



## MIT Sloan School of Management

MIT Sloan School Working Paper 4661-07  
7/1/2007

Using System Dynamics to Model and Better Understand  
State Stability

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**Working Paper CISL# 2007-03**

**July 2007**

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# Using System Dynamics to Model and Better Understand State Stability

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## Abstract

*The world can be complex and dangerous - the loss of state stability of countries is of increasing concern. Although every case is unique, there are important common processes. We have developed a system dynamics model of state stability based on an extensive review of the literature and debriefings of subject matter experts. We represent the nature and dynamics of the 'loads' generated by insurgency activities, on the one hand, and the core features of state resilience and its 'capacity' to withstand these 'loads', on the other. The challenge is to determine when threats to stability override the resilience of the state and, more important, to anticipate conditions under which small additional changes in anti-regime activity can generate major disruptions. With these insights, we can identify appropriate and actionable mitigation factors to decrease the likelihood of radical shifts in behavior and enhance prospects for stability.*

## Keywords

*Model, System Dynamics, State Stability, Terrorists, Insurgency, Regime Legitimacy*

## 1. Introduction

The loss of state stability in various parts of the world is a major threat to U.S. national security. While every case is unique, there are common processes tending toward instability. In its Preface, *The 9/11 Commission Report* states: “We learned that the institutions chartered with protecting...national security did not understand how grave this threat can be, and did not adjust their policies, plans, and practices to deter or defeat it.” [1: xvi]. Given current realities and uncertainties, “better preparedness” can be achieved by identifying, controlling and managing the linkages and situational factors that fuel hostilities and undermine stability and cohesion.

Over the course of six months<sup>1</sup>, researchers from MIT and elsewhere worked with DARPA<sup>2</sup> to develop computational social science models for understanding the nature of state stability as well as propensities for state failure and collapse. The MIT team developed a system dynamics model to understand and represent sources and consequences of stability, as well as ways in which the potential for disruptions could be reduced, managed or mitigated. This paper describes our conceptualization of how and when threats to stability might override the resilience of the state and undermine its overall capabilities and performance. More specifically, we isolate the conditions under which small changes in anti-regime activity can generate major disruptions – and then seek to identify appropriate actionable mitigation factors to reduce the potential for undesirable shifts in behavior and enhance prospects for stability.

## 2. Background and Context

We begin by placing the key issues in context, first by noting insights from the social sciences and then by highlighting some key system dynamics modeling features.

### 2.1 State Stability

The stability of a state is a process, in that states can be at different stages of ‘stability’ and subject to different pressures toward instability. There are multiple modes of fragility as well as different paths toward a range of ‘end points.’ It is well known that studies of state stability (and fragility) are closely connected to a wide range of issues in the social and the computational sciences such as the analyses of civil war, political mobilization, social disturbances, institutional development (or lack thereof), economic performance, social cohesion, ethnic violence and a range of issue areas that bear directly on the resilience of states and their capabilities, as well as on the pressures upon the state and the types of threats to its integrity and stability.

One of the most recognizable indications of state instability is the onset of civil war. While it may be impossible to predict an individual catalyst for a civil war, there are

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<sup>1</sup> From April to October 2005.

<sup>2</sup> Defense Advanced Research Projects Agency

many elements that make a state predisposed towards the breakout of civil war. For instance, the most likely states for civil war are those states that have recently undergone another war, states whose neighbors are involved in civil war, and states that are economically weak [2]. However, many social scientists and policy-makers identify the best device for preventing civil war as democracy [3; 4]. Yet, Siegle, Weinstein and Halperin show that on a global basis the evidence regarding which comes first, democracy or development, is still contentious [5]. By the same token, Hegre, et al. show that the greatest likelihood of civil war is not in a state which is the least-democratic, but rather civil war is much more likely to break out in a state which is semi-democratic [6].<sup>3</sup> Our approach to state stability takes these divergent perspectives into account, but adopts a rather different approach.

Given the wide range of contentions regarding sources and consequences of state stability, an initial step is to define the core proposition in order to render precision and direction for the computational and modeling strategy. The proposition is this:

*A state is stable to the extent that its resilience (capabilities) is greater than the load (or pressures) exerted upon it.*

Embedded in a high level model of state stability, this proposition helps guide formulation of the system dynamics model.

Social scientists in general, and political scientists in particular, are in general agreement regarding the nature of the state, its fundamental features, and its generic attributes – irrespective of specific manifestations or characteristics shaped by time or location. Rooted in the basic contributions of Aristotle’s *Politics* all states consist of, and are governed by, a complex body of relationships and institutions framed and guided by a constitution [7]. Many centuries later, Almond and Powell put forth a formal approach to state capacities by defining a set of specific capabilities (namely, extractive, regulative, responsive, distributive, and symbolic) [8]. These points support our premise that a state is stable to the extent that the loads or pressures upon it can be managed by its prevailing capabilities or performance capacities.

## **2.2 System Dynamics**

System dynamics is an approach for modeling and simulating (via computer) complex physical and social systems and experimenting with the models to design policies for management and change [9]. The core of the modeling strategy is representation of system structure in terms of *stocks* and of *flows*. In this connection, *feedback* loops are the building blocks for articulating the dynamics of these models and their interactions can represent and explain system behavior.

Created by Jay Forrester, system dynamics modeling (SDM) has been used as a method of analysis, modeling and simulation for more than 50 years. SDM has been used for a

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<sup>3</sup> This one-dimensional scale was originally constructed by Ted Robert Gurr in conjunction with the Polity project. Visit <http://www.cidcm.umd.edu/inscr/polity/> for the complete dataset.

wide range of purposes, such as to capture the dynamic relationship of energy and the economy [10], to model the world petroleum market over a period of thirty decades [11], to explore dynamics of economic growth [12] to analyze the environmental implications of international trade [13], to understand supply-chain management [14], to analyze different policies for nation-building [15], to model software development [16], and to examine the intricacies of the air force command and control systems [17].

SDM offers unique capabilities to contribute to social science, economics, or political science modes of analysis. SDM recognizes the complex interactions among many feedback loops, rejects notions of linear cause-and-effect, and requires the analyst to view a complete system of relationships whereby the ‘cause’ might also be affected by the ‘effect’. SDM enables analysts to uncover ‘hidden’ dynamics. Moreover, SDM allows the analyst an increased level of flexibility as SDM utilizes both conceptual understanding as well as empirical data collection. As Forrester explains, “the first step [in SDM] is to tap the wealth of information that people possess in their heads. The mental database is a rich source of information about the parts of a system, about the information available at different points in a system, and about the policies being followed in decision making.” [18: 5]

The system dynamics modeling process translates these elements of causal logic into systems of integral equations [19]. Empirical analysis is also used to explain the relationships between individual elements in the overall system. By understanding the dynamics of a state system, including interactions among actors, actions, structures and processes in complex environments, one can better identify how to reinforce state capabilities while diminishing the loads and pressures exerted upon it.

### **3. Modeling State Stability**

#### **3.1 Overview of Process**

For modeling purposes, the first step is to define the *overall domain* and system of elements tending toward state stability and the sources of instability. This step yields a high level view that is used for framing purposes, consistent with dominant lines of thinking in the social sciences. The value of system dynamics is that it also provides a method for empirical model grounding as well as policy crafting.

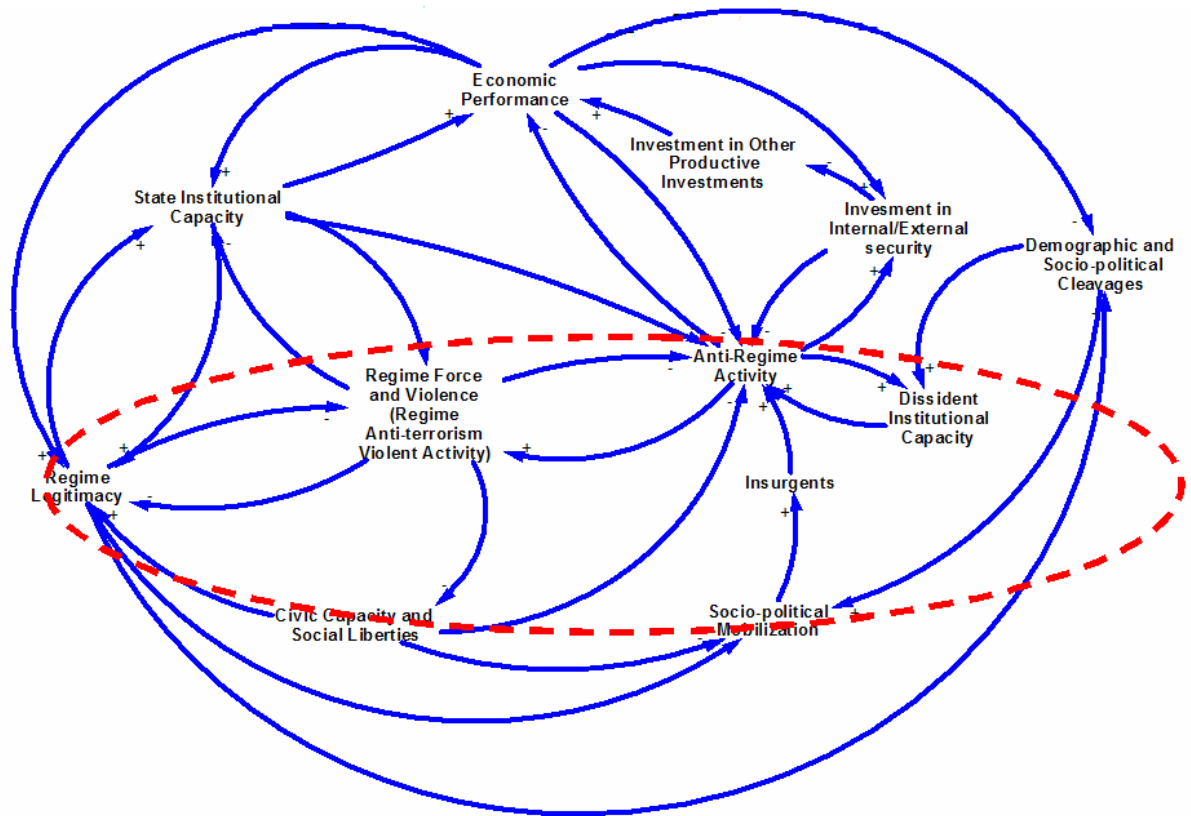
The next step is to select and ‘drill down’ to the most important, sensitive and *short-term processes* that shape the more immediate threats to stability and enhance the propensities for instability.

The third step is to formulate the overall computational *system dynamics model* for simulation and analysis drawing where possible on empirical data and observable cases. The computational system itself consists of interconnected modules that represent different facets of the overall processes at hand.

Drawing upon data from two real-world cases, we developed and then used the model to make further predictions about insurgency recruiting, recognize different policy implications, and make informed policy decisions based upon empirical measurements.

### 3.2 The High-Level View

We begin by creating a high-level causal loop diagram that captures the key elements of the system in question including the major feedback loops. The diagram reflects a range of potentially significant joint dependencies and feedback processes that explain the dynamics of the overall stability status of the state; over time.



**Figure 1: High-Level Diagram of State Stability. (Circled section signals the segments for detailed system dynamics modeling)**

Arrows show causal relationships between variables. A plus sign (+) indicates that a change in the first variable (at the tail of the arrow) causes a change in the second variable (at the head of the arrow) in the same directions. A minus sign (-) indicates that a change in the first variable causes a change in the second variable in the opposite directions. A path that begins at any variable and traces from arrow to arrow to returns to the original variable forms a feedback loop

Figure 1 presents the High-Level Diagram of overall state stability. We seek here only to define broadly the *overall domain* as well as the *SD model focus* (encompassed within the dashed lines).

In many cases, there were large bodies of literature that described each of the key relationships. Framed thus, we seek only to reflect some of the most dominant sets of relationships reflected in the literature, by way of developing an integrated device for representing the complexities of underlying dynamics.

### 3.3 Drilling Deeper

In Figure 1, the dotted line delineates several elements in the High-Level Diagram that we select as the focus for our detailed modeling process. These focus on Regime Legitimacy and the role of Insurgents in Anti-Regime activities.

Three factors are relevant here:

First, we chose a time horizon over which long-term ramifications might be significantly different than short-term outcomes. We wanted to choose examples where this would be especially pronounced.

Second, we wanted a model boundary sufficiently broad so as to allow us to explore and explain the strengths and weaknesses of a variety of policy options.

Third, we chose to focus on system-features that would best illustrate the contributions of system dynamics to policy analysis as well as to the social sciences.

Based on all these considerations, we selected to ‘drill down’ into *the dynamics of dissident and insurgent recruiting given the resilience of the state and its capacity to manage anti-regime activities*.<sup>4</sup>

The dynamic simulation and modeling analysis of insurgency-vs.-state-resilience would become our Proof of Concept Model.

### 3.4 Strategy for Proof of Concept

The starting point for modeling the potential growth of dissidents and insurgents was recruiting. We considered and sought to represent the different causes and effects of such recruiting. Model formulation was done in four interactive stages.

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<sup>4</sup> Many of these subjects were saved in case we had the opportunity to pursue future modeling. They ranged from analyzing instances of famine and food shortage to the mobilization and propagation of fundamental terrorism.



- (1) A thorough and comprehensive literature review in order to familiarize ourselves with the key terms and to capture the current state of understanding of insurgent recruitment.
- (2) A set of interviews conducted with relevant experts and personnel, namely military experts, country analysts, and scholars in order to generate further insight.
- (3) Use of existing empirical work to explain relationships that would hold for a range of states, and thus to develop generic representation of complex dynamics.
- (4) Testing with country-specific information for two test cases: Country A and Country B.<sup>5</sup> Country-specific information came from personnel, online newspapers, databases constructed by government organizations, non-governmental organizations, and experts.

Throughout the process, we considered how different policies would affect the dynamics of the model.

## **4. Proof of Concept Model**

Below we present the system dynamics state stability model, beginning first with an overview of the entire system and structure, and then addressing key components sequentially.

### **4.1 System Structure - Overview**

The model shows the sources and consequences of insurgent recruiting, constrained and limited by the resilience of the regime and the extent to which the state can manage anti-regime activities. To simplify, of the many actions that insurgents chose to perform in order to undermine regime legitimacy, we model those associated with activities that lead to stimulating, producing and circulating anti-regime “communications” and “messaging”<sup>6</sup>.

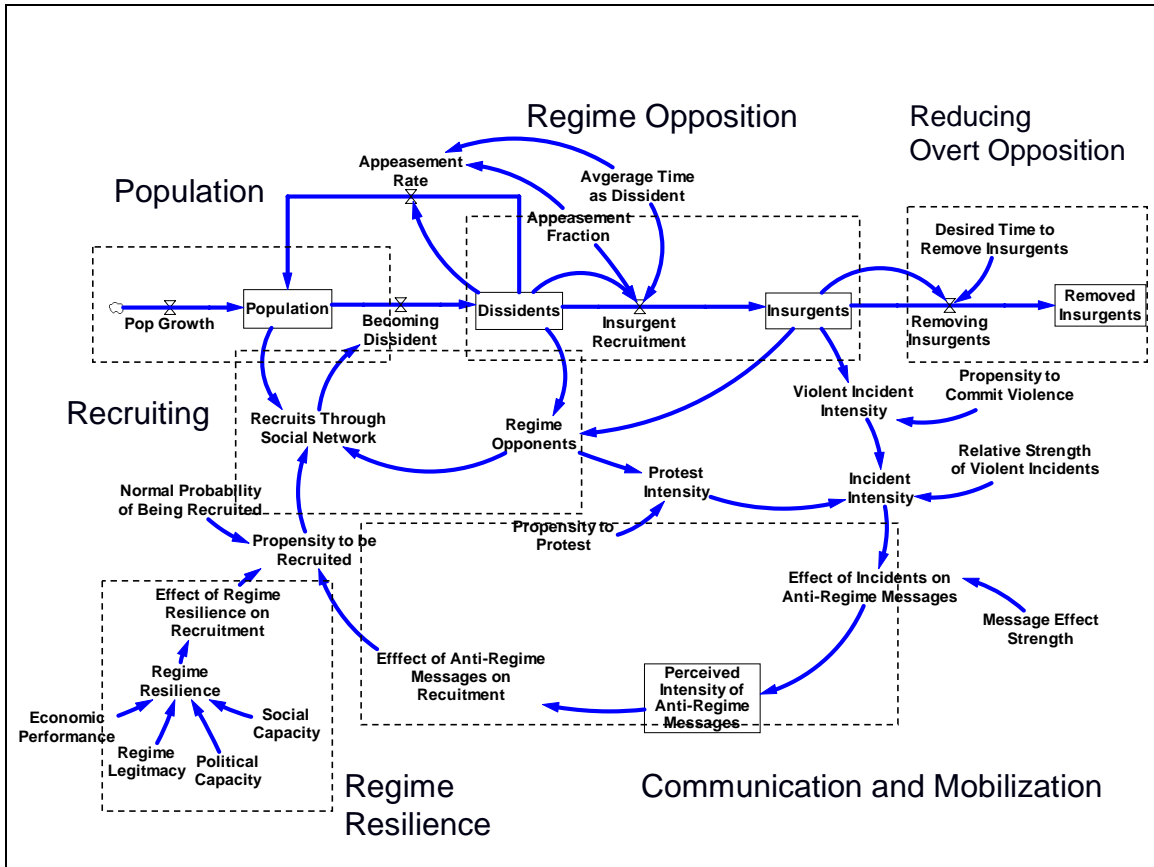
Anti-regime messaging and communication are thus major mechanisms for increasing insurgent recruitment and for mobilizing opponents to the regime. The context in which these activities occur is partly shaped by the regime. The state’s capabilities and the resilience of the regime operate such as to counter insurgency recruitment.

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<sup>5</sup> One of the requirements for the DARPA contract was that all teams make real predictions for two countries. Thus Country A and Country B represent two existing countries.

<sup>6</sup> Communications and messaging are broadly defined. For example, a successful terrorist attack is a form of “message” that can be “communicated” – even if only by word-of-mouth. Communication and messaging are both facilitated by social networks.

Figure 2 represents the segment of Figure 1 (bounded by the dotted line) that is further developed to constitute our proof-of-concept model. Figure 2 also includes a segmentation of the model into sub-systems, such as Population Growth, Regime Resilience, Anti-Regime Recruiting, Regime Opposition, Reducing Overt Opposition, and Communications and Mobilization. These are examined in greater detail below.



**Figure 2: Conceptual Model of Insurgent Activity and Recruitment (Simplified)**

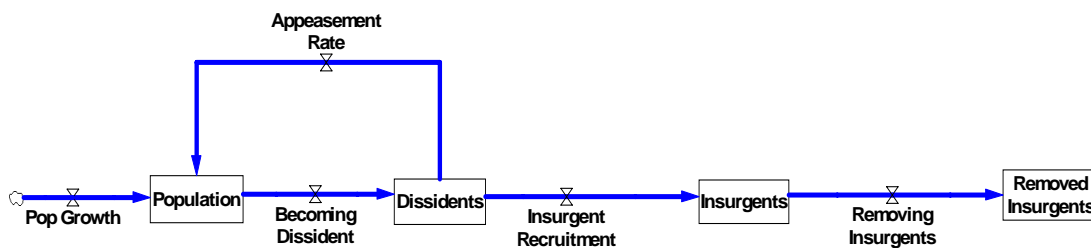
The logic of the model can account for many known patterns of insurgent recruiting in relation to the role and influence of the regime and its resilience<sup>7</sup>. The model structure and framework is based heavily on the social science literature and earlier studies in the computational social sciences, as well as on “tapping into the wealth of information that people possess in their heads” [18].

The remainder of this section presents the key components of the model and articulates the basic logic in the course of “unfolding” the structure of the behavior of the system. A list of some of the sources of information supporting each link in the model is presented in Appendix A.

<sup>7</sup> The formulated model includes about 140 equations.

## 4.2 Sources of Insurgents

We proceed from the assumption that in any given state with a given number of people there are some peaceful anti-regime elements (dissidents) and there are some violent anti-regime elements (insurgents). Thus, we divide the population into three stocks, labeled Population, Dissidents, and Insurgents, and shown as rectangles in Figure 3. The model shows transitions from one stock to the other with icons resembling pipes and valves<sup>8</sup>. People in the general population may become dissidents and after some time these dissidents may become insurgents. However, all dissidents do not necessarily become insurgents. , Dissidents might become appeased by the state and return to the general population. A peaceful regime change or a policy change may placate these dissidents into regime supporters. Alternatively, dissidents who become insurgents can be removed from the system by the state. This could occur through arrests, detentions, or state violence. These approaches to reducing the number of dissidents and insurgents, respectively, are shown as the “Appeasement Rate” and “Removing Insurgents” in Figure 3.



**Figure 3: Population-to-Insurgent Flow**

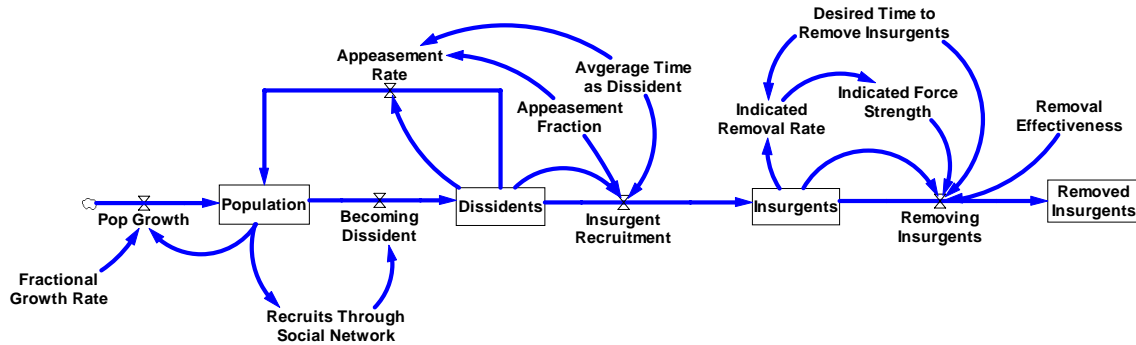
There are other conditions affecting the Population-to-Insurgent flows. Different elements can affect the transition of a normal member of society to a dissident to an insurgent, as we note below.

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<sup>8</sup> The valves control the rate of flow between the stocks. The factors that affect these rates are explained later.

### 4.3 Removal of Insurgents

The next level of complexity is presented in Figure 4.



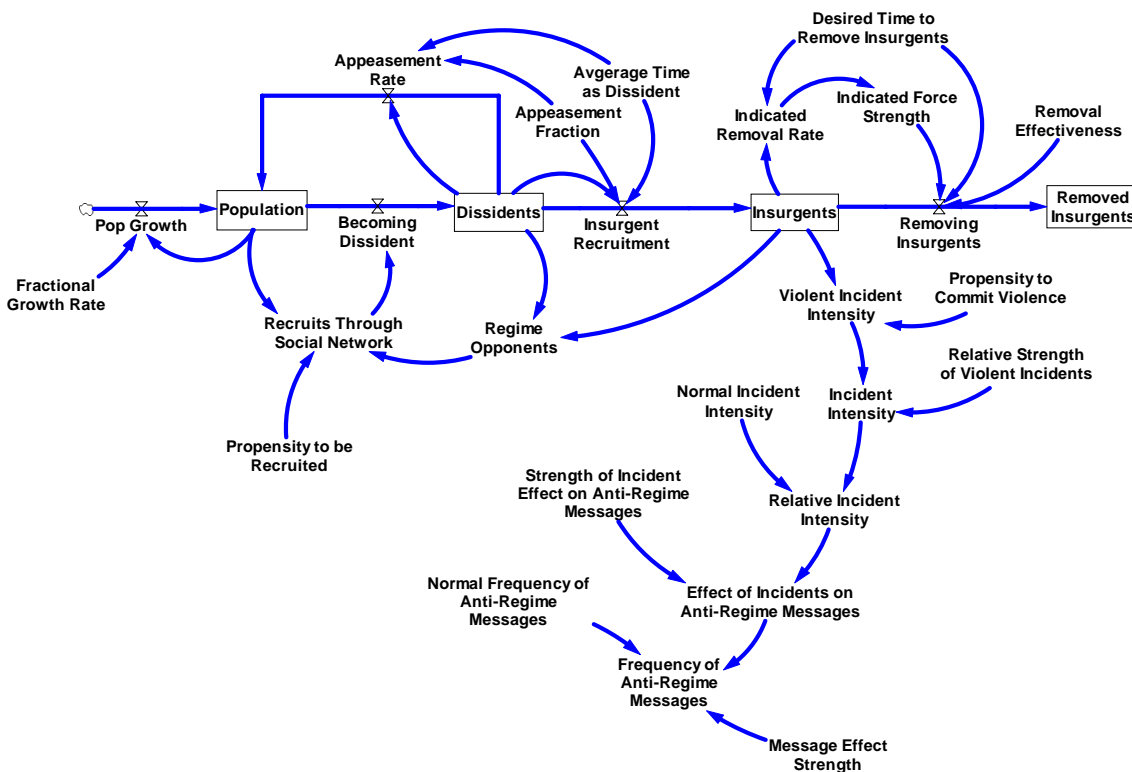
**Figure 4: Other Ways to Affect the Population-to-Insurgent Flow**

When considering the insurgent removal, we must also consider the removal effectiveness, the indicated force strength, and the desired time to remove insurgents in order to assess the rate at which insurgents are removed. Policy levers, such as the amount of resources allocated to each method, that effect these variables are exogenous to our model,, but we can test various policy options by varying these parameters.

### 4.4 Anti-Regime Messaging and the Flow of Communication

In Figure 5, we expand the model to show that dissidents and insurgents take actions we call anti-regime incidents which in turn generate anti-regime messages. Such incidents include protests, targeted attacks, or even civil war. ‘Messages’ include both formal and informal communications between individuals in a regime.

An anti-regime message based upon an intense incident might proclaim that the regime violently cracked down on *innocent* protestors, or that the regime can no longer effectively handle insurgent movements in a certain part of the country and is therefore incapable of controlling the state. Messages of this sort can undermine the legitimacy of the regime and represent an important form of loads on state capacity. The load becomes especially strong when it is reinforced by, and diffused through, social networks, thus facilitating recruitment further, as seen in Figure 5.

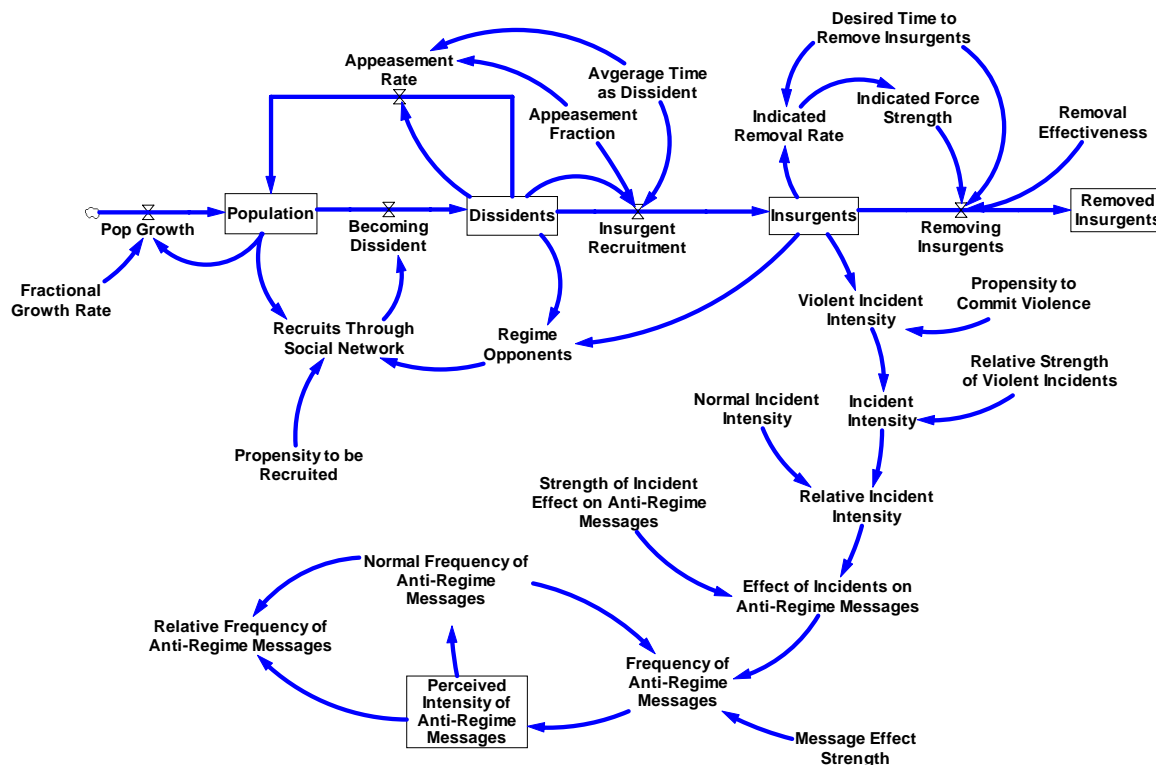


**Figure 5: Message Production Generated by Dissident and Insurgent Incidents**

Once again, there are many policy options available for limiting the flow of anti-regime messages. Such options are often utilized, in countries as diverse as France, (which imposed curfews on its citizens to quell riots in October and November of 2005) and Thailand (where the South has been in a state of martial law since March of 2005). At the same time, we recognize that perceptions may be different from actual behavior and there might be differences in the effectiveness of such attempts to limit the flow of anti-regime messages.

#### 4.5 The Role of Perceptions and Cognition

Accordingly, in Figure 6, we take into account the perceived intensity of anti-regime messages and the relative frequency of anti-regime messages.



**Figure 6: Accounting for Perceptions**

The effectiveness of the insurgent communications methods can either magnify the “apparent” intensity of the Anti-Regime messages, such as through the increased use of internet and satellite television, or diminish the “apparent” intensity if not effective. As Anti-Regime messages become more frequent than normal, the relative frequency of anti-regime messages increases, bolstering dissident and insurgent recruitment.

## 4.6 Regime Resilience

The critical constraint on insurgency expansion is the resilience of the state. The SDM model represents state resilience through an empirically derived function of key determinants, as indicated in the social science literature. Specifically, we combine measures of economic performance, regime legitimacy, political capacity, and social capacity, as shown at the lower left of Figure 7, to compute the aggregate regime resilience, via the relationship:

$$Regime\_Resilience_t = \alpha_t * \beta_t * \gamma_t * \delta_t * \varepsilon_t$$

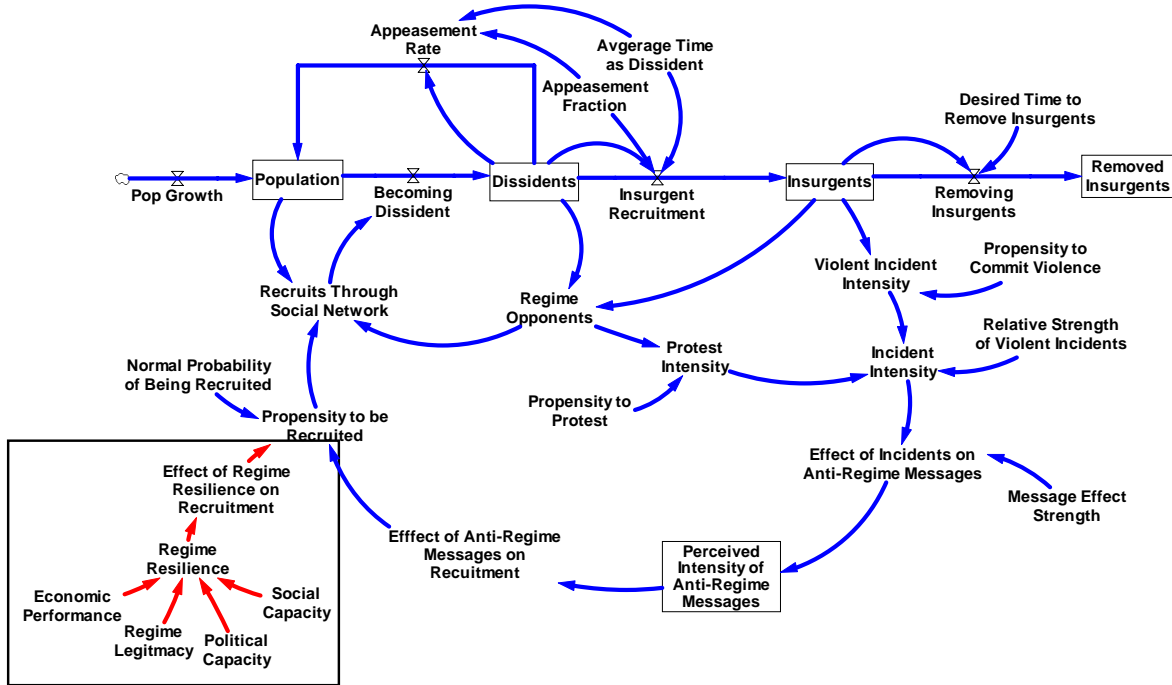
$$\text{Polity Index: } \alpha_t = |Polity_t / Polity_{1980}|$$

$$\text{Civil Liberties Index: } \beta_t = Civil\_Liberties_t / Civil\_Liberties_{1980}$$

$$\text{GDP Index: } \gamma_t = (GDP_t / Population_t) / (GDP_{1980} / Population_{1980})$$

$$\text{Employment Index: } \delta_t = Emp\_per\_Capita_t / Emp\_per\_Capita_{1980}$$

$$\text{Literacy Index: } \varepsilon_t = Literacy_t / Literacy_{1980}$$

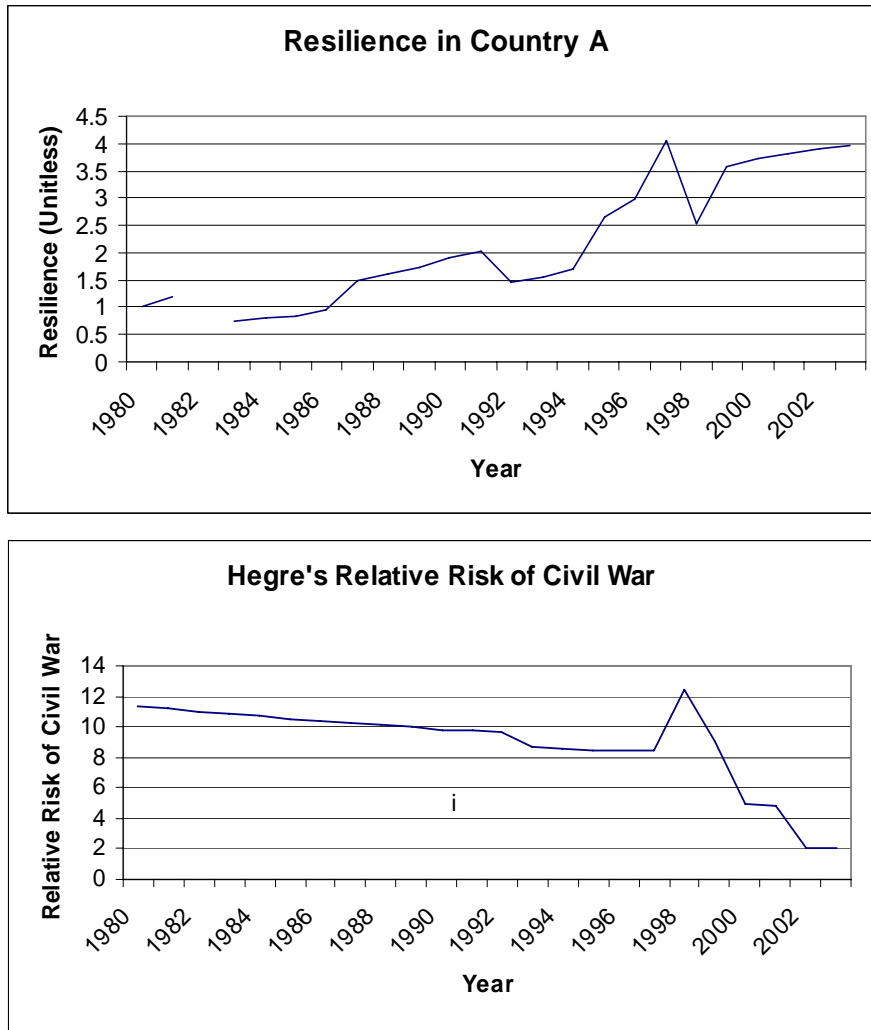


**Figure 7: Regime Resilience**

The effects of anti-regime messages on dissident recruitment are taken into account, as shown in Figure 7 where the “Normal Probability of Being Recruited” is modified (increased or decreased) as a result of the “Effect of Anti-Regime Messages on Recruitment” and the “Effect of Regime Resilience on Recruitment” to compute the “Propensity to be Recruited.”

Considering our earlier discussion of capacities versus loads, regime resilience can be considered as a measure of the long-term capacities of a state. The literature notes that the resilience of a state is inversely related to the occurrence of civil war. We find empirical support for this relationship when comparing the state resilience function to the determinants of civil war as determined by Hegre et al. [6]. Hegre, et al. looked at all occurrences of civil wars across the world over the last several decades. They were able to produce a measure that determines the likelihood of a civil war breaking out.

As we would expect, for the case of Country A, the Relative Risk of Civil War declines as the computed Resilience index rises, as shown in Figure 8. This suggests that insurgent movements are being contained from further breakouts at the national level.



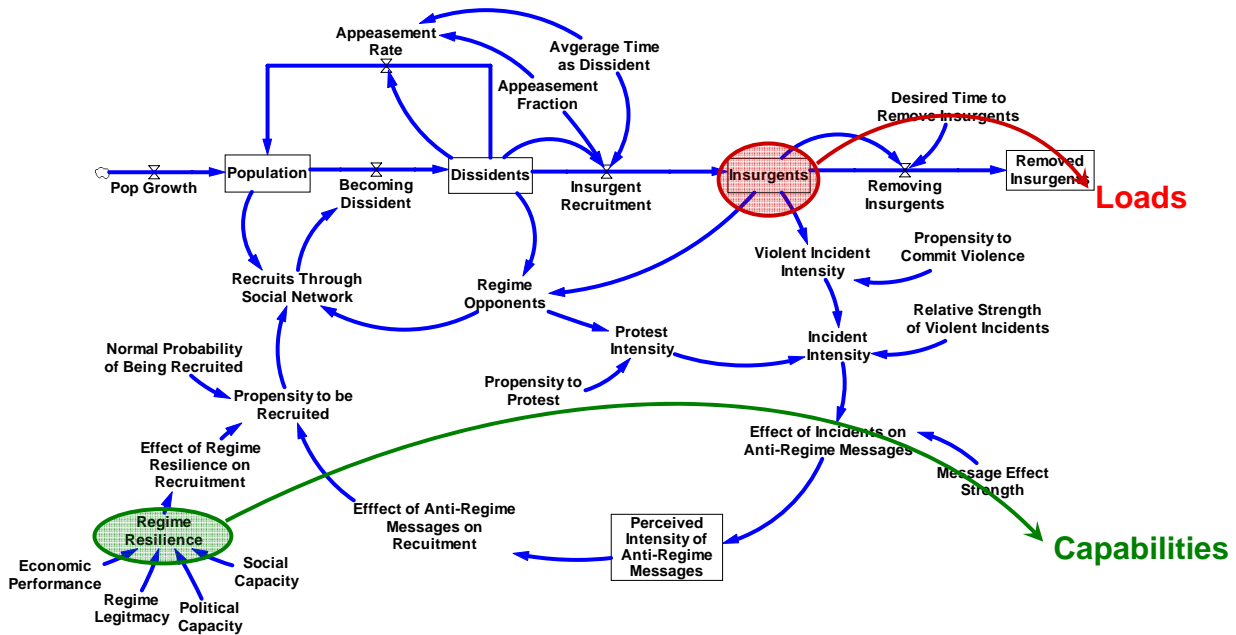
**Figure 8: Regime Resilience vs. Relative Risk of Civil War**

A detailed discussion of the factors and the calculation of the Relative Risk of Civil War (RCW) used in Figure 8 can be found in Appendix B: “Hegre-Relative Risk of Civil War Memo.”

#### 4.7 Review of Loads vs. Capabilities

Regime resilience can mitigate against insurgent recruitment, thereby preventing an increase in the load on the the system. For example, when the economy is doing well or when the regime is perceived as having increased legitimacy, the likelihood of an individual becoming a dissident or an insurgent becomes much smaller. The foci of the loads and capabilities of the system are highlighted in Figure 9.





**Figure 9: Identifying Loads and Capabilities**

Re-examining the usage of policies specifically designed to stem message flows through reductions in civil liberties, we see that in the short-term such policies can reduce the messaging capabilities but in the long-term such policies can undermine the social capacity of a state and will therefore undermine the regime resilience. This is an example of the potentially counter-intuitive “second order” affects of certain approaches to addressing insurgents.

As a result, while there are fewer avenues for messages to circulate, these messages are more effective at converting individuals into dissidents and insurgents as individuals are less happy with the regime. Therefore the state and the regime should be wary of enforcing short-term controls with deleterious effects and should instead create and foster policies focused on improving the capacities of the state, which in turn will balance the loads.

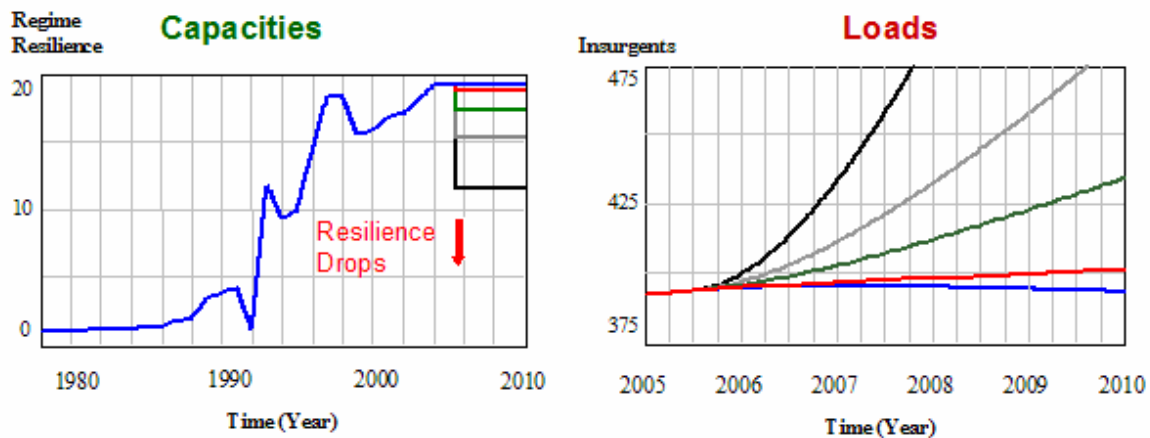
## 5. Results of Proof of Concept Model

We have used our model to explore the impact of various changes in the exogenous factors as well as the impact of various policy options. In this section, we will present two sets of simulation results, for the two different countries that we studied, that show two fundamentally different modes of behavior – long-term growth in the number of insurgents and long-term decline in the number of insurgents. In these simulations, we explore (a) the impacts of a decline in regime resilience and (b) an example of the impacts of different policy prescriptions, in particular, removing insurgents vs. reducing anti-regime messages and identify tipping points in which the system shifts from one mode of behavior to the other.

## 5.1 Decline in Regime Resilience

Recall our interest in identifying the conditions in which the loads on the system exceed the capacities to manage the loads. At such points, regime resilience will no longer be able to ‘fend off’ insurgency behavior. In Figure 10 we show several simulations, in the base case, depicted by the blue line, the number of insurgents is declining as of 2006. The simulations introduce various possible sudden drops in regime resilience (left graph) and the corresponding response in the number of insurgents that are generated by those reductions in the state capacity (right graph).

Specifically, these figures show the resulting growth in insurgency with various reductions in long-term state capacities (known as Regime Resilience in the model)<sup>9</sup>. Examples of situations that have caused reductions in regime resilience include election fraud, oil shock on economy, healthcare failure, and judicial breakdown. These figures are based upon observations, estimates, and predictions in a specific region of Country A, where insurgency has fluctuated for the last several years.



**Figure 10: Capacities and Loads**

Under the initial “base” case<sup>10</sup> (shown as the blue lines in both the Capacities and Loads diagrams), we see a slight reduction in insurgents and Loads on the system over time. But as the other scenarios show, even small declines in the capacities of the state change the direction to one of future insurgent growth and increase of the Loads on the system – thus a ‘tipping point.’<sup>11</sup> An initial small drop in resilience produces what appear at first

<sup>9</sup> Figure 10 was developed in color. If viewed in black and white, each of the four drops in resilience is matched with the four increasing curves of Insurgent Loads.

<sup>10</sup> For country A

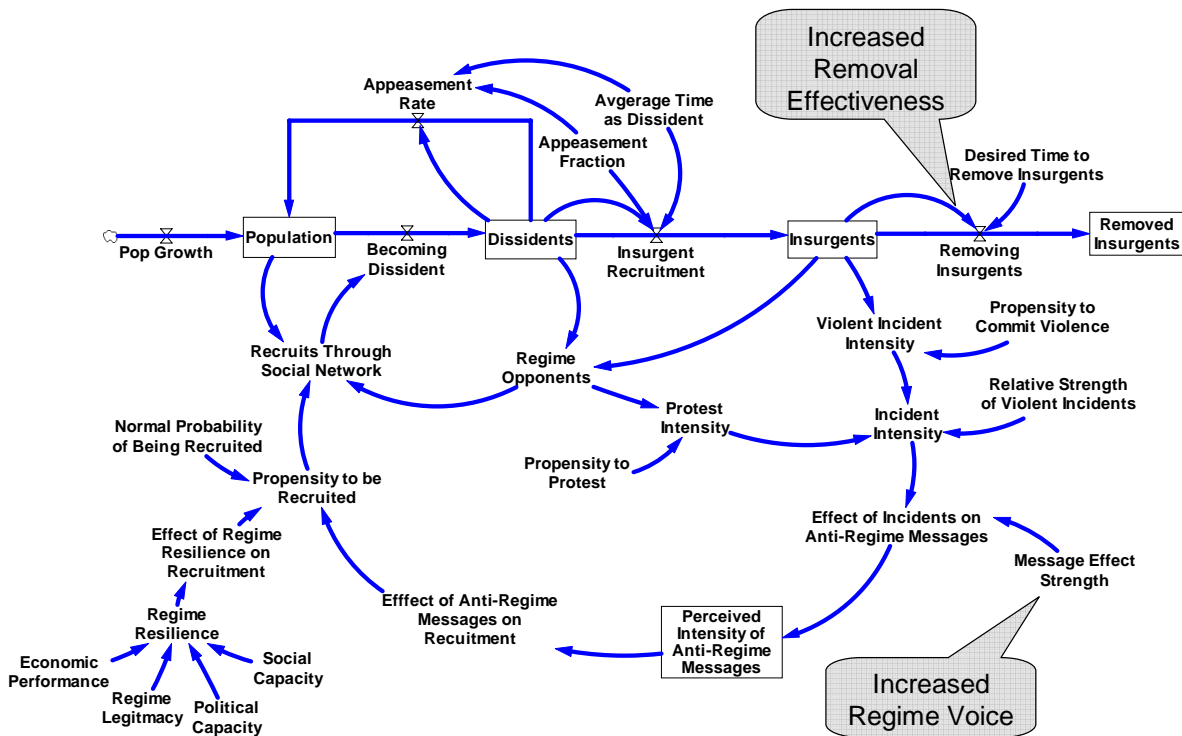
<sup>11</sup> The numbers presented in Figures 10a and 10b on the axes are based upon a specific case study. The true value of system dynamics does not come from empirical statements such as “if you reduce the economy 10%, you will increase insurgents by 10%,” but rather “if the economy drops even a little, one can expect to see an increase in insurgents, and based upon previous situations, if something is not done to re-establish the capacities, the state may tip into an unsustainable situation.”

to be small increases in the number of insurgents, i.e. the load on the system, but because the drop in resilience leads to more fruitful recruiting of dissidents, the ultimate consequence is a sustained increase in insurgent numbers. The drop in resilience has caused the system to cross the critical threshold, or tipping point, such that the reinforcing process of recruitment is now dominating the overall system behavior. This result shows the sensitivity of the system to the choice of policy prescriptions required for state stability.

## 5.2 Policy Alternatives: Removing Insurgents vs. Reducing Anti-Regime Messages

We now examine some different policy alternatives. In Figure 11, we identify two policy options:

- (1) the state might become better at removing insurgents, or
- (2) the state might improve its ability to respond to anti-regime messages, dampening the message strength.

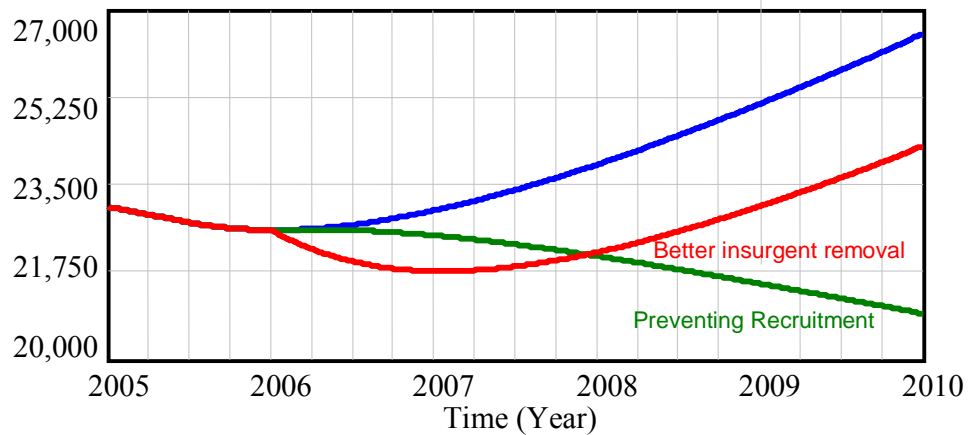


**Figure 11: Increasing the Regime Voice vs. Increased Removal Effectiveness**

Earlier, we identified that controlling the circulation of anti-regime messages (through curfews and other civil liberty limitations) would reduce the number of anti-regime messages in the short-term. Considering the broader system, we see that a policy

prescription which encourages choking messages, if done through the suppression of liberties, would undermine regime resilience, and in the long run, such a policy prescription would cause more harm than good. Increasing the ‘Regime Voice’ is different. It implies that the strength of the anti-regime messages might become diluted in an acceptable fashion.

For example, one such way to increase the regime voice is to sponsor a public campaign against the insurgents (to undermine their legitimacy). As we observed in Jordan in November of 2005, as a result of extreme terrorist acts by Al Qaeda, the state was able to garner public sentiment. That can become a very successful method for controlling anti-regime elements. There are many other ways that states can increase the regime voice to counter the threats. In Figure 12, we compare the results of changes in each of these inputs.



Better insurgent removal  
intelligence sharing

Preventing recruitment  
moderate rhetoric

**Figure 12: The Potential Effects of Increased Removal Effectiveness (Intelligence Sharing) versus Weakening the Message Strength (Moderate Rhetoric)**

The upper line<sup>12</sup> shows the expected number of insurgents in a “base” case<sup>13</sup> where the regime resilience measure is at a level such that if no action is taken, the result will be a continued growth in insurgents.

Both of the proposed policy alternatives produce a reduction from this projected growth. However, there are significant differences in the long-term impact. Although the use of better insurgent removal policies<sup>14</sup> does reduce the number of insurgents at any given time relative to the base case, the basic trajectory is not changed and insurgents do

<sup>12</sup> The blue line in colored version.

<sup>13</sup> For country B

<sup>14</sup> The red line in colored version.

continue to grow. On the other hand, when the state focuses on preventing recruitment through improving rhetoric, insurgent recruitment actually slows and insurgent levels actually decline, as shown as the lowest line<sup>15</sup>. The policy alternative of moderating rhetoric causes a fundamental shift in the system behavior to one of long-term decline in insurgent numbers. The system has crossed the tipping point and is now headed towards long-term stability because the policy intervention has significantly weakened the reinforcing processes of recruitment. The recruiting processes are too weak to overcome the capabilities of the state, so the balancing loops that maintain stability dominate the behavior of the system.

## **6. Conclusion**

This paper focused on particular segments of an overall modeling strategy designed to help better understand the sources and consequences of state stability. We hope to continue our research to create a comprehensive integrative computational model, one that addresses all of the key features of the High Level Diagram presented earlier.

Such an effort would enable us to integrate the dynamics of insurgency and dissidence within a more detailed and realistic representation of overall stability – all of the key loads vs. the entire major capacities. In this paper, we illustrated the underlying interplay between critical elements that can produce useful insights, and we have shown that system dynamics can yield fruitful results for policy prescriptions, in this case on combating insurgent recruitment.

System dynamics modeling enables us to understand, recognize and compare both short-term and the long-term effects, simplifying complex dynamics, and providing a tool for policy analysis. Scholars have been analyzing states, security, policy decisions, and nation-building for years: the military planners and policy analysts could gain insights from such work.

Finally, the use of system dynamics modeling, in conjunction with evidence from the social science is a major contribution to the development of computational social sciences. There is a long history exploring the complexity of sovereign states in the social sciences. Improving our understanding of the dynamics of complex systems with specific applications to the state will enhance the predictive value of modeling for purposes of policy and planning.

### **Acknowledgements**

Our system dynamics modeling efforts, reported in this paper, have benefited from interactions with, and contributions of, the subject matter experts and the other collaborators in this DARPA project.

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<sup>15</sup> The green line in colored version.

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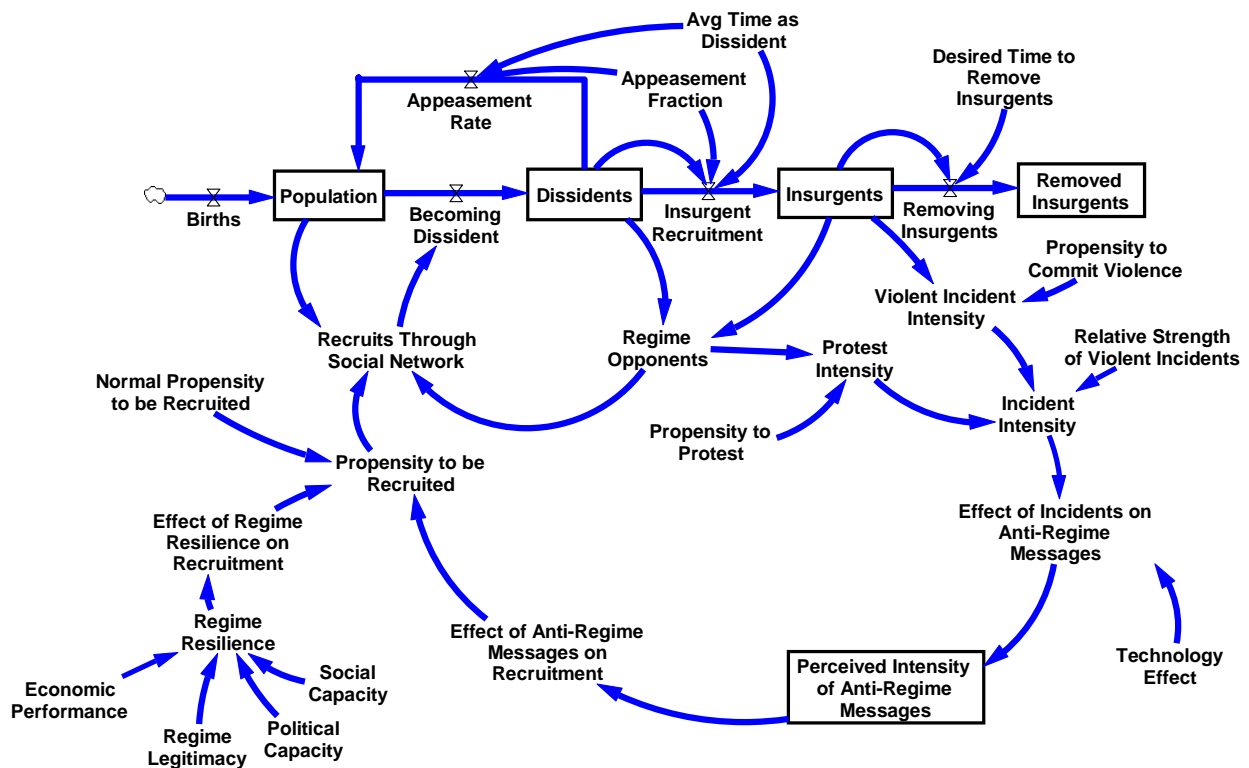
1. The 9/11 *Commission Report*, 2004.
2. Collier, P., V. L. Elliot, H. Hegre, A. Hoeffler, M. Reynal-Querol, N. Sambanis. (2003). *Breaking the Conflict Trap: Civil War and Development Policy*. Washington DC: The World Bank.
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# APPENDIX A

## Reference Sources for the Components of the Model

The purpose of this Appendix is to document the sources of the information about the causality between variables in this model. This Appendix shows that research in both the public and private sector supports all of the critical links in this model. The slide titles and “yellow oval” in the subsequent pages indicate which link the associated citations support.

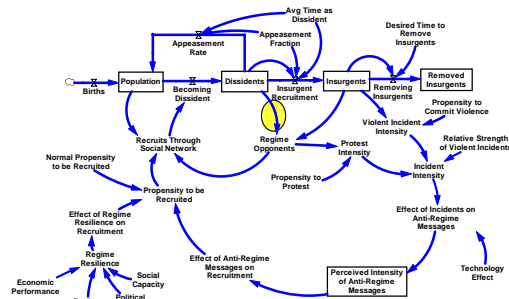




# Dissidents Produce Regime Opponents

- R. Petersen, *Resistance and Rebellion: Lessons from Eastern Europe*, Cambridge University Press: May, 2001.
- C. Tilly, *From Mobilization to Revolution*, Random House: 1978.
- E. Nyberg, *Insurgency: The Unsolved Mystery*, Available online: <http://www.globalsecurity.org/military/library/report/1991/NE.N.htm> (Accessed August, 2005).

More Dissidents Means More People Oppose the Regime



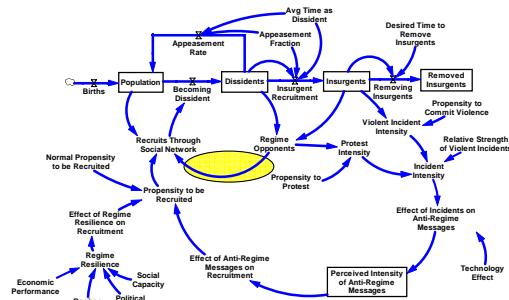
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# Regime Opponents Recruit Through Social Networks

- N. Berry, T. Ko, T. Moy, J. Smrcka, J. Turnley and B. Wu, "Emergent Clique Formation In Terrorist Recruitment," Sandia National Laboratories, 2005.
- R. Petersen, *Resistance and Rebellion: Lessons from Eastern Europe*, Cambridge University Press: May, 2001.
- P. Heymann, "Dealing with Terrorism," *International Security*, Vol. 26, No. 3, 2001: 24-38.
- F. Passy, "Socialization, Recruitment, and the Structure/Agency Gap. A Specification of the Impact of Networks on Participation in Social Movements," Available online: <http://www.nd.edu/~dmeyers/lomond/passy.pdf> (Accessed Aug. 2005).
- J. Weinstein, "Resources and the Information Problem in Rebel Recruitment," *Journal of Conflict Resolution*, Vol. 49, No. 4, 2005: 598-624.

More Regime Opponents actively recruit people to join an insurgency, increasing the number of Recruits Through Social Networks.



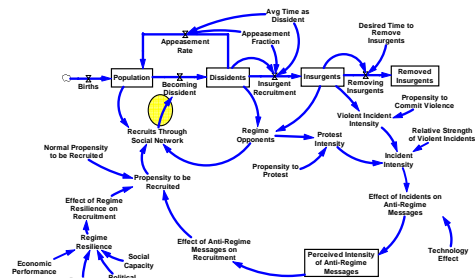
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# Recruits Through Social Network Leads to More People Becoming Dissident

- N. Berry, T. Ko, T. Moy, J. Smrcka, J. Turnley and B. Wu, *Emergent Clique Formation In Terrorist Recruitment*, Sandia National Laboratories, 2005.
- R. Petersen, *Resistance and Rebellion: Lessons from Eastern Europe*, Cambridge University Press: May, 2001.
- J. Weinstein, "Resources and the Information Problem in Rebel Recruitment," *Journal of Conflict Resolution*, Vol. 49, No. 4, 2005: 598-624.

More recruits in the social network leads to a larger number of individuals becoming dissidents.



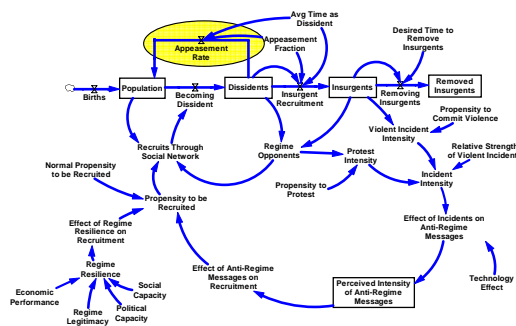
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# Appeasement Can Reduce the Number of Dissidents

- A. Smith, "The Politics of Negotiating the Terrorist Problem in Indonesia," *Studies in Conflict & Terrorism*, Vol. 28, 2005: 33-44.
- F. Passy, "Socialization, Recruitment, and the Structure/Agency Gap. A Specification of the Impact of Networks on Participation in Social Movements," Available online: <http://www.nd.edu/~dmyers/lomond/passy.pdf> (Accessed Aug. 2005).
- L. Kowalchuk, "The Discourse of Demobilization: Shifts in Activist Priorities and the Framing of Political Opportunities in a Peasant Land Struggle," *The Sociological Quarterly*, Vol. 46, No. 2, May, 2005: 237.

Dissidents can be reduced and reintegrated into the population, given the right conditions.



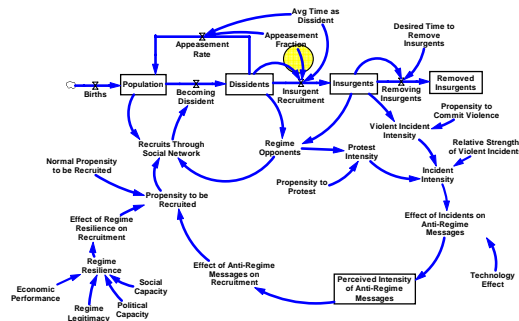
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# Appeasement Fractional Movement from Dissident to Insurgent

- A. Smith, "The Politics of Negotiating the Terrorist Problem in Indonesia," *Studies in Conflict & Terrorism*, Vol. 28, 2005: 33-44.
- F. Passy, "Socialization, Recruitment, and the Structure/Agency Gap. A Specification of the Impact of Networks on Participation in Social Movements," Available online: <http://www.nd.edu/~dmyers/lomond/passy.pdf> (Accessed Aug. 2005).
- L. Kowalchuk, "The Discourse of Demobilization: Shifts in Activist Priorities and the Framing of Political Opportunities in a Peasant Land Struggle," *The Sociological Quarterly*, Vol. 46, No. 2, May, 2005: 237.

A greater Appeasement Fraction means a lower Insurgent Recruitment



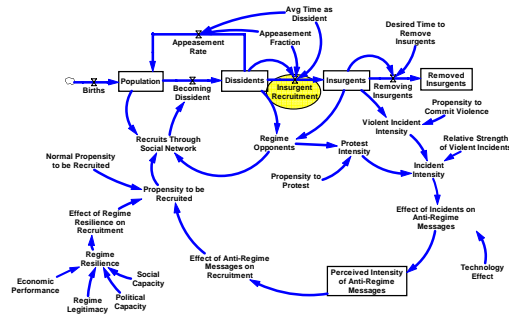
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# Dissidents Produce Increased Insurgent Recruitment and Increased Numbers of Insurgents

- P. Heymann, "Dealing with Terrorism," *International Security*, Vol. 26, No. 3, 2001: 24-38.
- F. Passy, "Socialization, Recruitment, and the Structure/Agency Gap. A Specification of the Impact of Networks on Participation in Social Movements," Available online: <http://www.nd.edu/~dmyers/lomond/passy.pdf> (Accessed August, 2005).
- E. Young, *The Other Rebellion: Popular Violence, Ideology, and the Mexican Struggle for Independence, 1810-1821*, Stanford University Press: 2001.
- E. Nyberg, *Insurgency: The Unsolved Mystery*, Available online: <http://www.globalsecurity.org/military/library/report/1991/NEN.htm> (Accessed August, 2005).

Some Dissidents eventually become Insurgents



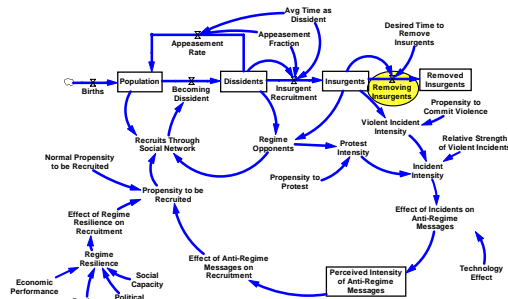
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# Insurgents Can Be Removed From The System I

- L. Langdon, A. Sarapu, and M. Wells, "Targeting the Leadership of Terrorist and Insurgent Movements: Historical Lessons for Contemporary Policy Makers," *Journal of Public and International Affairs*, Vol. 15, Spring, 2004.

A greater number of Insurgents means more people to remove, thus more Removed Insurgents per month



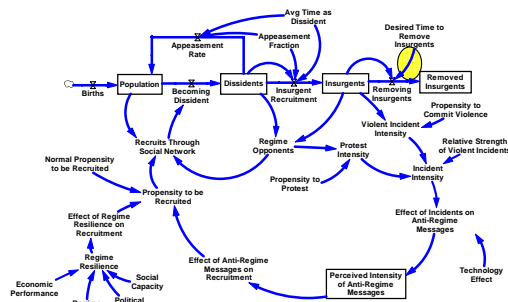
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# Insurgents Can Be Removed From The System II

- M. McClintock, *Instruments of Statecraft: US Guerilla Warfare, Counterinsurgency and Counter-Terrorism, 1940-1990*, Pantheon Books: 1992.
- S. Rosendorff, "Too Much of a Good Thing?" *Journal of Conflict Resolution*, Vol. 48, No.5, Oct. 2004: 657-671.

The longer Time to Remove Insurgents, the slower it is to remove insurgents, and the larger stock of insurgents building up behind the flow



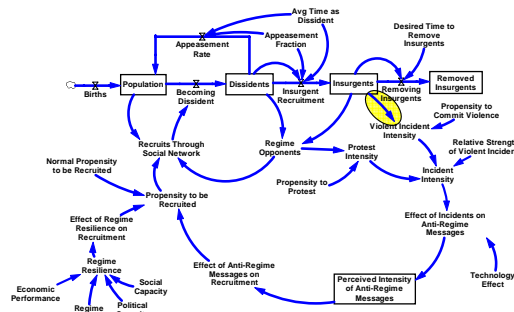
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# More Insurgents Lead to More Violence

- L. Hovil and E. Werker, "Portrait of a Failed Rebellion: An Account of Rational, Sub-optimal Violence in Western Uganda," Available online: <http://www.people.fas.harvard.edu/~werker/papers/adf.pdf> (Accessed Aug. 2005)
- J. Weinstein, "Resources and the Information Problem in Rebel Recruitment," *Journal of Conflict Resolution*, Vol. 49, No. 4, 2005: 598-624.
- S. Metz, "Insurgency and Counterinsurgency in Iraq," *The Washington Quarterly*, Vol. 27, No. 1, December, 2003: 25-36.

More Insurgents lead to more people available to commit Violent Acts



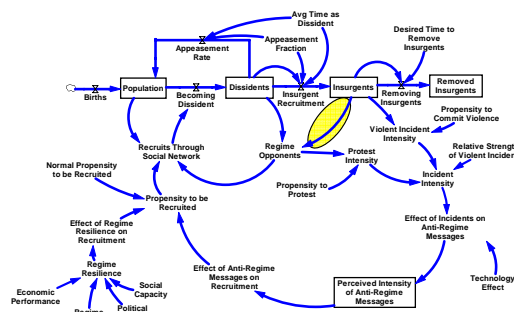
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# More Insurgents Lead to More Regime Opponents

- A. Malaquias, "Diamonds are a Guerrilla's Best Friend: The Impact of Illicit Wealth on Insurgency Strategy," *Third World Quarterly*, Vol. 22, Issue 3, June, 2001: 311-316.
- M. Ross, *Resources and Rebellion in Aceh, Indonesia*, For the Yale-World Bank project on "The Economics of Political Violence," June, 2003, Available online: <http://www.sscnet.ucla.edu/polisci/faculty/ross/ResourcesRebellion.pdf> (Accessed Aug. 2005).

Insurgents oppose the regime and also contribute to dissident recruitment networks.



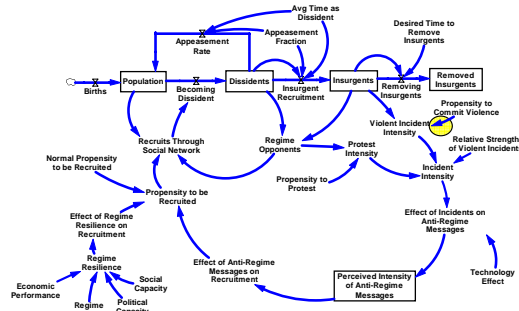
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# Insurgents have a Propensity to Commit Violent Acts

- J. Fearon and D. Laitin, "Ethnicity, Insurgency, and Civil War," *American Political Science Review*, Vol. 97, No. 1, February, 2003: 75-90.
- A. Croissant, "Unrest in Southern Thailand: Contours, Causes, and Consequences Since 2001," *Strategic Insights*, Vol. 4, Issue 2, Feb. 2005.
- M. Ross, *Resources and Rebellion in Aceh, Indonesia*, For the Yale-World Bank project on "The Economics of Political Violence," June, 2003, Available online: <http://www.sscnet.ucla.edu/polisci/faculty/ross/ResourcesRebellion.pdf> (Accessed Aug. 2005).

A greater Propensity to Commit Violence (# acts/ month/ Insurgent) means a greater Violent Incident Intensity



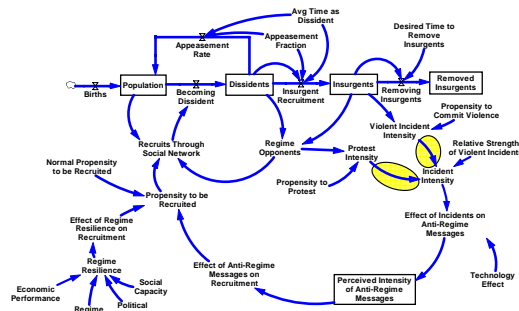
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# Violent Incident Intensity and Protest Intensity Cause Incident Intensity

- C. Bob, "Marketing Rebellion: Insurgent Groups, International Media, and NGO Support," *International Politics*, Vol. 38, No. 3, Sep. 2001: 311-334.
- M. Lipsky, "Protest as a Political Resource," *The American Political Science Review*, Vol. 62, No. 4, Dec. 1968: 1144-1158.
- S. Rosendorff, "Too Much of a Good Thing?" *Journal of Conflict Resolution*, Vol. 48, No.5, Oct. 2004: 657-671.
- L. Hovil and E. Werker, "Portrait of a Failed Rebellion: An Account of Rational, Sub-optimal Violence in Western Uganda," Available online: <http://www.people.fas.harvard.edu/~werker/papers/adf.pdf> (Accessed Aug. 2005)

The greater the Violent Incident Intensity or the Protest Intensity, the greater the Incident Intensity



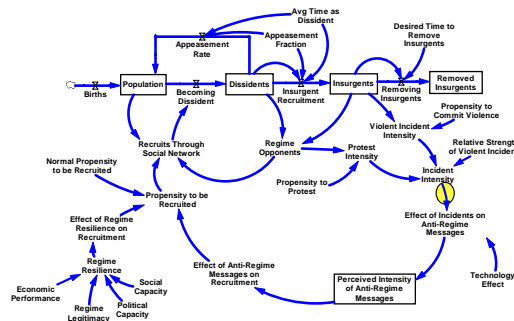
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# Fluctuations in Incident Intensity Cause Fluctuations in Effects of Incidents on Anti-Regime Messages

- M. Lipsky, "Protest as a Political Resource," *The American Political Science Review*, Vol. 62, No. 4, Dec. 1968: 1144-1158.
- C. Bob, "Marketing Rebellion: Insurgent Groups, International Media, and NGO Support," *International Politics*, Vol. 38, No. 3, Sep. 2001: 311-334.
- J. R. Faria and D. Arce, "Terror Support and Recruitment," Available Online: [http://www.aeaweb.org/annual\\_mtg\\_papers/2005/0109\\_1300\\_0403.pdf](http://www.aeaweb.org/annual_mtg_papers/2005/0109_1300_0403.pdf) (accessed Aug. 2005).

As the Incident Intensity rises, the Effect of Incidents on Anti-Regime Messages increases



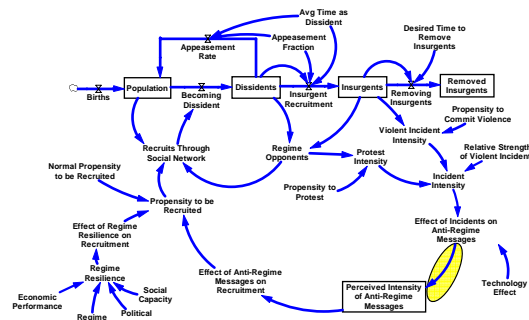
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# Effect of Incidents on Anti-Regime Messages Affects the Perceived Intensity of Anti-Regime Messages

- M. Lipsky, "Protest as a Political Resource," *American Political Science Review*, Vol. 62, No. 4, Dec. 1968: 1144-1158.
- C. Bob, "Marketing Rebellion: Insurgent Groups, International Media, and NGO Support," *International Politics*, Vol. 38, No. 3, Sep. 2001: 311-334.
- A. Croissant, "Unrest in Southern Thailand: Contours, Causes, and Consequences Since 2001," *Strategic Insights*, Vol. 4, Issue 2, Feb. 2005.
- J. R. Faria and D. Arce, "Terror Support and Recruitment," Available Online: [http://www.aeaweb.org/annual\\_mtg\\_papers/2005/0109\\_1300\\_0403.pdf](http://www.aeaweb.org/annual_mtg_papers/2005/0109_1300_0403.pdf) (accessed Aug. 2005).

A stronger Effect of Incidents on Messages increases the Perceived Intensity of Anti-Regime Messages



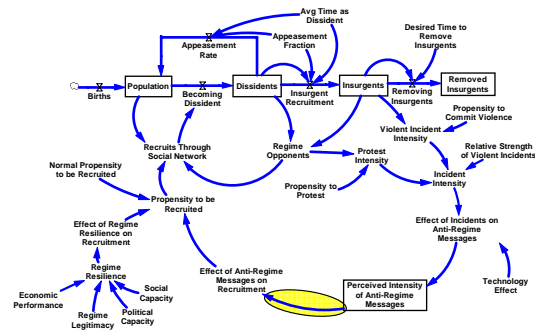
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# Perceived Intensity of Anti-Regime Messages Produces an Effect of Anti-Regime Messages on Recruitment

- A. Croissant, "Unrest in Southern Thailand: Contours, Causes, and Consequences Sine 2001," *Strategic Insights*, Vol. 4, Issue 2, Feb. 2005.
- C. Bob, "Marketing Rebellion: Insurgent Groups, International Media, and NGO Support," *International Politics*, Vol. 38, No. 3, Sep. 2001: 311-334.

A greater Perceived Intensity of Anti-Regime Messages means a greater Effect of Anti-Regime Messages on Recruitment



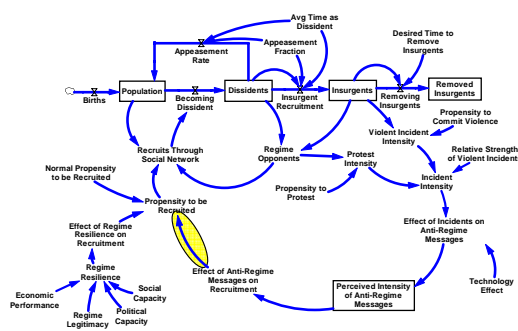
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# Effects of Anti-Regime Messages on Recruitment Affect the Propensity to Be Recruited

- C. Bob, "Marketing Rebellion: Insurgent Groups, International Media, and NGO Support," *International Politics*, Vol. 38, No. 3, Sep. 2001: 311-334.
- A. Smith, "The Politics of Negotiating the Terrorist Problem in Indonesia," *Studies in Conflict & Terrorism*, Vol. 28, 2005: 33-44.
- A. Malaquias, "Diamonds are a Guerrilla's Best Friend: The Impact of Illicit Wealth on Insurgency Strategy," *Third World Quarterly*, Vol. 22, Issue 3, June, 2001: 311-316.

A greater Effect of Anti-Regime Messages on Recruitment means a greater Propensity to be Recruited



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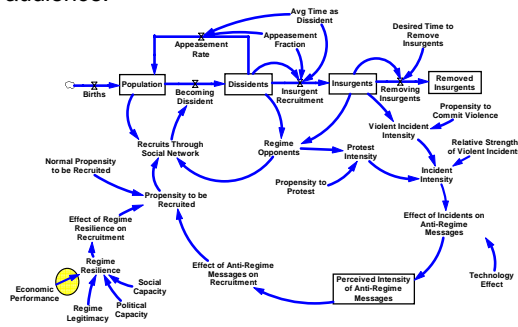
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# Economy Affects Regime Resilience

- P. Collier, L. Elliot, H. Hegre, A. Hoeffler, M. Reynal-Querol, N. Sambanis, *Breaking the Conflict Trap: Civil War and Development Policy*, The World Bank: 2003.
- H. Hegre, T. Ellingson, S. Gates, N. Gleditsch, "Toward a Democratic Civil Peace? Democracy Political Change, and Civil War, 1816-1992," *American Political Science Review*, Vol. 95, No. 1, March 2001: 33-48.
- J. Fearon and D. Laitin, "Ethnicity, Insurgency, and Civil War," *American Political Science Review*, Vol. 97, No. 1, February, 2003: 75-90.
- T. Gurr, *Why Men Rebel*, Princeton University Press: 1970.

As the economy is healthier, the regime does better. When the economy is worse, anti-regime messages are more likely to find a captive audience.



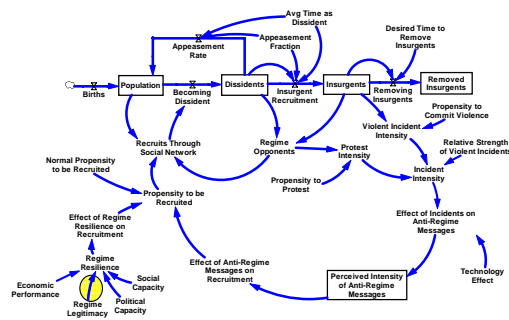
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# Regime Legitimacy Affects Regime Resilience

- P. Collier, L. Elliot, H. Hegre, A. Hoeffler, M. Reynal-Querol, N. Sambanis, *Breaking the Conflict Trap: Civil War and Development Policy*, The World Bank: 2003.
- H. Hegre, T. Ellingson, S. Gates, N. Gleditsch, "Toward a Democratic Civil Peace? Democracy Political Change, and Civil War, 1816-1992," *American Political Science Review*, Vol. 95, No. 1, March 2001: 33-48.
- T. Gurr, "A Causal Model of Civil Strife: A Comparative Analysis Using New Indices," *American Political Science Review*, Vol. 62, No. 4, Dec. 1968: 1104-1124.
- D. Hibbs, *Mass Political Violence: A Cross-National Causal Analysis*, Wiley: 1973.

As the regime does good things, the resilience becomes higher.



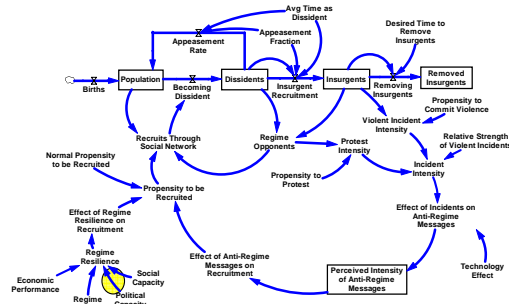
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# Political Capacity Affects Regime Resilience

- P. Collier, L. Elliot, H. Hegre, A. Hoeffler, M. Reynal-Querol, N. Sambanis, *Breaking the Conflict Trap: Civil War and Development Policy*, The World Bank: 2003.
- H. Hegre, T. Ellingson, S. Gates, N. Gleditsch, "Toward a Democratic Civil Peace? Democracy Political Change, and Civil War, 1816-1992," *American Political Science Review*, Vol. 95, No. 1, March 2001: 33-48.
- J. Fearon and D. Laitin, "Ethnicity, Insurgency, and Civil War," *American Political Science Review*, Vol. 97, No. 1, February, 2003: 75-90.
- K. Deutsch, *Nationalism and Social Communication*, MIT Press: 1953.

If there are strong political institutions, a corrupt regime may still find support in the short-run.



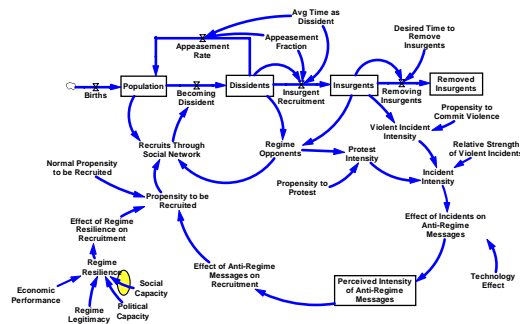
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# Social Capacity Affects Regime Resilience

- T. Gurr, *Why Men Rebel*, Princeton University Press: 1970.
- H. Hegre, T. Ellingson, S. Gates, and N. Gleditsch, "Toward a Democratic Civil Peace? Democracy Political Change, and Civil War, 1816-1992," *American Political Science Review*, Vol. 95, No. 1, March 2001: 33-48.
- R. Putnam, R. Leonardi, and R. Nanetti, *Making Democracy Work: Civic Traditions in Modern Italy*, Princeton University Press: 1993.
- D. Horowitz, *Ethnic Groups in Conflict*, Yale University Press: 1968.
- K. Deutsch, *Nationalism and Social Communication*, MIT Press: 1953.

As there are more inequalities within a society, more troubles are likely to occur.



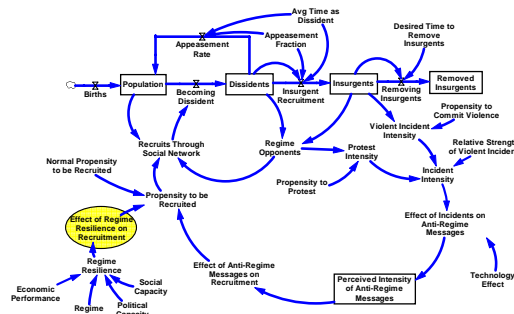
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# Regime Resilience Affects Recruitment

- P. Collier, L. Elliot, H. Hegre, A. Hoeffler, M. Reynal-Querol, N. Sambanis, *Breaking the Conflict Trap: Civil War and Development Policy*, The World Bank: 2003.
- H. Hegre, T. Ellingson, S. Gates, N. Gleditsch, "Toward a Democratic Civil Peace? Democracy Political Change, and Civil War, 1816-1992," *American Political Science Review*, Vol. 95, No. 1, March 2001: 33-48.
- J. Fearon and D. Laitin, "Ethnicity, Insurgency, and Civil War," *American Political Science Review*, Vol. 97, No. 1, February, 2003: 75-90.
- T. Gurr, *Why Men Rebel*, Princeton University Press: 1970.

Greater Regime Resilience means a stronger Effect of Regime Resilience on Recruitment.



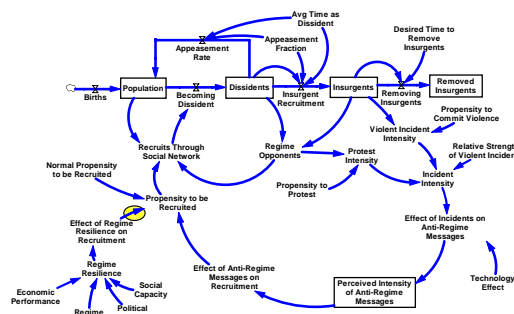
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# Regime Resilience Buffers the Propensity to be Recruited

- A. Malaquias, "Diamonds are a Guerrilla's Best Friend: The Impact of Illicit Wealth on Insurgency Strategy," *Third World Quarterly*, Vol. 22, Issue 3, June, 2001: 311-316.
- A. Croissant, "Unrest in Southern Thailand: Contours, Causes, and Consequences Since 2001," *Strategic Insights*, Vol. 4, Issue 2, Feb. 2005.
- H. Hegre, T. Ellingson, S. Gates, N. Gleditsch, "Toward a Democratic Civil Peace? Democracy Political Change, and Civil War, 1816-1992," *American Political Science Review*, Vol. 95, No. 1, March 2001: 33-48.

The greater the Effect of Regime Resilience on Recruitment, the larger the Propensity to be Recruited.



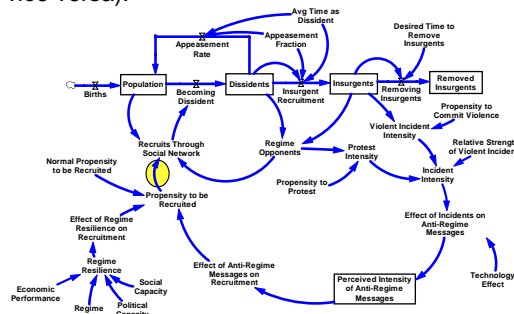
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# Propensity to Be Recruited Increases Recruits through Social Network

- N. Berry, T. Ko, T. Moy, J. Smrcka, J. Turnley and B. Wu, "Emergent Clique Formation In Terrorist Recruitment," Sandia National Laboratories, 2005.
- A. Malaquias, "Diamonds are a Guerrilla's Best Friend: The Impact of Illicit Wealth on Insurgency Strategy," *Third World Quarterly*, Vol. 22, Issue 3, June, 2001: 311-316.
- R. Petersen, *Resistance and Rebellion: Lessons from Eastern Europe*, Cambridge University Press: May, 2001.

As the propensity to be recruited increases, the likelihood of an interaction causing a supportive individual to become a recruit rises (and vice versa).

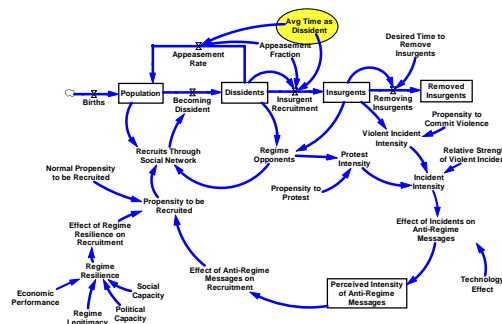


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## Average Time as a Dissident

- SME Interview
- "12-18 months for Thailand, and the same with Indonesia"

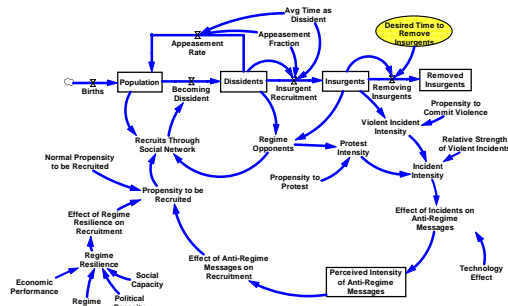


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# Desired Time to Remove Insurgents

- SME Interview
- “The timeline in Thailand would probably be more like 48 months”
- “In Indonesia 48-60 months may be a more appropriate time frame.”

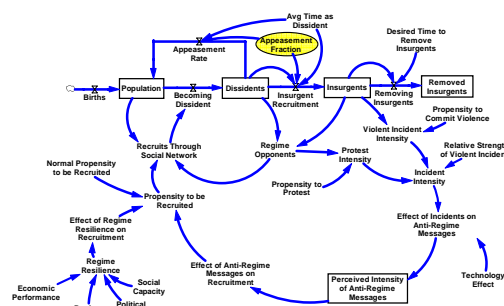


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# Appeasement Fraction

- SME Interview
- “The appeasement fraction for Thailand will be 75-80 percent back to supportive. Indonesia is more complex with more insurgencies, with the more mature insurgencies there I would put the percentage at 70-75%.”
- “certainly less than 10%, in Papua maybe less than 5%, and in Ache I don’t know... that is a good questions... 5% is a reasonable guess.”

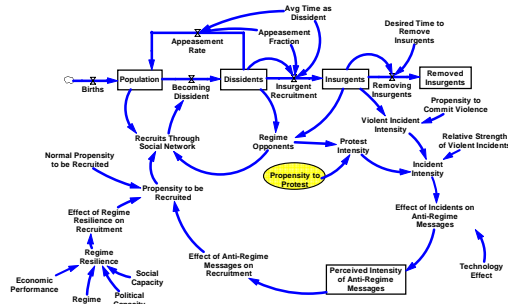


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# Propensity to Protest

- SME Interview
- “In Thailand it is between one protest a month and one each quarter. One every 1-3 months”

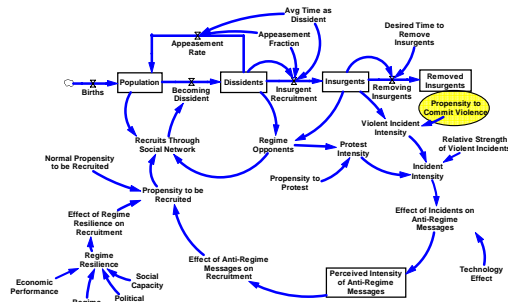


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# Propensity to Commit Violence

- SME Interview
- “Out of a pool of 100 armed insurgents, in a month they would average 3-5 incidents of violence.”



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## APPENDIX B

### Hegre-Relative Risk of Civil War Memo

#### 1. INTRODUCTION

The Relative Risk of Civil War (RRCW) is a measure constructed in “Toward a Democratic Civil Peace? Democracy, Political Change, and Civil War, 1816–1992” by Hegre, Ellingsen, Gates, and Gelditsch (2001).

The measure is a determinant of the likelihood of a civil war in a country.

This appendix presents the Hegre Method, the variables used, and our use of this method to ‘validate’ Regime Resilience in this paper.

#### 1.1 Hegre et al.’s Approach:

The functional form of the Relative Risk of Civil War (RRCW) equation is as follows:

$$\text{RRCW} = \exp((\exp(\alpha)*x1) + (\beta*x2) + (\beta^2*x3) + (\exp(\gamma) *x4) + (\exp(\delta) *x5) + (\varepsilon *x6) + (\zeta *x7) + (\eta *x8) + (\eta^2*x9) + (\theta *x10))$$

where

$\alpha$  = proximity of regime change

$\beta$  = level of democracy

$\beta^2$  = level of democracy squared

$\gamma$  = proximity of civil war

$\delta$  = proximity of independence

$\varepsilon$  = international war in country

$\zeta$  = neighboring civil war

$\eta$  = level of development

$\eta^2$  = level of development squared

$\theta$  = ethnic heterogeneity.

#### 1.2 RRCW and Regime Resilience

We have used the RRCW as a test against our own Regime Resilience measure by searching for an inverse relationship. The logic for such a relationship is that when Regime Resilience is high – when a country is being run well – the likelihood of civil war is low. Vice versa, when a regime is weak or threatened, there is a higher likelihood of civil war.

## 2. THE RRCW METHOD

### 2.1 Dependent Variable

The dependent variable in the Hegre research is the outbreak of civil war, as recorded in the Correlates of War Project. This measure is constructed by examining 152 countries from 1816-1992, with a civil war including any instance a country experiences a regime change.<sup>16</sup> Formally defined, a civil war is “an internal war in which ‘(a) military action was involved, (b) the national government at the time was actively involved, (c) effective resistance (as measured by the ratio of fatalities of the weaker to the stronger forces) occurred on both sides, and (d) at least 1,000 battle deaths resulted;” (Hegre, et al., 2001: 36, with inner quotation from Singer and Small, 1994: part 3).

Hegre et al. created two models: one where civil war is examined from 1816-1992, and one where civil war is examined post-World War II (from 1946-1992). The reason behind creating a more recent model is because of the substantial ways that both war and politics have changed over this time period. We use the second model (post-WWII on).

### 2.2 Independent Variables and Control Variables

Hegre and his team include several independent variables and control variables. Hegre et al. are interested in whether democracy and democratization stem civil war. However, to determine the effect of democracy and democratization, they had to control for several factors, partly including economic and social factors, as well as historical factors.

## 3. Operational Definitions

### 3.1 The Variables

Below is a brief definition of the variables and the source data used by Hegre, et al.:

- **Proximity of Regime Change:** This is the amount of time since the regime most recently changed. It is a measure for how long the current regime has been in power. It is located in the Polity IV dataset, and is listed as “durable’ or ‘duration.’ It is listed in years, but needs to be multiplied by -1 (since a more recent regime change means greater likelihood of civil war), divided by days, and have its exponent taken to be consistent with the strengths of the other measures and to eradicate the negative value. We simply multiply by -1, divide by 365 (ignoring leap years), and calculate the exponent.
- **Level of Democracy:** This is a measure that represents the level of democracy in a country, from 10 being a perfect democracy, to -10 being an autocracy. It is coded as polity2 in the Polity IV dataset.

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<sup>16</sup> Computationally, a regime change is defined as when a country undergoes a change of 2 or more on the commonly accepted democracy-autocracy scale, which ranges from -10 (totally autocratic) to 10 (totally democratic).



- **Level of Democracy Squared:** The logic for squaring the level of democracy is that much theory and research has suggested that strong autocracies are just as stable as strong democracies, and that states with weak regimes are the most vulnerable to conflict and civil war. Hegre et al. found that including this measure formed a far more accurate model.
- **Proximity of Civil War:** This is a measure of the number of days since the last civil war ended. It can be found in the Correlates of War database. This value is given in days. To make this measure consistent, we again multiply by -1, divide by 5840, and take the exponent.
- **Proximity of Independence:** This is a measure of the time since a country either formed or engaged in regime change. It can be found in the Correlates of War database. This value needs to be multiplied by -1, divided by days, and have its exponent taken, again so as to be consistent with the strengths of the other measures. We simply multiply by -1, divide by 365 (ignoring leap years), and calculate the exponent.
- **International War in Country:** This is a dummy variable for whether two countries are fighting within the country of analysis. The measure can be found in the Correlates of War database.
- **Neighboring Civil War:** This is a dummy variable for whether a neighboring country is undergoing civil war. It is constructed by examining the Correlates of War database to see if a civil war is taking place in a neighboring country.
- **Level of Development:** This is a measure of the level of development, and it is provided by the Correlates of War database. It is a measure of energy consumption.
- **Level of Development Squared:** The level of development of a country is clearly a decisive measure of civil war, and by squaring the value, the difference between developed and developing countries becomes more pronounced.
- **Ethnic Heterogeneity:** This is a measure of the ethnic composition of the country. This measure can be found in Appendix B of Hegre, et al.'s paper, along with a list of the civil wars that were included in the analysis. The values range from 0 to 1.

### 3.2 The Coefficients

Each of the values above is multiplied by a specific coefficient (x1 to x10), as determined by regression analysis.

Below are the coefficient for the specific variables:

- x1 = 1.270
- x2 = -0.002
- x3 = -0.012
- x4 = 1.160

- $x_5 = 1.510$
- $x_6 = 0.860$
- $x_7 = 0.097$
- $x_8 = -0.480$
- $x_9 = -0.066$
- $x_{10} = 0.800$

#### **4. CALCULATING THE RRCW**

Once a country is identified and the data is located across the years of interest, the calculation follows the above equation and directions.

Once the values are added, the exponent of the resulting summation needs to be taken in order to complete the calculations.

The exponent is taken to pronounce the relationship, largely so that changes can be more easily depicted, and also so that the value does not come out as negative, since a likelihood of civil war cannot be negative.

In order to make the RRCW value useful for our purposes, we had to perform an important transformation. The RRCW was a measure originally constructed based upon events as the unit of analysis. For our purposes, we wanted our unit of analysis to be in country-years, so we had to adapt the calculation method.

#### **5. EVALUATION**

Our use of civil war is only one of the possible ways of ‘validating’ our regime resilience measure. Others include ‘Political Capacity’ from the POFED model (J. Kugler). As such, the RRCW value was originally calculated to examine whether our measure of Regime Resilience was empirically plausible.

We have compared the RRCW to Regime Resilience in three countries now, and we have found the correlations to be very consistent.

#### **References for Appendix B**

1. Hegre, Håvard, Tanja Ellingsen, Scott Gates, and Nils Petter Gleditsch. 2001. *American Political Science Review* 95 (1): 33-48. Available online: <http://www.worldbank.org/research/conflict/papers/CivilPeace2.pdf>
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