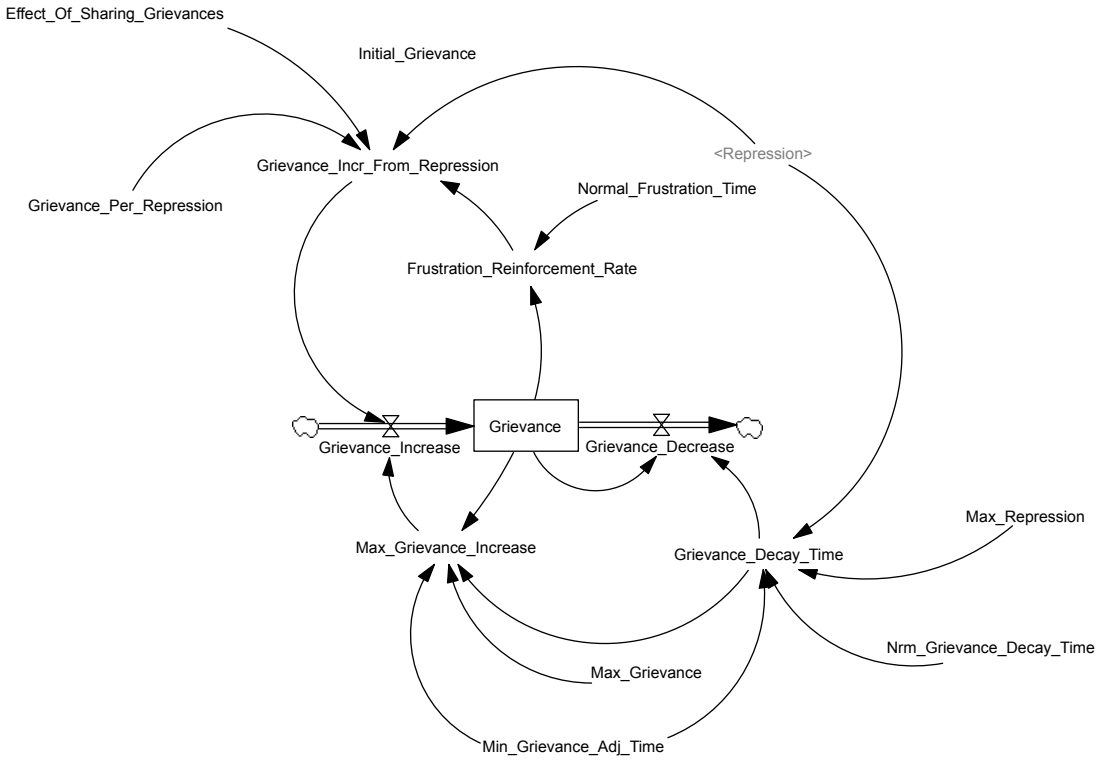

Figure 13. Grievance.

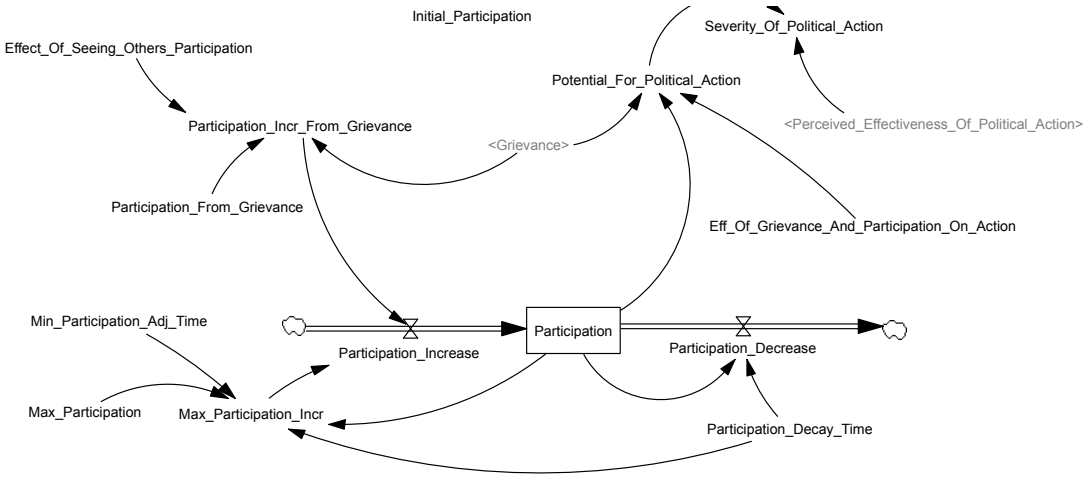

Figure 14. Participation.

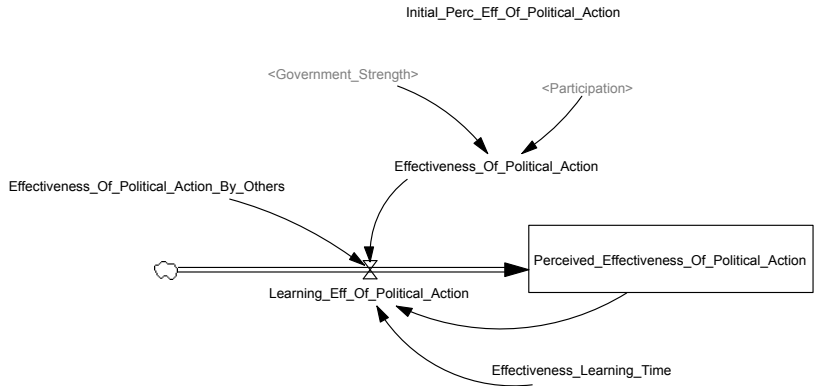

Figure 15. Perceived Success.

Equations*

**The odd naming convention for variable names is how Vensim explicitly stores variables with the underscore character. One has to remove the suppression of underscore characters in Vensim to see this. Underscores, in turn, allow for easy copying and pasting of Vensim equations into NetLogo.*

```
"Eff\_Of\_Grievance\_And\_Participation\_On\_Action" = 0.5
"Effect\_Of\_Seeing\_Others\_Participation" = 0
"Effect\_Of\_Sharing\_Grievances" = 0
"Effectiveness\_Learning\_Time" = 5
"Effectiveness\_Of\_Political\_Action" = IF THEN ELSE ( "Government\_Strength"
          > 0, Participation / "Government\_Strength" , 1)
"Effectiveness\_Of\_Political\_Action\_By\_Others" = 0
FINAL TIME = 40
"Frustration\_Reinforcement\_Rate" = Grievance / "Normal\_Frustration\_Time"
"Government\_Commitment\_To\_Repression" = 1
"Government\_Strength" = INTEG( "Government\_Strength\_Increase" -
"Government\_Strength\_Decrease"
               , "Initial\_Government\_Strength" )
"Government\_Strength\_Decrease" = MIN ( "Govt\_Strength\_Decr\_From\_Political\_Action"
          , "Max\_Govt\_Strength\_Decr" )
"Government\_Strength\_Increase" = ( "Max\_Government\_Strength" - "Government\_Strength"
          ) / "Government\_Strength\_Regeneration\_Time"
"Government\_Strength\_Regeneration\_Time" = 5
"Govt\_Strength\_Decr\_From\_Political\_Action" = "Severity\_Of\_Political\_Action"
     * "Effectiveness\_Of\_Political\_Action" * "Political\_Action\_Eff\_On\_Govt\_Strength"
Grievance = INTEG( "Grievance\_Increase" - "Grievance\_Decrease" , "Initial\_Grievance"
          )
"Grievance\_Decay\_Time" = MAX ( "Nrm\_Grievance\_Decay\_Time" * ( Repression
```

```
                / "Max\_Repression" ) , "Min\_Grievance\_Adj\_Time" )
"Grievance\_Decrease" = Grievance / "Grievance\_Decay\_Time"
"Grievance\_Incr\_From\_Repression" = Repression * "Grievance\_Per\_Repression"
           + "Frustration\_Reinforcement\_Rate" + "Effect\_Of\_Sharing\_Grievances"
"Grievance\_Increase" = MIN ( "Grievance\_Incr\_From\_Repression" , "Max\_Grievance\_Increase"
           )
"Grievance\_Per\_Repression" = 0.2
INITIAL TIME = 0
"Initial\_Government\_Strength" = 1
"Initial\_Grievance" = 0
"Initial\_Participation" = 0
"Initial\_Perc\_Eff\_Of\_Political\_Action" = 0
"Learning\_Eff\_Of\_Political\_Action" = ( "Effectiveness\_Of\_Political\_Action"
      - "Perceived\_Effectiveness\_Of\_Political\_Action" ) / "Effectiveness\_Learning\_Time"
           + "Effectiveness\_Of\_Political\_Action\_By\_Others"
"Max\_Government\_Strength" = 1
"Max\_Govt\_Strength\_Decr" = "Government\_Strength" / "Min\_Government\_Strength\_Adj\_Time"
"Max\_Grievance" = 1
"Max\_Grievance\_Increase" = ( "Max\_Grievance" - Grievance ) / "Min\_Grievance\_Adj\_Time"
           + "Max\_Grievance" / "Grievance\_Decay\_Time"
"Max\_Participation" = 1
"Max\_Participation\_Incr" = ( "Max\_Participation" - Participation ) /
"Min\_Participation\_Adj\_Time"
           + "Max\_Participation" / "Participation\_Decay\_Time"
"Max\_Repression" = 1
"Min\_Government\_Strength\_Adj\_Time" = 0.5
"Min\_Grievance\_Adj\_Time" = 0.5
"Min\_Participation\_Adj\_Time" = 0.5
"Normal\_Frustration\_Time" = 10
"Nrm\_Grievance\_Decay\_Time" = 5
Participation = INTEG( "Participation\_Increase" - "Participation\_Decrease"
                , "Initial\_Participation" )
"Participation\_Decay\_Time" = 5
"Participation\_Decrease" = Participation / "Participation\_Decay\_Time"
"Participation\_From\_Grievance" = 0.2
"Participation\_Incr\_From\_Grievance" = Grievance * "Participation\_From\_Grievance"
           + "Effect\_Of\_Seeing\_Others\_Participation"
"Participation\_Increase" = MIN ( "Participation\_Incr\_From\_Grievance" ,
           "Max\_Participation\_Incr" )
"Perceived\_Effectiveness\_Of\_Political\_Action" = INTEG( "Learning\_Eff\_Of\_Political\_Action"
           , "Initial\_Perc\_Eff\_Of\_Political\_Action" )
"Political\_Action\_Eff\_On\_Govt\_Strength" = 0.2
"Potential\_For\_Political\_Action" = Grievance * Participation *
"Eff\_Of\_Grievance\_And\_Participation\_On\_Action"
Repression = "Government\_Strength" * "Government\_Commitment\_To\_Repression"
SAVEPER = TIME STEP
"Severity\_Of\_Political\_Action" = "Potential\_For\_Political\_Action" * (
           "Perceived\_Effectiveness\_Of\_Political\_Action" ^ 3)
TIME STEP = 0.0625
```

Appendix C: NetLogo Model of Political Opportunity and Collective Action

```
breed [agents agent]
breed [governments government]
directed-link-breed [active-links active-link]

globals [

;; System Constants

  ;DT ;;This is "difference in time" or "delta time". Delta time is used as an approximation of
"derivative of time"
   ;;to iterate Euler integration forward.


;; All Others

  Government_Commitment_To_Repression
  Max_Government_Strength
  Max_Grievance
  Max_Participation
```

```
  Max_Repression
  Min_Government_Strength_Adj_Time
  Min_Grievance_Adj_Time
  Min_Participation_Adj_Time

;;Reporting
total-government-strength
total-grievance
total-participation
total-severity
total-effectiveness

]

governments-own [

  ;;Constants
  Initial_Government_Strength

  ;;Auxiliaries

  Govt_Strength_Decr_From_Political_Action
  Max_Govt_Strength_Decr
  Repression

  Total_Severity_Of_Political_Action
  Total_Effectiveness_Of_Political_Action

  ;;Flows
  Government_Strength_Increase
  Government_Strength_Decrease

  ;;Stocks
  Government_Strength

]

agents-own [
  active

  ;;Constants
  Initial_Grievance
  Initial_Participation
  Initial_Perc_Eff_Of_Political_Action

  A_Nrm_Grievance_Decay_Time
  A_Participation_Decay_Time
  A_Normal_Frustration_Time
  A_Effectiveness_Learning_Time

  ;; Network Diffusion Auxiliaries

  Effect_Of_Seeing_Others_Participation
  Effect_Of_Sharing_Grievances
  Effectiveness_Of_Political_Action_By_Others

  ;; Auxiliaries

  Total_Government_Strength
  Total_Repression

  Effectiveness_Of_Political_Action
  Frustration_Reinforcement_Rate
  Grievance_Decay_Time
  Grievance_Incr_From_Repression
  Max_Grievance_Increase
  Max_Participation_Incr
  Participation_Incr_From_Grievance
  Potential_For_Political_Action
  Severity_Of_Political_Action
```

```
  ;;Flows
  Grievance_Increase
  Grievance_Decrease

  Participation_Increase
  Participation_Decrease

  Learning_Eff_Of_Political_Action

  ;;Stocks
  Grievance
  Participation
  Perceived_Effectiveness_Of_Political_Action

]



patches-own [
  neighborhood        ; surrounding patches within the vision radius
]

active-links-own [
  current-flow        ; the amount of grievance, shared through a link in a given step
]

to setup
  ;; (for your model to work with NetLogo's new plotting features,
  ;; __clear-all-and-reset-ticks should be replaced with clear-all at
  ;; the beginning of your setup procedure and reset-ticks at the end
  ;; of the procedure.)
  __clear-all-and-reset-ticks

  ;; SET GLOBALS
  set-default-shape agents "circle"
  set-default-shape links "small-arrow-link"

  ask patches [
    ;; make background a slightly dark gray
    set pcolor gray - 1
    ;; cache patch neighborhoods
    set neighborhood patches in-radius vision
  ]

;; SET GLOBAL CONSTANTS

;; System Constants

set DT 0.25 ;;This is "difference in time" or "delta time". Delta time is used as an
approximation of "derivative of time"
              ;;to iterate Euler integration forward. Too large a value will produce artifacts in
the simulation due to inability
              ;;to integrate equations correctly.
set threshold-for-aggression .5

;; All Others

set Eff_Of_Grievance_And_Participation_On_Action 0.5

set Government_Commitment_To_Repression 1
set Government_Strength_Regeneration_Time 5
set Grievance_Per_Repression 0.2

set Max_Government_Strength 1
set Max_Grievance 1
set Max_Participation 1
set Max_Repression 1
set Min_Government_Strength_Adj_Time 0.5
set Min_Grievance_Adj_Time 0.5
set Min_Participation_Adj_Time 0.5
```

```
set Participation_From_Grievance 0.2
set Political_Action_Eff_On_Govt_Strength 0.2

;set Grievance_Sharing_Time 10
;set Participation_Sharing_Time 10
;set Effectiveness_Sharing_Time 10

;; create government
  create-governments round (initial-govt-density * .01 * count patches) [
    move-to one-of patches with [not any? turtles-here]
    display-government

;;set initial government stocks and constants
;        set Rnd_Government_Strength 0

        set Initial_Government_Strength 1 + random-float Rnd_Government_Strength
        set Government_Strength Initial_Government_Strength
  ]

  ;; create agents
  create-agents round (initial-agent-density * .01 * count patches) [
    move-to one-of patches with [not any? turtles-here]
    set active false
    display-agent

  ;;set initial agent stocks and constants

;    set Rnd_Grievance 0
;    set Rnd_Participation 0
;    set Rnd_Perc_Eff_Pol_Act 0

    set Initial_Grievance 0 + random-float Rnd_Grievance
    set Initial_Participation 0 + random-float Rnd_Participation
    set Initial_Perc_Eff_Of_Political_Action 0 + random-float Rnd_Perc_Eff_Pol_Act


    set A_Nrm_Grievance_Decay_Time Nrm_Grievance_Decay_Time + random-float Rnd_GDT
    set A_Participation_Decay_Time Participation_Decay_Time + random-float Rnd_PDT
    set A_Normal_Frustration_Time Normal_Frustration_Time + random-float Rnd_NFT
    set A_Effectiveness_Learning_Time Effectiveness_Learning_Time + random-float Rnd_ELT

    set Grievance Initial_Grievance
    set Participation Initial_Participation
    set Perceived_Effectiveness_Of_Political_Action Initial_Perc_Eff_Of_Political_Action

  ;; Network Diffusion

    set Effect_Of_Seeing_Others_Participation 0
    set Effect_Of_Sharing_Grievances 0
    set Effectiveness_Of_Political_Action_By_Others 0
;set Grievance_Sharing_Time 10
;set Participation_Sharing_Time 10
;set Effectiveness_Sharing_Time 10


  ]

  ask agents [
    create-active-links-to other agents in-radius (vision / 3)
  ]

  ;; plot initial state of system
  my-update-plots
  update-globals
end

to go

; update display
  ask agents [ determine-activeness ]
  ask agents [ display-agent ]
```

```
  ask governments [ display-government ]


;; FLOW EQUATIONS

  ;;set government flows
ask governments [

;Information for Flows

set Total_Severity_Of_Political_Action sum [Severity_Of_Political_Action] of agents / count
agents

set Total_Effectiveness_Of_Political_Action sum [Effectiveness_Of_Political_Action] of agents /
count agents

set Govt_Strength_Decr_From_Political_Action Total_Severity_Of_Political_Action *
Total_Effectiveness_Of_Political_Action *
Political_Action_Eff_On_Govt_Strength

set Max_Govt_Strength_Decr Government_Strength / Min_Government_Strength_Adj_Time

set Repression Government_Strength * Government_Commitment_To_Repression

;Actual Flows

set Government_Strength_Increase ( Max_Government_Strength - Government_Strength) /
Government_Strength_Regeneration_Time

ifelse Govt_Strength_Decr_From_Political_Action < Max_Govt_Strength_Decr
      [ set Government_Strength_Decrease Govt_Strength_Decr_From_Political_Action ]
      [ set Government_Strength_Decrease Max_Govt_Strength_Decr ]

]
  ;;set agent flows
ask agents [

;Information for Flows

set Total_Government_Strength sum [Government_Strength] of governments / count governments
set Total_Repression sum [Repression] of governments / count governments

ifelse Total_Government_Strength > 0
      [ set Effectiveness_Of_Political_Action Participation / Total_Government_Strength ]
      [ set Effectiveness_Of_Political_Action 1 ]

set Frustration_Reinforcement_Rate Grievance / ( A_Normal_Frustration_Time )

ifelse Nrm_Grievance_Decay_Time * ( Total_Repression / Max_Repression ) > Min_Grievance_Adj_Time
      [ set Grievance_Decay_Time  A_Nrm_Grievance_Decay_Time * ( Total_Repression /
Max_Repression )  ]
      [ set Grievance_Decay_Time Min_Grievance_Adj_Time ]


set Grievance_Incr_From_Repression Total_Repression * Grievance_Per_Repression +
Frustration_Reinforcement_Rate + Effect_Of_Sharing_Grievances

set Max_Grievance_Increase ( Max_Grievance - Grievance ) / Min_Grievance_Adj_Time + Max_Grievance
/ Grievance_Decay_Time

set Max_Participation_Incr ( Max_Participation - Participation ) / Min_Participation_Adj_Time +
Max_Participation / Participation_Decay_Time

set Participation_Incr_From_Grievance Grievance * Participation_From_Grievance +
Effect_Of_Seeing_Others_Participation

set Potential_For_Political_Action Grievance * Participation *
Eff_Of_Grievance_And_Participation_On_Action

set Severity_Of_Political_Action Potential_For_Political_Action * (
Perceived_Effectiveness_Of_Political_Action ^ 3)
```

```
;Actual Flows

ifelse Grievance_Incr_From_Repression < Max_Grievance_Increase
      [ set Grievance_Increase Grievance_Incr_From_Repression  ]
      [ set Grievance_Increase Max_Grievance_Increase ]

set Grievance_Decrease Grievance / Grievance_Decay_Time

ifelse Participation_Incr_From_Grievance < Max_Participation_Incr
      [ set Participation_Increase Participation_Incr_From_Grievance  ]
      [ set Participation_Increase Max_Participation_Incr ]

set Participation_Decrease Participation / A_Participation_Decay_Time

set Learning_Eff_Of_Political_Action ( Effectiveness_Of_Political_Action -
Perceived_Effectiveness_Of_Political_Action ) /
 A_Effectiveness_Learning_Time + Effectiveness_Of_Political_Action_By_Others

]


  ;; STOCK EQUATIONS

  ;;iterate governments stocks
ask governments [

  set Government_Strength Government_Strength + ( Government_Strength_Increase * DT ) -
  ( Government_Strength_Decrease * DT )

]

  ;;iterate agent stocks
ask agents [
  set Grievance Grievance + ( Grievance_Increase * DT ) - ( Grievance_Decrease * DT )

  set Participation Participation + ( Participation_Increase * DT ) - ( Participation_Decrease *
DT )

  set Perceived_Effectiveness_Of_Political_Action Perceived_Effectiveness_Of_Political_Action +
  ( Learning_Eff_Of_Political_Action * DT )
]

;; DIFFUSION

;Important Variables...
;set Effect_Of_Seeing_Others_Participation 0
;set Effect_Of_Sharing_Grievances 0
;set Effectiveness_Of_Political_Action_By_Others 0
;set Grievance_Sharing_Time 10
;set Participation_Sharing_Time 10
;set Effectiveness_Sharing_Time 10


; update agent Grievance via diffusion
  ask agents [
    let recipients out-active-link-neighbors
      ifelse any? recipients [
        let Grievance_Of_Sender Grievance
        ask recipients [

set Effect_Of_Sharing_Grievances ((Grievance_Of_Sender - Grievance) / (Grievance_Sharing_Time)) *
DT
               let efg Effect_Of_Sharing_Grievances
                                ask in-active-link-from myself [ set current-flow efg ]

         ;   ifelse Grievance_Of_Sender - Grievance >= 0
         ;    [set Effect_Of_Sharing_Grievances ((Grievance_Of_Sender - Grievance) /
(Grievance_Sharing_Time)) * DT
         ;      let efg Effect_Of_Sharing_Grievances
         ;                          ask in-active-link-from myself [ set current-flow efg ]
```

```
          ;      ]
          ;    [set Effect_Of_Sharing_Grievances 0
          ;      let efg Effect_Of_Sharing_Grievances
          ;                          ask in-active-link-from myself [ set current-flow efg ]
          ;      ]

        ]
      ]

            [
               set Effect_Of_Sharing_Grievances 0
               ]

  ]

;]



  update-globals
  tick
  my-update-plots


end

;; GOVERNMENT BEHAVIOR
to move ;; turtle procedure
    ;; move to a patch in vision; candidate patches are empty
    let targets neighborhood with
                [not any? governments-here and all? agents-here [active = false]]
    if any? targets [ move-to one-of targets ]

end

;; ZEALOTS
to Create_Zealot
;Pick a random agent and set its Grievance, Participation, and
Percieved_Effectiveness_Of_Political_Action to new values
ask one-of agents
[
set Grievance Zealot_Grievance
set Participation Zealot_Participation
set Perceived_Effectiveness_Of_Political_Action Zealot_Perc_Eff_Of_Pol_Act
set A_Nrm_Grievance_Decay_Time 1000
set A_Normal_Frustration_Time 1000
set A_Participation_Decay_Time 1000
set A_Effectiveness_Learning_Time 1000


]

end

;; VISUALIZATION

;; Visualation of Severity of Political Action
to determine-activeness
  set active ((Severity_Of_Political_Action) > threshold-for-aggression)
end

to display-agent  ;; agent procedure

  set size Grievance
  ifelse active
    [ set size Severity_Of_Political_Action * 2
      set color yellow
      set shape "fire"
      ]
    [ set size Grievance
      set color scale-color red Grievance 0 1.5
```

```
      set shape "circle"
      ]
end

to display-government
  set color cyan
  set shape "triangle"
  set size 1

end

to update-globals
  ask governments [ set total-government-strength sum [Government_Strength] of governments * 250
]
  ask agents [ set total-grievance sum [ Grievance ] of agents ]
  ask agents [ set total-participation sum [ Participation ] of agents ]
  ask agents [ set total-severity sum [Severity_Of_Political_Action] of agents ]
  ask agents [ set total-effectiveness sum [ Perceived_Effectiveness_Of_Political_Action ] of
agents / 4 ]
end

;; PLOTTING

to my-update-plots
  let active-count count agents with [active]

  ask active-links [
  set color scale-color gray  (current-flow ) 0 .005
     ]

  set-current-plot "Totals"
      set-plot-x-range (ticks - 100) ticks

    set-current-plot-pen "Govt Strength"
  plot total-government-strength
    set-current-plot-pen "Grievance"
  plot total-grievance
    set-current-plot-pen "Participation"
  plot total-participation
    set-current-plot-pen "Severity of Pol Actn"
  plot total-severity
    set-current-plot-pen "Effectiveness of Pol Actn"
  plot total-effectiveness



end
```